M.Sc PHYSICS

(I/II year program)

Under NEP 2020

Curriculum Structure for Two year PG Programme
(Semester I and II - Coursework only)

	Course Type	Course Name	Credits
Semester I Course Level 400	Core I	Classical Mechanics	4
	Core II	Mathematical Physics	4
	Core III	Quantum Mechanics I	4
	Core IV	Nuclear & Particle Physics	4
	Core V	Electronics	4
	Lab	Lab 1	4
	Total		24

	Course Type	Course Name	Credits
Semester II Course Level 500	Core I	Atomic & Molecular Physics	4
	Core II	Condensed Matter Physics	4
	Core III	Electrodynamics	4
	Core IV	Quantum Mechanics II	4
	Core V	Statistical Mechanics	4
	Lab	Lab 2	4
	Total		24

Curriculum Structure for Two year PG Programme
(Semester III and IV)
Or
Curriculum Structure for One year PG Programme
(Semester I and II)

<table>
<tr><th></th><th>Course Type</th><th></th><th>Course Name</th><th>Credit</th></tr>
<tr><td rowspan="11">Semester III
(For 2 yr PG)
OR
Semester I
(For 1 yr PG)

Course Level
500</td><td rowspan="6">Specialisation Core (Materials/ Theory/ Laser)</td><td rowspan="2">Materials</td><td>Condensed Matter Physics (Adv)</td><td>4</td></tr>
<tr><td>Physics & Technology of Semiconductor Devices</td><td>4</td></tr>
<tr><td rowspan="2">Theory</td><td>Classical Field Theory</td><td>4</td></tr>
<tr><td>Quantum Field Theory</td><td>4</td></tr>
<tr><td rowspan="2">Laser</td><td>Laser Physics</td><td>4</td></tr>
<tr><td>Quantum Optics</td><td>4</td></tr>
<tr><td>Elective</td><td colspan="2">To be chosen from the courses offered from the pool in a particular semester</td><td>4</td></tr>
<tr><td>Elective</td><td colspan="2">To be chosen from the courses offered from the pool in a particular semester</td><td>4</td></tr>
<tr><td>Compulsory</td><td colspan="2">Research Methodology</td><td>4</td></tr>
<tr><td>Lab</td><td colspan="2">Lab 3</td><td>4</td></tr>
<tr><td colspan="3">Total</td><td>24</td></tr>
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<tr><th></th><th>Course Type</th><th>Course Name</th><th>Credit</th></tr>
<tr><td rowspan="2">Semester IV
(For 2 yr PG)/
Semester II
(For 1 yr PG)</td><td>Project</td><td>Project
Presentation</td><td>16
4</td></tr>
<tr><td colspan="2">Total</td><td>20</td></tr>
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POOL OF ELECTIVE SUBJECTS

Growth and Characterisation of Materials	Introduction to Quantum Technologies and Applications
Physics of Novel Materials	Energy Materials and Devices
Photonics	Cosmology
Laser Spectroscopy	Band Topology and Quantum Transport
General Theory of Relativity	Advanced Nanoelectronics and VLSI
Particle Physics	Group theory for physicists
Computational Techniques in Condensed Matter	Advanced Mathematical Physics

SEMESTER I

	Course Type	Course Name	Course Code	Credits
Semester I Course Level 400	Core I	Classical Mechanics	26-PHY-C-401	4
	Core II	Mathematical Physics	26-PHY-C-402	4
	Core III	Quantum Mechanics I	26-PHY-C-403	4
	Core IV	Nuclear & Particle Physics	26-PHY-C-404	4
	Core V	Electronics	26-PHY-C-405	4
	Lab	Lab	26-PHY-C-400	4
	Total			24

Course Title – Classical Mechanics

Course Type – Core

Course Code - 26-PHY-C-401

Course Level – 400

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Mechanics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Student should be able to solve constrained system using Lagrangian and Hamiltonian systems. S/he should understand minimization problems in real life and solve them through action integrals. One should be able to transform a given Hamiltonian to another one having all cyclic coordinates to simplify the problem. One should understand general rotatory motion of rigid bodies in terms of principal axes rotations.

Reference Books:

1. Classical Mechanics: H. Goldstein.
2. Mechanics: L. D. Landau and E. M. Lifshitz
3. Classical Mechanics: N.C.Rana and P.S.Joag.
4. Theoretical Mechanics: Murray Spiegel.
5. Classical Mechanics Systems of Particles and Hamiltonian Dynamics:Walter Greiner

Course Syllabus

Unit I: Lagrangian Formalism

Newtonian mechanics and its limitations. Constrained motion. Constraints and their classification. Mechanics of a System of Particles, Lagrangian Formulation, Principle of virtual work. D' Alembert's principle. Generalised coordinates. Derivation of Lagrange's equations from D' Alembert's Principle. Generalised momenta and energy. Cyclic or ignorable coordinates. Rayleigh' s dissipation function. Integrals of motion. Symmetries of space and time with conservation laws. Small oscillations.

Unit II: Hamiltonian formalism

Calculus of Variations and the Euler-Lagrange's Equation, Brachistochrone Problem, Hamilton's Principle, Extension of Hamilton's Principle to Non-Holonomic Systems, Legendre Transformation and the Hamilton Equations of Motion, Physical Significance of Hamiltonian, Derivation of Hamilton's Equations of Motion from a Variational Principle, Routh's Procedure, Δ-Variation, Principle of Least Action

Unit III: Canonical Transformation

Canonical Transformations. Generating functions. Poisson bracket. Poisson's Theorem. Invariance of PB under canonical transformations. Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity, Angular momentum PBs. Hamilton-Jacobi equation. Connection with canonical transformation. The harmonic oscillator and Kepler's problem by Hamilton-Jacobi Method, Hamilton's characteristic function; Action angle variables. Kepler's problem in action angle variable.

Unit IV: Rigid Body Dynamics

The Independent co-ordinates of a Rigid Body, Orthogonal Transformations. The Euler angles. The Cayley-Klein parameters; Euler's Theorems on the Motion of a Rigid body, Infinitesimal Rotations, Rate of Change of a Vector, The Coriolis Force. Rigid Body Dynamics: Angular Momentum and Kinetic Energy of Motion about a Point. Inertia Tensor, Eigen values of Inertia Tensor and the Principal Axis Transformation. The Euler Equations of Motion, Torque-free motion of a rigid body. Symmetrical Top.

Course Title – Mathematical Physics

Course Type – Core

Course Code - 26-PHY-C-402

Course Level – 400

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Mathematical Physics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

To familiarize with application of complex analysis, Use of Green's functions for inhomogeneous equations, basic probability theory and various common distribution functions to calculate everyday probabilities. Basic framework of group theory to understand various internal symmetries of systems and equations and related conserved quantities. Use of integral equations.

Reference Books:

1. Complex variables and applications by Churchill & Brown, IV Ed, MGH
2. Mathematical Physics, Sadri Hassani, II Ed., Springer
3. Mathematical methods for physicists, 6^{th} Ed., Arfken& Weber, Elsevier
4. Tensors by De, Sheikh and Sengupta, Narosa

Course Syllabus

Unit I: Advanced complex analysis

Brief description, mappings, branch cut, Conformal mapping, application, Taylor and Laurent series : convergence, residues and poles, contour integrals, 2-dimensional Laplace equation, Integral representations for Hypergeometric, confluent Hypergeometric and related functions, Gamma function, Zeta function, Method of steepest descent.

Unit II: Inhomogeneous differential equations

Green's function : Method for boundary value problems, GF in one dimension, eigenfunction expansion of Green's function, multidimensional GF's, examples : elliptic, parabolic and hyperbolic equations

Unit III: Statistics

Basic concepts: Sample space and probability, Permutation, combination, average and standard deviation; Random Variables, Binomial, Poisson and Normal Distributions. Central Limit Theorem, Hypothesis Testing and Data Analysis in Statistics.

Unit IV: Group Theory

Abstract groups: subgroups, classes, cosets, factor groups, normal subgroups, direct product of groups; Examples, Homomorphism &isomorphism. Representations: reducible and irreducible, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations. Introduction to continuous groups: Lie groups, rotation and unitary groups. Representation of SO(3), SU(2), SU(3)

Unit V: Integral equations

Integral equations : Classification, Fredholm and Volterra integral equations, Transformation of a differential equation into integral eq., Hermitian Kernel, degenerate kernels, Fredholm alternative, integral transforms, successive approximations, successive substitution, resolvent kernel, Hilbert-Schmitt theory

Course Title – Quantum Mechanics I

Course Type – Core

Course Code - 26-PHY-C-403

Course Level – 400

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Quantum Mechanics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Development of formalism of matrix mechanics. Different methods to study system evolution, study of quantization of angular momentum, addition of angular momenta, total angular momentum of an electron in orbit for small and large atomic numbers. Extra effects arising from identical particles in QM.

Reference Books:

1. Quantum Mechanics : N. Zettili
2. Quantum Mechanics : Franz Schwabl
3. Modern Quantum Mechanics : J.J.Sakurai
4. Priciples of Quantum Mechanics : P. A. M. Dirac
5. Quantum Mechanics : Bohm
6. Quantum Mechanics : B.H. Bransden and C.J. Joachim

Course Syllabus

Unit I: Mathematical formulation of Quantum Mechanics

Mathematical properties of linear vector spaces. Dirac's bra and ket notation. Hermitian operators, eigenvalues and eigenvectors. Orthonormality, completeness, closure. Generalised uncertainty principle. Unitary transformations, change of basis.Matrix representation of operators. Position and momentum representations – connection with wave mechanics. Commuting operators. Change of basis and unitary transformation. Expectation values. Ehrenfest theorem. Postulates of quantum mechanics.

Unit II: Fundamental Concepts of Quantum Mechanics

Basic postulates of quantum mechanics. Measurement. Time evolution of system's state. Schr ¨odinger, Heisenberg and interaction pictures. Density operator. Pure state and mixed state density operators. Discrete and continuous spectra in 1-D. Solution of 1-D harmonic oscillator using algebraic method.

Unit III: Angular Momentum

Orbital, Spin and total angular momentum operators. Commutation relations of angular momentum operators. Eigenvalues, eigenvectors. Ladder operators and their matrix representations, Pauli spin matrices, their Commutation relations. Angular momentum as generator of rotation. Addition of angular momenta. Clebsch-Gordon coeficients. L-S coupling. Wigner - Eckart theorem.

Unit IV: Identical Particles

Many particle systems, systems of identical particles, exchange degeneracy, symmetrization postulate, construction of symmetric and anti-symmetric wave functions from unsymmetrized functions. The Puli exclusion principle. Introduction to second quantization. Creation and annihilation operators for Fermions and Bosons. Fock states.

Course Title – Nuclear &Particle Physics

Course Type – Core

Course Code - 26-PHY-C-404

Course Level – 400

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Nuclear Physics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

To study simple models of Nuclear forces which are most complicated forces in nature. To understand particle accelerators to study particle interactions through bombardment to know nature of forces between various types of particles. To classify various fundamental particles based on few intrinsic characteristics, to know about various symmetries and related conservation laws.

Reference Books:

1. Nuclei and Particles : Segre
2. Nuclear Physics : Cohen
3. Nuclear Physics : Enge
4. Physics of Nuclei and Particles : Marmur and Sheldon
5. Introduction to Nuclear and Particle Physics : Das and Ferbel

Course Syllabus

Unit I: Nuclear Model and Nuclear Forces

Angular momentum, Parity and symmetry, Magnetic dipole moment and electric quadrupole moment, Energy levels and mirror nuclei. Nuclear Shell Model and magic numbers.
Characteristics of nuclear forces -Range and strength, Simple theory of two nucleon system -deuterons, Spin states of two nucleon system, Effect of Pauli's exclusion principle, Magnetic dipole moment and electric quadrupole moment of deuteron -The tensor forces.

Unit II: Energy deposition and Particle detection

Interaction of charged particles with matter. Stopping power and range. Detectors for energetic charged particles; Cerenkov detectors, Solid State or Semiconductor detector. Working principle of Cloud chamber, Bubble chamber, Ionisation chamber. Proportional counter. G.M. Counter. Scintillation Counter, spark chamber.

Unit III: Particle Accelerators

Need for accelerator of charged particles, Classification of types of accelerators, Cyclotron, Synchrotron, Betatron; Alternating gradient accelerator, Colliding beam accelerator.

Unit IV: Elementary particles

Classification and properties of elementary particles; Resonances ; Interactions and their mediating quanta, Conservation rules in fundamental interactions; Strangeness and associated production, Isospin and its conservation. Parity and charge conjugation, Conservation of parity and its violation, Idea of eight fold way and quarks.

Course Title – Electronics

Course Type – Core

Course Code - 26-PHY-C-405

Course Level – 400

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Basic Electronics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Theory of semiconducting material. Functioning of various semiconductor devices like BJT, FET and MOSFET, and their applications. Negative feedback used for stabilizaing signal. Study of devices based on microwaves.

Reference Books:

1. Electronic Fundamentals and Applications : John D. Ryder
2. Electronic Devices and Circuits : Millman and Halkins
3. Solid State Electronic Devices : Ben G. Streetman
4. Electronics : Ramabhadran S.
5. Electronics Devices and Circuit theory : Boylested and Nashelsky
6. Pulse, Digital and Switching Waveforms : Millman and Taub
7. Fundamental of Transistor : S.W. Amos
8. Microwave Principle : W.J. Reich
9. Microwaves : K.L. Gupta
10. Introduction to Microwave : G.J.Wheeler;
11. Semiconductor Devices- Physics and Tecnology : S.M. Sze.

Course Syllabus

Unit I: Semiconductor Devices I

Semiconducting Materials, conduction in semiconductors, Charge densities in a semiconductors, PN junction, space charge and electric field distribution at junctions, forward and reverse biased conditions, Space charge capacitance, varactor diode, Zener and avalanche breakdowns, zener diode, tunnel diode, photodiode, LED, p-n-p-n devices and their characteristics, SCR.

Unit II: Semiconductor Devices II

Transistors: Bipolar junction Transistor (BJT), Ebers Moll Model, Analysis of CE amplifier using h-parameters, The T-network equivalent circuit, constants of CB and CE amplifier using emitter, base, collector resistance, Biasing technique to BJT, stabilization factor, temperature stabilization, operating point, fixed bias, emitter feedback bias, voltage feedback bias. Field-Effect Transistors (FET) and MOSFET: Structure, Working, Derivations of the equations for I-V characteristics under different conditions.

Unit III: Feedback Principle

Negative feedback, effect of negative feedback on input/output resistances and voltage gain, gain stabilization, effect of negative feedback on band width, voltage series feedback, voltage shunt feedback applied to BJT, current series feedback, current shunt feedback applied to BJT

Unit IV: Microwave Electronics

Microwaves, Principle of velocity modulation and bunching of electrons, Basic principles of two cavity klystrons and Reflex Klystrons, operation of magnetrons, characteristics of microwave diode.

Course Title - Lab 1

Course Type – Lab

Course Code - 26-PHY-C-400

Course Level – 400

Total Credits – 4

Classes /week – 8

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome

To get familiar with electronic circuits and experiments useful for physics such as transistor biasing, amplifiers, vibrators, oscillators and modulators (frequency and amplitude).

List of Experiments :

1. PN Junction : To find the band gap of the semiconductor.
2. CE Amplifier (Bread Board) : To find bandwidth of capacitive coupled common emitter amplifier
3. Transistor Biasing : To study various biasing techniques, viz i) self bias ii) fixed bias, iii) voltage divider biasing, and to find the best biasing by observing the temperature effect on output waveform
4. FET : To find input and transfer characteristics of Field Effect Transistor
5. MOSFET : To find input and transfer characteristics of MOSFET
6. Op-Amp : To make inverting/non-inverting amplifiers, buffer, integrator and differentiator circuits using operational amplifier
7. To study Feedback in Transistors : a) series-series b) series-shunt c) shunt-series iv) shunt-shunt feedbacks
8. IC555 (BB) : To make astable and monostable vibrator using IC555
9. Phase Shift Oscillator (BB) : To make RC phase shift oscillator using 3 and 4 RC networks and compare experimental and theoretical frequencies
10. To study Amplitude Modulation & Demodulation and to calculate modulation index
11. To make Astable multivibrator using bipolar transistor
12. Optoelectronic kit : to study characteristics of i) Light Emitting Diode, ii) Temperature Dependent Resistance, iii) light dependent transistor
13. To study Analog to Digital conversion
14. To study Digital to Analog conversion
15. To study Frequency Modulation & Demodulation and to calculate modulation index
16. To study PAM (Pulse Amplitude Modulation) circuit
17. To study PCM (Pulse Code Modulation) circuit
18. To study PWM (Pulse Width Modulation) and PPM (Pulse Position Modulation) circuit

SEMESTER II

	Course Type	Course Name	Course Code	Credits
Semester II Course Level 500	Core I	Atomic & Molecular Physics	26-PHY-C-501	4
	Core II	Condensed Matter Physics	26-PHY-C-502	4
	Core III	Electrodynamics	26-PHY-C-503	4
	Core IV	Quantum Mechanics II	26-PHY-C-504	4
	Core V	Statistical Mechanics	26-PHY-C-505	4
	Lab	Lab 2	26-PHY-C-500	4
	Total			24

Course Title – Atomic & Molecular Physics

Course Type – Core

Course Code - 26-PHY-C-501

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Quantum Mechanics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

To understand the structure and radiative transitions in hydrogenic atoms; Lasers - principles and examples; Fine structure and hyperfine structure of atomics energy levels; Interactions of atoms with magnetic and electric fields; Study of molecular spectra - rotational, vibrational and electronic.

Reference Books:

1. Physics of Atoms and Molecules : B.H. Bransden & C.J. Joachain
2. Elementary Atomic Structure : G.K. Woodgate
3. Introduction to Modem Physics : H.S. Mani & G.K. Mehta
4. Molecular Spectra : G. Herzberg
5. Fundamentals of Molecular Spectroscopy : C.N. Banwell
6. Laser Spectroscopy : W. Demtroder
7. Principle of Lasers : O. Svelto

Course Syllabus

Unit I :

Review of Solution of Schrödinger's equation for hydrogenic atoms, dipole approximation, transition rates of emission and absorption, selection rules for radiative transitions, life-times of atomic and molecular states. Profiles and intensities of spectral lines. Multilevel rate equations and saturation, coherence, laser pumping and population inversion, Rabi frequency. Examples of gas and solid-state lasers.

Unit II :

Fine structure of hydrogenic atoms, Mass correction, spin-orbit term, Darwin term, Lamb Shift, Lamb-Rutherford experiment, Intensity of fine structure lines, hyperfine structure, ground state and first excited state of two-electron atoms; Many-electron atoms; Central Field Approximation, LS and jj coupling schemes, Hund's Rule, Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.), Thomas-Fermi potential, Landé interval rule.

Unit III: Molecular Spectra

Atoms in an External Magnetic Field: Weak and Strong field Zeeman effect, Normal and Anomalous Zeeman effect, Paschen-Back effect. Atoms in external electric fields: Linear and Quadratic Stark effect, quenching of the metastable states.

Unit IV:

Born-Oppenheimer approximation for diatomic molecules, Rotational spectra of diatomic molecules; rigid and non-rigid rotors, isotope effect, Vibrational spectra of diatomic molecules; harmonic and anharmonic vibrators, Intensity of spectral lines, dissociation energy, The Franck Condon principle. Introduction to Raman Effect, ESR, NMR.

Course Title – Condensed Matter Physics

Course Type – Core

Course Code - 26-PHY-C-502

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Solid State Physics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

To explore the electronic structure of solids beyond the free electron theory and to understand the development of band structure of semiconductor. To understand magnetic properties of different materials, to correlate magnetic and optical properties of solids, to understand various magnetic quasi particles to better understand magnetic phenomena. To know basics of superconductivity and superfluidity. Study of defects and disorder and study of order in liquid crystals.

Reference Books:

1. Introduction to Solid State Physics : C. Kittel
2. Solid State Physics : Rita John
3. Introduction to Solids : L.V. Azaroff
4. Solid State Physics : N.W. Ashcroft and N.D. Mermin
5. Solid State Physics : H. Ibach and H. Luth
6. Superconductivity of Metals and Alloys : Pierre de Gennes.
7. Principles of the Theory of Solids : J.M. Ziman

Course Syllabus

Unit I: Electrons in Solids

Review of free electron and nearly-free electron theory, Tight-binding Model, Wannier functions, the LCAO approximation. Examples of band structures. Fermi surfaces of metals and semiconductors.

Unit II: Dielectric and Optical Properties of Solids:

Polarization and Susceptibility: The local electric field in solids, Dielectric Constant and Polarizability, Clausius-Mossotti Equation, frequency dependence of dielectric constants. Polar molecules and Langevin-Debye equation. Sources of Polarizability (Electronic, Ionic, Dipolar), Classical Theory of Electronic Polarizability. Frequency Dependence of Total Polarizability.
Optical response of Solids: Plasmons, polarons, polaritons, Kramers-Kronig relations, electronic inter-band and intra-band transitions. Band structure determination from optical spectra.

Unit III: Magnetism in Solids

Orbital and spin magnetic moments. Langevin's theory of diamagnetism and paramagnetism. Quantum theory of diamagnetism and paramagnetism. Paramagnetism in a two-level (spin 1/2) and higher level (L + S = J) system, Brillouin Function and the Curie Law. Paramagnetic susceptibility of conduction electrons - Pauli paramagnetism. Ferromagnetism: Weiss exchange field, mean field approximation, Curie temperature, Curie-Weiss law, temperature dependence of saturation magnetisation, hysteresis, domains and domain walls. Antiferromagnetic order and Neel temperature.

Unit IV: Superconductivity:

Historical Developments, Zero Resistivity, Meissner Effect, Supercurrents and Penetration Depth, London Equations, Critical Field and Critical Temperature, Type I and Type II Superconductors, Thermodynamical properties. Cooper Pairing and Introduction to BCS Theory, Flux Quantization, Josephson Effects. High Temperature Superconductors. Superfluidity in Helium (He4 and He3).

Course Title – Electrodynamics

Course Type – Core

Course Code - 26-PHY-C-503

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Electromagnetism

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

To understand and work out energy, momentum and angular momentum densities of electromagnetic fields. To understand retarded potential formalism to work out time dependent electric and magnetic fields of moving charges. To understand various types of special cases of radiations to understand real life situations. To work out covariant equations of E-M fields to understand electrodynamics is inherently a relativistic theory.

Reference Books:

1. Classical Electrodynamics : J.D.Jackson,
2. Classical Theorey of Fields : Landau & Lifshitz
3. Introduction to Electrodynamics: D. J. Griffiths
4. Foundations of Electromagnetic Theory : Reitz, Milford and Christy
5. Classical Charged Particle- Foundations of their Theory : Fritz Rohrlich

Course Syllabus

Unit I: Review of Maxwell’s Equation

Review of Maxwell’s equations. Scalar and vector potentials. Gauge transformations. Coulomb and Lorentz Gauge, Conservation of energy and momentum, Poynting theorem, Maxwell’s Stress tensor. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density.

Unit II: Potentials and Fields

Solution to Inhomogeneous wave equations for continuous distributions, Green’s functions for Poisson and Wave equations. Retarded and Advanced solutions for Maxwell’s equations. Jefimenko formulas for electric and magnetic field, Potentials and electromagnetic fields for moving point charge, Lienard-Wiechert Potentials.

Unit III: Radiation

Radiation from localized oscillating charges. Dipole and quadrupole radiation (electric and magnetic), Radiation from an arbitrary source, Multipole expansion, Radiation from moving point charge, Larmor’s formula and Lienard’s generalization (relativistic); Angular distribution of radiated power for linearly (Bremsstrahlung) and circularly accelerated charges, , Synchrotron, radiation from uniformly moving charge : Cerenkov radiation (qualitative treatment only). Radiation reaction from energy conservation, Abraham-Lorentz formula, Self force.

Unit IV: Covariant formulation of Electrodynamics

Review of STR. Lorentz transformations. Four-vectors, Tensors. Lagrangian for a free relativistic particle, for a charged particle in an E.M. field, for free electromagnetic field, for interacting charged particles and fields. Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field; Electromagnetic field tensor, Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion, Maxwell’s equations in co-variant form,; Field invariants; Hamiltonian of a charged particle in an electromagnetic field. Energy-momentum tensor and related conservation laws.

Course Title – Quantum Mechanics II

Course Type – Core

Course Code - 26-PHY-C-504

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Quantum Mechanics I

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Time independent and time dependent perturbation theory in quantum mechanics. Scattering of particles from different potentials, S and T matrix approach, relativistic spin zero and spin half equations, application in few simple cases, antiparticles.

Reference Books :

1. Quantum Mechanics : Franz Schwabl
2. Quantum Mechanics : Eugen Merzbacher
3. Quantum Mechanics : N. Zettili
4. Quantum Mechanics : P. M. Mathews and K. Venkatesan
5. Priciples of Quantum Mechanics : P. A. M. Dirac

Course Syllabus

Unit I: Approximation methods for stationary systems

Time independent perturbation theory. Perturbation of non-degenerate states: first and second order perturbation. Perturbation of a harmonic oscillator. Perturbation of degenerate states, removal of degeneracy. Application to one-electron system – Relativistic mass correction, Spin-orbit coupling (L-S and j-j),Zeeman and Stark effects. Variational and WKB methods.

Unit II: Approximation methods for time-dependent pertrbations

Schrodinger, Heisenberg and interaction pictures, Equations of Motion. Constant and harmonic perturbation. Discrete and continuous case, transition probability. Time-dependent perturbation theory. Transition to a continuum of final states, Fermi golden rule. Application to constant and harmonic perturbations. Adiabatic and sudden approximations.

Unit III: Scattering Theory

Laboratory and centre of mass frames, The differential and total Cross section, Scattering amplitude, Scattering by spherically symmetric potentials; Partial waves and phase shifts. Scattering of a wave packet, The Lippmann Schwinger equation. Formal treatment of scattering by Green's function method. The Born approximation. Definition and properties of S-matrix, T matrix. Optical theorem

Unit IV: Relativistic Quantum Mechanics

Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Nonrelativistic reduction of the Dirac equation; Helicity and chirality; Properties of γ matrices; Lorentz and CPT invariance of Dirac equation; Normalisation and completeness of spinors. Central forces and the hydrogen atom. Dirac electron in constant magnetic field, Foldy-Wouthuysen transformation, Hole theory, Time reversal symmetry, Non-hermitian open quantum system.

Course Title – Statistical Mechanics

Course Type – Core

Course Code - 26-PHY-C-505

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Thermodynamics

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Study of classical systems consisting of large number of particles. Distribution of particles. Various types of ensembles and their properties. Calculation of various thermodynamic properties. Study of quantum systems using indistinguishability of particles : B-E and F-D statistics. First and second order phase transition, scaling.

Reference Books:

1. Statistical and Thermal Physics : F. Reif
2. Statistical Mechanics : K. Huang
3. Statistical Mechanics : R K Pathria
4. Statistical Physics : Landau and Lifshitz
5. Thermodynamics and Statistical Mechanics : Greiner, Neise and Stocker
6. Statistical Physics : F. Mandl

Course Syllabus

Unit I: Statistical basis of thermodynamics

Objective of statistical mechanics. Central Limit Theorem, The macroscopic and the microscopic states, phase space, ensemble, trajectories and density of states, Ergodic hypothesis, postulate of equal a-priori probability and equality of ensemble average and time average. Boltzmann's postulate of entropy, Counting the number of microstates in phase space, Liouville's theorem, ensemble theory, the principle of maximum entropy, contact between statistical mechanics and thermodynamics, classical ideal gas, entropy of mixing Sackur-Tetrode equation and Gibb's paradox

Unit II: Canonical and grand-canonical ensembles

System in contact with a heat reservoir , Micro-canonical ensemble, Canonical ensemble, partition function, calculation of statistical quantities - entropy, Helmholtz free energy, Energy fluctuations. System in contact with a particle reservoir, chemical potential - The grand canonical ensemble, grand canonical partition function and grand potential, particle number fluctuation. Entropy in grand canonical ensemble, thermodynamic potentials. Chemical potential of ideal gas. Chemical equilibrium and Saha Ionisation Equation.

Unit III : Quantum Statistical Mechanics

Postulates of quantum statistical mechanics, density matrix, Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices. Statistics of indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose Einstein distribution, properties of ideal Bose and Fermi gases, Equation of state; Fermi gas at finite Temperature, Bose-Einstein condensation.

Unit IV: Phase transitions

Type of phase transitions, first and second order phase transitions. Ising model, partition function for one dimensional case, mean-field theories of the Ising model in two and three dimensions. Connection of Ising model to lattice gas and binary alloy models. Chemical equilibrium and Saha ionisation formula. Phase transitions – first order and continuous, critical exponents and scaling relations. Landau theory of phase transition, Landau free energy for second and first order transitions, Calculation of exponents from Mean Field Theory and Landau's theory, universality classes.

Course Title - Lab 2

Course Type – Lab

Course Code - 26-PHY-C-500

Course Level – 500

Total Credits – 4

Classes /week – 8

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome

To familiarise students with experiments in atomics physics and condensed matter physics: fundamental experiments in quantum physics such as Franck-Hertz, ESR experiment for Landé g-factor. Magnetic and dielectric measurements- susceptibility, hysteresis, magnetoresistance, Hall effect, Curie Temperature.

List of Experiments :

1. Study of radioactivity by using a G.M. tube to (i) Determine background radiation and (ii) Study absorption in air of β and γ radiation from ^{137}Cs and ^{60}Co sources.

2. Hall effect : Study of the dependence of Hall coefficient on temperature.

3. Determination of the magnetic susceptibility of $MnCl_2$ by Quincke's tube method.

4. Study of magnetoresistance of doped semiconductors.

5. Study of magnetic hysteresis in various ferromagnetic materials using a Hysterisis loop tracer .

6. Frank- Hertz experiment.

7. Fourier analysis of sinusoidal, triangular and square waveforms.

9. Determination of the Curie temperature of ferroelectric materials.

10. Determination of the forbidden energy gap of semiconductors.

11. Determination of the dielectric constants of amorphous and crystalline solids.

12. Determination of the Landé g factor of electrons using ESR.

13. Study of the temperature dependence of resistivity of semiconductors by the 4-probe method.

14. Study of I-V characteristics, and determination of the fill-factor and efficiency of a solar photovoltaic cell.

15. Study of Zener and avalanche breakdown in P-N junction diodes as a

SEMESTER III (2 year)/ SEMESTER I(1 year)

	Course Type		Course Name	Course Code	Credit
Semester III (For 2 yr PG) OR Semester I (For 1 yr PG) Course Level 500	Specialisation Core (Materials/ Theory/ Laser)	Materials	Condensed Matter Physics (Adv)	26-PHY-SC-517	4
			Physics & Technology of Semiconductor Devices	26-PHY-SC-518	4
		Theory	Classical Field Theory	26-PHY-SC-519	4
			Quantum Field Theory	26-PHY-SC-520	4
		Laser	Laser Physics	26-PHY-SC-521	4
			Quantum Optics	26-PHY-SC-522	4
	Elective	To be chosen from the courses offered from the pool in a particular semester			4
	Elective	To be chosen from the courses offered from the pool in a particular semester			4
	Compulsory	Research Methodology		26-PHY-C-516	4
	Lab	Lab 3		26-PHY-C-515	4
	Total				24

POOL OF ELECTIVE SUBJECTS

Course Name	Course Code	Course Name	Course Code
Growth and Characterisation of Materials	26-PHY-E-523	Introduction to Quantum Technologies and Applications	26-PHY-E-530
Physics of Novel Materials	26-PHY-E-524	Energy Materials and Devices	26-PHY-E-531
Photonics	26-PHY-E-525	Cosmology	26-PHY-E-532
Laser Spectroscopy	26-PHY-E-526	Band Topology and Quantum Transport	26-PHY-E-533
General Theory of Relativity	26-PHY-E-527	Advanced Nanoelectronics and VLSI	26-PHY-E-534
Particle Physics	26-PHY-E-528	Group theory for physicists	26-PHY-E-535
Computational Techniques in Condensed Matter	26-PHY-E-529	Advanced Mathematical Physics	26-PHY-E-536

Course Title – Condensed Matter Physics (Adv)

Course Type – Specialisation Core

Course Code - 26-PHY-SC-517

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Students will gain the ability to apply second-quantisation to many-electron systems, analyze transport phenomena using semiclassical Boltzmann theory, and understand key magnetic and quantum transport effects including Landau levels and the Quantum Hall Effects. They will also be able to explain major concepts in superconductivity and superfluidity, including BCS theory, pairing mechanisms, Ginzburg–Landau theory, and Josephson phenomena.

Reference Books:

1. Quantum Many-Body Physics: Alexander Altland and Ben Simons
2. Solid State Physics : Ibach and Luth
3. Solid State Physics : Ashcroft and Mermin
4. Quantum Theory of Solids : C. Kittel
5. Introduction to Superconductivity: Michael Tinkham
6. Superconductivity: R. Schreiffer
7. Introduction to Solid State Physics: C. Kittel

Course Syllabus

Unit I: Semiclassical Boltzman transport

Non-equilibrium Fermi distribution function, relaxation time approximation, scattering rate and its calculation using Fermi's Golden Rule, Boltzman transport equation. Electrical conductivity tensor, thermopower and thermal conductivity, Wiedemann-Franz Law, Mott's Rule.

Unit II: Introduction to second quantisation

Many electron systems, the Hartree-Fock approximation, Slater determinant. Introduction to Second, Quantisation and reformulation of tight-binding Hamiltonian in second quantised notation. Introduction to the quantum field and the Hamiltonian in terms of the quantum field operators. Electron-electron interaction, electron-phonon interaction: The Fröhlich Hamiltonian.

Unit III: Magnetism and Quantum Hall effect

Electronic system in presence of a constant magnetic field: Landau levels, degeneracy of each Landau levels, Landau diamagnetism. Van Vleck theory of Paramagnetism. Cooling by Adiabatic demagnetization, Exchange interaction of free electrons, Band model of Ferromagnetism, Landau theory of phase transition, super-exchange, double exchange, Hubbard model, spin wave, spin wave theory of anti-ferromagnetism, Neel temperature.
2D electron gas in a magnetic field : Concept of Time reversal symmetry, Krammers degeneracy, Integer Quantum Hall Effect. Dispersionless Landau level, Degeneracy. Filling fraction. Shubnikov-de Haas oscillation, de-Hass Alphen effect, Effects of Coulomb interaction on quantum Hall effect: Fractional quantum
Hall effect.

Unit IV: Theory of Superconductivity

Fundamental phenomena of superconductivity, Meissner effect, Pauli pair breaking, Ginzburg Landau Theory, Gross-Pitaevskii equation, Cooper pairs and origin of electron-phonon interaction, BCS theory. BCS wave functions, Bogoliubov-de Gennes (BdG) Hamiltonian, quasiparticle density of states, Types of pairing: s-wave pairing, p-wave pairing, d-wave pairing and inhomogeneous order parameter (LOFF state), Andreev reflection, Josephson Effect in GL theory, dynamics of Josephson junction: RCSJ, Shapiro steps, SQUIDS, Superfluidity.

Course Title – Physics & Technology of Semiconductor Devices

Course Type – Specialisation Core

Course Code - 26-PHY-SC-518

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Analyze MESFETs, Schottky contacts, and high-frequency semiconductor devices. Understand MOS-based devices and modern transistor technologies. Apply principles of quantum-effect and photonic devices. Evaluate thin-film formation and epitaxial growth techniques. Apply lithography, etching, and diffusion methods in semiconductor processing.

Reference Books:

1. Semiconductor Devices Physics and Technology : S.M. Sze
2. Introduction to Semiconductor Devices: S.M. Tyagi
3. Physics of Semiconductor Devices : S.M. Sze,
4. Solid State electronics : Ben G. Streetman
5. Material Science by engineers : James F. Shackelford
6. The Physics of Semiconductor Devices : D.A. Eraser, Oxford Physics Series (1986)
7. Thin Film Phenomena : K.L. Chopra.
8. Semiconductor Physics and Devices : S.S.Islam

Course Syllabus

Unit I: MESFET and Related Devices

Metal-semiconductor contacts; Basic Characteristics, Schottky Barrier, Ohmic Metal Semiconductor Contact, Current Transport process, Determination of Barrier Height, MESFET; Device Structures, Principles of Operations, Current Voltage Characteristics, High Frequency Performance, MODFET or HEMT; fundamentals, , Current -Voltage Characteristics, Cut off Frequency.

Unit II: MOSFET and Related Devices

MOS Diode; SiO_2-Si MOS Diode, Charge Coupled Device (CCD), MOSFET Fundamentals; Basic Characteristics, Types of MOSFET, Threshold Voltage Control, MOSFET Scaling; CMOS and BiCMOS; MOS Memory Structures.

Unit III: Quantum Effect and Photonic Devices

Quantum-Effect Devices; Resonant Tunneling Diode, Unipolar Resonant Tunnelling Transistor, Semiconductor Laser; Semiconductor Materials, population Inversion at a junction, Emission spectra for p-n junction Lasers, Basic Laser Structure, Photodetector; Photoconductor, Solar Cell; p-n junction Solar cell, conversion Efficiency.

Unit IV: Film Formation and Epitaxial Growth

Thermal Oxidation; Dielectric Deposition; Thin Films Deposition Techniques: Thermal evaporation, Sputtering, Chemical Vapour Deposition(CVD), LPCVD, Epitaxial Growth Techniques: Vapour phase Epitaxy, Molecular Beam Epitaxy (Elementary description).

Unit V: Lithography, Etching and Diffusion of impurities

Optical Lithography; Exposure Tools, Masks, Photoresist, Electron Beam Lithography (Elementary description) ,Wet Chemical Etching, Dry Etching, Reactive Plasma Etching techniques and Equipment, Basic Diffusion Process: Diffusion Equations, Doping of Semiconductor.

Course Title – Classical Field Theory

Course Type – Specialisation Core

Course Code - 26-PHY-SC-519

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Formulate and analyze classical and relativistic field theories. Apply advanced mathematical structures to modern field theories. Analyze global and local symmetries and the mechanisms of symmetry breaking. Evaluate topological and nonperturbative configurations in field theory.

Reference Books:

1. Classical mathematical physics: Walter Thirring.
2. Classical mechanics: Herbert Goldstein.
3. Gauge theory of elementary particle physics: Ta-Pei Cheng and Ling-Fong Li.
4. Quantum field theory: Michio Kaku.
5. Application of differential geometry to physics(lecture notes): Prof. Malcolm Perry

Course Syllabus

Unit I:

The transition from discrete to continuum system, the stress-energy tensor and conservation theorems, Hamiltonian formulation, Relativistic field theory, examples of relativistic field theories and Noether's theorem.

Unit II: Mathematical formalism

Manifolds, vectors, tensors and p-forms, operations on forms, electromagnetism and Yang-Mills theory, Vielbein formalism and it's application in general relativity, Integration, action for general relativity and Yang-Mills field.

Unit III:

Global symmetries in field theory, spontaneous breaking of global symmetry, the Goldstone theorem, local symmetries in field theory: Abelian gauge theory, Non-Abelian gauge symmetry(Yang-Mills fields), spontaneous breaking of gauge symmetry, the Higgs phenomena, Abelian and Non-Abelian cases, unitary gauge, pattern of symmetry breaking, the number of massive gauge bosons.

Unit IV: Solitons, Monopoles and Instantons

Definitions of the models, Soliton solutions, vertex solution, introduction of the gauge field, Bogomol'nyi bound for the energy, construction of monopole solution, Bogomol'nyi bound and BPS states, 't Hooft-Polyakov monopole, the topology of gauge transformations, Dirac theory of magnetic monopoles, Instanton and vacuum tunneling.

Unit V: Group theory

Elements of group theory, SU(2) group, SU(2) representation, SU(2) product representation, SU(3) group, SU(3) representation, tensor method in SU(n), irreducible representations and Yang tableaux, Lorentz and Poincare group.

Course Title – Quantum Field Theory

Course Type – Specialisation Core

Course Code - 26-PHY-SC-520

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Apply canonical quantization to relativistic fields. Formulate interacting quantum field theories using standard tools. Quantize the electromagnetic field and understand QED structure. Compute tree-level scattering amplitudes in QED. Analyze loop corrections and renormalization in QFT.

Reference Books:

1. Introduction to Relative Quantum Field Theory : S.S. Schwebber
2. Introduction to Quantized Field Theory : Bogolinbov & Shirkov
3. Relativistic Quantum Mechanics : Bjorken & Drell
4. Quantum Field Theory : Bjorken & Drell
5. Quantum Field Theory : Itzyksen & Zuber

Course Syllabus

Unit I: Canonical Quantization

Canonical quantization of neutral scalar, Charged scalar, spin 1/2 and massive spin-1 fields, Fock space and observables. Field commutation, anti-commutation relations.

Unit II: Interacting Fields

Interaction picture. Normal product. Wick's theorem. Feynman propagator. S-matrix. Feynman rules and diagrams

Unit III: Quantum Electrodynamics

Quantization of electromagnetic field. Gupta- Bleuler condition. Indefinite metric. Feynman diagrams of QED.

Unit IV: Scattering (tree level) in QED

Tree level calculations of Moller, Bhabha, Compton and Scattering in external field

Unit V: Some Special topics

1-loop corrections and renormalization. RG equations.

Course Title – Laser Physics

Course Type – Specialisation Core

Course Code - 26-PHY-SC-521

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

By the end of this course, students will be able to: Analyze and model optical resonators and Gaussian beams, Explain photon–atom interactions and spectral line broadening mechanisms, Apply principles of laser amplifiers to evaluate gain, stability, and noise and analyze laser oscillation, mode control, and pulsed-laser techniques.

Reference Books:

1. Introduction to Laser Physics : K.Shimoda
2. Principles of Lasers : O. Svelto
3. Lasers- Theory and Applications : Thyagarajan and Ghatak
4. Fundamentals of Photonics: B.E.A. Saleh and M.C. Teich

Unit I: Optical Resonators and Gaussian Beam

Brief review of matrix optics, Planar Mirror Resonators, Resonator Modes, Two- and Three-Dimensional Resonators, Spherical-Mirror Resonators, Ray confinement, Gaussian waves and its characteristics: The Gaussian beam, Transmission through optical component, Gaussian Modes, Resonance Frequencies, Hermite-Gaussian Modes, Finite Apertures and Diffraction Loss.

Unit II: Photons and Atoms

The Photon Optics theory of light in a resonator, Photon Polarization, Transmission and interference of photon, Photon time, Photon streams. Energy levels and Occupation of energy levels in thermal equilibrium, Interaction of single mode light with an atom, Spontaneous Emission, Transition Probabilities, Stimulated Emission and absorption, line shape function, Transition in presence of broadband light, Lineshape broadening: Homogeneous and Inhomogeneous Broadening. Lifetime broadening, Collision Broadening, Doppler Broadening.

Unit III : LASER Amplifiers

Theory of laser amplifiers, Gain and band width, Phase shift, Rate equations, pumping schemes, Common Laser amplifiers, Doped glass amplifiers, Amplifier Nonlinearity and stability saturation-saturated gain in homogeneously and inhomogeneously broadened media. Amplifier noise.

Unit IV: Lasers

Theory of laser oscillation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output, Mode selection, Common lasers; Selected characterises of common lasers, Pulsed lasers: Methods of pulsing lasers, Q-switching, Mode locking.

Course Title – Quantum optics

Course Type – Specialisation Core

Course Code - 26-PHY-SC-522

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

Apply the quantum theory of radiation to electromagnetic fields. Evaluate coherence properties, photon statistics, and atom–field interactions. Formulate quantum theories of damping, laser physics, and atom optics. Interpret foundational concepts of quantum nonlocality and measurement.

Reference Books:

1. Elements of quantum optics : Meytre-Sergent
2. Quantum optics : M.O.Scully and M.S. Zubairy
3. Optical coherence and quantum optics : Mandel and Wolf
4. Laser physics : Sargent,Scully and Lambs

Course Syllabus

Unit I: Quantum Theory of Radiation

Quantization of free electromagnetic fields, Fockstates, Lambshift, quantum beats, concept of photons, coherent and squeezed states of lights, quantum distribution theory and partially coherent radiation.

Unit II:

First and second-order coherence, HBT effect, photon bunching and anti bunching, Poissonian and sub-poissonian light, photon counting and photon statistics, Atom- field interaction : semi classical theory and quantum theory, coherent trapping, electromagnetically induced transparency and lasing without inversion.

Unit III: Quantum theory of damping

Density operator method and langevin approach, quantum theory of laser, squeezing of light in nonlinear optical process, Atom optics : mechanical effects of light, atomic interferometry, quantum noise in an atomic interoferometer, limits to laser cooling.

Unit IV:

Introductory ideas on EPR paradox, Bells inequality, QND measurements and two photon interferometry

Course Title – Growth and characterisation of materials

Course Type – Elective

Course Code - 26-PHY-E-523

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course provides a foundational understanding of vacuum science, thin-film deposition, and crystal growth techniques. Students will learn key vacuum principles, film-growth methods such as PVD, CVD, and epitaxy, and major single-crystal growth processes. The course covers crystal imperfections, nucleation mechanisms, and structural characterization tools including XRD, Raman, FTIR, electron and ion-based techniques, and scanning probe microscopies. Students will also gain insight into surface analysis methods, photoelectron spectroscopies, and the determination of electronic structure.

Reference Books:

1. Experimental techniques of surface science : Woodruff and Delchar
2. Solid State Physics : Ashcroft and Mermin
3. Solid Surfaces, Interfaces and Thin Films: Hans Lüth
4. Amorphous Materials : S.R.Elliot
5. Fundamentals of surfaces and thin film analysis : L.C.Feldman and J.W.Mayer
6. An introduction of X-ray crystallography : M.M.Wofson
7. Use of films in Physical investigations : J. C. Anderson
8. Rutherford backscattering Spectroscopy : W. K. Chu

Course Syllabus

Unit 1: Introduction to Vacuum and Thin Film Growth Techniques

Fundamentals of Vacuum, Concepts of Throughout & Pumping Speed, Vacuum Creation and Measurement: Pumps and Gauges, Leak Detection and Residual Gas Analysis.
Thin Film Growth: Physical and Chemical vapour deposition: Thermal and e-beam evaporation, Sputtering, Chemical Vapour Deposition(CVD), LPCVD(Low Pressure CVD), Laser Ablation. Thermal Oxidation; Dielectric Deposition. Epitaxial Growth Techniques: Vapour phase Epitaxy, Molecular Beam Epitaxy.

Unit II: Single Crystal Growth and Imperfections:

Bridgman-Stockbarger and Czochralski method, flux and hydrothermal method, purification of materials, zone refining. Homogenous and heterogenous nucleation, diffusion and screw dislocation mechanism of crystal growth. Atomic imperfections in crystals- one, two and three dimensional imperfections, Schottky and Frenkel defects, Burger's vector and Burger's circuit, energy of dislocations, grain boundaries and surface.

Unit III: Crystal Structure and Morphology:

XRD, Raman Spectroscopy, FTIR, UV-Visible Spectroscopy and Photoluminescence, Neutron Diffraction, RBS, SIMS, AFM & STM, SEM, TEM, AFM, STM, LEED & RHEED,

Unit IV:Surface Analysis Techniques: Electronic structure

X-ray and ultraviolet photoelectron spectroscopies and Auger electron spectroscopy. Calculation of electronic energy levels and their dispersion0 using angle-resolved photoemission spectra.
Chemical shift determination.

Course Title – Physics of Novel Material

Course Type – Elective

Course Code - 26-PHY-E-524

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor’s Name :

Course Advisor’s Email :

Expected Learning Outcome –

The student will understand quantum confinement in wells, wires, and dots, gain knowledge of carbon nanotubes including their bonding, growth, properties, defects, characterization, and applications, and learn about non-carbon nanostructures such as semiconductor heterostructures and chemically synthesized nanomaterials. They will also develop an understanding of MEMS and NEMS devices, their principles, fabrication, and nanoscale applications.

Reference Books:

1. Quantum Dot Heterostructures : D. Bimberg, M.Grundman, N.N. Ledentsov
2. Carbon Nanotubes: Synthesis,Structure, Properties and Applications : M.S. Dresselhaus, G. Dresselhaus, Ph.Avouris
3. Electronics in Non-crystalline materials : Mott and Davis
4. Physics of Amorphous materials : Elliot
5. Superconductivity : A. V. Narlikar
6. Introduction to Solid State Theory : O. Madelung

Course Syllabus

Unit I: Quantum Well Structures

Electron confinement in infinitely deep square well, confinement in one and two dimensional well, idea of a quantum well structure, quantum dots, quantum wires

Unit II: Carbon nanotubes

Carbon nanotubes and other carbon materials, bonding between carbon atoms, single and multiwalled nanotube growth and characterization, electronic structure, crsytal structure, junctions and defects of nanotubes. Electronic structure, transport, optical properties, thermal and mechanical properties of nanotubes. Electron spectroscopy and scanning probe microscopy of nanotubes. Applications of carbon nanotubes.

Unit III : Non-carbon nano structures

Semiconductor hetero-structures, synthesis of nano materials using chemical techniques.

Unit IV: MEMS & NEMS

MEMS (microelectromechanical systems) and NEMS (nano electromechanical systems), nano machines and applications.

Course Title – Photonics

Course Type – Elective

Course Code - 26-PHY-E-525

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course introduces the fundamental principles of polarization, electro-optic, acousto-optic, and nonlinear optical phenomena, along with their device applications. Students will understand birefringence, magneto-optic effects, modulators, photorefractive media, wave-mixing processes, optical bistability, and frequency-conversion techniques. The course also provides a foundational understanding of photonic-crystal optics, including multilayer theory, Bragg gratings, Bloch modes, and photonic band structures in 1D–3D systems.

Reference Books:

1. Fundamentals of Photonics: B.E.A. Saleh and M.C. Teich
2. Photonics: Ralf Menzel
3. Quantum Electronics : A.Yariv
4. Nonlinear Optics : R.W. Boyd
5. Optics and Lasers : M.Young
6. Optical Electronics : A. Ghatak & K. Thyagarajan

Course Syllabus

Unit I: Polarization Optics

Polarization of Light, Optics of anisotropic media: The index ellipsoid**,** Birefringence, Polarization devices: Wave retarders, rotators and optical isolators. Magneto-Optic effect: Optical activity and Faraday effect

Unit II: Electro-optics and Acousto-optics

Pockels and Kerr Effect- Electro-optics of Anisotropic media, Phase and amplitude modulators, Beam Deflection and scanning devices, Photorefractive materials. Acousto-optics, Bragg diffraction and acousto-optic devices and their applications.

Unit III: Non-linear Optics and Optical Bistability

Non-linear optical media, second order non-linear optics- SHG, Three wave mixing. Third order non-linear optics, THG and self phase modulation. Four wave mixing and Optical Phase conjugation. Frequency conversion, Parametric Amplification and Oscillation. Self focusing of light. Bistable Systems, Principle of optical bistability, Bistable Optical devices, Optical logic and switching.

Unit IV: Photonic-Crystal Optics

Optics of Dielectric Layered Media: Matrix theory of multilayer optics, Bragg Grating. One-dimensional photonic Crystals - Bloch modes, dispersion relation and photonic band structure. Two- and three dimensional photonic crystals.

Course Title – Laser Spectroscopy

Course Type – Elective

Course Code - 26-PHY-E-526

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course provides an overview of laser-based spectroscopic techniques and their instrumentation. Students will learn the principles and advantages of laser spectroscopy, Doppler-limited and Doppler-free methods, multiphoton and Raman techniques, and time-resolved measurements. The course also covers modern developments such as single-ion spectroscopy, high-precision frequency standards, and major applications in chemistry, atmospheric monitoring, biology, and medicine.

Reference Books:

1. Laser Spectroscopy : W. Demtroeder
2. Atomic and Laser Spectroscopy : A.Corney
3. Molecular and Laser Spectroscopy : Zu-Geng Wang, Hui-Rong Xia

Course Syllabus

Unit I: Laser Spectroscopic Instrumentation

Monochromators. Interferometers. Laser detectors: Photocells, Photomultipliers, Photon Counters, Optical multichannel analyzer, Boxcar averager. Laser powers/Energy meters.

Unit II:

Advantages of Lasers in spectroscopy. Doppler-limited absorption spectroscopy: Excitation spectroscopy, Optoaccoustic spectroscopy, Intracavity absorption. Optogalvanic spectroscopy, Ionization spectroscopy. Laser induced fluorescence. Stepwise excitation. Spectroscopy of Rydberg states. Multiphoton spectroscopy.

Unit III:

Doppler-free techniques in spectroscopy. Laser Raman spectroscopy: Stimulated Raman Scattering, Coherent Anti-stokes Raman spectroscopy(CARS), Experimental tehniques of Laser Raman spectroscopy, Applications of Laser Raman spectroscopy, Non-linear Raman spectroscopy. Time resolved Laser spectroscopy: Lifetime measurements with lasers.

Unit IV: Recent trends in Laser spectroscopy

Spectroscopy of single ions, Spectral resolution within the natural linewidth. Absolute frequency measurements and Optical frequency standards.

Unit V: Applications of Laser spectroscopy

Laser photochemistry, laser isotope separation, Laser monitoring of the atmosphere. Laser spectroscopy in biology. Medical applications of Laser spectroscopy.

Course Title – General Theory of Relativity

Course Type – Elective

Course Code - 26-PHY-E-527

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

A solid understanding of the geometrical foundations of general relativity, including tensors, covariant derivatives, geodesics, and spacetime curvature. They will be able to apply the principles of curved spacetime—such as the equivalence principle and Einstein's equations—to analyze gravitational phenomena like the Schwarzschild solution, gravitational redshift, light bending, and black-hole metrics. Students will also develop insight into linearized gravity and gravitational waves, understanding their production, energy loss, and methods of detection.

Reference Books:

1. General Relativity : M.P.Hobson, G.P. Efstathiou and A.N.Lasenby
2. Gravitation and Cosmology : S.Weinberg
3. The Classical Theory of Fields: L.D.Landau and E.M.Lifshitz
4. Gravity: J.B.Hartle
5. Spacetime, Geometry and Gravitation : Pankaj Sharan

Course Syllabus

Unit I: Geometrical Basis

Vector and tensor fields, Affine connections, Metric tensor, Covariant derivative, Parallel transport Geodesic equation, Riemann curvature tensor. Symmetry properties of Riemann tensor. Bianchi identity. Ricci and Einstein tensor.

Unit II: Physics in Curved Spacetime

Equivalence Principle, Gravity as spacetime curvature, Weak gravitational field limit, Stress-energy tensor for a perfect fluid. Conservation equation for matter, Einstein equations (From Action Principle), Weak field limit of Einstein equations.

Unit III: Gravity in Simple Situations

Einstein equation in vacuum, Schwarzschild solution, Motion along a geodesic, Newtonian approximation, Gravitational redshift, Planetary motion and precession of the perihelion. Bending of light by a gravitating body.

Unit IV: Black Holes

Singularities in the Schwarzschild metric, Schwarzschild solutions in Kruskal-Szekeres coordinates. Gravitational collapse and black formation, Spherically symmetric collapse of dust, Reissner Nordstrom solution, Kerr solution.

Unit V: Perturbation Theory and Gravitational Radiation

Linearised gravity, Gauge transformation, Degrees of freedom, Newtonian fields Photon trajectories, Gravitational wave solution, Production of gravitational waves, Energy Loss due to gravitational radiation, Detection of gravitational wave.

Course Title – Particle Physics

Course Type – Elective

Course Code - 26-PHY-E-528

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course introduces the symmetry principles and gauge foundations underlying modern particle physics. Students will learn the role of discrete symmetries, gauge theories, spontaneous symmetry breaking, and the Higgs mechanism. The Standard Model of electroweak interactions and the essentials of QCD will be covered, along with topics such as CP violation, asymptotic freedom, and deep inelastic scattering. The course concludes with brief insights into advanced themes including anomalies, supersymmetry, and string theory.

Reference Books:

1. Introduction to High Energy Physics : Perkins
2. Gauge Theory of Weak Interactions : Greiner & Muller
3. Gauge Theory and Particle Physics : Cheng Lee

Course Syllabus

Unit I: Invariance Principles and Symmetries

Charge conjugation, time reversal and partity , CPT theorem, Quark model and color and flavour quantum numbers, Weak isospin and hypercharge.

Unit II: Introduction to Gauge Theories

Abelian and non-abelian gauge theories, Spontaneous symmetry breaking, Goldstone theorem, Higgs phenomenon

Unit III: Standard Model

Historical introduction to Fermi theory and current algebra, Weinberg-Salam model, Basic Lagrangian, neutral current, GIM mechanism, KM matrix and CP violation.

Unit IV: Strong Interactions

Basic Lagrangian of QCD and its symmetries, Asymptotic freedom, Deep inelastic scattering

Unit V: Some Special topics

Anamolies, supersymmetry, string theory.

Course Title – Computational Techniques in Condensed Matter

Course Type – Elective

Course Code - 26-PHY-E-529

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course introduces the theoretical foundations and computational methods of electronic structure analysis. Students will learn band theory, many-body approximations, and the principles of Density Functional Theory (DFT), including Hohenberg–Kohn theorems, Kohn–Sham equations, and pseudopotentials. The course covers practical DFT techniques—basis sets, exchange–correlation functionals, geometry optimization, and DOS/band-gap evaluation—and teaches students to perform electronic structure calculations using LCAO and plane-wave methods for bulk materials, 2D systems, and nano materials.

Reference Books:

1. Solid State Physics : Ibach & Luth

2. Quantum Theory of Solids : Charles Kittel

3. Solid State Physics: Ashcroft and Mermin

4. Experimental Techniques of Surface Science : Woodruff and Delchar

5. Density Functional Theory: Kieron Burke.

6. Electronic Structure: Richard M. Martin

Course Syllabus

Unit I: Band Structures:

Basic concepts of periodic solids and band structure of metal. Approximation methods for many electron systems, Foundations of Density Functional Theory (DFT): Born-Oppenheimer approximation, Central Field Approximation and its extension, Thomas-Fermi-Dirac approximations: example of a functional

Unit-II: Many-body Problem:

Hohenberg-Kohn Theorems, their statement and proof. Kohn Sham orbitals, pseudo potentials, the self-consistent field method for the calculation of ground state energies in DFT.

Unit: III: Computational and Theoretical Methods:

Computational tools for DFT analysis, Computational methods, Modeling KS equation, Density functional theory (DFT) Basis sets, Pseudopotentials, Exchange-Correlation (XC) Functional, local density approximation (LDA), Generalized-gradient approximation (GGAs), LDA and GGA expressions for the potential, strengths of DFT, DFT- hybrid, Geometry Optimization, Determination of band gap, Density of states (DOS).

Unit-IV: Electronic Structure Calculations:

Linear combination of atomic orbitals (LCAO) and Plane waves methods, Basics - The independent particle Schrodinger equation in a plane wave basis. Pseudopotential method - Projector augmented waves (PAWs) - Simple crystals: structures, bands, - Definition of Supercells: Geometry optimization, total energy, force, and stress - illustrative examples - square lattice and any 2D materials planes - Examples of bands: semiconductors and metal, electronic structure of nanomaterials.

Course Title – Introduction to Quantum Technologies and Applications

Course Type – Elective

Course Code - 26-PHY-E-530

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

The student will understand the fundamentals of quantum computing, including qubits, superposition, entanglement, quantum gates, and basic quantum circuits. They will learn key quantum information concepts such as density matrices, entropy, coherence, and decoherence, along with major quantum algorithms, cryptography, and error correction. Students will also gain knowledge of experimental qubit platforms like superconducting, spin, and NV-center qubits and their applications in advanced quantum sensing.

Reference Books:

1. An introduction to Quantum Computing, Phillip Kaye, Raymond Laflamme et. al., Oxford University press.

2. Quantum Computation and Quantum Information, M. A. Nielsen &I.Chuang, Cambridge

3. Quantum Computing, A Gentle Introduction , Eleanor G. Rieffel and Wolfgang H. Polak MIT

Course Syllabus

UNIT 1

Classical Vs Quantum Computing, Dirac Formalism, Quantum Bits, Superposition, Entanglement and Bell States, Measurements in Arbitrary Basis, EPR Paradox, Bloch Sphere representation, Multi Qubit States, Quantum No Cloning Theorem

UNIT 2

Single and Multi Qubit Quantum Gates: I, X, Y, Z Gate, Hadamard Gate, CNOT Gate, Toffoli Gate, Universal gate sets, Basics Quantum Circuits, Quantum Teleportation, Super Dense Coding, Quantum information : The density matrix, mixed and pure states, Shannon and von Neumann entropy, Spin Relaxation and Coherence time, Decoherence, DiVincenzo criteria

UNIT 3

Quantum Algorithms : Deutsch algorithm, Deutsch Josza algorithm, Grovers Search Algorithm, Quantum cryptography, Fault-tolerance, Quantum Error Correction,

UNIT 4

Experimental Realization of Quantum Bits: Superconducting Qubits, Spin Qubits, NV centers in Diamond, Qubit Lifetime, Quantum Sensing: Atomic clock, Magnetometry, State of the art in Quantum Sensing

Course Title – Energy Materials and Devices

Course Type – Elective

Course Code - 26-PHY-E-531

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

The student will understand renewable and non-renewable energy resources and their role in sustainable development, along with the principles of solar, hydro, and geothermal energy systems. They will learn the fundamentals and applications of modern energy-storage technologies such as batteries, supercapacitors, hybrid systems, and fuel cells, as well as key energy-harvesting methods including piezoelectric and electromagnetic systems. Students will also gain knowledge of materials used in advanced energy-conversion devices like thermoelectrics, photovoltaics, fuel cells, self-powered nanodevices, and optoelectronic systems for efficient energy use.

Reference Books:

1. Non-conventional energy sources - G.D Rai - Kh^nna Publishers, New Delhi
2. Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.
3. Godfrey Boyle, "Renewable Energy, Power for a feustainable future", 2004, Oxford University Press, in association with The Open University.
4. Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook, 2009
5. J.Balfour, M.Shaw and S. Jarosek, Photovoltaics, Lawrence J Goodrich (USA).
6. Nanostructured materials, Processing, Properties and Potential Applications by Carl C. Koch, Noyes Publications, Norwich, New York, U.S.A.
7. Springer Handbook of Nanotechnology by Bhusan, Bharat.
8. William D. Callister , David G. Rethwisch, Materials Science and Engineering: An Introduction, John Wiley, New York, 2010 (8th Edition).

Course Syllabus

Unit I: Introduction of Energy Materials

Non-Renewable Energy resources and their availability, Energy and its role in Sustainable Development and Social Transformation, Renewable and,, Solar energy basics, Solar thermal systems, Solar heating/ cooling of buildings, Solar thermal power generation, Solar P.V., Hydro power: Classification of hydropower schemes, Classification of water turbine, Turbine theory, Essential components of hydroelectric system, Geothermal: Geothermal regions, Types of geothermal resources, Analysis of geothermal resources.

Unit II: Energy storage

Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Importance of energy storage systems in electric vehicles, Current electric vehicle market. **Batteries-**Working principle of battery, primary and secondary (flow) batteries, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery& Metal hydride battery vs lead-acid battery. **Supercapacitors**- Working principle of supercapacitor, types of supercapacitors, cycling and performance characteristics, difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors**, Fuel cell**: Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems

Unit III: Energy harvesting

Piezo-electric materials, Ferro-electric materials, Smart materials. Materials For Energy Transformation: Polymer membranes for **fuel cells**, PEM fuel cell, Acid/alkaline fuel cells, Light emitting diodes, Black Selective coating; Anti-reflection coating/layer; Concentrators: Refractive, reflecting materials/surfaces, Thermoelectrics, **Piezoelectric Energy harvesting**: Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, piezoelectric parameters and modeling piezoelectric generators, piezoelectric energy harvesting applications. Human power Electromagnetic Energy Harvesting: Linear generators, recent applications, Carbon captured technologies.

Unit IV: Materials for Energy Conversion Devices

Thermoelectric figure of merit; Kinetic formulation of thermoelectricity; Coupled electron heat transport; Electron engineering; Phonon engineering; Current thermoelectric materials: Classical thermoelectric materials; **Commercial materials**: oxides, half-Heusler; Nanostructures; Complex materials **Photovoltaics**: Evolution of new generation devices and materials; New Generation photovoltaic materials Chemical Energy Conversion: Fuel Cells Mechanical **Energy Conversion**: Piezoelectric nanogenerators; Self-powered nanodevices/nanosystems and thermoelectrics Energy Efficient Lighting: Optoelectronic devices for efficient energy usage including light emitting diodes and photodetectors

Course Title – Cosmology

Course Type – Elective

Course Code - 26-PHY-E-532

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor’s Name :

Course Advisor’s Email :

Expected Learning Outcome –

The student will understand the expanding universe, its thermal history, and the cosmological framework described by the FLRW metric and Friedmann equations. They will learn key concepts of the early universe such as recombination, BBN, neutrino cosmology, and the CMB, along with the motivation and dynamics of inflation and its observable signatures. Students will also gain knowledge of dark matter and dark energy, their evidence and models, and major observational probes. Additionally, they will understand cosmological perturbation theory, structure formation, matter power spectra, and CMB anisotropies, linking theoretical predictions to observations.

Reference Books:

1. Barbara Ryden, Introduction to Cosmology, Cambridge University Press (2nd Ed.).
2. J. A. Peacock, Cosmological Physics.
3. Steven Weinberg, Gravitation and Cosmology.
4. Scott Dodelson & Fabian Schmidt, Modern Cosmology.
5. V. Mukhanov, Physical Foundations of Cosmology.
6. Ta-Pei Cheng, Relativity, Gravitation, and Cosmology.
7. L. Amendola & S. Tsujikawa, Dark Energy: Theory and Observations.
8. D. Baumann, Cosmology, Cambridge University Press, 2022.
9. T. Padmanabhan, Structure Formation in the Universe.

Course Syllabus

Unit I: The Expanding Universe and Its Thermal History

Brief review of tensors and Einstein field equations, Cosmological principles: isotropy and homogeneity, Newtonian cosmology and its limitations, Friedmann–Lemaître–Robertson–Walker (FLRW) metric, Friedmann equations, cosmological parameters, energy conservation, age and size of the universe, distances in cosmology, Early universe thermodynamics: relativistic and non-relativistic species, radiation-dominated era, matter–radiation equality, recombination, Big Bang Nucleosynthesis (BBN), neutrino cosmology and effective relativistic degrees of freedom (N_{eff}), cosmic microwave background (CMB) radiation.

Unit II: Inflationary Cosmology

Problems of the standard Big Bang model (flatness, horizon, monopole), basic idea of inflation and scalar field dynamics, slow-roll approximation and inflationary parameters, generation of scalar and tensor perturbations, observational signatures in the CMB (spectral index, tensor-to-scalar ratio), introduction of inflationary reheating mechanism and primordial black holes.

Unit III: Dark Matter and Dark Energy

Evidence for dark matter: rotation curves, lensing, CMB constraints, cold, warm, and hot dark matter candidates, cosmological constant and vacuum energy, dynamical dark energy such as CPL and quintessence field, observational probes including SNe Ia, BAO, CMB, weak lensing, and future missions. Basic numerical solutions of Friedmann equations and analysis of observational data.

Unit IV: Cosmological Perturbation Theory and Observational Cosmology

Linear perturbation theory in Newtonian and relativistic frameworks, growth of density perturbations and Jeans instability, power spectrum of matter fluctuations and transfer functions, CMB: origin, spectrum, and anisotropies, large-scale structure of the universe.

Course Title – Band topology and quantum transport

Course Type – Elective

Course Code - 26-PHY-E-533

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite – Quantum mechanics-II, Mathematical physics and condensed matter physics.

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course will help students to familiarize with the newly developed Dirac materials based modern condensed matter physics, including some flavours of spintronics, non-trivial topological phases, non-Hermitian quantum system etc. Additionally, students will learn some powerful theoretical techniques of studying quantum transport, like linear response theory, Landauer-Buttiker's formalism etc. Students aiming to pursue research career in the field of condensed matter physics theory/experiment are advised to opt this course.

Reference Books:

1)Green function in Quantum Physics by E. N. Economou.

2)Mesoscopic physics of electron and phonon by Eric Akkermans and Gilles Montmbaux.

3)Theory of non-equilibrium superconductivity by N. Kopnin.

4)Condensed Matter field theory by Alexander Altland and Ben Simons

5)Topological insulators and topological superconductors by A. Bernevig

Course Syllabus

Unit-I : Band Topology: Topological insulators

Role of quantum geometry in condensed matter systems:Concept of band topology, Berry phase, Berry curvature, and Chern number, Bulk-boundary correspon- dence.Dirac systems: Graphene (2D system), Weyl semimetal (3D systems), Nodal line semimetal. Some unique phenomena related to Dirac systems: Klein tunneling, Interfacial modes: Volkov-Pankratov states.Non-trivial topological phases: Topological insulator (TI). Time reversal symmetry broken TI (Haldane model)-Topological Chern insulators, Time reversal invariant TI (Kane-Mele model)- Quantum spin-Hall insulators. Floquet Theory and Floquet topological insulator, Non-Hermitian quantum system and topology associated with it.Spin-orbit coupled non-Dirac quantum systems and related quantum phenomena: Rashba spin-orbit coupling and Dresselhaus spin-orbit coupling. Spin-Hall effects and inverse spin-Hall effect, Edelstein effect, etc.

Unit-II : Green's function in quantum system

Green's function in quantum system: Time independent Green function in 3D, 2D and 1D free particle case. Time dependent Green function: frequency representation or spectral representation, Imaginary time Green function: Matsubara Green function or Temperature green function. Density of states in terms of Green function. Green function for the Helmoltz equation. Green function for tight-binding Hamiltonian. Single impurity scattering. Self energy.

Unit-III : Electrical conductivity and localization phenomena

Electrical conductivity and localization phenomena: A general linear response theory. Electrical conductivity in terms of Matsubara's Green functions. Kubo-formula. Optical conductivity. Multiple impurity scattering-Dyson series, Electron diffusion and Cooperon, Ladder diagram, Weak localization and anti-localizaion, Anderson localization.

Unit-IV : Theory of non-equilibrium superconductivity

Theory of non-equilibrium superconductivity: Theory of non-equilibrium superconductivity: Gorkov's equation, Quasi classical theory - Eilenberger equation. Theory of dirty superconductor - Usadel equation. Norma-Superconductor hybrid junction and related phenomena: Andreev reflection, Andreev bound states, Majorana fermion.

Course Title – Advanced Nano electronics and VLSI

Course Type – Elective

Course Code - 26-PHY-E-534

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course introduces nanoscale quantum principles, semiconductor band theory, and modern nanofabrication and characterization methods. Students will learn advanced VLSI design, CMOS fundamentals, and emerging device technologies such as FDSOI, FinFETs, TFETs, nanosheets, and HEMTs. They will gain an understanding of nanoelectronic devices—including SETs, quantum dots, nanowire and GAA FETs—and their applications in neuromorphic computing, MEMS, RF/mixed-signal ICs, and packaging. The course also covers AI-integrated electronics, emphasizing ML-based design, automation, testing, hardware security, and edge-AI systems.

Reference Books:

1) C. P. Poole Jr., F. J. Owens, *Introduction to Nanotechnology*, Wiley

2)K. Goser, P. Glösekötter, J. Dienstuhl, *Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices*, Springer

3) Neil H. E. Weste, David Harris, *CMOS VLSI Design: A Circuits and Systems Perspective*, 4th Edition, Addison-Wesley

4)S. M. Sze, K. K. Ng, *Physics of Semiconductor Devices*, 3rd Edition, Wiley-Interscience

5) Kharat, *Nanoelectronics: Principles and Devices*, PHI Learning

6)George C. Smith, *VLSI Technology*, Cambridge University Press

Course Syllabus

Unit 1: Fundamentals of Nanoelectronics

Quantum Mechanics of Electrons - Fundamental quantum principles governing electron behavior at the nanoscale, Band Theory of Solids - Energy band structures and their implications for nanoscale materials, Top-Down and Bottom-Up Nanofabrication Methods - Advanced fabrication techniques for nanostructures, Nanoscale Characterization Techniques - X-ray diffraction, Spectroscopy, and Ellipsometry methods, Properties of Semiconductor Materials at the Nanoscale - Quantum confinement effects and size-dependent properties

Unit 2: Advanced VLSI Design

VLSI Design Flow and CMOS Inverter - Complete design methodology and fundamental building blocks, Physical and Logical Design Cycles - Hierarchical design approaches and verification strategies, Circuit Characteristic Analysis and Performance Evaluation - Timing, power, and area optimization, Implementation of CMOS Combinational and Sequential Logic - Advanced logic design techniques, Advanced MOS Devices - Field-effect technologies including: Fully Depleted Silicon-on-Insulator (FDSOI), FinFET (Fin Field-Effect Transistor), Tunnel FET (Tunneling Field-Effect Transistor), Nanosheet Transistors, High Electron Mobility Transistor (HEMT)

Unit 3: Nanoelectronic Devices and Applications

Novel Nanoelectronic Devices: Single Electron Transistors (SET), Quantum Dots and quantum computing applications, Nanowire MOSFETs, Gate-All-Around FET (GAA FET), Neuromorphic Computing - Brain-inspired computing principles and device implementations, MEMS and Nanomaterials in Sensors and Systems - Micro-electromechanical systems integration, Mixed Signal and RF IC Design - Analog-digital interface circuits and radio frequency design, Nanoscale Packaging and Micromachining Techniques - Advanced packaging for high-density integration

Unit 4: Integration with AI and Emerging Trends

Machine Learning Foundations for Electronics - Core ML concepts applied to electronic systems, AI-Driven Design and Testing in VLSI - Automated design space exploration and intelligent testing methodologies, Electronic System Modeling with AI Tools - Machine learning for circuit simulation and behavioral modeling, Design Automation and Optimization using AI/ML Algorithms -Evolutionary algorithms, neural networks for EDA, Emerging Areas: Hardware Security - AI for vulnerability detection and secure design, Edge AI Chips - Low-power AI accelerators for edge computing, AI for Fault Prediction - Predictive maintenance and reliability analysis,

Course Title – Group theory for Physicists

Course Type – Elective

Course Code - 26-PHY-E-535

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course provides a systematic introduction to group theory and its applications in physics. Students will learn the fundamentals of discrete and continuous groups, their representations, characters, and Lie algebras. They will understand how group-theoretical methods explain symmetry in quantum mechanics, including level splitting, selection rules, and angular-momentum addition. The course also covers crystallographic and molecular symmetries, space groups, and the role of symmetry in solid-state phenomena such as crystal fields, reciprocal lattices, and electronic band structures.

Reference Books:

1. Elements of group theory for physicists, 4th Ed., A W Joshi, New Age Int.
2. Group Theory by Abbas, Taylor & Francis
3. Mathematical methods for physicists, 6th Ed., Arfken & Weber, Elsevier
4. Group Theory by Hamermesh
5. Mathematical Physics, by Sadri Hassani, II Ed., Springer

Course Syllabus

Unit I : Discrete groups

Examples, multiplication table, conjugate elements and classes, subgroups, normal subgroups, factor groups, direct product of groups, isomorphism & homomorphism, group of symmetries of regular polygon, permutation groups, disjoint and non-disjoint cycles, transpositions, parity, generators, classes, character table, representations, partitioning of n, Young diagrams, Young tableau

Unit II : Continuous groups

Topological groups and Lie groups, SO(2), SO(3), SU(2), Lorentz group, generators of U(n) and SU(n), Lie algebra and representations of Lie group, SU(3).

Unit III: Representation of groups

Invariant subspaces and reducible representations, Schur's lemmas and the orthogonality theorem, characters of a representation, regular representation, symmetrized basis functions for irreducible representation, transfer and projection operators, direct product of representations, representations of a direct product group, examples

Unit IV : Group Theory in quantum Mechanics

Level splitting under perturbation, selection rules, molecular vibrations, dynamical symmetries, addition of angular momenta

Unit V : Crystallography, molecular symmetries and solid state physics

Crystallographic Point Groups, Translation Group and the Space Groups, Molecular Point Groups, Crystal Field Splitting of Atomic Levels, Translation Group and the Reciprocal Lattice, Energy Bands: One, Two and three Dimensional Lattices

Course Title – Advanced Mathematical Physics

Course Type – Elective

Course Code - 26-PHY-E-536

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

This course provides a foundation in linear vector spaces, Hilbert spaces, and operators, followed by a comprehensive introduction to group theory and its representations. Students will learn the structure of discrete and continuous groups, including permutation groups, Lie groups, and their algebras. The course covers key concepts such as invariant subspaces, characters, Schur's lemmas, projection operators, and Young diagrams, enabling learners to apply group-theoretical methods to physical and mathematical systems.

Reference Books:

Reference Books:

1. Elements of group theory for physicists, 4th Ed., A W Joshi, New Age Int.
2. Group Theory by Abbas, Taylor & Francis
3. Mathematical methods for physicists, 6th Ed., Arfken & Weber, Elsevier
4. Group Theory by Hamermesh
5. Mathematical Physics, Sadri Hassani, II Ed., Springer

Course Syllabus

Unit I:

Linear vector spaces : Vector spaces, inner product spaces, Cauchy sequence: eigenvalues, diagonalization and spectral theory , direct sum and product of matrices, Hilbert space : properties, function spaces, dual space, direct sum of function spaces, operators.

Unit II:

Discrete Groups : examples, multiplication table, conjugate elements and classes, subgroups, normal subgroups, factor groups, direct product of groups, isomorphism & homomorphism, group of symmetries of regular polygon, permutation groups,

Unit III:

Invariant subspaces and reducible representations, Schur's lemmas and the orthogonality theorem, characters of a representation, regular representation, symmetrized basis functions for irreducible representation, transfer and projection operators, direct product of representations, representations of a direct product group, examples

Unit IV:

Continuous groups : Topological groups and Lie groups, axial rotation group SO(2), 3-D rotation group SO(3), Lorentz group, Special Unitary group SU(2), generators of U(n) and SU(n), Lie algebra and representations of Lie group, Special Unitary group SU(3), examples

Unit V:

Permutation group, disjoint and non-disjoint cycles, transpositions, parity, generators, classes, character table, representations, partitioning of n, Young diagrams, Young tableau

Course Title – Research Methodology

Course Type – Compulsory

Course Code - 26-PHY-C-516

Course Level – 500

Total Credits – 4

Classes /week – 4

Max. Marks - 100

Prerequisite –

Course Advisor's Name :

Course Advisor's Email :

Expected Learning Outcome –

To familiarize the students to the principles of scientific methodology in business enquiry, to develop analytical skills of business research, and to develop the skills for scientific communications

Reference Books:

1. V. Rajaraman, Computer Programming in Fortran 90 and 95, Prentice Hall.
2. Erwin Kreyszig, Advanced Engineering Mathematics.
3. W Feller, An Introduction to Probability Theory and Its Applications (Wiley & Sons).
4. van Kampen, Stochastic Processes in Physics and Chemistry.
5. Risken, The Fokker Planck equation
6. A. Einestien and L. Infeld: Evolution of physics
7. R.P.Feynman: The character of Physical Laws

Course Syllabus

Unit 1: Introduction

Meaning, objectives and motivations in research, Characteristics and limitations of research – Components of research work - Criteria of good research, Research process – Types of Research. History and philosophy: Brief history of Physics, philosophy of science, and the role of research.

Unit 2: Data Analysis: Probability, Statistics and Stochastic Methods

Random Experiment, Events, Definitions of Probability, Conditional Probability, Independence of Events, Random Variables, Probability Distribution of a Random Variable, Moments, Special discrete and continuous distributions, Moments and moment generating function, characteristic function, Joint Distributions, Product Moments, Correlation, Multivariate distributions. Confidence intervals, Hypothesis Testing. Stochastic processes in physics; stationary processes; Markov processes; Fokker-Planck and Langevin equation; Brownian motion.

Unit 3: Computational Techniques

Any one programming language (FORTRAN / C / Python), Typesetting and plotting using Latex and gnuplot, Introduction to Mathematica or Matlab.
Numerical problems like finite and infinite series, integration, random number generation, linear algebra and matrix manipulations, Ordinary differential equations using Euler, Runge-Kutta methods. Boundary value problems and partial differential equations etc.

Unit 4: Scientific communication and Ethics

Writing: Technical and report writing, including structuring articles, reviews, and thesis. Presentation: Presenting research at seminars and conferences, Publication: Understanding the publication process, peer review, and impact factors. Ethics: Ethical conduct in research, including plagiarism, citation, and authorship. IPR: Intellectual property rights, patents, and copyright

Course Title - Lab 3

Course Type – Lab

Course Code - 26-PHY-C-515

Course Level – 500

Total Credits – 4

Classes /week – 8

Max. Marks - 100

Prerequisite –

Course Advisor’s Name :

Course Advisor’s Email :

Expected Learning Outcome

To familiarise students with experiments in atomics physics and condensed matter physics: Determination of spectra of hydrogen, helium and mercury, fundamental experiments in quantum physics such as electron diffraction and specific charge, Zeeman effect in mercury spectra, Efficiency of a Fuel Cell. Quantitative determination of diffraction of light, and laser light transmission in optical fibres.

List of Experiments :

1. Study of characteristics of single mode and multi mode optical fibres and determination of transmission losses.

2. Determination of ultrasonic velocity in liquids.

3. Determination of the grating constant with a Hg lamp.

4. Rydberg constant with hydrogen spectrum and determination of He spectrum.

5. Quantitative study of Fraunhofer diffraction of light from a laser light source through single/ multiple slits using a photo-cell.

6. Determination of the specific charge of the electron by the Millikan's oil drop method.

7. Study of the Zeeman effect in Hg light spectra.

8.Study of electron diffraction upon transmission through a thin graphite film.

9. Study of the characteristics and efficiency of a PEM fuel cell system.

10. Determination of the e/m ratio of electrons by Thomson's method using a fine beam electron tube and Helmholtz coils.

SEMESTER IV (2 year PG) / SEMESTER II (1 year PG)

	Nature of the Course	Course Name	Course code	Credit
Semester IV (For 2 yr PG)/ Semester II (For 1 yr PG)	Project	Project Part II Presentation	26-PHY-C-555	16 4
	Total			20