SNU
SISTER NIVEDITA UNIVERSITY

2023

SYLLABUS

School of Natural Sciences

M.Sc. in Physics under UGC – CBCS

Department of Physics - Sister Nivedita University

M.Sc. Physics Course Structure

Category definition with credit breakup

Semester	Credit					
	CC	DSE	GE	SEC	USC	Total/Sem
First	20		4	1	2	27
Second	20	4		1	2	27
Third	20	0		1	2	23
Fourth	12				2	14
Total Credit/ Course	72	4	4	3	8	
Total Credit						91

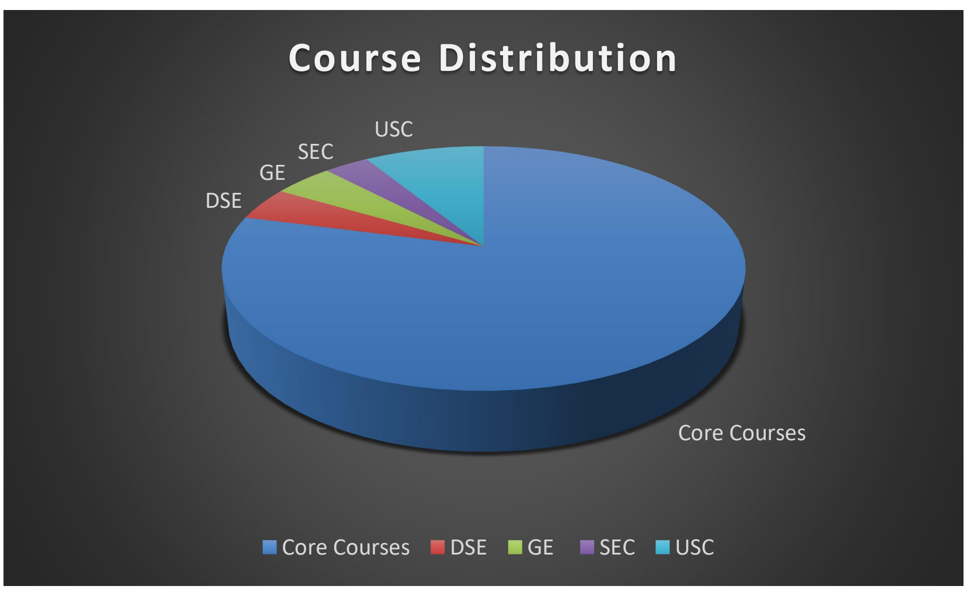
CC: Core Courses; **GE**: General Elective; **SEC**: Skill Enhancement Courses;
DSE: Discipline Specific Elective; **USC:** University specified course

First Year

Category	Course name	Credit	Teaching Scheme		
			L	T	P
Semester – I					
CC – 1	Classical Mechanics	4	4	0	0
CC – 2	Mathematical Methods	4	4	0	0
CC – 3	Statistical Mechanics	4	4	0	0
CC – 4	Quantum Mechanics-I	4	4	0	0
CC – 5	General Lab -I	4	0	0	8
GE - 1	Generic Elective (Student's choice)	4	4	0	0
USC – 1	Foreign language – I	2	2	0	0
SEC – 1	Mentored Seminar – I	1	1	0	0
Total Credit = 27			Teaching Hour = 31		
Semester – II					
CC – 6	Electrodynamics	4	4	0	0
CC – 7	Quantum Mechanics-II	4	4	0	0
CC – 8	Condensed Matter Physics	4	4	0	0
CC - 9	Nuclear and Particle Physics	4	4	0	0
CC – 10	General Lab II	4	0	0	8
DSE – 1	Numerical Analysis /Biophysics	4	3	0	2
USC – 2	Foreign language – II	2	2	0	0
SEC – 2	Mentored Seminar – II	1	1	0	0
Total Credit = 27			Teaching Hour = 31		

Second Year

Category	Course name	Credit	Teaching Scheme		
			L	T	P
	Semester – III				
CC – 11	Quantum Field Theory and Particle Physics	4	4	0	0
CC – 12	Atomic, Molecular and Laser Physics	4	4	0	0
CC – 13	Introduction to Material Science and Nanotechnology	4	4	0	0
CC – 14a	General Theory of Relativity (Elective)	4	4	0	0
CC – 14b	Astrophysics and Cosmology (Elective)	4	4	0	0
CC– 15	General Lab III	4	0	0	8
USC – 3	Foreign language – III	2	2	0	0
SEC – 3	Mentored Seminar – III	1	1	0	0
	Total Credit = 23		Teaching Hour = 27		
	Semester – IV				
CC – 16	Master Project / Dissertation	12	0	0	24
USC – 4	Foreign language – IV	2	2	0	0
	Total Credit = 14		Teaching Hour = 26		



Detailed Core Subjects Syllabus
(Including Program and Course Outcome)

Program Outcomes for M.Sc. in Physics

Serial No.	Program Outcomes (PO)
1	Graduates will be able to apply assimilated knowledge to evolve tangible solution to emerging problems.
2	Graduates will be able to analyze and interpret data to create and design new knowledge.
3	Graduates will be able to engage in innovative and socially relevant research and effectively communicate the findings.
4	Graduates will become ethically committed professional and entrepreneurs upholding human values.
5	Graduates imbibed with ethical values and social concern will be able to understand and appreciate cultural diversity, social harmony and ensure sustainable environment.

SEMESTER 1

CC1: Classical Mechanics (Credit 4)

Unit 1: Lagrangian and Hamiltonian Formulation

Applications of Lagarange's equation; small oscillations, normal modes and frequencies. Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action.

Unit 2: Canonical Transformations

Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations.

Unit 3: Hamilton – Jacobi Theory

The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function; Action angle variables.

Unit 4: Fluid Mechanics

Elements of fluid mechanics, Euler Equation and Navier-Stokes equation, **Introduction to Prandtle's boundary layer theory**

Unit 5: Classical Perturbation Theory

Unit 6: Introduction to Non-linear dynamics and chaos

Periodic motions and perturbations; Attractors; Chaotic trajectories and Liapunov exponents; The logistic equation.

References:

1. H.Goldstein: Classical Mechanics

2. A.K.Raychaudhuri: Classical Mechanics - ACourseofLectures
3. Landau and Leifshitz : Volume 1
4. Feynman Lectures, Vol. 1
5. N.C.Rana andP.S.Joag:ClassicalMechanics
6. T. Kibble and F. Berkshire, Classical Mechanics

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Apply and formulate the Lagrangian and Hamiltonian to solve problems in mechanics. Derive normal mode frequencies for small oscillations.
CO2	Develop understanding of Canonical Transformations. Demonstrate generating functions; Lagrange and Poisson brackets, angular momentum poisson bracket relations.
CO3	Explain Hamilton – Jacobi Theory. Solve the harmonic oscillator problem. Learn about Hamilton's characteristic function; Action angle variables.
CO4	Evaluate the concept of fluid mechanics
CO5	Elaborate Classical Perturbation Theory
CO6	Learn and discuss non-linear dynamics and chaos.

CC2: Mathematical Methods (Credit 4)

Unit 1 : Linear Vector spaces
Vector space: Definition, linear independence , bases, dimensionality, inner product; Gram-Schmidt orthogonalisation ; Space of Complex numbers as a vector space and the ,triangle and Schwarz inequalities. Matrices: Representation of linear transformations and change of base; Eigenvalues and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Commuting matrices with degenerate eigenvalues ; Orthonormality of eigenvectors.

Unit 2 : Theory of complex variables and Contour Integration

Convergence of infinite series; tests for convergence; absolute convergence; Function of a complex variable; single and multiple-valued functions ; limit and continuity; Classification of singularities; Branch point and branch cut; Cauchy-Riemann equations and their applications; Analytic and harmonic function;

Complex integrals, Cauchy'stheorem ; converse of Cauchy's theorem; Cauchys Integral Formula; and its corollaries; Series—Taylor and Laurent expansion; Residue theorem and evaluation of integrals.

Unit 3 : Theory of second order linear differential equations
Singular points—regular and irregular singular points; Frobenius method; Fuch's theorem; Linear independence of solutions—Wronskian, second solution ; Sturm-Liouville theory; Hermitian operators; Completeness.

Unit 4 : Introduction to Group Theory

Unit 5: Integral Equations and Integral transforms
Fourier, Laplace, Fredholm, Voltera

Unit 6 : Special functions (single lecture)
Basic properties of Bessel, Legendre, Hermite and Laguerre functions.

Unit 7: Solution of Differential equation by perturbative method

Unit 8: Basic introduction to Tensors

References:

1. G. Arfken: Mathematical Methods for Physicists
2. J. Mathews and R.L.Walker: Mathematical Methods of Physics
3. P.Dennery and A.Krzywicki: Mathematics for Physicists
4. R.V.Churchill and J.W.Brown: Complex variables and Applications
5. M.R. Spiegel: Theory and Problems of Complex Variables
6. S.L.Ross: Differential Equations

8. Bernt Oksndal : Stochastic Differential Equations
9. Stuart J. Russell and Peter Norvig: Artificial Intelligence : A Modern Approach
10. Mathematics of Classical and Quantum Physics, F. W. Byron and R. W. Fuller (may be added in the list)
11. Advanced Mathematical Methods for Scientists and Engineers by C.M. Bender, S.A. Orszag

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Demonstrate Linear Vector spaces, Solve Eigenvalues and eigenvector problems. Explain Orthonormality of eigenvectors.
CO2	Comprehend the Convergence of infinite series; Function of a complex variable, Classification of singularities. Cauchy-Riemann equations and their applications. Analytic and harmonic function. Evaluate complex integrals using Cauchy’s residue theorem. Learn about Taylor and Laurent expansion
CO3	Solve second order linear differential equations.
CO4	Understand and discuss Group Theory and Tensor.
CO5	Describe Basic properties of Bessel, Legendre, Hermite and Laguerre functions.
CO6	Solve differential equations by perturbative method

CC3: Statistical Mechanics (Credit 4)

Unit 1: Microstates and macrostates; Phase space and concept of an ensemble;
Unit 2: Liouville’s theorem and concept of equilibrium; Ergodic hypothesis and postulate of equal a priori probability;
Unit 3: Microcanonical ensemble: Boltzmann’s definition of entropy and derivation of thermodynamics; The equipartition theorem; Microcanonical ensemble calculations for a classical ideal gas; Gibbs paradox;
Unit 4: Canonical ensemble; Energy fluctuations in the canonical ensemble;
Unit 5: Grand canonical ensemble; Density fluctuations in the grand canonical ensemble;
Unit 6: Quantum statistical mechanics: Postulate of equal a priori probability and postulate of random phases
Unit 7: Density matrix; Ensembles in quantum statistical mechanics;
Unit 8: The ideal quantum gas: Microcanonical and grand canonical ensembles;
Unit 9: Fermi-Dirac and Bose-Einstein statistics; Bose-Einstein condensation.
Unit 10: First and Second order phase transitions

References:

1. F.Reif:Fundamentals of Statistical and ThermalPhysics
2. R.K.Pathria: Statistical Mechanics
3. K.Huang: Statistical Mechanics
4. F.Mandl: Statistical Physics
5. H.B.Callen:Thermodynamics and an Introduction toThermostatics
6. Enrico Fermi : Thermodynamics
7. J.K. Bhattacharjee : Statistical Mechanics
8. Abhijit Lahiri : Statistical Mechanics
9. S. K. Ma, Modern Theory of Critical phenomena
10. H.E.Stanley,Introduction to Phase transitions and Critical Phenomena
11. J.Yeomans, Statistical Mechanics of Phase Transitions
12. S.Sachdev, Quantum Phase transitions
13. Jayanta K. Bhattacharjee , Statistical Physics: Equilibrium and Non-equilibrium Aspects
14. Statitical Mechanics of Particles by M. Kardar
15. Statistical Mechanics of Fields by M. Kardar

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Understand Microstates and macrostates. Develop the concept of Phase space and ensemble. Comprehend Liouville's theorem and concept of equilibrium.
CO2	Demonstrate Microcanonical, Canonical and Grand canonical ensemble. Learn about the equipartition theorem. Calculate Microcanonical ensemble for a classical ideal gas.
CO3	Analyse Energy fluctuations in the canonical ensemble and Density fluctuations in the grand canonical ensemble.
CO4	Learn about Quantum statistical mechanics: Postulate of equal a priori probability and postulate of random phase. Develop understanding of Density matrix; ideal quantum gas.
CO5	Develop understanding of Fermi-Dirac, Bose-Einstein statistics. Describe Bose-Einstein condensation.
CO6	Evaluate and check the knowledge from phase transitions

CC 4: Quantum Mechanics I (Credit 4)

Unit 1: Heisenberg Uncert ainty Principle; Principle of superposition, Postulates of quantum mechanics
Unit 2: Symmetries
Unit 3: Single particle formulation of non-relativistic quantum mechanics, Representation theory for vectors and operators in quantum mechanics; Coordinate and Momentum representations; Time evolution operator; Schrödinger, Heisenberg and Dirac (Interaction picture) pictures
Unit 4: Solutions of the Schrödinger for various potentials and applications to physical systems
Unit 5: Angular momentum in quantum mechanics ; the angular momentum algebra; addition of angular momentum for two spin half particles; Clebsch-Gordon coefficients

References:

1. P.A.M. Dirac : The Principles of Quantum Mechanics
2. Feynman Lectures , Vol.3
3. Feynman and Hibbs : Path Integral
4. J. J. Sakurai : Modern Quantum Mechanics
5. Messiah : Vol 1 and Vol 2
6. Claude Cohen-Tanaudji : Quantum Mechanics Vol 1-3.
7. Landau and Leifshitz : Quantum Mechanics
8. Nielsen and Chuang : Introduction to Quantum Computation
9. S. Gasiorowicz, Quantum Physics
10. S. Weinberg, Lectures on Quantum Mechanics

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Demonstrate Heisenberg Uncertainty Principle; Principle of superposition.
CO2	Learn about Symmetries
CO3	Derive the Single particle formulation of non-relativistic quantum mechanics
CO4	Understand representation theory for vectors and operators in quantum mechanics; Coordinate and Momentum representations. Learn about Time evolution operator; Schrödinger, Heisenberg and Dirac (Interaction picture) pictures.
CO5	Solve the Schrödinger equation for various potentials and analyse the applications to physical systems
CO6	Develop the concept of Angular momentum in quantum mechanics. Evaluate the addition of angular momentum for two spin half particles. Learn Clebsch-Gordon coefficients

SEMESTER 2

CC6: Electrodynamics (Credit 4)

Unit 1: Static Charges , Multipole expansions

Scalar and vector potentials; Gauge transformations; Multipole expansion of (i) scalar potential and energy due to a static charge distribution (ii)vector potential due to a stationary current distribution. Electrostatic and magnetostatic energy. Poynting's theorem. Maxwell's stress tensor.

Unit 2: Radiation from time-dependent sources of charges and currents

Inhomogeneous wave equations and their solutions; Radiation from localised sources and multipole expansion in the radiation zone.

Unit 3: Lagrangian formulation for continuous systems and Relativistic electrodynamics

Idea of a classical field as a generalized coordinate. Euler-Lagrange equation for the field from the Lagrangian density. The field momentum and the Hamiltonian density. Poisson brackets for the fields. Equation of motion in an electromagnetic field; Electromagnetic field tensor, covariance of Maxwells equations and Electromagnetic duality (concept of magnetic monopole); Maxwell's equations as equations of motion; Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion; Field invariants; Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field; The generalized momentum; Energy-momentum tensor and the conservation laws for the electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Unit 4: Radiation from moving point charges

Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Fields due to an accelerated charge; Radiation at low velocity; Larmor's formula and its relativistic generalisation; Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung; Radiation when velocity and acceleration are perpendicular, Synchrotron radiation; Cherenkov radiation (qualitative treatment only). Thomson and Compton scattering.

Unit 5: Radiation reaction

Radiation reaction from energy conservation; Problem with Abraham-Lorentz formula; Limitations of CED.

Unit 6: Plasma physics

Definition of plasma; Its occurrence in nature; Dilute and dense plasma; Uniform but time-dependent magnetic field: Magnetic pumping; Static non-uniform magnetic field: Magnetic bottle and loss cone; MHD equations, Magnetic Reynold's number; Pinched plasma; Bennett'srelation; Qualitative discussion on sausage and kink instability.

References:

1. Feynman Lectures , Vol 2
2. J.D.Jackson: Classical Electrodynamics
3. W.K.H.Panofsky and M.Phillips: Classical Electricity and Magnetism
4. D.J.Griffiths:IntroductiontoElectrodynamics
5. L.D.Landau and E.M.Lifshitz: Vol 2 and Electrodynamics of Continuous Media
6. J.A.Bittencourt, Fundamentals of PlasmaPhysics
7. Modern Electrodynamics, A. Zangwill

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Demonstrate Scalar and vector potentials, Gauge transformations, Multipole expansion. Develop the concept of Electrostatic and magnetostatic energy, Poynting's theorem.
CO2	Derive inhomogeneous wave equations and find their solutions. Analyse radiation from localised sources
CO3	Formulate Lagrangian for continuous systems and Relativistic electrodynamics
CO4	Elaborate radiation from moving point charges
CO5	Understand radiation reaction from energy conservation
CO6	Develop an understanding of Plasma physics.

CC7: Quantum Mechanics II (Credit 4)

Unit 1 : Time independent Perturbation Theory
Unit 2 : Time dependent Perturbation Theory
Unit 3 : WKB Method
Unit 4 : Variational Method, Sudden Approximation
Unit 5 : Quantum theory of scattering
Unit 6 : Path integral formulation of quantum mechanics
Unit 7: Quantum computation: Qubit, Bloch sphere representation, Quantum logic gates; Quantum Algorithms; Deutsch Problem; The Deutsch-Jozsa Algorithm; Grover Search; Phase Estimation and Quantum Fourier Transform; Entanglement ; Bell states ; Bell states as an orthogonal basis ;

Teleportation ; Projective Measurement ; Device

References:

1. P.A.M. Dirac : The Principles of Quantum Mechanics
2. Feynman Lectures , Vol.3
3. Feynman and Hibbs : Path Integral
4. J. J. Sakurai : Modern Quantum Mechanics
5. Messiah : Vol 1 and Vol 2
6. Claude Cohen-Tanaudji : Quantum Mechanics Vol 1-3.
7. Landau and Leifshitz : Quantum Mechanics
8. Nielsen and Chuang : Introduction to Quantum Computation
9. S. Gasiorowicz, Quantum Physics
10. S. Weinberg, Lectures on Quantum Mechanics

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Understand and elucidate Time independent and Time dependent Perturbation Theory.
CO2	Solve time independent Schrödinger equation by WKB approximation.
CO3	Use variational method to find approximations to the ground state
CO4	Elaborate Quantum theory of scattering
CO5	Understand Path integral formulation of quantum mechanics
CO6	Develop an understanding of Quantum computation.

CC8: Condensed Matter Physics (Credit 4)

Unit 1: Structure of solids Bravais lattice, primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; point group and space group (information only); Common crystal structures: NaCl and CsCl structure, close-packed structure, Zinc blende and Wurtzite structure, tetrahedral and octahedral interstitial sites, Spinel structure; Intensity of scattered X-ray, Friedel's law, Anomalous scattering; Atomic and geometric structure factors; systematic absences; Reciprocal lattice and Brillouin zone; Ewald construction; Explanation of experimental methods on the basis of Ewald construction; Electron and neutron scattering by crystals (qualitative discussion)

Unit 2: Band theory of solids Bloch equation; Empty lattice band; Number of states in a band; Effective mass of an electron in a band: concept of holes; Classification of metal, semiconductor and insulator; Electronic band structures in solids - Nearly free electron bands; Tight binding method - application to a simple cubic lattice; Band structures in copper, GaAs and silicon; Topology of Fermi-surface; Boltzmann transport equation - relaxation time approximation, Sommerfeld theory of electrical conductivity.

Unit 3: Lattice dynamics and Specific heat Classical theory of lattice vibration under harmonic approximation; Dispersion relations of one dimension lattices: monatomic and diatomic cases, Characteristics of different modes, long wavelength limit, Optical properties of ionic crystal in the infrared region; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals - thermal expansion.

Unit 4: Dielectric properties of solids Electronic, ionic, and orientational polarization; static dielectric constant of gases and solids; Complex dielectric constant and dielectric losses, relaxation time, Debye equations; Cases of distribution of relaxation time, Cole - Cole distribution parameter, Dielectric modulus; Ferroelectricity, displacive phase transition, Landau Theory of Phase Transition.

Unit 5: Magnetic properties of solids Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: classical and quantum theory of para- Syllabus-Physics, CU 2018 20 magnetism; case of rare-earth and iron-group ions; quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, Ferromagnetic domains - calculation of wall thickness and energy; Ferrimagnetism and antiferromagnetism.

Unit 6: Imperfections in solids Frenkel and Schottky defects, electrical conductivity of ionic crystals; classifications of dislocations; role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors

Unit 7: Superconductivity Phenomenological description of superconductivity - occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; Flux quantisation; a.c. and d.c. Josephson effect; Vortex state (qualitative discussions); High Tc superconductors (information only).

References:

1. N.W.Ashcroft and N.D.Mermin: Solid State Physics
2. J.R.Christman: Fundamentals of Solid State Physics
3. A.J.Dekker: Solid State Physics
4. C.Kittel: Introduction to Solid State Physics
5. J.P.McKelvey: Solid State and Semiconductor Physics
6. P.M.Chaikin and T.C.Lubensky, Principles of Condensed Matter Physics
7. M.Tinkham: Group Theory and Quantum Mechanics
8. M.Sachs: Solid State Theory
9. A.O.E.Animalu: Intermediate Quantum Theory of Crystalline Solids
10. J.M. Ziman: Principles of the Theory of Solids

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Describe Bravais lattice, primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; point group and space group (information only); Intensity of scattered X-ray, Anomalous scattering; Reciprocal lattice and Brillouin zone
CO2	Understand and demonstrate Band theory of solids
CO3	Demonstrate Classical theory of lattice vibration under harmonic approximation
CO4	Elaborate Dielectric properties of solids. Analyse Origin of magnetism; Diamagnetism: Paramagnetism: Ferromagnetism
CO5	Learn about Imperfections in solids
CO6	Develop an understanding of Superconductivity

CC9: Nuclear and Particle Physics (Credit 4)

Nuclear Physics:

Unit 1: Charge, mass, constituents, binding energy and separation energy, level scheme, excited states, spin, parity and isospin, nuclear size and form factors, static electromagnetic moments.
Unit 2: a) Exchange forces and saturation b) General properties of nucleon-nucleon forces; Yukawa potential.
Unit 3: Brief idea of Complex– nuclear structure: a) need for nuclear models b) Fermi Gas model c) Static Liquid Drop model d) Shell Model e) Collective Model f) Unified Model.
Nuclear Reactions: a) types of reactions and conservation principles b) Compound Nuclear Reactions – Resonances and the Breit Wigner formula c) Direct Reactions, Optical Model, Nuclear Fission – Bohr – Wheeler theory, Electromagnetic Transitions – Multipole transitions and selection rules

Particle Physics:

Unit 5: Relativistic kinematics: Mandelstam variables; collision and decay kinematics; reaction thresholds; phase space, cross-section and decay formulae,

Unit 6: Types of interactions and their relative strengths, Discovery of positron, muon, pion, neutrino and other particles, Symmetry, conservation laws and Quantum numbers,

Unit 7: Classification of elementary particles, Determination of quantum numbers of different particles, Hadrons – classification by isospin and hypercharge, Quarks, colour, Leptons and gauge bosons

Unit 8: Brief idea of The Standard Model of Particle Physics

References:

1. J.S.Lilley, Nuclear Physics
2. M.K.Pal:Theory of Nuclear Structure
3. R.R.Roy and B.P.Nigam: Nuclear Physics
4. S.N.Ghoshal: Atomic and Nuclear Physics (Vol.2)
5. D.H. Perkins: Introduction to High Energy Physics
6. D.J.Griffiths: Introduction to Elementary Particles
7. W.E.Burcham and M.Jobes: Nuclear and particle physics
8. Halzen and A.D. Martin: Quarks and Leptons
9. J. Donoghue, E.Golowich and B.Holstein: Dynamicsof the StandardModel
10. T.-P.Cheng and L.-F.Li: Gauge Theories in Particle Physics
11. E.Leader and E.Predazzi: An Introduction to Gauge Theories and Modern Particle Physics
12. F.E.Close: An Introduction to Quarks and Partons

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Learn about charge, mass, constituents, binding energy, separation energy, level scheme, excited states, spin, parity and isospin.
CO2	Describe Exchange forces, saturation, General properties of nucleon-nucleon forces and Yukawa potential.
CO3	Develop brief idea of Complex– nuclear structure and Nuclear Reactions
CO4	Elaborate relativistic kinematics: mandelstam variables; collision and decay kinematics
CO5	Learn about types of interactions and their relative strengths, positron, muon, pion, neutrino and other particles, Symmetry, conservation laws and Quantum numbers. Determine quantum numbers of different particles.
CO6	Understand the Standard Model of Particle Physics

SEMESTER 3

CC11: Quantum Field Theory (Credit 4)

Unit 1 : Relativistic quantum mechanics and the Dirac equation and its solutions,
Unit 2 : Canonical quantisation: Free scalar field, electromagntic field, Dirac field,
Unit 3 : Wick's Theorem, Correlation functions,
Unit 4 : Propagators for the scalar, Dirac and electromagnetic field.
Unit 5 : Simple introduction to interacting theories and Feynman diagrams.

References:

1. Bjoerken and Drell : Vol 1 and Vol 2
2. Bogolubov and Shirkov : An Introduction to Quantum field theory
3. Peskin and Shroeder : An Introduction to Quantum Field Theory
4. Feynman : Theory of Fundamental processes
5. Feynman : Quantum Electrodynamics
6. Steven Weinberg : The Quantum Theory of Fields (Vol 1 & 2)

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Describe Relativistic quantum mechanics and the Dirac equation and its solutions
CO2	Learn about Wick's Theorem, Correlation functions
CO3	Explain Canonical quantization: Free scalar field, electromagnetic field, Dirac field
CO4	Understand Propagators for the scalar, Dirac and electromagnetic field
CO5	Develop basic understanding of interacting theories and Feynman diagrams.

CC12: Atomic, Molecular and Laser Physics (Credit 4)

Unit 1: One Electron Atom Introduction: Quantum States; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.

Unit 2: Fine and Hyperfine structure Relativistic correction to the energy of one electron atom. Fine structure of spectral lines; Selection rules; Lamb shift. Effect of external magnetic field - Strong, moderate and weak field. Hyperfine interaction and isotope shift; Hyperfine splitting of spectral lines; selection rules.

Unit 3: Interaction of an atom with electromagnetic wave: Transition rates, dipole approximation, selection rules and spectrum of one electron atoms, Line intensities and lifetimes of excited states, Line shapes and widths

Unit 4: Many electron atom Independent particle model; He atom as an example of central field approximation; Central field approximation for many electron atom; L-S and j-j coupling; Equivalent and nonequivalent electrons; Energy levels and spectra; Spectroscopic terms; Hund's rule; Lande interval rule; Alkali spectra.

Unit 5: Molecular Electronic States Concept of molecular potential, Separation of electronic and nuclear wavefunctions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wavefunctions; Shapes of molecular orbital; π and σ bond; Term symbol for simple molecules.

Unit 6: Rotation and Vibration of Molecules Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.

Unit 7: Spectra of Diatomic Molecules Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra.

Unit 8: Laser Physics Basic elements of a laser; Threshold condition; Four-level laser system, CW operation of laser; Critical pumping rate; Population inversion and photon number in the cavity around threshold; Output coupling of laser power. Optical resonators; Cavity modes; Mode selection; Pulsed operation of laser: Q-switching and Mode locking; Experimental technique of Q-switching and mode locking Different laser systems: Ruby, CO2, Dye and Semiconductor diode laser.

References:

1. Bransden, B.H. and Joachain, C.J., Physics of Atoms and Molecules, (2nd edn, Prentice Hall, 2003)

2. Demtr¨oder, W., Atoms, Molecules and Photons, (Springer-Verlag, 2006)

3. Haken, H. and Wolf, H.C., The Physics of Atoms and Quanta, (7th edn, Springer-Verlag, 2005)

4. Hertel, I.V. and Schulz, C.-P., Atoms, Molecules and Optical Physics Vol. 1: Atoms and Spectroscopy, (Springer-Verlag 2015)

5. Hooker, S. and Webb, C., Laser Physics (Oxford, 2010)

6. Foot, Atomic Physics (Oxford, 2005)

7. Silfvast, Laser Fundamentals (2nd edition, Cambridge, 2004)

8. Svelto, Principles of Lasers (4th edn, Plenum, 1998)

9. Woodgate, Elementary Atomic Structure (Oxford, 1980)

10. Yariv, Optical Electronics in Modern Communications (5th edition, Oxford, 1997)

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Describe Quantum States; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.
CO2	Demonstrate Fine and Hyperfine structure, as well as Interaction of an atom with electromagnetic wave.
CO3	Explain Central field approximation for many electron atom; L-S and j-j coupling. Evaluate Spectroscopic terms and ground state.
CO4	Learn about Molecular Electronic States
CO5	Explain Rotation and Vibration of Molecules. Demonstrate rotational, vibrational and raman spectra.

CC13: Introduction to Material Science and Nanotechnology (Credit 4)

Unit 1: Introduction to materials: Classification, Properties and Requirements

Introduction, Classification of Engineering Materials, Metals, Alloys, ceramics, Polymers and Semiconducting materials. Crystalline and Non-crystalline Solids, Classification of Bonds, Ionic Bond or Electrovalent Bond, Covalent Homopolar Bonds, Metallic Bonds, Molecular Bonds, Hydrogen Bond, van der Walls bond (Inter-molecular and Intra-molecular bonds).

Unit 2: Properties of Materials

Introduction, Classification of Optical Materials, Interaction of light with matter, Absorption in Metals, Insulators and Semiconductors, Reflection, Refraction, Transmission and Scattering, Traps, Excitons, Colour Centers, Tauc and Lambert-Beer laws, Optical properties of Photonic material.

Unit 3: Materials characterization using microscopy, diffraction, and spectroscopy

Electron beam instruments: Transmission electron and scanning electron microscopes, Auger electron spectroscope, x-ray spectrometers, electron microprobe, electron spectrometers. Interpretation of diffraction information: selected area and convergent beam Electron diffraction patterns. Analysis of micrographs in TEM, SEM, and HRTEM: Theories of diffraction contrast in TEM, analysis of images in TEM and SEM

Bulk averaging techniques: Optical spectroscopy: Atomic absorption spectroscopy, infrared spectroscopy and Raman spectroscopy, Atomic Force Microscopy. Electrical Characterization, I-V, C-V, Hall effect, Low and High-temperature effect.

Unit 4: Materials for Energy
Photovoltaics: Solar energy and energy conversion, Fundamentals of semiconductor physics and photovoltaic cells, Current status of silicon-based solar cells, Advancement in photovoltaic research and design of new generation solar cells (hybrid, quantum dot, dye-sensitized and perovskite solar cells)

Batteries & Supercapacitors: Basic concepts of Batteries, Supercapacitors and Fuel cells, Thermodynamics and kinetics involved in electrochemical reactions, Primary and rechargible batteries, Li-ion Battery, Components and processes in batteries (Battery operations), Components of supercapacitors, Elecetrochemical properties (Charging/discharging cycles, Cyclic Voltametry and impedance spectroscop, lifetime stability), Different applications.
Thermoelectric Materials: Fundamentals of thermoelectricity (Seebeck, Peltier and Thomson effects), Thermoelectric Effects and Transport Properties, Basics of Thermoelectric devices, Heat Conduction in Bulk Thermoelectric Materials (Heat Conduction by Phonons, Heat Conduction by Electrons), Progress in Thermoelectric Materials (Bulk Thermoelectric Materials, Nanostructured Thermoelectric Materials), Reduction of Thermal Conductivities in Bulk and Nanostructured Materials), Thermoelectric Devices.

Unit 5: Introduction to Nanomaterials: Influence of dimensionality of the object at nanoscale on their properties; size and shape controlled synthesis of nanomaterials and their future applications in industry, Features of nanosystems, Characteristic length scales of materials and their properties, Density of states in 1-D, 2-D and 3-D bands, Variation of density of states and band gap with size of crystal.

Unit 6: Quantum Size Effect: Electron confinement in infinitely deep square well, Confinement in one dimensional well, Idea of quantum well structure, Formation of quantum well, Quantum dots and quantum wires.

Unit 7: Synthesis Methods: Top-down and bottom-up approach, cluster beam evaporation, ion beam deposition, chemical bath deposition with capping techniques, mechanical milling, chemical methods and self-assembly

Unit 8: Properties of Nanomaterials: Size and shape dependence of optical, electronic, photonic, mechanical, magnetic and catalytic properties.

Unit 9: Nanomaterials and their applications: Nanoparticles, Nanocoatings and Nanocomposites, Nanotubes, Fullerenes, Thin film chemical sensors, gas sensors, biosensors, Carbon fullerenes and Carbon nanotubes, Thin film chemical sensors, biosensors, Solar cells, Drug deliveries and optoelectronic devices.

References:

1.Materials Science : V. Rajendran, A. Marikani, Tata MC Graw Hill

2. Materials Science & Engineering: Raghavan, Tata MC Graw Hill

3. Materials Science: Arumugam

4. Materials Science & Metallurgy : O. P. Khanna

5. Materials Science and Engineering: Callister S.

6. Anke Krueger, "Carbon Materials and Nanotechnology", Wiley-VCH, 2010.

7. Yury Gogotsi, "Carbon Nanomaterials", Taylor and Francis, 2006

8 Bimerg, D., Grundmann, M., and Ledentsov, N.N., Quantum Dot Heterostructures, John Wiley (1999).

9. Poole,C.P., Owens,F.J., Introduction to Nanotechnology, John Wiley &Sons (2003)

10. Jain, K.P., Physics of Semiconductor Nanostructures, Narosa (1997).

11. Fendler, J.H., Nano particles and Nano-structured Films, John Wiley &Sons (1998).

12. Timp, G., Nanotechnology, Springer-Verlag (1999).

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Learn about Classification and Properties of materials.
CO2	Learn and demonstrate Materials characterization using microscopy, diffraction, and spectroscopy
CO3	Describe Materials for Energy applications.
CO4	Develop an understanding of nanomaterials and quantum size effect.
CO5	Understand different Synthesis Methods and Properties of Nanomaterials
CO6	Elaborate different applications of Nanomaterials.

CC14 a: General Theory of Relativity (Credit 4)

Unit 1: The Equivalence Principle

Non-inertial frames and non-Euclidean geometry; General coordinate transformations and the general covariance of physical laws.

Unit 2: Geometrical Basis

Contravariant and covariant vectors; Tangentvectors and 1-forms; Tensors: product, contraction and quotient laws; Wedge product, closedforms; Levi-Civita symbol; Tensor densities, the invariant volume element.
The Electromagnetic field tensor and its transformation under Lorentz transformations: relation to known transformation properties of E and B. Electric and magnetic fields due to a uniformly moving charge. Equation of motion of charged particle & Maxwell's equations in tensor form. Motion of charged particles in external electric and magnetic fields.

Parallel transport and the affine connection; Covariant derivatives; Metric tensor, raising and lowering of indices; Christoffel connection on a Riemannian space; Geodesics; Space-time curvature; Curvature tensor; Commutator and Lie derivative; Equation for geodesic deviation; Symmetries of the curvature tensor; Bianchi identities; Isometries and Killing vectors.

Unit 3: Einstein's Equations (10)

Energy-momentum tensor and conservation laws; Einstein's equation; Hilberts variational principle;
Gravitational energy-momentum pseudotensor. Maxwell equations in GR
Newtonian approximation. Linearised field equations; Gravitational waves; gravitational radiation.

Unit 4: Simple Solutions and Singularities

Static, spherically symmetric space-time; Schwarzschild's exterior solution; Motion of perihelion of Mercury; Bending of light; Gravitational redshift. Radar echo delay.
Blackholes; Kruskal-Szekeres diagram.

Schwarzschilds interior solution; Tolman-Oppenheimer-Volkov equation; Collapse of stars; Kerr metric; Ergosphere; Reissner-Nordstrom metric; Kerr-Newman metric.
Weyl's postulate and the cosmological (Copernican) principle; Robertson-Walker metric; Anisotropies, vorticity and shear; Raychaudhuri equation; Singularity theorems of Hawking and Penrose.

References:

1. J.V.Narlikar: Lectures on General Relativity and Cosmology
2. S.Weinberg: Gravitation and Cosmology
3. P.A.M.Dirac: General Theory of Relativity
4. L.D.Landau and E.M.Lifshitz: The Classical Theory of Fields
5. C.W.Misner, K.S.Thorne and J.A.Wheeler: Gravitation
6. R.M.Wald: General Theory of Relativity
7. A.Raychaudhuri, S.Banerjee and A.Banerjee: General Theory of Relativity
8. A.Zee, Einstein's relativity in a nutshell

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Learn about The Equivalence Principle
CO2	Understand Geometrical Basis
CO3	Describe Einstein's Equations
CO4	Derive Simple Solutions and Singularities

CC15: Astrophysics (Credit 4)

Unit1: Celestial Sphere and observational astronomy
Unit 2: Sky coordinates and motions: Earth Rotation , Sky coordinates and seasons
Unit 3: Phases of the Moon, the Moon's orbit and eclipses ; timekeeping (sidereal vs synodic period);
Unit 4: Planetary motions; Kepler's Laws - Gravity; Light & Energy - Telescopes - Optics - Detectors; present list of planets ; Planets and the Solar System ; types of planet ; planet atmospheres ; extrasolar planets ;
Unit 5: Stars ; Measuring stellar characteristics (temperature, distance, luminosity, mass, size) ;
Unit 6: Hertzsprung Russell diagram; Stellar structure (equilibrium, nuclear reactions, energy transport) ; birth , evolution and final fate of a star ; types of stars ; Galaxies; Our Milky Way ; Galactic structure ; Galactic rotation ; Galaxy types ; Galaxy formation

References:

1. T.Padmanabhan: Theoretical Astrophysics, vols.1-3
2. S.Weinberg: Gravitation and Cosmology
3. M.Rowan-Robinson: Cosmology
4. E.W.Kolb and M.S.Turner: TheEarly Universe
5. J.V.Narlikar: Introduction to Cosmology
6. T.T.Arny: Explorations, An Introduction to Astronomy
7. M.Zeilik and E.V.P.Smith: Introductory Astronomy and Astrophysics
8. D.Clayton: Introduction to Stellar Evolution and Nucleosynthesis
9. A.Liddle: An Introduction to Modern Cosmology
10. J.B.Hartle: Gravity
11. V.Mukhanov: Physical Foundations of Cosmology

Course Outcome:

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

CO Number	Course Outcome (CO)
CO1	Learn about Celestial Sphere and observational astronomy. Sky coordinates and motions: Earth Rotation , Sky coordinates and seasons
CO2	Understand Phases of the Moon, the Moon's orbit and eclipses ; timekeeping (sidereal vs synodic period); Planetary motions; Kepler's Laws - Gravity; Light & Energy - Telescopes - Optics - Detectors; present list of planets ; Planets and the Solar System ; types of planet ; planet atmospheres ; extrasolar planets ; Stars
CO3	Learn about Measuring stellar characteristics (temperature, distance, luminosity, mass, size) ; Hertzsprung Russell diagram; Stellar structure (equilibrium, nuclear reactions, energy transport) ; birth , evolution and final fate of a star ; types of stars ;
CO4	Develop basic idea of Galaxies; Our Milky Way ; Galactic structure ; Galactic rotation ; Galaxy types ; Galaxy formation

COMPONENT: PRACTICAL

SEMESTER 1

CC5: General lab I

1. Acousto-optical effect using piezo-electric crystal and determination of the velocity of ultrasonic wave in liquids.

2. Determination of e/m of electrons by magnetic focusing method.

3. Calibration of audio oscillator by the method of propagation of sound wave and formation of Lissajous' figures.

4. Energy band gap of a semiconductor by four probe method.

5. Verification of Bohr's atomic theory by Franck Hertz Experiment.

6. Hall coefficient of a semiconductor.

7. Estimation of Energy loss for different magnetic materials by hysteresis loop tracer using CRO

8. Determination of the characteristics of a Solar cell

SEMESTER 2

CC10: General lab II

1. Study of the absorption spectrum of Iodine vapour using a spectrometer

2. Study of para-ferromagnetic phase transition

3. Study of Dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibration

4. Study of amplitude modulation and demodulation.

5. Filter circuits: passive and active filters (1st and 2nd order), Notch filter.

6. Interferometry with Michelson's interferometer.

7. Determination of beam diameter and beam divergence of a Laser beam

SEMESTER 3

CC15: General lab III

1. Determination of numerical aperture and acceptance angle of an optical fiber using a Laser source

2. Designing and fabrication of an experiment using Autodesk Inventor software

3. Design and fabrication of a photodetector (Learning to use simulation software and PCB)

4. Design and fabrication of a mechanical shutter for Laser

1. Design and fabrication of a sensor (Breadboard)

2. Designing an external cavity diode laser (using different softwares)

3. Data Analysis using Matlab and Origin Lab softwares.

OR

Electronics Experiments

1. Transistors and OPAMPs

2. Amplitude modulation and demodulation.

3. Filter circuits: passive and active filters (1st and 2nd order), Notch filter.

4. Design and study of multivibrators.

5. Studies on FET and MOSFET.