

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
MSc in Physics	The programme ensures that the learners **PSO1**: Acquire core competency in the areas of Basic and Applied 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.

1. **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.
2. **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.

3. **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.

4. 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

5. 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

6. Programme and Frame Work

<table>
<tr><th>Semester</th><th>Discipline Specific Core Course (DSC)</th><th>Discipline Specific Elective (DSE)/ Generic Elective (GE)</th><th>Skill Enhancement Course (SEC)/ Project/ Dissertation</th><th>Value Addition Course (VAC)/ Ability Enhance ment Course (AEC)</th><th>Total Credits earned</th></tr>
<tr><td rowspan="3">1.</td><td>DSC1: Mathematical Physics</td><td>DSE1/GE1</td><td rowspan="3">Seminar/Project (2 Credits)</td><td rowspan="3">-</td><td rowspan="3">22</td></tr>
<tr><td>DSC2: Classical Physics</td><td rowspan="2">DSE2/GE2</td></tr>
<tr><td>DSC3: Quantum Mechanics</td></tr>
<tr><td rowspan="3">2.</td><td>DSC4: Electrodynamics</td><td>DSE3/GE3</td><td rowspan="3">Seminar/Project (2 Credits)</td><td rowspan="3">-</td><td rowspan="3">22</td></tr>
<tr><td>DSC5: Condensed Matter Physics</td><td>DSE4/GE4</td></tr>
<tr><td>DSC6: Atomic and Molecular Physics</td></tr>
<tr><td rowspan="4">3.</td><td>DSC7: Computational Physics</td><td>DSE5/GE5</td><td rowspan="3">Seminar/Project (2 Credits)</td><td rowspan="3">-</td><td rowspan="4">22</td></tr>
<tr><td>DSC8: Statistical Mechanics</td><td>DSE6/GE6</td></tr>
<tr><td></td><td>DSE7/GE7</td></tr>
<tr><td colspan="4">OR</td></tr>
<tr><td colspan="5">(i) Seminar (2 Credits)
(ii) Dissertation/Academic Project/Entrepreneurship (20 Credits)</td></tr>
<tr><td rowspan="4">4.</td><td rowspan="2">DSC9: Energy Materials and Semiconductor Devices</td><td>DSE8/GE8</td><td rowspan="3">Seminar/Project (2 Credits)</td><td rowspan="3">-</td><td rowspan="4">22</td></tr>
<tr><td>DSE9/GE9</td></tr>
<tr><td>DSC10: Advanced Condensed Matter Theory</td><td>DSE10/GE10</td></tr>
<tr><td colspan="4">OR</td></tr>
<tr><td colspan="5">(i) Seminar (2 Credits)
(ii) Dissertation/Academic Project/Entrepreneurship (20 Credits)</td></tr>
</table>

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	PHE510	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	PHS601	Seminar		0	0	2	2
	PHD601	Dissertation/Academic Project/Entrepreneurship		20			
Total Credits 22							

Semester IV							
1	PHS651	Seminar		0	0	2	2
	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 andDetectors)
8.	Optoelectronics 2 (Optical Fiber communication, Integratednonlinear optics)
9.	Optoelectronics 3 (Applied Optics)
10.	Nanotechnology
11.	Lab IV-Computational Lab (Quantum Mechanics, Statistical Mechanics and Electrodynamics)
12.	Atomistic Modelling andSimulations
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 atmasters' level.
2. To enable to solve problems in complex analysis, vector spaces.
3. To understand the concepts of Fourier and Laplace transform.

Course Outcomes:

CO1	Students will be able to learn basics of Complex Analysis, Vector spaces, matrices, Integraltransforms, ordinary differential equations and special functions.
CO2	After this course students are capable to use the applications of these methods in basic physics problems
CO3	Explain the concepts of differential equations and special functions.

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 ·

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:

The course aims

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 which allow for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics.

Course Outcomes:

CO1	This paper enables the students to understand the Lagrangian approach in classical mechanics
CO2	Students will be able to try finding solution of a time evolution of state of a system employing Lagrangian and Hamiltonian approaches.
CO3	Students will be able to understand Hamiltonian formulation with applications
CO4	Students will be able 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.
CO5	The paper also enables the students to know about relativistic system.

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. **(18 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. **(5 Lectures)**

UNIT 5

Special Theory of Relativity: Lorentz transformation, relativistic kinematics and dynamics, Equation of energy in relativistic mechanics; mass energy relation. Problem solving. **(4 Lectures)**

Reference Books:

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

PHC503: Quantum 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:

1. To grow the understanding of Quantum mechanics for more application point of view on the Foundations of basics learned in the previous quantum mechanics' course.
2. To develop the basic understanding and mathematical formulation of Quantum mechanics.
3. To provide an understanding of the formalism and language of non-relativistic quantum mechanics.
4. To understand the concepts of the time-dependent perturbation theory and their applications to physical situations.
5. To understand the basics of scattering theory.

Course Outcomes:

CO1	Student will be able to grow the understanding on the applied problem of quantum mechanics based on Schrödinger equation.
CO2	Students will develop the basic understanding of mathematical formulation of quantum mechanics.
CO3	Students will learn the formalism and language of non-relativistic quantum mechanics.
CO4	Students will able to understand the concepts of the time-dependent perturbation theory and their applications to physical situations.
CO5	Students will be able to understand the basics of scattering theory.

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. **(7 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. **(10 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.

(10 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.

(6 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.

(14 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. **(13 Lectures)**

Reference Books:

- D. J. Griffiths, Introduction to Quantum Mechanics (Pearson).
- J. J. Sakurai, Advanced Quantum Mechanics (Wesley).
- N. Zettili, Quantum Mechanics Concepts and Applications (Wiley)
- K. Ghatakh and S. Lokanathan, Quantum Mechanics 3rded. (MacMillan).
- L. I. Schiff, Quantum Mechanics (McGraw Hill).
- C. Cohen-Tannoudji, Quantum Mechanics (Volume I and II).

SEMESTER-II
PHC551: Electrodynamics

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. Understand Fundamental Laws of Electrostatics and Magnetostatics – Develop a strong foundation in Gauss's law, Laplace and Poisson equations, boundary value problems, Biot-Savart law, and Ampere's theorem to analyze electric and magnetic fields.
2. Comprehend Maxwell's Equations and Their Applications – Learn the formulation of Maxwell's equations in free space and material media, boundary conditions, gauge invariance, and their role in describing classical electrodynamics.
3. Analyze Electromagnetic Wave Propagation – Study wave solutions in free space, dielectrics, and conductors, including reflection, refraction, polarization, interference, coherence, and diffraction phenomena.
4. Explore the Dynamics of Charged Particles in Electromagnetic Fields – Understand the motion of charged particles in static and dynamic electromagnetic fields, including applications in plasmas and accelerators.
5. Investigate Radiation and Advanced Electromagnetic Concepts – Examine radiation from moving charges, dipoles, and retarded potentials, along with transmission lines, waveguides, and the Lorentz invariance of Maxwell's equations.

Course Outcomes:

CO1	Understand the fundamental concepts of electrostatics, including Gauss's law, Laplace and Poisson equations, and boundary value problems.
CO2	Analyze magnetostatics and electromagnetic induction using Biot-Savart law, Ampere's theorem, and Faraday's law.
CO3	Comprehend Maxwell's equations, their derivation, boundary conditions, and applications in electromagnetic field theory.
CO4	Study electromagnetic wave propagation in free space, dielectrics, and conductors, including reflection, refraction, polarization, and diffraction.
CO5	Explore advanced electrodynamics topics such as dispersion in plasmas, waveguides, transmission lines, and radiation from moving charges.

Course Content:

UNIT 1

Electrostatics: Gauss's law and its applications, Laplace and Poisson equations, boundary value problems. Electrostatic potential and energy. Conductors, capacitors, and electrostatic boundary conditions. **(10 Lectures)**

UNIT 2

Magnetostatics and Electromagnetic Induction: Biot-Savart law, Ampere's theorem, vector potential, gauge invariance. Magnetic fields in materials, boundary conditions. Faraday's law of electromagnetic induction, energy in magnetic fields. **(10 Lectures)**

UNIT 3

Maxwell's Equations and Electromagnetic Waves: Maxwell's equations in free space and linear isotropic media. Boundary conditions on the fields at interfaces. Scalar and vector potentials, gauge transformations. Electromagnetic waves in free space, wave equations in dielectrics and conductors. **(12 Lectures)**

UNIT 4

Wave Propagation and Optics: Reflection and refraction, polarization, Fresnel's equations. Interference, coherence, and diffraction. Dynamics of charged particles in static and uniform electromagnetic fields. **(10 Lectures)**

UNIT 5

Advanced Topics in Electrodynamics: Dispersion relations in plasma, Lorentz invariance of Maxwell's equations, transmission lines, and waveguides. Radiation from moving charges, dipoles, and retarded potentials. **(08 Lectures)**

Reference Books:

- Classical Electrodynamics – J.D. Jackson (Wiley) – A rigorous graduate-level book covering Maxwell's equations, radiation, and relativistic electrodynamics.
- Introduction to Electrodynamics – David J. Griffiths (Cambridge) – A student-friendly undergraduate book with clear explanations of electromagnetism concepts.
- Electromagnetic Theory – J.A. Stratton (McGraw-Hill) – An advanced book focusing on theoretical formulations, waveguides, and boundary conditions.
- Principles of Electrodynamics – Melvin Schwartz (Dover) – A concise introduction bridging classical and modern electrodynamics.
- Modern Electrodynamics – Andrew Zangwill (Cambridge) – A graduate-level book incorporating contemporary techniques and applications.
- The Feynman Lectures on Physics (Vol. II) – R.P. Feynman (Addison-Wesley) – A conceptual book providing deep physical insights into electrodynamics.

PHC552: Condensed Matter 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:

1. To impart the extended knowledge of solid-state physics.
2. To understand the concept of structure in reference to properties of materials.

Course Outcomes:

CO1	The students shall be able to learn the concepts of lattice and crystals, long range forces, X-ray diffraction, Vibrational analysis and concepts of phonons.
CO2	The quantum mechanical treatment of solids particularly focusing upon the study of the energy (states) as a function of spatial configuration of atoms.
CO3	The students will be able to formulate basic models for electrons and lattice vibrations for describing the physics of crystalline materials; and develop an understanding of relation between band structure and properties of a material

Course Content:

UNIT 1

Crystalline and amorphous solids, Bravais lattice, symmetry operations and classification of Bravais lattices, Three dimensional crystal systems, Directions and planes incrystals, Closed packed structures, common crystal structures **(6 Lectures)**

UNIT 2

X-ray diffraction by crystals, Laue theory, Interpretation of Laue equations, Bragg's law, Atomic scattering factor, Experimental methods of X-ray diffraction, Neutron and electron diffraction. Reciprocal lattice, Brillouin zones. Bragg's law in Reciprocal Space, Ewald construction.

(8 Lectures)

UNIT 3

Interatomic Forces and types of bonding. Ionic Bonds, Covalent bonds, Metallic bonds, Van der Waals' bonds, Hydrogen Bonds, Binding Energy of Ionic crystals, Cohesive energy of inert gas solids. Cohesive energy and bulk modulas of ionic crystals. Madelung constant, Lennard - Jones Potential. **(6 Lectures)**

UNIT 4

Vibrations of one-dimensional monatomic and diatomic lattices. Infrared absorption in ionic crystals (one-dimensional model). Normal modes and phonons. Normal and Umclapp Process, Frequency distribution function, Specific Heat, Classical Theory and Einstein's Theory Lattice Specific Heat, Debye's theory of lattice specific heat. Anharmonic effects, Thermal Conductivity **(10 Lectures)**

UNIT 5

Drude-Lorentz's Classical Theory (Free electron Gas Model), Quantized free electron theory (Sommerfeld's Quantum Theory), Fermi energy, wave vector, velocity and temperature, Density of states. Electronic specific heats. Sommerfeld's model for metallic conduction **(7 Lectures)**

UNIT 6

Energy bands in solids, The Bloch theorem, Bloch functions, Kroning penney model, Number of states in the band, Band gap in the nearly free electron model, The tight binding model, The fermi surface, Electron dynamics in an electric field, Theeffective mass, Concept of hole.

(8 Lectures)

Reference Books:

- 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).
- Charles A Wert and Robb M Thonson: Physics of Solids
- J. P. Srivastava: Elements of solid state physics (Prentice Hall India; 2nd edition)
- Christmaan-solid state physics (academic press)

PHC553: Atomic and Molecular 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:

The course aims

1. To make students understand and apply key Atomic Spectroscopy concepts.
2. To study multi-electron atom and Coupling Models.
3. To analyze spectral effects under external magnetic and electric fields.
4. To explore Molecular Spectroscopy fundamentals.
5. To analyze and interpret electronic transitions in molecules.

Course Outcomes:

CO1	Students will be able to understand the basics of atomic spectroscopy such as quantum mechanical hypothesis of atomic spectra.
CO2	Students will demonstrate the various coupling models and their influence on atomic spectra.
CO3	Students will learn the quantum behavior of atoms in external electric and magnetic fields and apply these concepts to real world scenarios.
CO4	Students will able to understand and distinguish between different types of molecular spectroscopic techniques.
CO5	Students will be able to interpret and identify that how the electronic transitions provide insights into molecular structure, binding and reactivity.

Course Content:

UNIT 1

Atomic Spectroscopy: Fine structure of Hydrogen lines, magnetic dipole moments, electron spinand vector atom model, identical particles, Pauli's exclusion principle, multielectron atoms- Hartree's self-consistent field theory, L-S and j-j coupling schemes, alkali atom spectra, equivalent and non-equivalent electrons, normal and anomalous Zeeman effect, Paschen-Back Effect, hyper fine structure, Stark effect, width of spectral lines, X-ray spectra. **(22 Lectures)**

UNIT 2

Molecular Spectroscopy: Born-Oppenheimer approximation, molecular orbital theory, rotational spectra of diatomic molecules, non-rigid rotator, vibrational spectra, anharmonic oscillator, explanation of rotational vibrational spectra in infrared, Raman

effect and intensity alternation of the rotational bands, applications of infrared and Raman spectroscopy, electronic spectra of molecules, Fortrat Parabola, vibrational structure of electronic bands, Intensities of electronic transitions, Franck Condon principle, Condon parabola.

(23 Lectures)

Reference Books:

- Atomic Spectra- H.E white, Cambridge University Press, Newyork, (1935).
- Atomic and molecular spectra: Laser- R. Kumar
- Fundamentals of Molecular Spectroscopy- C.B.Banewell
- Molecular Spectroscopy– A. Das
- Spectra of atoms and molecules- P. F. Bemath

SEMESTER-III

PHC601: Computational 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 the essentials of computational methods and techniques usedto solve physics problems numerically.

Course Learning Outcome:

CO1	Students shall be able to learn a computer programming language and basics of computational methods in interpolation, root finding, differentiation, integration, eigenvalue determination, FFT, solution of differential equation etc.

Course Content:

UNIT 1

Basics of programming and syntax: FORTRAN or C/C++ or PYTHON **(8 lectures)**

UNIT 2

Numerical Techniques: Root finding of single variable function, interpolation, regression, curve fitting, solution of linear equations, numerical differentiation and integration, Solution of first and second order differential equation using initial conditions. Random number generation and its usage in computation. **(20 lectures)**

UNIT 3

Data Science using python: Python programming for data science using libraries such as Numpy, Pandas, Scikit- learn, basics of statistics, data visualization using python libraries, machine learning for building model with data, machine learning algorithms, such as supervised learning, and reinforcement learning**.** **(17 lectures)**

Small project: One credit project based upon the problems based upon or related to the syllabus.

Reference Books:

- V. Rajaraman, Computer Programming in Fortran 77, Prentice Hall
- W.H. Press, B.P. Flannery, S.A. Teukolsky and W.T. Vetterling, Numerical Recipes: The Art of Scientific Computing, Cambridge University Press
- H.M. Antia, Numerical Methods for Scientists and Engineers, Hindustan Book Agency
- Mahendra K. Verma, Practical Numerical Computing Using Python: Scientific & Engineering Applications.
- D.W. Heermann, Computer Simulation Methods in Theoretical Physics, Springer
- H. Gould and J. Tobochnik, An Introduction to Computer Simulation Methods, Addison- Wesley
- J.M. Thijssen, Computational Physics, Cambridge University Press
- Joel Grus. Data Science from Scratch
- David Spiegelhalter, The Art of Statistics, How to learn from Data
- Roger Pend and Elizabeth Matsui, The Art of Data Science

PHC602: Statistical 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 build the theoretical understanding towards the thermodynamics on the basis of underlying statistical formulation.
2. To have an understanding for the various aspects of equilibrium and non-equilibrium statistical physics.
3. To describe the features and examples of Maxwell-Boltzmann, Bose-Einstein and Fermi Dirac statistics

Course Outcomes:

CO1	This paper enables the students to understand the basics of probability and different types of probability distributions.
CO2	Students shall be able to learn the basics of thermodynamics and the required mathematical tools.
CO3	A treatise to the derivation of such phenomenon is presented on the basis of statistical mechanical analysis employing classical and quantum mechanics-based approaches.

Course Content:

UNIT 1

Elementary Probability theory: Probability distributions, Binomial, Poisson and Gaussian distributions, central limit theorem. Problem solving. **(6 Lectures)**

UNIT 2

Review of Thermodynamics: Extensive and intensive variables, laws of thermodynamics, Legendre transformations and thermodynamic potentials, Maxwell relations, applications of thermodynamics to (a) ideal gas, (b) magnetic material, and (c) dielectric material. **(10 Lectures)**

UNIT 3

Formalism of Equilibrium Statistical Mechanics: Concept of phase space, Liouville's theorem, basic postulates of statistical mechanics, ensembles: microcanonical, canonical, grand canonical, and isobaric, connection to thermodynamics, fluctuations, applications of various ensembles, equation of state for a non-ideal gas, Van der Waals' equation of state, Meyer cluster expansion, virial coefficients.

(14 Lectures)

UNIT 4

Quantum Statistics: Fermi-Dirac and Bose-Einstein statistics. Applications of the formalism to: (a) Ideal Bose gas, Debye theory of specific heat, properties of black-body radiation, Bose- Einstein condensation, experiments on atomic BEC, BEC in a harmonic potential. (b) Ideal Fermi gas, properties of simple metals, Pauli Para-magnetism, electronic specific heat and white dwarf stars. Problem solving.

(15 Lectures)

Reference Books:

- F. Reif, Fundamentals of Statistical and Thermal Physics.
- K. Huang, Statistical Mechanics.
- R.K. Pathria, Statistical Mechanics.
- D.A. McQuarrie, Statistical Mechanics.
- S.K. Ma, Statistical Mechanics.

SEMESTER III/IV
PHD601/PHD651: Dissertation

Total Credits: 20

Total Hours: Practical – 600

L	T	P	Cr
0	0	20	20

L	T	P	Cr
0	0		4

Course Objectives:

1. This course is focused to facilitate student to carry out extensive research anddevelopment project or technical project through problem and gap identification,
2. Development of methodology for problem solving, interpretation of findings,presentation of results and discussion of findings.
3. To expose the students to advances in the various research areas worldwide.

Course Outcomes:

CO1	Students will be able to gain in depth knowledge of the area of research.
CO2	Learn experimental synthesis of various materials for certain applications.
CO3	Learn various mathematical/ computational tools for theoretical studies.
CO4	Understand and learn the working of various characterization tools.
CO5	Analyze and critically evaluate different technical/research solutions
CO6	Students will learn to discuss present their research work in a systematic manner.
CO7	Identify the issues that must be addressed within the framework of the specific dissertation in order to take into consideration

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:

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.

1. 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. Master Digital Electronics Concepts – Understand logic circuits, registers, counters, comparators, A/D and D/A conversion, and microprocessor basics for digital system applications.
4. Develop Expertise in Signal Processing and Communication – Study filtering, noise reduction, Fourier transforms, modulation techniques, and shielding methods essential for communication systems.
5. Analyze High-Frequency Devices and Their Applications – Explore high-frequency generators and detectors, understanding their role in advanced communication and instrumentation systems.

Course Outcomes:

CO1	Understand semiconductor devices, including diodes, transistors, field-effect devices, and optoelectronic components like LEDs and solar cells.
CO2	Gain proficiency in analog electronics, covering operational amplifiers (Op-Amps), signal conditioning, impedance matching, and feedback circuits.
CO3	Develop expertise in digital electronics, including logic circuits, registers, counters, microprocessors, and A/D & D/A conversion techniques.
CO4	Analyze signal processing and communication techniques such as filtering, noise reduction, shielding, Fourier transforms, and modulation and Explore high-frequency devices.

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)

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 Outcomes:

CO1	Students will be able to design the adder circuit and analyze it.
CO2	Students will be able to design the Op-Amp circuit on the bread board by themselvesand learn the characteristics of Op-Amp along with CMRR.
CO3	Students will gain the knowledge of CRO for various applications.
CO4	Students will be able to perform logical operations using microprocessor.

List of Experiments:

Minimum 8 experiments have to be completed during the semester.

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/Ofrequency.

(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 numbersusing 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

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:

1. To make students learn the basics of physics through experimental methods.
2. To relate the theory through experiments of solid-state physics, spectroscopy and electronics.
3. To analyze the data obtained through the experiments and keep the record of theexperiments.
4. 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 experimentand analyze it.
CO3	Students will learn and calculate the Hall coefficient, Hall angle, carrierconcentration of Ge through Hall effect experiment.
CO4	Design and learn the circuit designing in the experimental lab through theseexperiments.
CO5	Learn to analyze the data.

List of Experiments:

Minimum 8 experiments have to be completed during the semester.

1. To study the variation of resistivity of Ge crystal with temperature by four probemethod and hence to determine the band gap for it.
2. Determination of Plank's constant using LED.
3. I-V characteristics of solar cell and determination of its efficiency.
4. 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.
5. To study the Hall effect and hence to determine the Hall coefficient and Carrier concentration.
6. To determine the magnetic susceptibility (diamagnetic or paramagnetic) of a given compound using Quincke's tube.
7. Fabrication of thin films by drop casting, spin coating and thermal evaporation methods.
8. Study the band gap (Tauc plot) of the materials by using UV-vis characterization.
9. To plot magnetic hysteresis loop of a ferromagnetic rod and study the magnetic hysteresis
10. To measure dielectric constant of a ferroelectric material as a function of temperature and to observe ferroelectric to paraelectric transition.

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 condensedmatter.
2. To enable the students to develop an understanding of relation between band structureand 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, bandgap 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-T_c 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 UniversityPress; 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:

1. To provide the practical knowledge through experiments on optics and optoelectronics.
2. Learn to acquire data in various experimental systems and to understand the use of 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.
5. 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 determinationof 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 anddiamagnetic materials by performing the experiment and analyzing it.
CO6	The student will relate the concepts of longitudinal, transverse and standing waves usingMelde's experiment.

List of Experiments:

Minimum 8 experiments have to be completed during the semester.

1. To determine the wavelength of laser using Michelson interferometer.
2. To determine fringe width and wavelength of light using Young's Double Slit Experiment.
3. To determine the numerical aperture and acceptance angle of an optical fiber.
4. Measurement of Laser Beam Divergence & Spot Size.
5. To study the Characteristics of a Photodiode (I-V characteristics) under different light intensities.
6. 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.
7. 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.
8. To study the V-I characteristics of a photodiode under different illumination levels and to determine its response time and sensitivity.
9. To determine the variation of resistance of an LDR with changing light intensity.
10. To study the working of an optocoupler and observe the signal isolation between input and output.
11. 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:

1. To make students learn the basic theories of optoelectronics particularly applied in Lasers and detectors.
2. To understand the concepts semiconductor laser sources.
3. 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 – Transverseand 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, CO_2 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 ofIndia).
- 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

PHE508: 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:

1. To make students learn the basic theories of optoelectronics particularly applied in optical fiber and nonlinear optics.
2. 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, fibertypes, Refractive index profiles, Concept of modes, Electromagnetic analysis of guided modesin 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 2^{nd} order and 3^{rd} 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)
- A. Yariv, Quantum Electronics (John Wiley).
- J. M. Senior, Optical fiber Communications, Principles & Practice, (Prentice Hall ofIndia).
- 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

PHE509: 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:

1. 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 ofan 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 secondorder 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 frequencyDivision 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 ofIndia).
- 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

PHE510: 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:

1. To enable the students to understand the basic concepts of nanotechnology.
2. To understand the concepts of 1D, 2D and 3D confinement along with the densityof states.
3. To acquaint the students with nanoscale systems, 1D, 2D and 3D systems.
4. To understand about the growth and synthesis of nanostructure materials by various deposition processes along with the growthmechanism 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 thegrowth models.
CO3	Characterization of nanostructured materials using X-ray diffraction, electronmicroscopy, 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).

PHE: 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:

1. To understand the mathematical concepts of molecular modeling.
2. To understand about empirical force fields models with examples.
3. 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 thestructural 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, Electroncorrelation, 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.

PHE: 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:

1. 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.
2. 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 andtransport phenomena.
CO2	Solve qualitative and quantitative problems, using appropriate statistical mechanics andcomputing 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 centrifugationSedimentation 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

PHE: 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:

1. To introduce computational algorithms and data processing strategies used in modernbiophysics and structural biology.
2. To provide the basic idea on the structure and information of proteins.
3. 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 computingstrategies used in processing of 3D structural data.
CO3	Acquire a working knowledge of freely available software and algorithms by learningthe molecular simulation method.

Course Content

UNIT 1

Introduction to experimental methods (X-ray and NMR) of protein structure determination.

(9 Lectures)

UNIT 2

Basicideas 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

PHE: 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:

1. To familiarize participants with basic of research and the research process andethics in research.
2. To enable the students to choose right problem and methodology.
3. To explain the students about conducting research work and formulating researchsynopsis and report.
4. To familiarize participants national and international journals.
5. 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: Journalabbreviations, 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 posterdisplay. 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, Overviewof 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) Practicalskills 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).