Final
~~29/05/2025~~
19/01/2026

M.Sc. (PHYSICS)

SCHEME AND SYLLABUS

OF

M.Sc.

IN

Physics

CREDIT BASED CURRICULUM

(From the academic year 2023-2025 onwards)

DEPARTMENT OF PHYSICS

National Institute of Technology, Kurukshetra-136119

KURUKSHETRA, INDIA

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M.Sc. (PHYSICS)

VISION OF THE INSTITUTE

To be a role-modelling technical education and research, responsive to global challenges.

MISSION OF THE INSTITUTE

- To impart quality technical education that develops innovative professionals and entrepreneurs.
- To undertake research that generates cutting-edge technologies and futuristic knowledge, focusing on the socio-economic needs.

VISION OF THE DEPARTMENT

To impart quality education and focus on the state-of-art research in Physics, Materials Science, Nanotechnology, and Instrumentation to meet the dynamic global challenges.

MISSION OF THE DEPARTMENT

To develop the understanding of fundamentals of Physics essential for engineering and Science graduates and integration of research in Materials, Nanotechnology and Instrumentation to make the Nation scientifically and technologically self-sustained.

VISION OF THE PROGRAMME

To disseminate state-of-the-art education to develop competent professionals& researchers in Physics to serve the society.

MISSION OF THE PROGRAMME

To educate the students in cutting-edge research by offering latest in the field of Physics for the sustainable development.

M.Sc. (PHYSICS)

Program Educational Objectives

PEO-1	To impart quality education in Physics to the students through courses of fundamental interest and of technological importance.
PEO-2	To create foundation of research and development in Physics and to strengthen student skills related to research, education and industry for social needs.
PEO-3	To enrich knowledge through problem solving, practical training, project work, seminars, tutorials, participation in scientific events, academic visits, etc.
PEO-4	To inculcate scientific bent of mind and attitude relevant to science and Technology such as accuracy and precision, integrity, effective communication, ethical responsibilities, initiative and innovations.
PEO-5	To opt for higher education in multi-disciplinary research and to be a life-long learner.

Program Articulation Matrix

PEO / Mission Statements	PEO 1	PEO 2	PEO 3	PEO 4	PEO 5
To attract motivated and talented students by providing a learning environment and develop skills needed to formulate and solve real-world problems.	2	3	3	3	3
To foster an environment conducive to quality research with clear thinking and determination capable of meeting the dynamic challenges of science and engineering.	3	3	3	2	2
To keep up with the rapid advancements of technology while improving academic standards through innovative teaching and learning processes.	3	3	2	2	3
To satisfy the country's human resource and scientific manpower requirements in Physics through learner- centered contemporary education and research.	3	2	3	3	3

1-Slightly; 2-Moderately; 3-Substantially

Program Outcomes

At the end of the program the graduates will be able to:

PO-1	Utilize domain knowledge for analysing and resolving real world scientific problems.
PO-2	Apply the theoretical and practical skills to investigate and undertake innovative projects of inter-disciplinary nature with wide societal impact.
PO-3	Function efficiently as an individual, as a member or leader in diverse groups to manage projects in multidisciplinary environments.
PO-4	Demonstrate the comprehension and analysis in materials research and device development.
PO-5	Formulate and present a technical report of the comprehended problem and its recommended solution.
PO-6	Understand the relationship between society, environment and work towards sustainable development.

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Department of Physics
National Institute of Technology Kurukshetra
Proposed Scheme for M.Sc. in Physics

Semester-I:

S. No.	Course Code	CourseTitle	L	T	P	Credits
1.	PHPC501	Classical Mechanics	3	0	0	3
2.	PHPC503	Quantum Mechanics	3	0	0	3
3.	PHPC505	Mathematical Physics	3	0	0	3
4.	PHPC507	Electrodynamics	3	0	0	3
5.	PHPC509	Nuclear and Particle Physics	3	0	0	3
6.	PHPC511	Physics Lab	0	0	6	3
7.	PHPC513	Computational Physics Lab	0	0	4	2
8.	**NC###	Sports/Yoga	0	0	4	2
		IKS/French Language /German Language	2	0	0	
			Total Credit			22

Semester-II:

S. No.	Course Code	Course Title	L	T	P	Credits
1.	PHPC 502	Solid State Physics	3	0	0	3
2.	PHPC 504	Advanced Quantum Mechanics	3	0	0	3
3.	PHPC 506	Thermodynamics and Statistical Physics	3	0	0	3
4.	PHPC 508	Electronics	3	0	0	3
5.	PHPC 510	Atomic and Molecular Physics	3	0	0	3
6.	PHPC 512	Electronics Lab	0	0	4	2
7.	PHPC 514	Advanced Physics Lab	0	0	6	3
8.	**NC ###	Sports/Yoga	0	0	4	2
		IKS/French Language /German Language	2	0	0	
			Total Credit			22

Semester-III:

S. No.	Course Code	Course Title	L	T	P	Credits
1.	PHPC 515	Advanced Electronics	3	0	0	3
2.	PHPC 517	Condensed Matter Physics	3	0	0	3
3.	PHPE 5##	Programme Elective – I	3	0	0	3
4.	PHPE 5##	Programme Elective –II	3	0	0	3
5.	PHOE ###	Open Elective – I	3	0	0	3
6.	PHPC 519	Analytical Instrumentation Lab	0	0	6	3
7.	PHPC 521	Seminar	0	0	1	1
7.	PHPC 523	Preparatory Research Project	0	0	4	2
			Total Credit			21

Semester-IV:

S. No.	Course Code	Course Title	L	T	P	Credits
1.	PHPE 5##	Programme Elective – III	3	0	0	3
2.	PHPE 5##	Programme Elective - IV*	3	0	0	3
3.	PHOE ###	Open Electives-II*	3	0	0	3
4.	PHPC 524	Research Project (Dissertation)	0	0	18	9
			Total Credit			18

Total Credit of the Programme = 22 + 22+ 21+ 18 = 83

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PC: Program Core **PE:** Program Elective

OE: OpenElective **AU:** Audit Course

Program Elective-I, II and III: List of Programme Electives Courses are given in Annexure-A.

Open Elective I: List of Open Elective Courses are given in Annexure-B.

Program Elective-IV and Open Elective-II: Students may opt courses either from the list provided by the Department or online courses (NPTEL/SWAYAM/edX) on satisfying the minimum pre-requisite ofthespecificcourse(s). The online opted courses should not have overlap with the other courses.

Students are encouraged to go for summer internship or training after the second semester.

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Annexure-A

Programme Elective – I (Semester-III):

S.No.	Course Code	CourseTitle
1.	PHPE 551	Quantum Field Theory
2.	PHPE 553	Lasers and Spectroscopy
3.	PHPE 555	Functional Materials and Characterization

Programme Elective – II (Semester-III):

S.No.	Course Code	CourseTitle
1.	PHPE 557	Radiation Physics and Nuclear Fragmentation
2.	PHPE 559	Nonlinear Spectroscopy
3.	PHPE 561	Materials Science

Programme Elective – III (Semester-IV):

S.No.	Course Code	CourseTitle
1.	PHPE 552	High Energy Physics
2.	PHPE 554	Photonics
3.	PHPE 556	Thin Film Physics and Applications

Programme Elective – IV(Semester-IV):

S.No.	Course Code	CourseTitle
1.	PHPE 558	Nuclear Technology
2.	PHPE 560	Physics of Optoelectronics Devices
3.	PHPE ###	NPTEL/SWAYAM/edX

Programme Elective NPTEL/SWAYAM/edX Courses:

S.No.	Course Code	CourseTitle
1.	PHPE ###	Accelerator Physics
2.	PHPE ###	Neutron Scattering for Condensed Matter Studies
3.	PHPE ###	Scientific Computing Using Python
4.	PHPE ###	Numerical Methods and Simulation Techniques for Scientists and Engineers
5.	PHPE ###	Computational Physics
6.	PHPE ###	A Brief Course On Superconductivity
7.	PHPE ###	Physics Of Linear And Nonlinear Optical Waveguides
8.	PHPE ###	Solar Photovoltaics Fundamentals, Technology and applications

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Annexure-B

Open Elective – I (Semester-III):

S.No.	Course Code	CourseTitle
1.	PHOE 581	Energy Materials and Devices
2.	PHOE 583	Polymers, Ceramics and Composite Materials
3.	PHOE 585	Fiber Optics and Optical Communication Systems

Open Elective – II (Semester-IV):

S.No.	Course Code	CourseTitle
1.	PHOE 582	Semiconductor Devices
2.	PHOE 584	Biomedical Instrumentation
3.	PHOE ###	NPTEL/SWAYAM/edX

Open Elective NPTEL/SWAYAM/edX Courses:

S.No.	Course Code	CourseTitle
1.	PHOE ###	Fundamentals of Artificial Intelligence
2.	PHOE ###	Cyber Security and privacy
3.	PHOE ###	Educational Leadership
4.	PHOE ###	Artificial Intelligence: Search methods for problem solving
5.	PHOE ###	Entrepreneurship
6.	PHOE ###	Machine Learning and Deep Learning—Fundamentals and Applications
7.	PHOE ###	Learning Analytics Tools

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SWAYAM / NPTEL COURSES:

1. A student may complete SWAYAM-NPTEL courses and transfer equivalent credits to partially complete the mandatory credit requirements for *Program Elective andOpen Elective courses* of the M.Sc. Physics Program.

2. The Department may permit students to register from other platforms, by taking care of evaluation and grading.

3. Before the commencement of each Semester, Department shall release a list of SWAYAM-NPTEL courses approved as Program Elective and Open Elective courses.

4. A student shall only request for transfer of credits from such notified SWAYAM-NPTEL Courses as published by the Department.

5. SWAYAM-NPTEL courses are considered for transfer of credits only if the concerned student has successfully completed and obtained the SWAYAM-NPTEL Certificate to this effect.

6. A student cannot transfer credits from SWAYAM-NPTEL Courses for any other type of Courses not permitted in the Curriculum.

7. Students shall register for the approved Courses as per the schedule announced by SWAYAM-NPTEL.

8. The credit equivalence for SWAYAM-NPTEL Courses: 12 weeks/8 weeks – 3 credits; 4 weeks – 2 credits.

9. The grading system for such SWAYAM-NPTEL Courses with transfer of credits is specified in Table given below:

Table: Grading System for SWAYAM-NPTEL Courses

Final Score on the SWAYAM-NPTEL Certificate	Grade Awarded
90% and above	S
From 80% to 89%	A
From 70% to 79%	B
From 60% to 69%	C
From 50% to 59%	D
From 40% to 49%	E

10. A student must submit the original SWAYAM-NPTEL Course Certificates to the Head of Department concerned, with a written request for the transfer of the equivalent credits. On verification of the SWAYAM-NPTEL Course Certificates and approval by the Head of the Department, the SWAYAM-NPTEL Course(s) and equivalent Credits will be included in Course (with associated Credits) Registration of the concerned student in the Semester immediately following the completion of the SWAYAM-NPTEL Course(s).

11. If any faculty is assigned for the evaluation of the courses taken through these platforms, he/she can evaluate like any regular course by following the assessment and evaluation guidelines.

12. A student may submit a request for credit transfer from SWAYAM-NPTEL Courses before the last instruction day of the *fourth (4th) Semester* of the M.Sc. program as specified in the Academic Calendar.

13. The Institute shall not reimburse any fees/expenses, a student may incur for the SWAYAM-NPTEL Courses.

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DETAILED SYLLABUS FOR COURSE

M.Sc. (Physics): First Year Semester-I

Course Code PHPC 501	Classical Mechanics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To explain the difference between Newtonian mechanics and analytical mechanics.
CEO1	To understand and answer problems on damped and forced oscillatory systems, and simple coupled systems.
CEO1	Understand the physical principle behind the derivation of Lagrange's and Hamilton's equations, and the advantages of these formulations.

UNIT-1 6 L

Introduction: Newtonian mechanics: Mechanics of a particle and a system of particles; Constraints and their classification, Examples of constraints, Degrees of freedom, Constraints, Generalized coordinates, Virtual displacement, Virtual work, and generalized forces, Two body Collisions - scattering in laboratory and Centre of mass frames, moment of inertia tensor, Non-inertial frames and pseudoforces.

UNIT-2 12 L

Lagrangian Dynamics: D'Alembert's principle and Lagrange's equations,Velocity-dependent potentials and dissipation function, Simple applications of the Lagrangian formulation,Variational principles and Lagrange's equations.

Central Force: Definition and properties of central force, Reduction to the equivalent one-body problem, The equation of motion and first integrals, The equivalent one-dimenmsional problem, and classification of orbits; The Virial theorem,The Kepler problem: Inverse-square law of force, Orbits of artificial satellites.

UNIT-3 9 L

Rigid Body Motion: The independent coordinates of a rigid body: Degrees of freedom and kinetic energy; orthogonal transformations, Eulerian Angles, Finite and infinitesimal rotation, Rate of change of a vector, The Coriolis effect, Angular momentum and kinetic energy of motion about a point, The inertia tensor and the moment of inertia, The eigenvalues of the inertia tensor and the principal axis transformation, Euler equations of motion, Torque free motion of rigid body.

Small Oscillations: Theory of small oscillations, Frequencies of free vibration and normal coordinates Free vibrations of a linear tri-atomic molecule, Forced vibrations and the effect of dissipative forces.

UNIT-4 9 L

The Classical Mechanics of the Special Theory of Relativity: Basic postulates of the special theory, Lorentz transformations, relativistic kinematics and mass–energy equivalence.

Hamiltonian Dynamics: Legendre transformations and the Hamilton equations of motion, Cyclic coordinates and conservation theorems, The Hamiltonian formulation of relativistic mechanics, Derivation of Hamilton's equations from a variational principle, The principle of least action, Hamilton's canonical equations, Hamilton's variational principle, Poisson brackets and other canonical invariants, The angular momentum Poisson bracket relations, Phase space and Liouville's theorem, The Hamilton-Jacobi theory, invariance and Noether's theorem.

Reference Books:

1. **Goldstein, H.**, (2011), Classical Mechanics, Pearson New.
2. **Rana, N. C. and Joag, P. S.**, (1991), Classical Mechanics, Tata McGraw Hill.
3. **Landau, L. D. and Lifshitz, E. M.**, (1960), Mechanics, Pergamon Press.
4. **Meirovitch, L.**, (1999), Methods of Analytical Dynamics, McGraw Hill.
5. **SrinivasaRao, K. S.**, (2003), Classical Mechanics, Universities press.

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Course Outcomes: Students will be able to:	
CO1	Relate symmetries to conservation laws in physical systems, and apply these concepts to practical situations.
CO2	Solve dynamical problems involving classical particles by using the Lagrangian and Hamiltonian formulation.
CO3	Demonstrate a working knowledge of classical mechanics and its application to standard problems such as central forces.

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Course Code PHPC 503	Quantum Mechanics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To familiarize the foundation of quantum mechanics.
CEO1	To introduce time evolution of quantum states & operators, and various quantum parameters.
CEO1	To familiarize students to the quantum dynamics and quantum analysis of angular Momentum.

UNIT-1 9 L

Fundamental Concepts: Problems with classical physics, Principle of superposition, Postulates of Quantum Mechanics, The corpuscular and wave models of light, Particle nature of radiation: Photoelectric and Compton effect, De Broglie's hypothesis: Wave-particle duality, The Davisson-Germer experiment, Stern- Gerlach experiment, The Franck-Hertz experiment.

UNIT-2 9 L

Formalism: Vectors and vector spaces, Hilbert space, Inner products, Matrices, Eigenvectors and eigenvalues, Hermitian transformations, Representations of Dirac delta function, The bra and ket notation, Linear operators. Observables, The completeness condition, Hermitian operators, Matrix representations, Heisenberg uncertainty principle, Commutators and uncertainty relations, Wave-functions in position and momentum space, Eigenfunctions of Hamiltonian operators.

UNIT-3 9 L

Schrodinger Wave Equation: Time-independent and time-dependent Schrödinger wave equation, Eigenvalue problems: particle in a box, the harmonic oscillator; Tunneling through a barrier, Dirac notation for state vectors. Delta function potential, energy eigenkets, Time dependence of expectation values, Spin precession; Schrödinger and Heisenberg picture.

UNIT-4 9 L

Theory of Angular Momentum: Quantum theory of orbital angular momentum, Raising and lowering operators, Eigenvalues and Eigenfunctions, Spin angular momentum, Addition of angular momenta, Symmetry, Invariance and conservation laws, Relation between rotation and angular momentum, commutation rules, Matrix representations, Clebsch-Gordan coefficients, Pauli spin matrices, Schrodinger Equation in Spherical Polar Coordinate, Hydrogen atom.

Reference Books:

1. Modern Quantum Mechanics: **J.J. Sakurai**, (Pearson Education (LPE), 2017).
2. Introduction to Quantum Mechanics: **David J. Griffiths** (Cambridge University Press, 2016).
3. Quantum Mechanics: Concept and Applications: **N. Zettili** (Wiley, 2009).
4. Principles of Quantum Mechanics: **R. Shankar**: (Springer, 1994).
5. Quantum Mechanics: Theory and Applications:**A.Ghatak and S. Lokanathan** (Macmillan, 2004).
6. Quantum Mechanics: **B. C. Reed** (Jones & Bartlett, 2010).
7. A Text book of Quantum Mechanics**, P.M. Mathews and K. Venkatesan** (Tata McGraw Hill).

Course Outcomes: Students will be able to:

CO1	Understand the concepts and methods in quantum mechanics.
CO2	Explore with different formalism of quantum mechanics, approximate methods and angular momentum algebra.
CO3	Understand the foundation equations and experiments.

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Course Code PHPC 505	Mathematical Physics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To train the students in the mathematical methods which are routinely used in the study of Physical Sciences.
CEO1	Will help the students in understanding the fundamentals of mathematical methods and how to use them inproblems routinely encountered in Physics.
CEO1	Will be familiar with vectors, complex analysis, Fourier series, integral transforms and special functions.

UNIT-1 **10 L**

Delta and Beta-Gamma Functions: Dirac delta function, Delta sequences for one-dimensional function, properties of the delta function, Gamma function, factorial notation and applications, Beta function.

Linear Vector Space and Matrices: Definition of Linear Vector Space, Basis and dimension, Scalar Product, Orthogonal And Orthonormal Basis, Gran-Schmidt orthogonalization, Linear operators, Matrices; Orthogonal, Unitary and Hermitian matrices, Eigenvalue and Eigenvectors, diagonalization, Hermitian and Unitary operator, Infinite dimensional space, Hilbert space, Linear vector space.

UNIT-2 **8 L**

Special Functions: Bessel's functions: Bessel's functions of first and second kind, Spherical Bessel function. Legendre functions: generating function, recurrence relations and special properties, orthogonality, and various definitions of Legendre polynomials. Associated Legendre functions: recurrence relations, parity, orthogonality, Hermite functions, Laguerre functions.

UNIT-3 **8 L**

Green Functions: Boundary value problems and Green functions, Green function for one-dimensional problems, Eigen function expansion of Green's function, Fourier transform method of constructing the Green function.

Fourier series and Integral Transforms: Fourier series, Dirichlet conditions. Fourier transforms Development of the Fourier integral, Inversion theorem, Momentum representation.

Laplace transforms: Laplace transforms of derivatives, and Properties of Laplace transform, Inverse Laplace transformation. Applications.

UNIT-4 **10 L**

Complex Variables: Functions of Complex Variable, Cauchy-Riemann conditions, Cauchy Integral Theorem, Cauchy Integral Formula, Taylor and Laurent Series, Singularities and their classification, The Residue Theorem, Evolution of Integral Using Residue Theorem.

Reference Books:

1. Mathematical Methods for Physicists: **G. Arfken and H.J.Weber** (Academic Press,San Diego) 7th edition,2012.
2. Mathematical Physics: **P.K.Chattopadhyay**(WileyEastern,NewDelhi),2004.
3. Mathematical Physics: **A.K.Ghatak,I.C.GoyalandS.J.Chua**(MacMillan,India,Delhi),1986.
4. Mathematical Methods in the Physical Sciences–**M.L.Boas**(Wiley,NewYork)3rd edition,2007.
5. Special Functions: **E.D.Rainville** (MacMillan,NewYork),1960.

Course Outcomes: Students will be able to:

CO1	Understand Linear vector calculus. They will learn about the general coordinate transformation and the relevant transformation equations.
CO2	Familiar with various special functions, solve corresponding differential equations and learn about their properties.
CO3	Familiar with the Fourier series and Laplace transformation and apply the learned concepts to some well-known examples.

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Course Code PHPC 507	Electrodynamics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	The course will enable the students to understand various laws of Electrostatics and Magneto statics including boundary value problems.
CEO1	Maxwell Equations for understanding propagation of electromagnetic waves in various media.
CEO1	It will also help the student to understand the origin of the electromagnetic radiations from an accelerating charge particle.

UNIT-1 **10 L**

Electrostatics and its applications: Electric field and electric potential, Electric dipole and multipole expansion, Divergence and curl of electric field and application of Gauss law, Poisson and Laplace equations in Cartesian and spherical polar coordinates, Electrostatic boundary conditions, Electrostatic energy- potential energy of a point charge and group of point charges-energy density of an electrostatic field, Force and torques, Conductors: Induced charges, Surface charge and force on conductors, capacitors, Electric fields in dielectric media, Polarization.

UNIT-2 **8 L**

Electrostatic boundary value problems with Green's function: Method of Images–Point charge near the grounded conducting sphere, insulated conducting sphere, conducting sphere in a uniform electric field, Green function for the sphere, general solution for the potential,

Magneto statics: Biot-Savart law, Ampere's circuital theorem, Divergence and curl of magnetic field, Applications of Ampere's law, Magnetic vector potential, Boundary conditions, Magnetic field in matter, Electromotive force, Electromagnetic induction, Faraday's law of induction, self-inductance and mutual inductance magnetic energy of steady current distributions. Conservation laws, Equation of continuity.

UNIT-3 **8 L**

Potentials and Fields: Maxwell equations in vacuum and medium, Displacement current, Vector and scalar potentials, Gauge transformations, Coulomb and Lorentz gauges, Green's function for wave equation, Retarded Potential, Jefimenko equations, Lienard-Wiechart potentials, field of moving point charges, Power radiated by a moving point charge, electromagnetic energy and momentum, Electromagnetic energy – Poynting vector, wave equation, Electric and magnetic dipole radiation. Lorentz invariant form of Maxwell equation, Field tensors, Electrodynamics in tensor notation, Relativistic potentials.

UNIT-4 **10 L**

Electromagnetic Waves: Plane waves in a dielectric medium, Plane waves in conducting media, Propagation of electromagnetic waves, Reflection and refraction at dielectric interfaces, Complex Fresnel coefficients – reflection from a conducting plane, Reflection and transmission by a thin layer- interference, Dispersion relations in plasma, Optical dispersion in materials; dielectric constant and anomalous dispersion, Frequency dependence of permittivity; Electromagnetic radiation: Radiation from moving charges and dipoles. Transmission lines and waveguides.

Reference Books:

1. **John R. Reitz, Frederic J. Milford and Robert W. Christy,** Foundations of Electromagnetic Theory,3rd Edition, Narosa Publishing House, New Delhi. (2012).
2. **D.J. Griffiths**, Introduction to Electrodynamics. 4th Edition, PHI Learning, New Delhi.(2012).
3. **J.D. Jackson**, Classical Electrodynamics. 3rdEdition,Wiley India.(1998).
4. **Jordan E.C. and Balmain K. G.**, Electromagnetic Waves and Radiating Systems, 2nd Edition, Prentice Hall.

Course Outcomes: Students will be able to:

CO1	Learn Fundamentals and applications of various laws of electricity and magnetism.
CO2	Solve Maxwell equations in free space and for harmonically varying fields.
CO3	Solve Electromagnetic wave equations in conducting as well as in non-conductingmedia.

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Course Code PHPC 509	Nuclear and Particle Physics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To give understanding of basics of atomic nuclei and nuclear forces.
CEO1	To gain knowledge about origin of different types of radiation decay theories.
CEO1	To develop the understanding of nuclear energy and nuclear reactors for energy generation.

UNIT-1 **8 L**

Properties of nuclei: Nuclear radii and measurements, nuclear binding energy, nuclear moments and systematic, wave-mechanical properties of nuclei, Hyperfine structure, effect of external magnetic field, Nuclear magnetic resonance. Nuclear forces, types of nuclear potential, Ground and excited states of deuteron, dipole and quadruple moment of deuteron, n-p scattering at low energies, Scattering length, spin-dependence of n-p scattering, effective-range theory, coherent and incoherent scattering, p-p scattering, meson theory of nuclear forces, Deuteron problem.

UNIT-2 **10 L**

Radio Active Decays: Kinematics of alpha-decay, naturally occurring decay chains, Range of alpha particles (Bragg Curve), Geiger-Nuttal law, Gammow's theory of alpha decay.
Beta decay and electron capture, Neutrino hypothesis, Energy relations and Q-valuesin beta decays, Fermi theory of beta decay, Kurie plots, Comparative half-life, Classification of beta transitions, selection rules for allowed and forbidden transitions, violation of parity conservation, Electric and magnetic multipole gamma transitions, selection rules, Internal Conversion process, Transition rates, directional correlation in gamma emission.

UNIT-3 **8 L**

Nuclear Models: The Liquid drop model, semi-empirical mass formula, Shell model, Physical concepts of the unified model.
Particle Accelerators: Cosmic rays, radioactive sources, Accelerators: Vande Graff, Tandem, LINAC, 15UD Pelletron, Cyclotron and Betatron, Ion sources, Applications of accelerators in research and Technology.
Synchrotron radiation: Polarization, coherence and emittance.

UNIT-4 **10 L**

Particle Physics: Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, the Eightfold way, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics, Introduction to Standard Model of Particle Physics.

Reference Books:

1. Nuclear Physics: **Irving Kaplan** (Narosa), 2002.
2. Basic Ideas and Concepts in Nuclear Physics: **K. Hyde** (Institute of Physics) 2004.
3. Introduction to Nuclear Physics; **Herald Enge** (Addison-Wesley) 1971.
4. Theory of nuclear structure by **M.K. Pal** (Affiliated East-Wast Press, 1982)
5. Nuclear reaction and nuclear structure by **P.E. Hodgson** (Clarendon Press, 1971)
6. Nuclear Instrumentation: **W. J. Price**.

Course Outcomes: Students will be able to:

CO1	Understand different types of radiation sources.
CO2	Improve regarding origin of radiation and its applications.
CO3	Understand the production of energy using reactors.

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Course Code PHPC 511	Physics Lab	Credits 0-0-6: 3

Course Educational Objectives :

CEO1	To familiarize with the operation of basic laboratory instruments and will gain practical knowledge for the laboratory procedures and techniques.
CEO2	To learn steady and dynamic phenomena along with instruments' calibration
CEO3	To be able to used computer-controlled instruments and data acquisition.

S. No. Experiments

1. Michelson interferometer: determination of thin optical film thickness.
2. Find the type of charge carriers and their concentration for a semiconductors sample using Hall Effect.
3. Determination of Planck's constant through photoelectric effect.
4. Find the electrical resistivity and activation energy of semiconducting thin film by four probe method.
5. Study the effect of temperature on luminescence phenomena.
6. Determination of magneto resistance for the given semiconductor.
7. Study the ferromagnetic behavior of the ferromagnetic sample.
8. Solar cell performance evaluation.
9. Ultrasonic Interferometer (measurement of velocity of sound in solids and liquids)
10. To verify the inverse Square law for Gamma rays with sodium Iodide based Scintillation Counter using Single channel analyzer.
11. To study the calorimeter for determination of concentration of the given solution.

Reference Books:

1. Optics and Nuclear Physics lab manual provided at M.Sc. Lab, Department of Physics, NITKurukshetra.

Course Outcomes: Students will be able to:

CO1	Familiarize with the operation of basic laboratory instruments and will gain practical knowledge for the laboratory procedures and techniques.
CO2	Measure steady and dynamic phenomena and calibrate instruments.
CO3	Utilize computer-controlled instruments and data acquisition techniques.

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Course Code PHPC 513	Computational Physics Lab	Credits 0-0-4: 2

Course Educational Objectives :

CEO1	To give some hands-on experience learning various computational methods in Physics.
CEO2	To Provide training to apply real time problems numerically.
CEO3	Application of Computational Methods in Physics.

S. No. Experiments

MATLAB:

1. Write code to generate Fibonacci Numbers and golden ratio.
2. Least Chi-Squre fitting of linear and non-linear functions to a given experimental data sets and its Likelihood.
3. Write code to determine various order of propagation coefficients of modes in optical wave guides using Taylor series.
4. Write code to solve time independent Schrodinger equation for the 1D potential box and print spectrum of modes.
5. Write code to find the equation of motion for a simple pendulum and show graphical output.
6. Write code for decay and half-life of Radioactive Nucleus.
7. Write code to find out Eigenvalues of the given vectors and inverse of the vectors.

COMSOL:

8. Software basics geometry and materials using wave optics module in COMSOL Multiphysics, Messing a model.
9. Determination of effective refractive indices of various propagating modes in optical fiber.
10. Determination of propagation loss in the optical fibers and waveguides.
11. Determination of Dispersion of various modes propagating in waveguides

Reference Books:

1. Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers-- RudraPratap, Oxford University Press.
2. COMSOL Multiphysics-- https://www.comsol.com/

Course Outcomes: Students will be able to:

CEO1	Write code in programing languages to build up some logic to solve Physics problems.
CEO2	Use some advance language and functions/modules therein for solving simulation models, analysis and simulation verification.
CEO3	Perform analytical integrations as well as numerical integrations using software.

M.Sc. (PHYSICS)

Course Code PHPC 502	Solid State Physics	Credits 3-0-0: 3

Course Educational Objectives:

CEO1	To familiarize the students about the fundamentals of Solid State Physics.
CEO1	To develop understanding of crystal structures, defects, thermal and electronic properties of solids.
CEO1	To develop understanding of classification of various condensed matter systems

UNIT-1 **10 L**

Crystal Physics: Crystalline and non-crystalline solids, Bonding in solids- Ionic; covalent and metallic solids; van der Waals interaction; hydrogen bonding, Bravais lattice; lattice planes and directions; typical crystal structures, Reciprocal lattice; Bragg's law of diffraction; structure factor, Defects and dislocations- Point defects- Frenkel and Schottky defects, colour centers, excitons. Dislocations- models of screw and edge dislocations. Surface imperfections- grain boundaries, tilt boundaries, twin boundaries and stacking faults, Volume defects, Quasi Crystals, Liquid Crystals.

UNIT-2 **8 L**

Lattice Vibrations and Thermal Properties: Monoatomic and diatomic lattices, normal modes of lattice vibration, phonons and density of states, dispersion curves, specific heat- classical, Einstein and Debye models, Electronic contribution to specific heat. Thermal expansion, thermal conductivity, Seebeck effect, Peltier effect, Thomson effect.

UNIT-3 **8 L**

Electronic Properties: Classical Free Electron (Drude–Lorentz) theory, Electrical Conductivity, mobility, Sommerfeld Free Electron Theory, Concept of Fermi level, Fermi-Dirac distribution function, Charge carrier density, Thermal Conductivity, Wiedemann-Franz law, Motion of electron in a magnetic field: cyclotron resonance and Hall effect, Failures of free electron theory.

UNIT-4 **10 L**

Energy Band Theory: Energy spectra of atoms, molecules and solids- formation of energy bands, Kronig-Penny Model, Wave equation of electron in periodic potential, Bloch theorem and crystal momentum, E-K diagram, Brillouin Zones, construction of Brillouin zones- extended, reduced and periodic zone schemes, effective mass of an electron, nearly free electron model, tight binding approximation, Classification into metals, semiconductors and insulators.

Reference Books:

1. **Kittel, C.**: Introduction to Solid State Physics, Wiley (2007).
2. **Ashcroft and Mermin**: Solid state Physics, Thomson (2007).
3. **Ali Omar:** Elementary Solid State Physics, Addison-Wesley (2005).
4. **M A Wahab:** Solid State Physics-Structure and Properties of Materials, Narosa (2005).

Course Outcomes: Students will be able to:

CO1	Understand the basics of crystal structures, crystal structure determination, crystal defects and their role in various applications.
CO2	Predict electronic and thermal properties of materials and explain their origin.
CO3	Explain the concept of energy bands and effect of the same on electronic properties and classification of various condensed matter systems.

M.Sc. (PHYSICS)

M.Sc. (Physics): First Year Semester-II

Course Code PHPC 504	Advanced Quantum Mechanics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	to enable the students to understand the basic techniques & methods of quantum mechanics
CEO2	Student will be made familiar with, scattering theory, perturbation theory and relativistic quantum mechanics
CEO3	Students may apply these methods in various fields of research and development.

UNIT-1 10 L

Perturbation Theory: Time-independent perturbation theory for non-degenerate and degenerate states. First and second-order perturbation, Applications to theanharmonic oscillator, The fine structure of Hydrogen atom, Normal and anomalous Zeeman effect, Hyperfine splitting.

UNIT-2 8 L

Variational Principle: Introduction to variational Principle, Ground state energy of one-dimensional Harmonic Oscillator, Delta function potential, Infinite Square well, Quadratic Potential. The ground state of Helium.

UNIT-3 10 L

WKB Approximation: Introduction to WKB approximation, Classical region, Potential well with two vertical walls, variational Step potential with tunnelling, Gamow's Theory of Alpha decay.

Time-Dependent Perturbation Theory: Time-dependent perturbation theory, transition probability, constant and harmonic perturbation, Fermi golden rule, Electric dipole radiation and selection rules. Applications—Zeroth order, first order, second order, two-level systems, Spontaneous emission, Einstein's A and B coefficient.

UNIT-4 8 L

The Adiabatic Approximation: The Adiabatic Theorem, Problems of time-dependent potential wells. Applications. **Scattering:** Classical ScatteringTheory, Partial Wave analysis for Spherically Symmetric potential, The Born approximation.

Reference Books:

1. **S.Gasiorowicz**, Quantum Physics, Wiley
2. Modern Quantum Mechanics: **J.J. Sakurai**, (Pearson Education (LPE), 2017).
3. Introduction to Quantum Mechanics: **David J. Griffiths** (Cambridge University Press, 2016).
4. Principles of Quantum Mechanics: **R. Shankar**: (Springer, 1994).
5. Quantum Mechanics: **B. C. Reed** (Jones & Bartlett, 2010).

Course Outcomes: Students will be able to:

CO1	Learning how scattering amplitude and scattering cross-section are related to each other.
CO2	Demonstrate fundamental knowledge of relativistic quantum mechanics and quantum field theory.
CO3	Develop second quantization method for free fields.

M.Sc. (PHYSICS)

Course Code PHPC 506	Thermodynamics and Statistical Physics	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To understand the fundamental aspects of Statistical Physics and thermodynamical properties.
COE2	To understand the behavior of thermodynamical system in terms of macroscopic and microscopic variables.
COE3	To construct statistical formalism for fermion as well as bosonic system and analyze their properties.

UNIT-1 **10 L**

Fundamental Concepts:Basic concepts and definitions. State variables and equations of state. Work, heat, and energy. Laws of thermodynamics and their significance. Thermodynamic potentials: Maxwell relations. Significance of entropy.Need for statistical physics, models of macroscopic systems, Macroscopic and Microscopic states, Phase space, Liouville's theorem, energy quantization, Probability distributions, Boltzmann's principle, Partition function, Ensembles: Micro-canonical, canonical, and grand canonical.Statistical interpretation of entropy

UNIT-2 8 L

Classical Statistics: Maxwell-Boltzmann distribution, Equipartition theorem, Virial theorem, Langevin and Brillouin functions, Applications: Specific heat of gases, Real gases, Paramagnetism, Curie's law, Nuclear spins, Ortho and para hydrogen, Negative temperature concept, System of harmonic oscillators

UNIT-3 **10 L**

Bose Einstein and Fermi Dirac Statistics: Systems of identical, Indistinguishable particles, Spin and symmetry of wavefunctions, Bosons, Fermions, Pauli's exclusion principle, Bose-Einstein and Fermi-Dirac distributions, Degeneracy, Ideal Fermi gas and ideal Bose gas, Applications of Bose Einstein and Fermi Dirac Statistics –Statistical treatment of blackbody radiation,Liquid helium, Free electron gas and its behaviour, Specific heat of crystalline materials – Einstein and Debye theories.

UNIT-4 8 L

Phase Transitions and Critical Phenomena: Introductory ideas on phase transitions,Phase equilibrium and phase diagrams, First order phase transition: Theory of Lang and Lee, Dynamical model of phase transitions: Weiss theory of ferromagnetism, Second order phase transition: Landau theory, Order parameter and Landau free energy expansion, Critical point exponents.Transfer matrix approach.

Reference Books:

1. **R. K. Pathria,** Statistical Mechanics (II Ed.), Butterworth-Heinemann (1996).
2. **Kerson Huang**, Statistical Mechanics, II Ed, John Wiley (1987).
3. **Herbert B. Callen,** Thermodynamics (II Ed.) Wiley (1985).
4. **E. Atlee Jackson,** Equilibrium Statistical Mechanics, Prentice-Hall (1968).
5. **F. Reif,** Fundamentals of Statistical and Thermal Physics, McGraw-Hill (1985).

Course Outcomes: Students will be able to:

CO1	Develop the concept to understand the thermodynamical many particles system in terms of microscopic and macroscopic variables.
CO2	Apply statistical mechanics as a tool to investigate Fermionic system as well as bosonic system.
CO3	Understand new state of matter called Bose-Einstein Condense states for bosonic system.

M.Sc. (PHYSICS)

Course Code PHPC 508	Electronics	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To familiarize the students about Bias the transistors and FETs for amplifier applications.
COE2	To develop understanding of design op-amp circuits to perform arithmetic operations.
COE3	To develop understanding of design simple analog circuits.

UNIT-1 9 L

Active and Passive Components: Resistors, capacitors and Inductors, Thevenin's, Norton's and superposition theorems; Diodes and its applications: Rectifiers, Clippers and Clampers, Voltage multipliers, Bipolar Junction Transistors (BJT): Characteristics, parameters and configurations, Field Effect Transistors: JFET and MOSFET Characteristics.

UNIT-2 9 L

Amplifiers: Classification of Amplifiers, Cascading of amplifiers, Types of power amplifiers, Amplifier characteristics, Feedback in amplifiers, Feedback amplifier topologies, Effects of negative feedback;
Operational Amplifiers: Basics, Feedback, Mathematical operations, Circuits and Applications;
Oscillators and Multivibrators: Classification and basic principle of oscillator, Feedback concepts, Types of oscillator, Classes of multivibrators, The 555 Timer.

UNIT-3 9 L

Boolean algebra: Number system, binary codes, DeMorgan's Theorem;
Logic Operations/Gates : OR, AND, NOT, NAND, NOR, XOR, XNOR);
Minimization of logic functions: Karnaugh map (K-map), K-map reduction and logic function implementation, K-maps for SOP, POS.

UNIT-4 9 L

Digital Circuits: Combinational circuits: Adder, Multiplexer, DE multiplexer, Encoder, and Decoder; Clock and timing circuits: Clock waveform, Schmitt Trigger, 555 Timer-A stable and Monostable; Sequential logic elements: Flip-Flops (SR, J-K, Master slave, T-flip flops etc.), Registers and counters, D/A and A/D conversions.
Microprocessor and Microcontroller Basics: Introduction, Outline of 8085/8086 processor, Data analysis.

Reference Books:

1. **J. Millman& Grable**, Microelectronics.
2. **Malvino and Leach**, Digital Principles & Applications
3. **J. D. Ryder**, Electronic fundamental and applications.
4. **Ramesh S. Gaonkar** , Microprocessor Architecture, Programming and its Applications with the 8-85/8080A latest edition
5. **Fraser**, Telecommunications.

Course Outcomes: Students will be able to:

CO1	Illustrate the basic concepts and applications of different modern electronic devices.
CO2	Apply fundamental concepts of digital electronics for construction of logic circuits.
CO3	Design different active and passive electronic circuits such as amplifiers and oscillators.

M.Sc. (PHYSICS)

Course Code PHPC 510	Atomic and Molecular Physics	Credits 3-0-0: 3

Course Educational Objectives:

COE1	To understand the fundamental aspects of atomic physics and analysis of spectra
COE2	To understand the behavior of atoms in external applied electric and magnetic
COE3	To construct and analyze the rotational, vibrational spectra of molecules.

UNIT-1 10 L

Atomic Physics: Electron spin and vector atom model, Fine structure of hydrogen and hydrogen-like atoms-mass correction, Spectrum of He atom, Spin-orbit term, Darwin term, Intensity of fine structure lines, the ground state of two-electron atoms-perturbation theory and variation method. Many electron atoms- LS and JJ coupling schemes, Lande interval rule. Terms for equivalent & non-equivalent electron atom, Space Quantization: Stern-Gerlach experiment, normal & anomalous Zeeman effect, Stark effect, Paschen-Back effect; Intensities of spectral line: General selection rule, Hyperfine Structure, Isotope Shifts and Nuclear Size Effects, Spectra of Alkali elements.

UNIT-2 8 L

Molecular Physics: Separation of Electronic and Nuclear motion, Description of Molecular Orbital and Electronic Configuration of Diatomic Molecules: H^2, H^{2+}, Co-relation diagram for hetero-nuclear molecules, Rotational spectra of diatomic molecules: Molecule as a Rigid Rotator and non rigid rotator, Isotope effect on rotational spectra, Vibrational spectra of Diatomic molecules: Molecule as a Harmonic oscillator and anharmonic oscillator, Isotope effect on vibrational levels, fine structure of Infrared bands: Molecule as vibrating rotator.

UNIT-3 8 L

Molecular Spectra: Types of molecular spectra: Infrared and Far-infrared spectra, Theory of Raman scattering, Pure rotational Raman Spectra, vibrational Raman spectra, Nuclear spin and intensity alternation in Raman spectra, Isotope effect and Raman spectrometer.

UNIT-4 10 L

Electronic Spectra: Born-Oppenheimer approximation, Vibrational coarse structure of electronic bands, Intensity of electronic bands-Franck Condon Principle, Dissociation and pre-dissociation, Dissociation energy, Rotational fine structure of electronic bands, The Fortrat-parabole, Electronic structure of diatomic molecules; UV-Visible Absorption spectroscopy: Lambert-Beer law, Absorption spectrometer, Emission spectroscopy: Jablonski diagram,Fluorescence and Phosphorescence, Kasha's rule, Quantum Yield, Non-radiative transition,Spectrofluorometer.

Reference Books:

1. Concept of Modern Physics by **Arthur Beiser** (McGraw-Hill Book Company, 1987).
2. Atomic spectra & atomic structure, **Gerhard Hertzberg**, Dover publication, New York.
3. Molecular structure & spectroscopy, **G. Aruldhas**, Prentice – Hall of India, New Delhi.
4. Fundamentals of molecular spectroscopy, **Colin N. Banwell& Elaine** M. McCash,
5. Introduction to Atomic spectra by **H.E. White.**
6. Spectra of diatomic molecules by **Gerhard Herzberg.**
7. Principles of fluorescence spectroscopy by **Joseph R. Lakowicz.**

Course Outcomes: Students will be able to

CO1	Distinguish between Normal Zeeman effect and Anomalous Zeeman effect and will understand Hyperfine structure and Lamb shift.
CO2	Explain LS Coupling, J-J Coupling and Paschen Back effect.
CO3	Interpret Infrared Spectroscopy and Rotational Raman Spectra.

Awasthi

M.Sc. (PHYSICS)

Course Code PHPC 512	Electronics Lab	Credits 0-0-4=2

Course Educational Objectives :

COE1	To familiarize with the operation of basic laboratory instruments and will gain practical knowledge for the laboratory procedures and techniques.
COE2	To learn steady and dynamic phenomena along with instruments' calibration
COE3	To be able to used computer-controlled instruments and data acquisition.

S. No. Experiments

1. Measurement of displacement using LVDT and study its characteristics (Linear Variable Differential Transformer).
2. To study the working of Operational amplifier 741 and to conduct following experiments:
   (a) Input bias current measurement
   (b) Input offset current measurement
   (c) Gain measurement in the inverting and non-inverting configuration.
   (d) Verification of existence of drift
3. To study the features of an IC integrated timer circuit 555 and to setup and operate the following basic circuits using the timer:
   (a) A free running a-stable-multivibrator
   (b) A mono-stable-multivibrator
   (c) A long duration multivibrator
4. To study IC 723 as a current and voltage regulator.
5. To study the frequency response of a low pass filter using FunctionGenerator and CRO.
6. Characterization of moving objects with Stroboscope.
7. Investigation of properties of Temperature controller
8. Familiarization and Characterizations of Lock-In-amplifier.
9. Design and set up a 4:1 Multiplexer (MUX) using only NANDgates. And to design and set up a 1:4 De-multiplexer(DE-MUX) using only NAND gates.
10. To verify the truth table of basic gates (NOT, AND, OR) and universal gates (NAND and NOR).
11. To determine the frequency Signal by comparing the frequencies of two oscillators using Lissajous Figures.

Reference Books

1. Physics lab manual provided at M.Sc. Lab, Department of Physics, NITKurukshetra.

Course Outcomes: Students will be able to:

CO1	Learn how to handle electronic equipment such as DSO, Function generator, Spectrum analyzer, etc.
CO2	Design different electronic circuits and study their performances.
CO3	Examine the output results of different electronic components as well as complete circuit.

M.Sc. (PHYSICS)

Course Code PHPC 514	Advanced Physics Lab	Credits 3

Course Educational Objectives:

COE1	To familiarize with the operation of Advanced Physics laboratory experiments and techniques.
COE2	To familiarize the students on the analysis of real-time samples.
COE3	To accomplish the experimental verification of the theatrical concepts using sophisticated experimental set-ups.

S. No. Experiments

1. Determine the structure and phase of a given sample using X-ray Diffractometer (XRD).
2. Determine the particle size and morphological properties of a given sample using Scanning Electron Microscope (SEM).
3. Analysis of Polarization vs. Electric Field (P-E) Characteristics of a given ferroelectric sample.
4. Analysis of dielectric properties of a given sample.
5. Construct the Hartley Oscillator and study its properties.
6. Analysis of Junction Field Effect Transistor (JFET) Characteristics.
7. Analysis of Metal-Oxide-Field Effect Transistor (MOSFET) Characteristics.
8. Particle size/ diameter of wire using He-Ne Laser.
9. Determination of wavelength of Laser.
10. Characterization of the single mode and multimode optical fibers for their losses.
11. Striping and Cleaving of Optical Fibers for integration into optical devices.
12. To record the Franck-Hertz characteristic curve for neon.
13. To observe the Zeeman splitting of the green mercury line using Fabry-Perot etalon for normal transverse and longitudinal configuration.
14. Measurement of Numerical Aperture of Optical Fibers and the beam profile of a single mode optical fibre
15. Assignment of the vibrational modes of a given sample using Fourier-Transform-Infrared Spectrometer (FTIR).
16. To Determine the Energy bandgap of a given solid sample using Diffused Reflectance Spectroscopy (DRS).
17. To study the characteristics of GM counter.
18. To study the nuclear counting statistics using GM counter.

Reference Books

1. Advanced Physics Lab manual provided at M.Sc. Lab, Department of Physics, NIT Kurukshetra.

Course Outcomes: Students will be able to:

CO1	Gain practical knowledge for the laboratory procedures and techniques towards their research career.
CO2	Apply the analytical skills for the real-time societal applications.
CO3	Design and develop the practical devices for societal applications.

M.Sc. (PHYSICS)

M.Sc. (Physics): Second Year Semester-I

Course Code PHPC 515	Advanced Electronics	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To familiarize the students about advanced electronic devices and their applications.
COE2	To develop understanding of design Digital circuits and interfacing simple systems using Microcontrollers.
COE3	To develop understanding of Communication systems.

UNIT-1 **9 L**

SemiconductorDevices: Drift and diffusion of carriers, Generation and recombination of charges, Direct and indirect semiconductors. P-N junction, diode equation, barrier width and Capacitance of PNjunctions,Varactor, switching diode, FET as switch and amplifier, Optoelectronic Devices: LEDs, Diodes Lasers, Photodetectors and Solar Cells,

UNIT-2 **9 L**

Advanced Electronic Devices: Metal Oxide Field Effect Transistors (MOSFET), Short Channel Effects in MOSFET, Fin Field-Effect Transistors (FinFETs),Ferroelectric field effect devices and 2D nanosheet devices; Emerging Memory devices: DRAM, ReRAM, FeRAM and Phase Change memory (PCM) and universal memory devices.

UNIT-3 **9 L**

Analog Systems: Phase-lock loop and its applications frequency multiplication; Analog multiplier and its applications; log and antilog amplifiers; Instrumentation amplifiers;
Sensors: Temperature, Magnetic field, Displacement, Light intensity and Force sensors
Design of combinational circuits: Programming logic devices and gate arrays, 7- segment and LCD display system, digital gain control, analog multiplexers, PC based measurement system;
Design of Sequential circuits: Different types of A/D and D/A conversion techniques, TTL, ECL, MOS & CMOS operation and specifications.

UNIT-4 **9 L**

Communication Systems: Concepts of communication systems, role of electromagnetic spectrum, elementary ideas about terminology of communication systems, Need for modulation, amplitude, frequency, pulse amplitude, pulse position, pulse code modulation, Information in communication system, Coding, Types of Pulse modulation, Pulse width modulation (PWM), Pulse position Modulation (PPM), Principle of Pulse code modulation (PCM); Introduction to digital communication.

Reference Books:

1. **S. M. Sze**, Physics of semiconductor devices.
2. **J. Millman& Grable**, Microelectronics.
3. **Santosh K. Kurinec**, Nanoscale Semiconductor Memories.
4. **Malvino and Leach**, Digital Principles & Applications.
5. **Fraser**, Telecommunications
6. **J. D. Ryder**, Electronic fundamental and applications.
7. **G. Kennedy,** Electronic Communication Systems.

Course Outcomes: Students will be able to:

CO1	Illustrate the basic concepts and applications of different Analog systems.
CO2	Design different digital electronic circuits such as 7 segment and LCD display systems.
CO3	Illustrate the basic concepts of Communication systems and emerging electronic memory devices.

M.Sc. (PHYSICS)

Course Code PHPC 517	Condensed Matter Physics	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To familiarize the students about the fundamentals of Semiconductor Physics and its applications.
COE2	To develop understanding of dielectric behavior of materials in electro- magnetic fields.
COE3	To develop understanding of magnetic and superconducting behavior of various condensed matter systems.

UNIT-1 **10 L**

Semiconductors: Semiconductor materials, Crystal structure, Elemental and compound semiconductors, Energy bands, Direct and indirect Band gap semiconductors, Density of states, effective mass, donors and acceptors, Degenerate and Non-degenerate Semiconductors, Equilibrium and extrinsic carrier concentration, carrier transport, Drift and Diffusion current, mobility, Einstein relation, Excess carrier generation and recombination, Hall effect in semiconductors, Diodes, solar cell, LEDs.

UNIT-2 **8 L**

Dielectrics: Polarization, Bound Charges, Electric displacement, susceptibility, dielectric coefficient, and permittivity, Dielectrics in AC fields, Clausius- Mossotti equation, polarizability- classical theory of electronic polarizability, dipolar polarizability, Effect of temperature and frequency on dielectric constant and dielectrics loss factor, Piezo-, Pyro- and ferroelectric solids, ferroelectric domains, ferroelectricity, anti-ferroelectricity and ferrielectricity, Applications of dielectrics.

UNIT-3 **8 L**

Magnetism: Classification of magnetic materials, origin of permanent magnetic moments, Langevin's classical theory of diamagnetism, Magnetic susceptibility, Quantum theory of paramagnetism, ferromagnetism, Weiss theory, ferromagnetic domains, Ferromagnetic order, Hysteresis, anti-ferromagnetism, Curie temperature and Neel temperature, ferrimagnetism and anti-ferrimagnetism, Susceptibility measurements- Guoy Balance; Quincke's method.

UNIT-4 **8 L**

Superconductors: Zero resistivity, Critical temperature, Meissner effect, London equation, Type I and II superconductors, thermodynamics, superconducting band gap, Cooper pairs, flux quantization, BCS theory, Josephson Effect, SQUIDS, High temperature superconductors, Applications of superconductivity.

Reference Books:

1. **Kittel, C.**: Introduction to Solid State Physics, Wiley (2007).
2. **Ben G. Streetman**, Prentice-Hall of India, Solid State Electronic Devices, 2012
3. **Jaspreet Singh**, John Wiley, Semiconductor Devices-Basic Principles, publication 2008
4. **M A Wahab**: Solid State Physics-Structure and Properties of Materials, Narosa (2005).

Course Outcomes: Students will be able to:

CO1	Understand the Semiconductor Physics and strategies for realizing its various applications.
CO2	Disseminate their understanding on behaviour of dielectric materials in electro- magnetic fields.
CO3	Understand the concept of superconductivity and magnetism.

M.Sc. (PHYSICS)

Course Code PHPC 519	Analytical Instrumentation Lab	Credits 0-0-6: 3

Course Educational Objectives :

COE1	To familiarize with the operation of basic laboratory instruments and will gain practical knowledge for the laboratory procedures and techniques.
COE2	To learn steady and dynamic phenomena along with instruments' calibration.
COE3	To be able to used computer-controlled instruments and data acquisition.

S. No. Experiments

1. To understand the microstructural features of ceramics/metals by optical microscopy.
2. Complex impedance spectroscopy for electronic property evaluation.
3. Investigate the electrical polarization properties of a given compound by tracing its P-E curve.
4. To monitor the Reflection and Transmission spectrum of thin film using Charge coupled detector.
5. FTIR study of an inorganic and organic compound.
6. Measurement of Thermal and Electrical conductivity of metals.
7. Testing of a metal bar using Ultrasonic flaw detector.
8. NaI Scintillation detector: Energy calibration of the sodium iodide based gamma-ray Scintillation detector.
9. NaI Scintillation detector: Determination of potassium activity of unknown radioactive sample using 8 K Multi- channels Analyzer System.
10. To record and analyze electroencephalograms (EEGs) from a volunteer to look at the effect of various interfering signals.
11. Photo luminescence spectrum of an inorganic phosphor.
12. To study and analyse the UV visible spectrum of a sample.

Reference Books

1. Analytical Instrumentation lab manual provided at M.Sc. Lab, Department of Physics, NITKurukshetra.

CO1	Learn the instrumentation details of the analytical equipment and the importance and function of each individual component.
CO2	Learn how to handle analytical equipment such as SEM, XRD, UV-Vis spectrometer, XRF, FTIR and P-E loop tracer.
CO3	Learn the output data analysis and understand the material properties.

M.Sc. (PHYSICS)

Course Code PHPE551	Quantum Field Theory	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To familiarize the students about interaction among fundamental entities of the universe.
COE2	To develop understanding of perturbation theory and Feynman Rules to apply in high energy scattering measurements.
COE3	To develop understanding of bound state structure.

UNIT-1 **10 L**

Relativistic Electrodynamics: Maxwell's Equations in Relativistic Form, four-current, four-potential, The Field Strength Tensor, Maxwell's inhomogeneous and Homogeneous equations, Transformation Law for Electric and Magnetic Fields.

The Klein-Gordon Field: Elements of Classical Field Theory, The Klein-Gordon field as Harmonic Oscillator, The Klein-Gordon field in Space-time, Classical Propagator and particle creation by a classical source.

UNIT-2 **8 L**

The Dirac Field: Lorentz invariance in Wave Equations. The Dirac equations and Weylspinors, Free particle solutions of the Dirac Equations and Spin sum rule, Dirac Matrices and Dirac Field Bilinears, Quantization of the Dirac Field, The Dirac Propagator, Discrete symmetries of the Dirac Theory, Parity, Time Reversal, Charge Conjugation.

UNIT-3 **8 L**

Quantum Electrodynamics and Feynman diagrams: Perturbation Theory and expansion of Correlation functions. Wick's Theorem, Feynman Diagrams, Cross-sections and the S-matrix calculation from Feynman diagrams, Feynman Rules for Fermions, Yukawa Theory, Feynman Rules for Quantum Electrodynamics, The Coulomb Potential.

UNIT-4 **10 L**

Applications to Elementary process: Electron Muon High Energy Scattering, Trace technology, Unpolarized Cross-Sections, Helicity Structure, Crossing Symmetry, Mandelstam Variables, Compton Scattering, Photon Polarization Sum, Klein-Nishina Formula, Pair annihilation into photons.

Reference Books:

1. Quarks and Leptons: An Introductory Course in Modern Particle Physics, **F. Halzen and A. Martin**, John Wiley & Sons, 1993.
2. Introduction to elementary Particles, **D. J. Griffiths**, John Wiley & Sons, 2006.
3. The strange Theory of Light and Matter, **RichardP**. Feynman, Prinston University Press, 1983.
4. Quantum Electrodynamics, **W. Greiner, J. Reinhart**, Springer, 2003.
5. Photons and Atoms: Introduction to quantum electrodynamics, **C. Cohen-Tannoudji, J. D. Roc, G. Grynberg**, WILEY VCH Verlag GmbH & Co. KGaA, 1997.
6. A first Book of Quantum Field Theory, A. Lahiri, P. B. Pal, Narosa Publication, 2007.

Course Outcomes: Students will be able to:

CO1	Estimate the interaction strength among fundamental constituent of the universe.
CO2	Apply Feynman rules technique to the high energy scattering process measured in experiments like LHC, COMPASS, HERA, LEP etc.
CO3	Cultivate critical thinking on symmetries and conservation laws involved in cutting edge research.

M.Sc. (PHYSICS)

Course Code PHPE 553	Lasers and Spectroscopy	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To develop the understanding of Laser technology and Laser based devices.
COE2	To learn Vibrational spectroscopy and related technologies.
COE3	To understand various laser based detection techniques and instrumentation.

UNIT-1 9 L

Laser fundamentals: Einstein coefficients, Population inversion, Line shape function, Line broadening, Three level system, Four level system, Optical resonators, Laser cavity design; cavity modes, laser spiking, gain saturation, Laser properties, Pulse amplification techniques (Q-Switch, Mode-locking), Coherence properties of light, optimization of laser output.

UNIT-2 9 L

Laser devices: Solid State Lasers: Concept, design and applications, Nd:YAG Laser, Semiconductor lasers, Gas laser systems: He:Ne, CO_2 laser, Excimer laser; Dye laser; Fiber laser, Quantum cascade laser.

UNIT-3 9 L

Infrared and Raman Spectroscopy: Vibrational Degree of freedom, Normal coordinates, Normal vibrations and mathematical formulations, Degenerate vibrations, Infrared spectra: Active and inactive vibrations, Overtone and combination vibrations, Vibrational Raman Spectra: concept, Mathematical Formulations, Polarizability ellipsoid, Overtone and combination vibrations, Polarization of Rayleigh and Raman Scattering.

UNIT-4 9 L

Spectroscopic techniques: Spectroscopic processes, Absorption and fluorescence spectroscopy, Steady-state and time-resolved emission spectroscopy, Raman Spectroscopy, Stand-off Laser Spectroscopy, Cavity ring-down laser absorption spectroscopy, Laser Induced Breakdown Spectroscopy, Photoacoustic Spectroscopy.

Reference Books:

1. Laser Fundamentals, **William T. Silfvast**, Cambridge University Press, 2003.
2. Industrial Applications of Lasers, **John F. Ready**, Acedamic Press.
3. Laser Processing of Engineering Materials: Principles, Procedure and Industrial Applications, **John Ion**, Elsevier.
4. Fundamentals of molecular spectroscopy, **Colin N.**Banwell& Elaine M. McCash.
5. MOlecular structure and Spectroscopy, **G. Aruldhas**: Prentice - Hall of India.

Course Outcomes: Students will be able to:

CO1	Learn the concept of lasers, its instrumentation and will be able to design and develop lab scale lasers.
CO2	Use vibrational spectroscopy for various applications related to molecular analysis.
CO3	Develop new spectroscopic technique and perform experiments.

M.Sc. (PHYSICS)

Course Code PHPE 555	Functional Materials and Characterization	Credits 3-0-0: 3

Course Educational Objectives :

COE1	To provide an overview of functional materials' design, composition, processing processes, structure, and physical properties.
COE2	To familiarize the students with different techniques associated with the fabrication and physical property testing of functional materials.
COE3	To impart knowledge and develop the understanding of applications of a range of advanced functional materials.

UNIT-1 9 L

Functional Materials And Nanotechnology: Introduction to functional materials (magnetism, ferroelectricity, piezoelectricity, semiconductors, polymers, and storage) and nanotechnology: definitions and background, a brief history, scales and sizes, size effects, elegant examples from nature and materials science, nanotechnology, environmental and health impact.

UNIT-2 9 L

Functional Materials Synthesis: Top-down and Bottom-up approaches for synthesis of functional materials; Ball milling, Electron Beam Lithography, Atomic Layer Deposition, Pulse Laser Deposition, Spray pyrolysis, Chemical Vapor Deposition (CVD), Sol-gels, Hydrothermal methods, Microwave, Spin and Dip coating techniques.

UNIT-3 9 L

Functional Materials Characterization: XRD, Raman, UV-VIS-Spectroscopy, Microscopy (SPM, TEM, SEM), Vibrating sample magnetometer (VSM), PE-loop tracer, Electrochemical workstation.

UNIT-4 9 L

Functional Materials Applications: Applications of functional materials in electronics, optics and photovoltaic cells, sensors, fuel cells, batteries, supercapacitors H_2 storage and waste water treatment.

Reference Books:

1. Principle of Nanoscience & Nanotechnology: **M.A. Shah and T. Ahmad**, Narosa, 2010.
2. Nanoscale Multifunctional Materials: **S. M. Mukhopadhyay**, Wiley, 2012.
3. Elements of X-ray Diffraction, **B. D. Cullity**, 4th Edition, Addison Wiley, 1978.
4. Physics of Functional Materials, **HasseFredriksson& Ulla Akerlind**, Wiley, 2015.
5. Functional Materials; Electrical, Dielectric, Electromagnetic, Optical, and Magnetic Applications, **Deborah DL Chung**, World Scientific, 2010.
6. Functional Materials: Preparation, Processing and Applications, **S. Banerjee, AK Tyagi**, Elsevier, 2011.
7. Functional Molecular Materials: An Introductory Textbook, **Matteo Atzori, F. Artizzu**, CRC Press, 2018.

Course Outcomes: Students will be able to:

CO1	Understand functional materials behaviour to the design of new materials with novel properties.
CO2	Utilize lithographic methods to fabricate functional materials.
CO3	Use relationships between composition, processing route, microstructure, properties and applications of advanced functional materials.

M.Sc. (PHYSICS)

Course Code PHPE 557	Radiation Physics and Nuclear Fragmentation	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To give understanding of different types of radiations and their interaction of with matter.
CEO2	To gain knowledge about design and working of gas filled and semiconductor radiation detectors.
CEO3	To develop the understanding of Solid state nuclear track detectors working and their application for measurement of environmental radioactivity.

UNIT-1 **8 L**

Biological Effects of Radiation: Types of Radiation, Radiation Doses- Exposure dose, Absorbed dose, Effective dose, special parameter, Weighting factor, Tissue Factor, background levels, LET and Radiation Biological Effectiveness.

Health effects: Schostic effects, Delayed Effect. Recomdation doses. Induction of chromosomal aberrations and its application in biological dosimetry of absorbed radiation. Cell killing and induction of mutations.

Radiation protection standards: Need for protection, ALARA principle. Radiation Shielding, Time, distance, shielding. External and internal exposure. ICRP and AERB recommendations.

UNIT-2 **10 L**

Environmental Radiation Detection Devices: Track etch generation mechanisms, conditions for tracks formation, etching and counting of tracks, properties and applications of SSNTD, detection thresholds, restricted energy loss, Active measurement techniques for environmental radioactivity; beta/gamma radiation survey meter, Scintillation Radon Monitor (SRM), Scintillation Thoron Monitor (STM).

UNIT-3 **8 L**

Nuclear Fragmentation: High energy heavy ions, heavy ions interactions in matter, Energy loss in matter by heavy particles, odd-even effect in fragmentation, fragmentation cross sections of heavy ions in various targets, total fragmentation, charge-changing nuclear reactions of relativistic ions during the passage of matter, charge-changing cross sections, partial-charge changing cross-section, fragmentation of ultra-relativistic heavy ions, electromagnetic dissociation.

UNIT-4 **10 L**

Radiation therapy: photon therapy, electron therapy, charge particle therapy, hadrontherapy, systematics of heavy ion therapy, Bragg's peak analysis.

Special techniques in radiation therapy: Total Body Irradiation, Total Skin Electron Therapy, Stereotactic Radiosurgery (SRS); SRS Delivery Systems, Linac based, Gamma Knife, Robotic LINAC.

Reference Books:

1. Radiation Detection and Measurement by **G F Knoll.**
2. Nuclear Instrumentation: **W. J. Price**.
3. Solid State Nuclear Track Detectors-Principal and Applications: **R. L. Fleischer, P. B. Price**& R. M. Walker.
4. Techniques for nuclear and particle physics experiments: **W. R. Leo**.

Course Outcomes: Students will be able to:

CO1	Understand different types of radiations and their interaction of with matter.
CO2	Understand design and working of gas filled and semiconductor radiation detectors with associated electronics.
CO3	Understand solid state nuclear track detectors and their application for measurement of environmental radioactivity.

M.Sc. (PHYSICS)

Course Code PHPE 559	Nonlinear Spectroscopy	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To develop the understanding of nonlinear spectroscopy and various processes therein.
CEO2	To learn various nonlinear experimental methods.
CEO3	To understand multiphoton absorption process and instrumentation

UNIT-1 **9 L**

Fundamental: Wave Propagation in Nonlinear Medium, Nonlinear Polarization Density and Nonlinear Susceptibility, nonlinear optical coefficient, Saturable absorber, Phase Matching conditions, types of phase matching.

UNIT-2 9L

Second order Nonlinear process: Second Harmonic Generation (SHG), Sum and difference frequency generation, Parametric oscillation, Optical parametric oscillator, Singly and Doubly resonant oscillator, Examples of SHG in KDP and LiNbO3 crystals.

UNIT-3 9L

Third order Nonlinear process: Third Harmonic Generation, Self focusing, Photo-thermal spectroscopy; Optical Kerr effect, Self phase modulation, Four wave mixing concept and measurements, Multiphoton absorption process, Upconversion process.

UNIT-4 9L

Raman Spectroscopy: Raman Spectroscopy, Stimulated Raman scattering (SRS), Quantum theory, Coupled wave concept of SRS, Inverse Raman Effect, Coherent anti-stokes Raman Spectroscopy, Hyper-Raman effect, Stimulated Raman Gain and Loss Spectroscopy.

Reference Books:

1. Laser Fundamentals, **William T. Silfvast**, Cambridge University Press, 2003.
2. Military Laser Technology for Defense, **Alastair D. McAulay**, Wiley, 2011.
3. Industrial Applications of Lasers, **John F. Ready**, Acedamic Press.

Course Outcomes: Students will be able to:

CO1	learn laser technology and its advancement for defence.
CO2	Design and develop lab scale lasers and 3D objects.
CO3	Develop various laser detection techniques and perform experiments.

M.Sc. (PHYSICS)

Course Code PHPE 561	Materials Science	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To impart knowledge in the field of material and their applications in engineering.
CEO2	To understand the origin of mechanical and thermal properties of materials.
CEO3	To prepare the students to take up the future challenges related to advanced materials for developing futuristic devices.

UNIT-1 — 7 L

Introduction: Historical perspective of Materials Science, Classification of materials, Structure property relationship in material, multiphase materials, Advance materials- polymers, ceramics and composites, Crystallinity and its effect on physical properties, metal, ceramic, polymers, Future materials, Materials and environment, Applications of materials.

UNIT-2 — 7 L

Diffusion in Solids: Introduction, Mechanisms of diffusion, Types of diffusion, Fick's law of diffusion, Concept of different types of diffusion coefficients, Factors affecting diffusion coefficient, Temperature dependence of diffusion coefficient, The Kirkendall effect, Darken analysis, Applications of diffusion.

UNIT-3 — 7 L

Mechanical Properties: Introduction, elastic deformation- Stress-strain response of materials; yield and tensile strength, modulus of elasticity, toughness, Elastic Properties of Materials; plastic deformation- fatigue, creep and fracture; Tensile Properties, True Stress and Strain, Elastic recovery after plastic deformation, Compressive, Shear, and Torsional deformation, Hardness, Variability of material properties.

UNIT-4 — 7 L

Thermal Properties: Introduction, specific heat, thermal conductivity, Thermal expansion, thermal stress, thermal stability, Thermal radiation, emissivity, Relationship between structure and thermal properties of materials, Phase Transition, Experimental methods for thermal analysis of materials, Thermoelectric properties.

Reference Books:

1. Material Science and Engineering, 6th edition, **V. Raghavan**, 2014.
2. Materials Science and Engineering, **William D. Callister, Jr. D. G. Rethwisch**, 2014.
3. Introduction to Materials Science for Engineers, **James F. Shackelford**, 2014.
4. Diffusion in Solids, **P. Shewmon**, 2016.

Course Outcomes: Students will be able to:

CO1	Understand different types of materials for various applications.
CO2	Understand thermal properties of materials.
CO3	Develop futuristic devices.

M.Sc. (PHYSICS)

Course Code PHOE 581	Energy materials and devices	Credits 3-0-0: 3

Course Educational Objectives :	
CEO1	To make graduates understand the use of nanomaterials in energy generation and storage.
CEO2	To exhibit understanding of the sources of energy and the methods of energy conversion in Nanotechnology.
CEO3	To gain the knowledge solar energy, electrochemical storage of energy and fuel cells.

UNIT-1 **7 L**

Introduction: Energy challenges, Energy consummation, Current sources of energy, Status of energy map, Energy policies, Conservation of energy, Alternative energy sources, Development and implementation of renewable energy technologies, role of renewable energy sources, Energy transport, conversion and storage, Sustainable Energy.

UNIT-2 **7 L**

Solar Energy: Fundamentals of solar cells, Types of solar cells, Photovoltaic effect, Semiconducting materials bandgap theory, Band gap engineering, Solar cell properties and design, p-n junction, Photodiodes, electron and hole transports, charge carrier generation, recombination, I-V characteristics, Tandem structure, Single junction and triple-junction, solar panels, thin film solar cells, solar cell applications, solar cell manufacturing process.

UNIT-3 **7 L**

Electrochemical Energy Storage Devices: Thermodynamics of electrochemical reaction Li- ion batteries, Nanostructured materials for Li-ion batteries, Principle of supercapacitor, Advanced supercapacitor technology,. Basics of Fuel cells - working principle of fuel cells and related thermodynamics, Fuel cell electrochemistry, Fuel cell types ; SOFC, MCFC, PAFC, PEFC, Water management in PEFCs-Current issues in PEFCs.

UNIT-4 **7 L**

Thermoelectric and Piezoelectric Energy: Thermoelectric and Pizoelectric materials, Fabrication and characterization of thermoelectric devices, Bulk thermoelectric materials performance, Thermoelectric modules, Piezoelectric harvester design, Micro and nanoscale energy harvesting, Fabrication and characterization of piezoelectric devices, Strategies for optimizing efficiency, Future directions.

Reference Books:

1. Energy for a sustainable world by **L. Freris, D. Infield**, Wiley, 2008.
2. Nanomaterials for Sustainable Energy by **Quan** (Ed.), Springer, 2016.
3. Nanomaterials in Energy Devices by **Jun HiengKait** CRC Press, 2017.
4. Advanced nanomaterials and their applications in renewable energy by **J. Louise, L. S. Bashir**, 2015.

Course Outcomes: Students will be able to:	
CO1	Technically skilled to comprehend the principles behind energy storage mechanism.
CO2	To gain a broad understanding of concepts and applications of batteries and super capacitors.
CO3	Design and fabricate solar cells, electrochemical storage devices and fuel cells.

M.Sc. (PHYSICS)

Course Code PHOE 583	Polymers, Ceramics And Composite Materials	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To impart fundamental knowledge about polymer, ceramic and composite materials.
CEO2	To understand processing techniques of polymer and ceramics.
CEO3	To prepare the students to develop the advanced materials through composite materials.

UNIT-1 7 L

Polymers and Chemical Bonding: Polymerization mechanism, Addition and Condensation polymerization, Molecular weights and their distribution, Simple and hindered rotation, Crystallinity and melting, Glass transition, Thermosetting and Thermoplastic Polymers, Conducting polymers and their types, Doping and De-doping of conjugated polymers, Solatron and polaron formation in conducting polymers.

UNIT-2 7 L

Composite Materials: Introduction and overview, Types of Composite Materials, Carbon based Reinforcements, Matrix materials, Factors affecting mechanical and electronic properties, Property Enhancement, case studies of composite materials for defense applications.

UNIT-3 7 L

Ceramics and Polymers Matrix Composites: Bonding and crystal structure; Defects in Ceramics, Diffusion and Electrical conductivity of ceramic materials. Synthesis of ceramic powder and nanoparticles and their consolidation; Processing of ceramics and polymers matrix composites, Interfaces and properties of ceramics matrix composites, Thermal shock resistance, Biodegradable Polymer Composites, Applications.

UNIT-4 7 L

Metal-Matrix Composites: Aluminium and Magnesium based Matrix Composites; Titanium based Matrix Composites, Fabrication and Applications.

Reference Books:

1. Polymer Science, **V.R. Gowariker, N.V. Viswanathan and JayadevSreedhar**, Halsted Press, John Wiley & Sons, New York.
2. Principles of Polymerization, **George Odian**, John Wiley & Sons. 4th Ed.
3. Introduction to Ceramics, **W.D. Kingery, H.K. Bowen and D.R. Uhlmann**.
4. Fundamentals of ceramics, **W.M. Barsoum**.
5. Composite Materials Science and Engineering, **Krishnan K. Chawla**, Springer (2012).

Course Outcomes: Students will be able to:

CO1	Understand different types of materials for various applications.
CO2	Understanding will improve regarding mechanical properties of materials.
CO3	Understand the properties of new materials useful for developing futuristic devices.

M.Sc. (PHYSICS)

Course Code PHOE 585	Fiber Optics and Optical Communication Systems	Credits 3-0-0: 3

Course Educational Objectives:

CEO1	To provide essential knowledge about fiber optic technology.
CEO2	To convey the idea of the principles of light guidance inside the optical fibers.
CEO3	To provide understanding of various potential applications of the optical fibers in optical communication systems and other fields.

UNIT-1 7 L

Introduction: Guided wave Optics, Ray analysis, Modes of planar waveguide, Physical understanding of modes.Confinementof photonsand electrons, Classification of optical fibers; Characteristics of the optical fibers; Materials for fibers and their characteristics; Effective refractive index of modes and its relation with the phase propagation constant, Basic idea about thefiber optic communication system.

UNIT-2 7 L

Mechanism of light guidance: Electromagnetic waves (EM waves), Propagation of EM waves in anisotropic materials, Uniaxial and biaxial materials, Mode theory for circular waveguides: step index optical fibers; Propagation characteristics of step index optical fibers; graded index optical fibers.

UNIT-3 7 L

Losses and Dispersion: Fiber losses, Attenuation coefficient, Dispersion in single mode fibers- dispersion induced limitations- dispersion management, Signal degradation in optical fibers due to dispersion and attenuation; Pulse dispersion in graded index optical fibers, Material dispersion, Waveguide dispersion and design considerations.

UNIT-4 7 L

Fiber Devices, Applications, and Sustainability: Optical fiber amplifiers: EDFA, Gain spectrum and gain band width, EDFAs for WDM transmission,Fiber Raman Amplifier,Wide band amplifiers. Various potential applications of the optical fibers other than the telecommunication industry: Fiber lasers and fiber optic sensors.

Reference Books:

1. **Ghatak and Thyagarajan,** "An introduction to Fiber Optics", Cambridge University Press 1998.
2. **G. P. Agrawal,** "Fibre Optic Communication Systems", John Wiley and Sons, 2002.
3. **Keiser,** "Fiber optic communication" McGraw Hill, 2009.
4. **F. C. Allard,** "Fiber Optics Handbook for engineers and scientists", McGraw Hill, 2009.
5. **B. D. Gupta,** "Fibre optic sensors – principles and applications", New India Publishing, 2006.

Course Outcomes: At the end of the course students will be able to:

CO1	Apply the concept of optical fiber technology, their applications, and the relevant physics concepts for realizing and solving light guidance in different structures.
CO2	Solve technical and strategic problems related to the fabrication of optical fibers.
CO3	Realize the various potential applications of the optical fibers in telecommunication and other industries.

M.Sc. (PHYSICS)

Course Code PHPE 552	High Energy Physics	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To familiarize the students about fundamental entities of the universe and their interactions and how the universe is made off!
CEO2	To develop understanding of perturbation theory and Feynman Rules to apply in high energy scattering measurements.
CEO3	To develop understanding of Standard model of particle Physics and the formation of bound states.

UNIT-1 8 L

Elementary Particles: Introduction to Four Fundamental Forces and the interactions-- EM force, Gravitational force, Strong force and Week forces; Fundamental entities—quarks, leptons, mediators, Quarks and colors; Basics of Quantum Chromodynamics, Strong coupling and Asymptotic freedom.

UNIT-2 10 L

Symmetries and Quarks: Symmetries, Conservation laws and Groups. The Group SU(2), SU(2) of Isospin for particles and antiparticles, The Group SU(3)—Isospin and strangeness, Quark structures of Mesons and Baryons. Construction of wave function for bound states. Magnetic moments of proton and Neutron. Color factors.

UNIT-3 10L

Standard Model (SM) of Particle Physics: Local gauge transformation, Global gauge transformation, Symmetry, Noether's theorem, spontaneous symmetry breaking, Higgs Mechanism, The Higgs Boson, Standard Model of Particle Physics.

UNIT-4 8 L

Applications in High Energy Scattering Experiments: Photon self-energy correction,Radiative corrections, Soft Bremsstrahlung--Classical Computation, Quantum computation. The electron vertex function in formal structure and evaluation through Feynman Parameterization.

Reference Books:

1. Quarks and Leptons: An Introductory Course in Modern Particle Physics, **F. Halzen and A. Martin**, John Wiley & Sons, 1993.
2. Introduction to elementary Particles, **D. J. Griffiths**, John Wiley & Sons, 2006.
3. The strange Theory of Light and Matter, **Richard P. Feynman**, Prinston University Press, 1983.
4. Quantum Electrodynamics, **W. Greiner, J. Reinhart**, Springer, 2003.
5. Photons and Atoms: Introduction to quantum electrodynamics, **C. Cohen-Tannoudji, J. D. Roc, G. Grynberg**, WILEY□VCH Verlag GmbH & Co. KGaA, 1997.
6. A first Book of Quantum Field Theory, **A. Lahiri, P. B. Pal**, Narosa Publication, 2007.

Course Outcomes: Students will be able to:

CO1	Illustrate the fundamental constituent of the universe.
CO2	Apply Feynman rules technique to the high energy scattering process measured in experiments like LHC, COMPASS, HERA, LEP etc.
CO3	Cultivate critical thinking on symmetries and conservation laws involved in cutting edge research.

M.Sc. (PHYSICS)

Course Code PHPE 554	Photonics	Credits 3-0-0: 3

Course Educational Objectives :	
CEO1	To impart the fundamental knowledge about the light matter interaction.
CEO2	To give the proper understanding of novel developments in the area of photonics.
CEO3	To provide understanding of the principles of photon generation, propagation and manipulation.

UNIT-1 9 L

Introduction: Dual nature of light, Photon energy, Photon position, Photon, momentum, Photon Polarization, Mean photon flux, Photon number statistics, Quantum states of light: Coherent-state light and Squeezed-state light; Propagation of EM waves in anisotropic materials, Uniaxial and biaxial materials.

UNIT-2 9 L

Fiber Optics Losses and Dispersion: Linear and nonlinear losses, Signal degradation in optical fibers due to dispersion and attenuation; Pulse dispersion in graded index optical fibers, Material dispersion, Waveguide dispersion and design considerations.

UNIT-3 9 L

Photonic Crystal: Basic Concepts, Photonic Bandgap Structures, Features of Photonic Crystals, Photonic Crystal Fibers, Photonic crystal Sensors, Method of Fabrication.

UNIT-4 9 L

Fabrication of photonic structures: Fabrication techniques of photonic structures: Fabrication steps, Coating techniques, etching processes: wet and dry; types of masks, Basic idea of photolithography and electron beam lithography, Applications of photonic devices.

Reference Books:

1. Fundamental of Photonics by **Baha E.A.**, Saleh and M.C. Teich: John Wiley and Sons 2010.
2. Photonics by **Ralf Menzel**: Springer Verilog 2001.
3. Nonlinear Optics by **Boyd**: Academic Press 2010.
4. Nonlinear Fiber Optics by **G. P. Aggarwal**: Elsevier 2013.

Course Outcomes: At the end of the course students will be able to:	
CO1	Understand the concept of the photons, their generation and manipulation.
CO2	Apply the relevant concepts of the photonics for the development of novel photonic technologies.
CO3	Solve technical and strategic problems related to the light-matter interaction.

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M.Sc. (PHYSICS)

Course Code PHPE 558	Nuclear Technology	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To give understanding of different types of radiations and their interaction of with matter.
CEO2	To gain knowledge about design and working of gas filled and semiconductor radiation detectors.
CEO3	To develop the understanding of Solid state nuclear track detectors working and their application for measurement of environmental radioactivity.
CEO4	To understand design and working of accelerators.

UNIT-18 L

Interaction of Radiations with Matter: Charge Particles (Heavy & Light), Electromagnetic Radiations (Photoelectric effect, Compton scattering, Pair production) and Neutrons.
Nuclear Radiation Detectors, Various Types of Radiation Detectors: Gas ionization based detectors, ionization chambers, Proportional counters, G.M. detectors, & their design considerations.

UNIT-210L

Radiation Detectors: Split Anode detector, Multi-wire detectors, Particle by Particle identification, Time of flight spectroscopy, Bubble chamber, Cloud chamber, Scintilation detector.
Semiconductor radiation detectors: Mechanism of Electron-Hole Pair generation, Fano Factor, Energy Resolution and recombination, Characteristics of Homogeneous and Junction type detectors fabrication and design considerations, Signal Generation and Frequency Response.

UNIT-38 L

Nuclear Reactors: Nuclear reaction and their type, Conservation laws, Direct and compound nucleus reaction, Q – value and a classical approach of compound nucleus formation as a possible mechanism of nuclear reaction, Different examples of nuclear reactions, Energy release in nuclear fission and fusion reactions, Nuclear fission products, Mass and energy distribution of fission products, nuclear fission reactors, Critical size, reproduction factor, Nuclear Fuel, design of a power reactor with fuel core, moderator, reflector, coolant, control and safety, Fast Breeder reactor, Control rods, nuclear breeding process, nuclear fusion–controlled thermonuclear reactions; Lawson criteria, heating of plasma, confinement of plasma in magnetic mirror and tokamak, basic concepts of plasma instabilities, generation of nuclear power and future challenges.

UNIT-410 L

Accelerators: Cyclotron, Tandem, LINAC and Pelletron, LHC
Ion source, role of accelerators in research and technology; Production of various radioactive isotopes, application of the isotope in therapeutic process like gamma ray therapy, boron neutron capture therapy, heavy ion therapy applications of radioisotopes in imaging process like, gamma camera, positron emission tomography and magnetic resonance imaging.
Analytical process based on nuclear techniques- Rutherford back scattering spectrometry, nuclear reaction analysis, neutron activation analysis for detailed composition and trace element analysis of various materials.

Reference Books:

1. Radiation Detection and Measurement by **G F Knoll.**
2. Nuclear Instrumentation: **W. J. Price.**
3. Solid State Nuclear Track Detectors- Principal and Applications: **R. L. Fleischer, P. B. Price & R. M. Walker.**
4. Techniques for nuclear and particle physics experiments: **W. R. Leo.**

Course Outcomes: Students will be able to:

CO1	Understand different types of radiations and their interaction of with matter.
CO2	Understand design and working of gas filled and semiconductor radiation detectors with associated electronics.
CO3	Understand solid state nuclear track detectors and their application for measurement of environmental radioactivity.
CO4	Understand accelerators and their applications for the human beings.

M.Sc. (PHYSICS)

Course Code PHPE 556	Thin Film Physics And Applications	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	Student will gain fundamental knowledge of thin film growth processes and techniques.
CEO2	Student will be able to understand basic physics behind various thin film growth techniques.
CEO3	Student will learn the hybrid thin film growth approaches and design thin film based devices.

UNIT-1 8 L

Introduction: Technological status, Physics of solidification, cooling curve, Thermodynamics and kinetics of Nucleation and growth mechanisms, Critical radius of nuclei, Grain formation, Defects in thin films, Adsorption and desorption, Surface conditioning and modification methods: Cleaning methods, Thermal annealing, Surface Ozonisation, Plasma processing.

UNIT-2 8 L

Fabrication techniques: Film thickness uniformity and purity, Evaporation hardware and techniques, Resistance heating and electron beam evaporation, Fundamentals of Chemical Vapor Deposition, Sputtering, Pulsed laser deposition, Langmuir Blodgett technique, Spin and Dip coating techniques, Doctor blade technique, Film patterning techniques: wet and dry etching.

UNIT-3 10 L

Characterization Techniques: Film Thickness measurement- Optical techniques: Interferometry and Ellipsometry, Mechanical techniques: Stylus Profilometry, Structural studies: Energy Dispersive Studies by X-Rays, Surface studies: Surface topography and thin film morphological studies by SEM and AFM, Film composition and depth profiling techniques: Photoelectron spectroscopy- XPS, UPS, Auger Electron Spectroscopy (AES).

UNIT-4 8 L

Thin Film Properties And Applications: Multilayer Optical Film Applications: reflecting and anti-reflecting optical coating, Photo-thermal Coatings, Optical Filters, single layer and multilayer Organic Light Emitting Diodes (OLEDs), single layer and multilayer Polymeric Light Emitting Diodes (PLEDs), Thin film solar cells, Thin Film Transistors, Thin film battery.

Reference Books:

1. Solid State Electronic Devices, **Ben G. Streetman**, (Prentice-Hall of India,2012).
2. Semiconductor Devices-Basic Principles, **Jaspreet Singh**, (John Wiley publication,2008).
3. Physical vapour deposition of thin films, **John E. Mahan**, (John Wiley & Sons, 2000) .
4. Materials science of thin films: Deposition and structure, **Milton Ohring**, (Elsevier, Inc., 2002).
5. Thin film Phenomena, **K. L. Chopra**, (McGraw-Hill, New York, 1969).

Course Outcomes: Students will be able to:

CO1	Have knowledge of the physics of various thin film growth approaches.
CO2	Analyze practical problems on various thin film growth techniques.
CO3	Design thin film based devices.

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M.Sc. (PHYSICS)

Course Code PHPE 560	Physics of Optoelectronic Devices	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To develop the understanding of optoelectronic processes in Optoelectronic Devices.
CEO2	To understand the optoelectronic mechanisms in various optical devices.
CEO3	To utilize the optical sources and devices for research and industrial application.

UNIT-1 (8 L)

OPTICAL PROCESSES: Optical Materials, Optical Processes- Absorption, Emission, Photoluminescence, Electroluminescence, cathodoluminescence, Plasmonics- Bulk and Surface Plasmons, Carrier Generation and Recombination Processes, Excitons- weakly and tightly bound excitons, Nonlinear optical susceptibilities, Second and Third order Harmonic Generation, Magneto-optic effects- Faraday and Kerr effects.

UNIT-2 **10 L**

ELECTRONIC PROCESSES: Quantum wells, Quantum Confinement, Coupling between Quantum wells, Superlattice, Band gap engineering, Electronic properties of metals and semiconductors (Inorganic and Organic), Electrical contacts- Metal-Semiconductor and Semiconductor-Semiconductor contacts, Carrier injection and Tunneling, Electronic conduction- Band and hopping Transport.

UNIT-3 (10L)

OPTICAL SOURCES: Conventional Sources for UV, VIS and IR radiations, Light emitting diode (LED:): Mechanism, Design and Fabrication, Inorganic LEDs, Organic LEDs, Polymeric LEDs, Quantum Dot LEDs, Laser Diode, Solid State Lasers, Quantum well Lasers, Some Recent developments on lighting and displays.

UNIT-4 (8 L)

OPTOELECTRONIC DEVICES: Photo-Conductive Devices- Photoresistors, Phototransistors, Photo-Emissive Devices-Photomultiplier Tube, Photo-voltaic Devices- PN junction photodetector, PIN photo diode, Avalanche photo diode, Solar Cell (SC)- Organic SC, Polymeric SC, Quantum dot SC, Plasmonic SC, Dye Sensitized SC, Some Recent developments- Flexible Solar cell, Charge couple detectors, UV-VIS spectrophotometers – Single beam and Dual beam, Optical Fiber Sensors: Active and passive optical fiber sensor, intensity modulated, displacement type sensors.

Reference Books:

1. Optoelectronics: An introduction, John Wilson, **J. F. B. Hawkes**, Prentice Hall Europe.
2. Textbook of Illuminating Engineering by **T.W.T. Walsh**.
3. Photoelectronic Devices by **J. B. Danoe**.
4. Lasers and optical engineering by **P. Das**.
5. Lasers by **Ghatak&Thyagrajan**.

Course Outcomes: Students will be able to:

CO1	Understand the underlying fundamental optoelectronic processes.
CO2	Imply the mechanisms of various optical detectors.
CO3	Utilise optical sources and devices for research and industries.

M.Sc. (PHYSICS)

Course Code PHOE 582	Semiconductor Devices	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To develop the understanding of Physics essential for Electronics Engineering students.
CEO2	To gain knowledge of electronic and semiconducting properties of materials.
CEO3	To understand theories relevant to the engineering principles of Semiconductor devices.

UNIT-1 **4 L**

Review of Band theory of solids: Metal, Insulator, and Semiconductors;Periodic structures, Origin of Energy Bands- Bloch Theorem, Kronig-Penney Model (qualitative), E-K diagram, Brillouin Zones-extended, reduced and periodic zone schemes, Concept of Fermi energy Electrons and Holes, Concept of effective mass, Material classification, Direct and Indirect Band gap semiconductors. Effect of temperature and electric field on the band structure.

UNIT-2 **10 L**

Semiconductor Physics: Crystal properties, Elemental and compound semiconductors, Density of states, Doping- donors and acceptors, Equilibrium and extrinsic carrier concentration, Carrier transport, Drift and Diffusion current, Mobility, Einstein relation, Excess carrier generation and recombination, Hall-Shockley-Reed theory of recombination, Equilibrium and non-equilibrium processes, Charge transport equation;
Electrical conductivity and mobility of charge carriers, mechanisms of scattering; Four probe and Hall effect for the measurement of conductivity, carrier concentration and mobility; Measurement of bandgap- optical absorption spectroscopy and Effective mass- Cyclotron resonance experiment.

UNIT-310 L

Junctions and Devices: Types of junctions, Ohmic and Schottky contacts, Schottky barrier and barrier lowering effects, Theory of p-n junction, the concept of depletion later, resistance and capacitance across the depletion layer Charge transport in a p-n junction; Practical junctions and Ideality factor; Space charge and diffusion capacitances. Impurity profiling through capacitance measurements.
Typical Single layer and multilayer devices and their characteristics: PN diode; Light Emitting Diodes; Solar cells; Photodetectors; Tunnel diode, Transistors; Field Effect Transistors.

UNIT-4 **8 L**

Fabrication Tools and Techniques: Importance of Vacuum in fabrication- methods of achieving vacuum, Crystal growth techniques, Wafer cleaning techniques, Surface conditioning and modification techniques, Concept of Photolithography, Doping techniques (Diffusion and Ion implantation), Metallization (Physical Vapor Deposition), semiconductor device sealing and packaging.

Reference Books:

1. **S. M. Sze**, Semiconductor Devices: Physics and Technology, John Wiley publication, 2013.
2. **Donald A.** Neamen, Semiconductor Physics and Devices: Basic Principles, McGraw-Hill publication, 2012.
3. **Ben G. Streetman**, Solid State Electronic Devices, Prentice-Hall of India, 2012.
4. **Jaspreet Singh**, Semiconductor Devices-Basic Principles,John Wiley publication, 2008.
5. **Charles Kittel**, Introduction to Solid State Physics, John Wiley publication, 2013.

Course Outcomes: Students will be able to:

CO1	Solve and realize Electronics Engineering problems and challenges.
CO2	Understand fundamentals of semiconducting properties of materials for technological applications.
CO3	Realize the operation mechanism of various electrical and electronic devices.

M.Sc. (PHYSICS)

Course Code PHOE 584	Biomedical Instrumentation	Credits 3-0-0: 3

Course Educational Objectives :

CEO1	To understand the utilization of different types of Biomedical Instruments for diagnosticpurposes.
CEO2	To gain comprehensive knowledge of various processes related to human body and its organs.
CEO3	To apply the diagnostics and therapeutic tools in medical field.

UNIT-1 8 L

Bio-Potentials and Electrodes: Introduction to the main biomedical instrumentation system and its components, problems encountered in the design of biomedical instrumentation system. Origin of Bioelectric potentials; The electrode-electrolyte system, Polarization, polarizable and non- polarizable electrodes, skin contact impedance, electrodes for ECG, EEG & EMG, microelectrodes, Biomedical Recorders: Electrocardiograph, electroencephalograph and electromyograph. Blood pressure measurement: Direct and indirect methods.

UNIT-2 10 L

Blood Flowmeters: Electromagnetic, Ultrasonic, NMR and Laser Doppler Blood flowmeters. Pulmonary Function Analysers: Respiratory volumes, wedge and ultrasonic spirometers, Fleischpneumo-tachometer.

UNIT-310L

Biomedical Imaging Techniques: X-ray·machine, Image intensifiers & image noise. Principles and theory of Tomographic Imaging, parallel and fan beam illumination, X-ray computed tomography, Emission computed tomography. Nuclear imaging techniques: PET, SPECT. Optical imaging and microscopy. Molecular and Cellular imaging, Contrast agents.

Nuclear Magnetic Resonance imaging and its application in the field of diagnostics, MRI, Benefits and limitations of MRI.

UNIT-48 L

Ultrasound Imaging and Therapy: Ultrasound, Ultrasonic scanning: A-scanners & B-scanners, Real time ultrasonic imaging systems, Therapy with ultrasonic waves, Biological effects of ultrasonic waves, Radiotherpy: Radiobiology and radiation physics treatment planning, radiation therapy, Particle beam therapy (hadrontherapy), biological effects of radiations, instrumentation for the medical use of radioisotopes, Dosimetryin modern radiation therapy, Dose measurement.

Reference Books:

1. **A handbook of Biomedical Instrumentation**, R S Khandpur, McGraw-Hill Education (India) Pvt Limited.
2. **Biomedical Instrumentation & Measurement**, LeslieCromwell, Fred J Weibell&ErichAPfeiffer.Prentice-Hall.
3. **Medical Instrumentation: ApplicationandDesign**. John G. Webster, John Wiley & Sons.
4. **Medicine &ClinicalEngineering,** Bertil Jacobson & John GWebster.

Course Outcomes: At the end of the course students will be able to:

CO1	Graduates will develop the understanding of utilization of different types of Biomedical Instruments.
CO2	Graduates will have comprehensive knowledge of various processes related to human body and its organs.
CO3	Graduates will be able to apply the diagnostics and therapeutic tools in medical field.