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.

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 Enhancement 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
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							
		Seminar		0	0	2	2
1	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							

6.1 Discipline Specific Core Papers (DSC): (Credit: 04 each)

A student will study following Discipline Specific Core Courses in four semesters. The semester wise distribution of DSC courses over is listed in Table 3.

Table 3: Details of Discipline Specific Core (DSC) Courses

Course	Semester	Name of the Course
DSC1	I	Mathematical Physics
DSC2	I	Classical Mechanics
DSC3	I	Quantum Mechanics
DSC4	II	Electrodynamics
DSC5	II	Condensed Matter Physics
DSC6	II	Atomic and Molecular Physics
DSC7	III	Computational Physics
DSC8	III	Statistical Mechanics
DSC9	IV	Energy Materials and Semiconductor Devices
DSC10	IV	Advanced Condensed Matter Theory

6.2 Details of Discipline Specific Elective Papers: (4 credits each)

The Discipline Specific Electives (DSEs) are a pool of credit courses offered by the Department of Physics from which a student will choose to study based on his/ her interest. A student of Master of Science in Physics gets an option of choosing two DSE courses of Physics in semesters I to II, while the student has an option of choosing a maximum of three DSE courses of Physics in semesters III and IV. The distribution of DSE courses is listed in Table 4.

Table 4: Pool of Discipline Specific Elective Courses (DSE)*

S. No.	Name of the Course
1.	Electronics and Devices
2.	Lab I- Electronics Laboratory
3.	Lab II- Solid State Physics Lab
4.	Advanced Condensed Matter Physics
5.	Nuclear and Particle Physics
6.	Lab III- Optoelectronics
7.	Optoelectronics I (Lasers and Detectors)
8.	Optoelectronics 2 (Optical Fiber communication, Integrated nonlinear optics)
9.	Optoelectronics 3 (Applied Optics)
10.	Nanotechnology
11.	Lab IV-Computational Lab (Quantum Mechanics, Statistical Mechanics and Electrodynamics)
12.	Atomistic Modelling and Simulations
13.	Bio Physics
14.	Computational Structural Biology
15.	Research Methodology
16.	Introduction to Particle Physics
17.	Astronomy and Astrophysics
18.	Physics of Devices and Instrumentation
19.	Medical Physics
20.	Research Methodology
21.	Characterization Techniques of Materials
22.	Elements of Spectroscopy
23.	Computational Techniques for Solid State Materials

In addition to the above proposed courses, students may select courses from the Swayam.org as MOOCs courses upto the permissible limit.

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, Integraltransforms, ordinary differential equations and special functions.	B1, B2 *(Remember, Understand)*
CO2	After this course students are capable to use the applications of these methods in basic physics problems	B3, B4 *(Apply, Analyze)*
CO3	Explain the concepts of differential equations and special functions.	B2, B4 *(Understand, Analyze)*

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.
- 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

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:

To provide a strong foundation in the fundamental principles of quantum mechanics.

1. To develop proficiency in the mathematical framework of quantum mechanics.
2. To familiarize students with the use of Dirac notation and formal quantum mechanical tools.
3. To introduce perturbation techniques in quantum mechanics.
4. 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 too 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-½ 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. Ghatakh and S. Lokanathan, Quantum Mechanics 3rded. (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)

Lecture1: Degenerate perturbation theory
Lecture2: Application to harmonic oscillator
Lecture3: Stark effect in hydrogen (first order)
Lecture4: Variational principle: concept
Lecture5: Helium atom ground state using variational method
Lectur6: Electron interaction energy
Lecture7: Extension to excited states
Lecture8: 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

DISCIPLINE SECIFIC ELECTIVES

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.

   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.

2. 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.

3. To understand logic circuits, registers, counters, comparators, A/D and D/A conversion, and microprocessor basics for digital system applications.

4. 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)

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.

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.

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:

1. To study the various digital analog circuits:
4-bit discrete binary adder network, 8-bit DAC using 0808 IC without OP-amp.

2. To draw transfer characteristics of

(a) An OP-amp (741IC) in inverting mode in close loop.

(b) To determine offset voltage

(c) To determine CMRR of the OP-amp

3. To determine the band gap of a semiconductor (Ge)

4. To study the amplitude modulation with the help of CRO

(a) with I/O frequency at constant I/O voltage

(b) To study variation of percentage of modulation with I/O voltage at constant I/O frequency.

(c) Plotting modulated and demodulated wave

(d) 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 c
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

PHE503 - Solid State Physics Lab
LAB-II

Total Credits: 04 (Credits: Practical: 04)

Total Hours: Practical:120

L	T	P	Cr
0	0	4	4

Course Objective:

- To make students learn the basics of physics through experimental methods.
- To relate the theory through experiments of solid-state physics, spectroscopy and electronics.
- To analyze the data obtained through the experiments and keep the record of the experiments.
- To expose the students to handle the experiments with confidence and ease.

Course Outcomes:

CO1	Students will be able to study and understand the I-V characteristics of solar cells
CO2	Students will be able to understand the concept of band gap through experiment and analyze it.
CO3	Students will learn and calculate the Hall coefficient, Hall angle, carrier concentration of Ge through Hall effect experiment.
CO4	Design and learn the circuit designing in the experimental lab through these experiments.
CO5	Learn to analyze the data.

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List of Experiments:

Minimum 8 experiments have to be completed during the semester.

- To study the variation of resistivity of Ge crystal with temperature by four probe method and hence to determine the band gap for it.
- Determination of Plank's constant using LED.
- I-V characteristics of solar cell and determination of its efficiency.
- To measure magnetoresistance of a thin (0.5 mm) sample of p-doped (or n-doped) Germanium as a function of magnetic field for 3 different sample current.
- To study the Hall effect and hence to determine the Hall coefficient and Carrier concentration.
- To determine the magnetic susceptibility (diamagnetic or paramagnetic) of a given compound using Quincke's tube.
- Fabrication of thin films by drop casting, spin coating and thermal evaporation methods.
- Study the band gap (Tauc plot) of the materials by using UV-vis characterization.
- To plot magnetic hysteresis loop of a ferromagnetic rod and study the magnetic hysteresis
- To measure dielectric constant of a ferroelectric material as a function of temperature and to observe ferroelectric to paraelectric transition.

PHE504 – Computational Lab- IV
(Quantum Mechanics, Statistical Mechanics and Electrodynamics)

Total Credits: 04 (Credits: Practical: 04)

Total Hours: Practical:120

L	T	P	Cr
0	0	4	4

Course Objective

The objective of this laboratory course is to introduce students to numerical and computational techniques for solving fundamental physics problems. Using C++ programming, students will learn to model and simulate basic concepts of Quantum Mechanics, Statistical Mechanics, and Electrodynamics.

Course Outcomes

After successful completion of this course, students will be able to: 1. Write and execute basic C++ programs. 2. Convert physical equations into computational algorithms. 3. Generate and analyse numerical data. 4. Simulate elementary systems of Quantum Mechanics, Statistical Mechanics, and Electrodynamics.

Course Content

UNIT I: Basics of C++ Programming for Computational Physics (Lecture 10)

This unit introduces students to fundamental concepts of C++ programming required for computational physics. Topics include structure of a C++ program, input and output operations, data types, variables, constants, and operators. Conditional statements such as if–else and switch

case are covered, followed by looping constructs including for, while, and do–while loops. Arrays and user-defined functions are introduced for handling numerical data. Basic mathematical functions and algorithm development are discussed. Students learn to convert physical formulas into C++ programs through simple numerical examples.

Unit–I: Quantum Mechanics (Lecture 6)

C++ program to calculate energy eigenvalues of a particle in a one-dimensional box. Program to evaluate and plot the wave function of a particle in a 1D box for different quantum numbers. Numerical evaluation of probability density for a particle in a box. Program to calculate tunnelling probability through a finite potential barrier. Introductory numerical solution of the Schrödinger equation using the finite difference method.

Unit–II: Statistical Mechanics (Lecture 6)

C++ program to compute Maxwell–Boltzmann velocity distribution. Program to calculate most probable, mean, and RMS velocities of gas molecules. Evaluation of partition function for discrete energy levels. Calculation of average energy using Boltzmann statistics.

Unit–III: Electrodynamics (Lecture 8)

Program to calculate electric field due to a point charge as a function of distance. Program to calculate electric potential variation with distance. Simulation of RC circuit charging and

discharging characteristics. Numerical solution of one-dimensional Laplace equation using iterative method.

References Books

- Nicholas J. Giordano – Computational Physics
- Computational Physics: Problem Solving with Python Book by Cristian C. Bordeianu,
- Manuel J. Paez, and Rubin H. LandauR. W. Hamming – Numerical Methods for
- Scientists and Engineers
- Computational Physics: A Practical Introduction to Computational Physics and Scientific
- Computing (using C++) by Konstantinos N. Anagnostopoulos.
- A First Course in Computational Physics and Object-Oriented Programming with C++ by
- David Yevick.

PHE505: Solid State Physics II

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 make students learn more about the theoretical models for studying condensed matter.
2. To enable the students to develop an understanding of relation between band structure and the electrical/optical properties of a material.
3. To introduce the concept of defects in materials with respect to structures.

Course Outcome:

CO1	Students will be able to grow their understanding about the quantitative hypotheses of energy levels, band gap computation based upon different approaches.
CO2	Understand the defects in crystals that will be make their foundation strong for the research
CO3	Learn the magnetic properties and superconductivity and their applications
CO3	Learn and have understanding about carbon nanostructures and their properties
CO4	Basic understanding about principle of scanning electron microscope and its utility

Course Content:

UNIT 1

Intrinsic and extrinsic semiconductors. carrier concentration and Fermi levels of intrinsic and extrinsic semi-conductors. Bandgap. Direct and indirect gap semiconductors. Hydrogenic model of impurity levels. **(6 Lectures)**

UNIT 2

Band Theory (Advanced form Solid State Physics I), Tight Binding, Pseudo potential methods, De Haas von Alfen Effect, AC conductivity and optical properties, plasma oscillations.

(7 Lectures)

UNIT 3

Defects in Crystals: Vacancy formation, Mechanism of Plastic deformation in solids, Stress Imperfections in crystals: Lattice defects & configurational entropy, vacancies, Schottky & Frankel pairs, Edge & screw dislocations (qualitative ideas), Frank-Read Sources, Dislocations in FCC, BCC and HCP structures Experimental methods of detecting defects. **(7 Lectures)**

UNIT 4

Magnetic properties of solids. Diamagnetism, Langevin equation, Quantum theory of paramagnetism, Curie law. Hund's rules, Paramagnetism in rare earth and iron group ions, Frustrated magnetism, quantum paramagnet, Ferromagnetism, Curie-Weiss law, Heisenberg exchange interaction, Antiferromagnetism, Neel point, Hall effects, Elementary ideas of Quantum Hall effect **(11 Lectures)**

UNIT 5

Superconductivity, Survey of important experimental results. Critical temperature. Meissner effect. Type I and type II superconductors. Thermodynamics of superconducting transition. London equation. London penetration depth. Basic ideas of BCS theory. High-Tc superconductors, Josephson junctions. (**10 Lectures)**

UNIT 6

Carbon nanostructures, Properties and Applications, Basic concepts of scanning electron microscope **(4 Lectures)**

Reference Books:

- John Singleton: Band theory and Electronic properties of Solids (Oxford University Press; Oxford Master Series in Condensed Matter Physics).
- Ibach& Luth: Solid State Physics
- Elementary Dislocation Theory: Weertman and Weertman
- M. Ali Omar: Elementary solid state physics (Addison-wesley)
- C. Kittel: Solid-state physics (Wiley eastern)(5th edition)
- Solid State Physics, A.J.Dekker, Macmillan India Ltd
- Material Science & Engineering, V.Raghavan, Prentice –Hall of India, New Delhi (2001)

PHE506- Nuclear and Particle Physics

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Outcome:

CO1	Students should be able to explain the fundamental interactions and principles governing nuclear forces, radioactive decay, and special relativity.
CO2	Students should be able to apply nuclear models to describe nuclear structure, binding energy, stability, and reactions such as fission and fusion.
CO3	Students should be able to analyze the working principles of particle detectors and accelerators, and assess methods for detecting charged particles, photons, and neutrons.
CO4	Students should be able to interpret experimental evidence for elementary particles, neutrino oscillations, and quark structures using Feynman diagrams and conservation laws.

Course Content:

UNIT 1

Introduction: Historical overview, weak and strong interactions, units: length, mass and energy, review of special relativity, radioactive decay. **(9 Lectures)**

UNIT 2

Nuclear Force: Deuteron problem, nucleon-nucleon scattering. Structure of Nuclei: distribution of mass within nucleus, liquid drop model, nuclear binding energy, semi-empirical mass formula, beta stability, ground state properties: the shell model, magic numbers. (**15 Lectures**)

UNIT 3

Nuclear reactions: excited states of nuclei, beta decay, alpha decay, gamma decay, nuclear fission and fusion. **(12 Lectures)**

UNIT 4

Experimental Methods: Accelerators, beams, interaction of particles with matter, particle detectors gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM counter, Basic principle of Scintillation detectors and construction of photo-multiplier tube (PMT). Semiconductor detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector. **(15 Lectures)**

UNIT 5

Elementary Particles: leptons and the weak interaction, baryons, nutrinos, conserved quantities, nutrino oscillations, evidence for quarks, hadrons, color quantum number and gluons, parity violation, CP violation, asymptotic freedom,Feynman diagrams. **(9 Lectures)**

Reference Books:

- An Introduction to Nuclear Physics by W.N. Cottingham, Cambridge.
- Particle Physics by B.R. Martin and G. Shaw, Wiley.
- NUCLEAR PHYSICS: Problem-based Approach including Matlab, published by PHI (2016).

PHE507: Optoelectronics

LAB – III

Total Credits: 04 (Practical :04)

Total Hours: Practical: 120

L	T	P	Cr
0	0	4	4

Course Objectives:

- To provide the practical knowledge through experiments on optics and optoelectronics.
- Learn to acquire data in various experimental systems and to understand the use of electronic systems.
- To design a circuit on the bread-board for a particular experiment.
- To keep the record of the experiments, performed in the laboratory.
- To Interpret the results using the correct physical scientific framework and tools.

Course Outcomes:

CO1	Students will learn various experiments of optics and optoelectronics.
CO2	The students will learn to calculate wavelength of laser using Michelson system.
CO3	The students will understand the diffraction through grating, experimental determination of aperture of optical fiber.
CO4	Students will learn to operate a GM counter and relate it with the theory.
CO5	Students will relate the concept of magnetic susceptibility for paramagnetic and diamagnetic materials by performing the experiment and analyzing it.
CO6	The student will relate the concepts of longitudinal, transverse and standing waves using Melde's experiment.

List of Experiments:

Minimum 8 experiments have to be completed during the semester.

- To determine the wavelength of laser using Michelson interferometer.
- To determine fringe width and wavelength of light using Young's Double Slit Experiment.
- To determine the numerical aperture and acceptance angle of an optical fiber.
- Measurement of Laser Beam Divergence & Spot Size.
- To study the Characteristics of a Photodiode (I-V characteristics) under different light
- intensities.
- To determine the I-V characteristics of a solar cell under illumination and to calculate open-circuit voltage, short-circuit current, fill factor, and efficiency.

- To study the transmission of analog and digital signals through an optical fiber and to demonstrate the processes of modulation and demodulation in an optical communication system.
- To study the V-I characteristics of a photodiode under different illumination levels and to determine its response time and sensitivity.
- To determine the variation of resistance of an LDR with changing light intensity.
- To study the working of an optocoupler and observe the signal isolation between input and output.
- To interface a photodiode with a microcontroller and observe the change in output
- voltage with light intensity.

PHE508: Optoelectronics I

(Lasers and Detectors)

Total Credits: 04 (Credits: Theory:04)

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- To make students learn the basic theories of optoelectronics particularly applied in Lasers and detectors.
- To understand the concepts semiconductor laser sources.
- To make the students understand about photo detectors.

Course Outcomes:

CO1	Students will be able to study the matter-radiation interaction, basics of Lasers, and optical resonance, properties of electromagnetic waves in cavity, LED, LD, Quantum dots, DBR lasers, different displays etc.
CO2	To understand in detail about direct/indirect band gap in reference to optoelectronic applications

.

Course Content:

UNIT 1

Physics of interaction between Radiation and Atomic systems-stimulated emissions, line shape functions, Einstein Coefficients, Light Amplification, threshold condition, Laser Rate Equations, Two, three and four level systems. Line Broadening Mechanisms – Natural, Collision and Doppler, Theory of optical resonators – Fabry Perot Resonator, Modes of a Confocal resonator system, Planar resonator, General Spherical resonator, Gaussian Beam Propagation and ABCD law, Optical cavity stability criteria **(5 Lectures)**

UNIT 2

Losses in the cavity – quality factor, line width of the Laser, Mode selection – Transverse and longitudinal, Q – Switching – Peak Power, Total Energy, Pulse duration, Techniques for the control of laser output employing Q-switching, mode-locking and mode- dumping, Laser Systems – Ruby Laser, He-Ne Laser, Nd:YAG, Nd: Glass, CO2 Laser, Excimer Laser, Fiber lasers, Properties of Lasers – Directionality, Coherence etc. **(13 Lectures)**

UNIT 3

Semiconductor Optical sources: Direct and Indirect Band Gap semiconductors, Light source Material Heterojunction structure. Light Emitting Diode (LED) Laser Diodes (LD), Basics of Quantum dots, Quantum wire Laser and VCSELs, Distributed feedback laser (DFB), Distributed feedback reflector (DBR) laser. **(12 Lectures)**

UNIT 4

Photo Detectors: Principle of operation, Performance parameters, Quantum efficiency, Responsibility, Cut off wave length, Photo detector Material. Frequency Response, Thermal Noise, Shot-Noise Signal to noise ratio, Noise Equivalent Power (NEP) structure of PIN and APD, CCD, LED and LCD display. **(15 Lectures)**

Reference Books:

- M. Born and E. Wolf, Principles of Optics, Macmillan, New York.
- A.K. Ghatak and K. Thyagarajan, Optical Electronics (Cambridge University Press)
- A Yariv, Quantum Electronics (John Wiley).
- K. Thyagarajan and A.K.Ghatak, Laser: Theory and Applications. (McMillan India. New Delhi)
- W.T. Silfvast, Laser Fundamentals, (Cambridge University Press).
- G.H.P. Thompson, Physics of Semiconductor laser Devices, (John Wiley & Sons)
- J. M. Senior, Optical fiber Communications, Principles & Practice, (Prentice Hall of India).
- G. Kaiser, Optical fiber Communications, McGraw Hill Book Company.
- AjoyGhatak, K. Thyagarajan, Introduction to Fiber optics.
- A. E. Siegman, Lasers
- Baa E Saleh, Fundamentals of Photonics

PHE509: Optoelectronics II

(Optical Fiber Communication, Integrated Nonlinear Optics)

Total Credits: 04 (Credits: Theory:04)

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- To make students learn the basic theories of optoelectronics particularly applied in optical fiber and nonlinear optics.
- To understand about the basics of optical fibers.

Course Outcomes:

CO1	Students will be able to understand the basics of optical fibers and light propagation through it, fiber attenuation, Fiber fabrication, waveguides and nonlinear optical effects, SHG phenomenon and its applications.
CO2	Student will learn about the wave propagation in nonlinear media and their effects in optical fibers.

Course Content:

UNIT 1

Introduction to optical fibers, Light guidance in an optical fiber, Numerical aperture, fiber types, Refractive index profiles, Concept of modes, Electromagnetic analysis of guided modes in an optical fiber. Concepts of Normalized Frequency, V-Parameter, Losses and Pulse dispersion in fibers. Pulse dispersion in single mode optical fibers, Concept of Dispersion shifted and Dispersion flattened Fibers, Fiber attenuation, Misalignment losses, Fiber material, Fiber fabrication, Splices & Connectors.

(15 Lectures)

UNIT 2

Electromagnetic analysis of guided modes in symmetric step index planar waveguides. Basic idea of asymmetric planar waveguides. Various kinds of channel waveguides - slab guide geometries: strip, raised strip, embedded strip, ridge, strip coated guides. Beam and waveguide couplers: Transverse couplers, the prism-coupler, the Grating coupler, the thin- film tapered coupler, wave guide-to-fiber couplers. Electro-optic Effects, Acousto-optic Effect, Raman-Nath, Acousto-optic modulator, Bragg modulator, Acousto-optic deflectors, Acousto-optic spectrum analyzer. **(20 Lectures)**

UNIT 3

Origin of non-linear optical effects. Wave propagation in a nonlinear media. Nonlinear Optical susceptibility. Second harmonic generation and phase matching techniques. Physical phenomena related to 2nd order and 3rd order susceptibility, three wave interaction, sum and difference generation. Manley Rowe relations, Parametric conversion and amplification. Basic idea of optical phase conjugation, Introduction to Nonlinear effects in optical fibers.

(10 Lectures)

Reference Books:

- A.K. Ghatak and K. Thyagarajan, Optical Electronics (Cambridge University Press)
- Yariv, Quantum Electronics (John Wiley).
- J. M. Senior, Optical fiber Communications, Principles & Practice, (Prentice Hall of India).
- G. Kaiser, Optical fiber Communications, McGraw Hill Book Company.
- Ajoy Ghatak, K. Thyagarajan, Introduction to Fiber optics.
- D. Marcuse: Theory of Dielectric Optical waveguides, (Academic press, New York).
- Nishihara, Integrated Optical Circuits
- N.S. Kapani: Fibre Optics (Academic Press, New York).
- Y. R. Shen, The principles of Nonlinear Optics (Wiley, New York)
- R. W. Boyd, Nonlinear Optics

PHE510: Optoelectronics III
(Applied Optics)

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objective:

- To impart knowledge about the applied optics in the field of optoelectronics.
-

Course Outcomes:

CO1	Students will be able to learn the basics of holographic photography and holograms, holographic interferometry, optical data processing, Quantization of Analog signals, Multiplexing and the devices involved, system design and Rise time budget calculations.

Course Content:

UNIT 1

Conventional versus holographic photography, Hologram of a point source, hologram of an extended object, Off-axis technique in the recording of holograms. Three dimensional holograms – Reflection holograms. Basic idea of holographic data storage, Holographic interferometry – double exposure, real time, time average holographic interferometry. Optical correlation. Fourier Transform holograms and their use in character recognition. **(10 Lectures)**

UNIT 2

Introduction to Optical data processing, Abbe's theory. Spatial filters – low pass, high pass, band pass filters. Fraunhofer Diffraction and the Fourier Transform – mathematical concept. Young's experiment. Michelson Stellar interferometer and its limitation. Hanbury Brown and Twiss interferometer. Classical and quantum coherence functions, first and second order coherence, coherent states. Discussion of Young's experiment in quantum mechanical terms. Introduction to Fourier optics and optical information processing.
(15 Lectures)

UNIT 3

Quantization of Analog signal, A/D & D/A conversion, Bit Rate, Pulse Code Modulation, NRZ, RZ and Manchester Coding, Base Line Wander Effect, Advantages of Optical Communication, Eye pattern Technique Time Division Multiplexing, Wave length Division Multiplexing WDM Devices, Multiplexers & De-Multiplexers. **(10 Lectures)**

UNIT 4

Direct Detection and Coherent Heterodyne Detection concept of Optical frequency Division Multiplexing, NEP Heterodyne, Optical Amplifiers, Erbium Doped Fiber Amplifier, Semiconductor Optical Amplifier, Fiber Bragg Grating, System Design, Power Budget, Band width Budget and Rise Time Budget Calculations. **(10 Lectures)**

Reference Books:

- A.K. Ghatak and K. Thyagarajan, Optical Electronics (Cambridge University Press)
- J. M. Senior, Optical fiber Communications, Principles & Practice, (Prentice Hall of India).
- G. Kaiser, Optical fiber Communications, McGraw Hill Book Company.
- Ajoy Ghatak, K. Thyagarajan, Introduction to Fiber optics.
- N.S. Kapani, Fibre Optics (Academic Press, New York).
- Baa E. Saleh, Fundamentals of Photonics
- P. Hariharan, Optical holography, (Cambridge University Press, 1984).
- Fourier Optics by Joseph Goodman, Tata McGraw H

PHE511: Nanotechnology

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- To enable the students to understand the basic concepts of nanotechnology.
- To understand the concepts of 1D, 2D and 3D confinement along with the density of states.
- To acquaint the students with nanoscale systems, 1D, 2D and 3D systems.
- To understand about the growth and synthesis of nanostructure materials by various deposition processes along with the growth mechanism models.

Course Outcomes:

CO1	Concept of Quantum confinement, 1D,2D, and 3D nano systems with examples.
CO2	Different synthesis techniques including PVD and CVD systems along with the growth models.
CO3	Characterization of nanostructured materials using X-ray diffraction, electron microscopy, Atomic Force Microscopy and Scanning Tunneling Microscopy.
CO4	Physical, electronic, magnetic and optical properties of nanostructured materials.

Course Content:

UNIT 1
Physics of low-dimensional materials, 1D, 2D and 3D confinement, Density of states.
(10 Lectures)

UNIT 2
Excitons, Coulomb blockade, Surface plasmon, Size and surface dependence of physical, electronic, optical, luminescence, thermo-dynamical, magnetic, catalysis, gas sensing and mechanical properties. **(12 Lectures)**

UNIT 3
Physical and chemical techniques for nanomaterial synthesis, Physical Vapor Deposition, Glow Discharge and Plasma, Sputtering–mechanisms and yield, Chemical Vapor Deposition, Chemical Techniques - Spray Pyrolysis, Electrodeposition, Sol-Gel. **(10 Lectures)**

UNIT 4

Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of nanostructure growth, Growth mechanisms. **(13 Lectures)**

References:

- The Physics of Low Dimesional Semiconductors: An Introduction by John H. Davies
- Materials Science of Thin Films by Milton Ohring
- Nanotechnology: Gregory L.Timp
- Thin Film Phenomena by K.L. Chopra
- F.C. Phillips: An introduction to crystallography (wiley)(3rd edition)
- Introduction of Solids: L.V. Azaroff
- Solid State Physics-Structure and Properties of Materials: M.A. Wahab
- Solid State Physics: N.W. Ashcroft and N.D. Mermin
- C. Kittel: Solid-state physics (Wiley eastern) (5th edition).

PHE512: Atomistic Modelling and Simulations

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objective:

- To understand the mathematical concepts of molecular modeling.
- To understand about empirical force fields models with examples.
- To understand about Advanced *ab initio* methods and density functional theory.

Course Outcomes:

CO1	To learn the mathematical concepts of molecular modeling.
CO2	To know about molecular mechanics force fields, bond stretching, angle bending, Van der Waals interactions, pair potentials.
CO3	To learn and apply *ab-initio* methods and density function theory to calculate the structural and other parameters of a system.
CO4	To learn the basic concepts of simulations and molecular dynamics methods to calculate the thermodynamic properties, potentials etc. for a particular system.

Course Content:

UNIT 1
Useful concepts of Molecular modeling: Mathematical concepts and review of related basics.
(6 Lectures)

UNIT 2
Empirical Force Field Models: Molecular Mechanics force fields, bond stretching, angle bending, Van der Waals interactions, pair potentials, Common and popular force field potentials.
An Introduction to the Computational Mechanics: One electron atom. **(12 Lectures)**

UNIT 3
Advanced *ab initio* methods, Density Functional Theory: Open shell systems, Electron correlation, Valence bond theories, The Hartree-Fock equations, semi-empirical methods.
(11 Lectures)

UNIT 4
Energy minimization and related methods: Non-derivate minimization methods, Second derivative methods, Quasi Newton methods.
(8 Lectures)

UNIT 5
Simulations and molecular dynamics methods: (overview only) Calculating thermodynamic properties, Truncation of potentials, Long range potentials, Constraint dynamics, Time dependant properties, Monte Carlo methods. **(8 Lectures)**

References:

- R. Leach, Molecular Dynamics.
- R. M. Martin, Electronic Structure: Basic theory and practical methods.
- J. Kohnoff, Electronic structure calculations for solids and molecules.
- D. Frenkel, Understanding Molecular Dynamics.
- J. M. Haile, Molecular Dynamics Simulations.
- M. P Allen, Computer Simulations of Liquids.

PHE513: Bio Physics

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- To enable the students to relate application of physics to biological systems, from the first picture of the structure of DNA, to the treatment of cancer, and the understanding of allergic reactions.
- To understand the concepts and techniques of biophysics find applications in bioelectronics, medicine/health, and population dynamics and are closely related to statistical mechanics and transport processes.

Course Outcomes:

CO1	Explain models of biological systems and models dealing with statistical mechanics and transport phenomena.
CO2	Solve qualitative and quantitative problems, using appropriate statistical mechanics and computing techniques.
CO3	Understand the mechanical and magnetic properties of biomaterials with the concepts of physics.

Course Content:

UNIT 1

Introduction: The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales. Universality of microscopic process and diversity of macroscopic form (**12 Lectures**)

UNIT 2

Living State Thermodynamics: Interaction in biology system, Structure of Biomolecules: and confirmations of protein and nucleic acids, Secondary, tertiary and quaternary structure of protein, Primary and secondary structure of RNA and DNA, Method of conformational analysis and prediction of conformation, Thermodynamics and kinetics of conformational transition of proteins, Protein folding, techniques for studying Macromolecular structure, Ultra centrifugation Sedimentation velocity and equilibrium determination of molecular weights.

(13 Lectures)

UNIT 3

Bioenergetics and Molecular motors: Kinesin and Dynein, microtubule dynamics, Brownian motion, ATP synthesis in Mitochondria, Photosynthesis in Chloroplasts, Light absorption in bio- molecules.

(8 Lectures)

UNIT 4

Mechanical properties of Biomaterials: Elastic Moduli, Electric stresses in Biological Membranes, Mechanical effects of microgravity during spaceflight. **(7 Lectures)**

UNIT 5

Bio magnetism: Bio magnetic field Sources, nerve Impulses, magnetostatic bacteria, SQUID magnetometry. **(5 Lectures)**

References:

- Introductory Biophysics, J. Claycomb, JQP Tran, Jones & Bartelett Publishers
- Aspects of Biophysics, Hughe S W, John Willy and Sons.
- Essentials of Biophysics by P Narayanan, New Age International
- M.V. Volkenstein, General Biophysics, Academic Press

PHE514: Computational Structural Biology

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- To introduce computational algorithms and data processing strategies used in modern biophysics and structural biology.
- To provide the basic idea on the structure and information of proteins.
- To introduce the students with various molecular simulations methods.

Course Outcomes:

CO1	To Characterize the role of structural biology in concurrent biomedical research.
CO2	Describe the functionality, advantages, and limitations of standard computing strategies used in processing of 3D structural data.
CO3	Acquire a working knowledge of freely available software and algorithms by learning the molecular simulation method.

Course Content

UNIT 1
Introduction to experimental methods (X-ray and NMR) of protein structure determination. **(9 Lectures)**

UNIT 2
Basic ideas on structure and conformations of proteins**.** **(8 Lectures)**

UNIT 3
Structural motifs and analysis of information from protein databank, Homology modeling and protein structure prediction. **(11 Lectures)**

UNIT 4
Aspects of biomolecular forces. **(6 Lectures)**

UNIT 5
Introduction to various molecular simulations methods, Molecular dynamics (GROMACS, VMD and NAMD), Molecular docking (protein ligand docking). **(11 Lectures)**

References:

- Thomas E. Crieghton, Proteins: Structures and Molecular Properties
- Andrew Leach, Molecular Modeling: Principles and Applications
- Branden &Tooze, Introduction to Protein Structure
- Tamar Schlick, Molecular Modeling and Simulation: An Interdisciplinary Guide

PHE515: Research Methodology

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

Total Hours: Theory: 45, Tutorial: 15

L	T	P	Cr
3	1	0	4

Course Objectives:

- To familiarize participants with basic of research and the research process and ethics in research.
- To enable the students to choose right problem and methodology.
- To explain the students about conducting research work and formulating research synopsis and report.
- To familiarize participants national and international journals.
- To impart knowledge about scientific writing.

Course Outcomes:

CO1	Develop understanding on various kinds of research, objectives of doing research, research process, research designs and sampling.
CO2	Understanding of research ethics.
CO3	Have basic knowledge on qualitative research techniques.
CO4	Ability to define problems and select the journals for publishing research work.

Course Content:

UNIT 1

Introduction: Philosophy of research, Introduction to research methods, Relevance and ambiguity in applied research, Ethics in research, Scientific explanation and understanding in science, characteristics of scientific research and logic of scientific enquiry, Introduction to different perspectives and types of research.Designing Research: Meaning, Elements and Need of research design, features of a good design, Different types of research design, developing a research plan, Defining the research problem and hypothesis, selecting a problem, Necessity of defining the problem, Techniques involved in defining a problem; Hypothesis – Types of hypotheses, Differences between hypothesis and research problem. Priority Setting in Research: Introduction to setting research priorities - Process – Links with planning, participation, time and information, Steps – choosing the right problem, defining objectives and Options, Choosing and evaluating, preparing for implementation, Type of research, Choosing a Methodology, Methods of setting research priorities.

(14 Lectures)

UNIT 2
Review of Published Research: Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples. Digital: Web resources, E-journals, Journal access, TOC alerts, Hot articles, Citation index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and Wiki-Databases, Academic databases and search engines: Science Direct, Sci Finder, Scopus, Web of knowledge. Finding and citing published information. **(13 Lectures)**

UNIT 3
Methods of Scientific Writing: Reporting practical and project work. Writing literature surveys and reviews. Organizing a poster display. Giving an oral presentation. Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism. Introduction to LaTeX. **(10 Lectures)**

UNIT 4
Communicating Results for Application: Identifying users and their needs, Channels of communication with users, Type of research – user linkages, Management options for strengthening researcher-user communication; Communicating Scientific Results: Importance of research communication in science, Overview of research communication process in science, Role of scientific journals – quality of journals, citation index, other options for communicating results.
(8 Lectures)

References:

- Research Methodology in Chemical Sciences: Experimental and Theoretical Approach Tanmoy Chakraborty, Lalita Ledwani, CRC Publishers.
- Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011) Practical skills in chemistry. 2nd Ed. Prentice-Hall, Harlow.
- Hibbert, D. B. & Gooding, J. J. (2006) Data analysis for chemistry. Oxford University Press. 4. Topping, J. (1984) Errors of observation and their treatment. Fourth Ed., Chapman Hall, London.
- Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis. Cambridge Univ. Press (2001) 487 pages.

- Date, C. J. An Introduction to Database System, Addision Wesley, U.K (1986).
- Caulcutt R, R Boddy, Statistics for Analytical Chemists, First Ed. 1983, By, Chapman & Hall.
- Medhi, J. Statistical Methods. Wiley Eastern, New Delhi (1992).