DEPARTMENT OF PHYSICS

JADAVPUR UNIVERSITY

SYLLABUS FOR CHOICE BASED CREDIT SYSTEM

IN

M.Sc. PHYSICS (DAY & EVENING)

2020

M.Sc, Physics (DAY) : Two-Year, Four-Semester Programme

MSc, Physics (EVENING): Three-Years, Six-Semester Programme

PROGRAM OUTCOMES (POs):

Followings are the outcomes of the Master's programme under faculty council of Science, Jadavpur University.

PO1: Foundation of Scientific Knowledge: Apply the knowledge of Mathematics and natural sciences to the solution of scientific problems.

PO2: Critical Thinking and Problem Analysis: Identify the problems and formulate the various requirements for obtaining a solution.

PO3: Design/Development of Solutions: Design a system and to prepare formal methodical plans leading to solutions.

PO4: Conduct investigations of complex problems: Formulate the structure and component of a complex problem and investigate for obtaining a solution

PO5: Usage of Modern Methods and Tools: Develop/ select and apply appropriate methods/tools for problem solution with an understanding of the limitations.

PO6: The Science and Society: Apply scientific knowledge to assess and address critical societal issues.

PO7: Environment and Sustainability: Appreciate social and environmental issues and provide scientific nohouse for the use of renewable resources.

PO8: Ethics: Understand professional, ethical, legal, security, social issues and responsibilities.

PO9: Individual and team work: Work both independently and as a team member within the organization.

PO10: Communication: Communicate effectively with superiors, colleagues, other team members as well as society at last.

PO11: Project Management and Finance: Understand management principles and appreciate financial aspects and issues pertaining to any scientific project.

PO12: Life-long learning: Identify contemporary issues due to changing technical, political and social scenarios and engage in lifelong learning to update himself/herself.

MSc Physics course under CBCS systems at a glance

Two- year four-semester course

Year	Semester	Marks Distribution		Credit Distribution
1st	I	Theory	200	16
		Practical	150	8
		Total	350	24
	II	Theory	200	16
		Practical	200	8
		Total	400	24
2nd	III	Theory	150	12
		Practical	200	8
		Comprehensive Viva	50	4
		Total	400	24
	IV	Theory	100	8
		Practical	100	4
		Project	50	4
		Total	250	12
1st + 2nd	Total (I+II+III+IV) 350+400+400+250 = 1400			Total (I+II+III+IV) 24+24+24+12 = 88

Three- year Six-semester course

Year	Semester	Marks Distribution		Credit Distribution
1st	I	Theory	100	8
		Practical	100	6
		Total	200	14
	II	Theory	100	8
		Practical	100	4
		Total	200	12
2nd	III	Theory	100	8
		Practical	100	4
		Total	200	12
	IV	Theory	100	8
		Practical	100	4
		Total	200	12
3rd	V	Theory	150	12
		Practical	150	6
		Comprehensive Viva	50	4
		Total	350	22
	VI	Theory	100	8
		Practical	100	4
		Project	50	4
		Total	250	16
1st + 2nd + 3rd	Total (I+II+III+IV+V+VI) 200+200+200+200+350+250 = 1400			Total (I+II+III+IV+V+VI) 14+12+12+12+22+16 = 88

Course Curriculum Structure

Two-Year, Four-Semester Programme

Semester	Course Type	Course Code	Subject	Marks (Credit)
I	CORE	PG/SC/CORE/PHY/TH/101	Classical Mechanics	50(4)
		PG/SC/CORE/PHY/TH/102	Mathematical Methods	50 (4)
		PG/SC/CORE/PHY/TH/103	Quantum Mechanics(I)	50 (4)
		PG/SC/CORE/PHY/TH/104	Statistical Mechanics	50 (4)
		PG/SC/CORE/PHY/PR(C+F)/501	Computational Lab	100 (4)
		PG/SC/CORE/PHY/PR(C)/502	Core Lab I	50 (4)
		Total Marks		350 (24)
II	CORE	PG/SC/CORE/PHY/TH/105	Quantum Mechanics (II)	50 (4)
		PG/SC/CORE/PHY/TH/106	Electrodynamics	50 (4)
		PG/SC/CORE/PHY/TH/107	Solid State Physics	50 (4)
		PG/SC/CORE/PHY/TH/108	Electronics	50 (4)
		PG/SC/CORE/PHY/PR(C+F)/503	Core Lab II	100 (4)
		PG/SC/CORE/PHY/PR(C+F)/504	Core Lab III	100 (4)
		Total Marks		400 (24)
III	CORE	PG/SC/CORE/PHY/TH/109	Atomic and Molecular Physics	50 (4)
		PG/SC/CORE/PHY/TH/110	Nuclear & Particle Physics	50 (4)
		PG/SC/CORE/PHY/PR(C+F)/505	Core Lab IV	100 (4)
	CBS (Any one)	PG/SC/CBS/PHY/TH/201	Biophysics (I)	50 (4)
		PG/SC/CBS/PHY/TH/202	High Energy Physics	
		PG/SC/CBS/PHY/TH/203	X-Ray Crystallography (I)	
		PG/SC/CBS/PHY/TH/204	General Relativity & Cosmology (I)	
		PG/SC/CBS/PHY/TH/205	Physics of Semiconductor Devices	
		PG/SC/CBS/PHY/TH/206	Optoelectronics	
		PG/SC/CBS/PHY/TH/207	Condensed Matter Physics (I)	
		PG/SC/CBS/PHY/TH/208	Atomic, Molecular & Optical Physics (I)	
		PG/SC/CBS/PHY/PR(C)/506	Advanced Common Lab	50 (2)
		PG/SC/CBS/PHY/PR(C)/507	Advanced Elective Lab I	50 (2)
		PG/SC/PHY/GV/601	Comprehensive Viva	50 (4)
		Total marks		400 (24)

IV	CBS (Any one)	PG/SC/CBS/PHY/TH/301	Plasma Physics	50 (4)
		PG/SC/CBS/PHY/TH/302	Dynamical Systems	
		PG/SC/CBS/PHY/TH/303	Quantum Field Theory	
		PG/SC/CBS/PHY/TH/304	Computational Physics**	
		PG/SC/CBS /PHY/TH/305	Soft Condensed Matter Physics	
		PG/SC/CBS/PHY/TH/306	Differential Geometry and Radio Astrophysics	
	CBS (Any one)	PG/SC/CBS/PHY/TH /401	Biophysics (II)	50 (4)
		PG/SC/CBS/PHY/TH /402	Nucleus Under Different Conditions	
		PG/SC/CBS/PHY/TH /403	X-Ray Crystallography (II)	
		PG/SC/CBS/PHY/TH /404	General Relativity & Cosmology (II)	
		PG/SC/CBS/PHY/TH/405	Advanced Electronic Circuit, Microprocessor and Microcontroller	
		PG/SC/CBS/PHY/TH /406	Microwave Electronics	
		PG/SC/CBS/PHY/TH /407	Condensed Matter Physics (II)	
		PG/SC/CBS/PHY/TH /408	Atomic, molecular and optical physics (II)	
		PG/SC/CBS/PHY/PR (C+F) /508	Advanced Elective Lab II	100 (4)
		PG/SC/PHY/PROJ/701	Project	50 (4)
Total marks				250 (16)
Grand Total				1400 (88)

** 2-0-2 (25 + 25)

PG: Post Graduate ; **SC**: Science; **PHY**: Physics; **TH**: Theory;

PR: Practical **PROJ**: Project **CBS**: Choice Based Subject

C: Continuous Evaluation; **F**: Final Evaluation;

For all theoretical papers 20% marks is allotted to internal assessment and 80% marks is allotted to end semester examination.

For papers with code (C + F) 50% marks is allotted to continuous evaluation and 50% marks is allotted to final evaluation.

Course Curriculum Structure

Three-Year, Six-Semester Programme

Semester	Course Type	Course Code	Subject	Marks (Credit)
I	CORE	PG/SC/CORE/PHY/TH/101	Classical Mechanics	50(4)
		PG/SC/CORE/PHY/TH/102	Mathematical Methods	50 (4)
		PG/SC/CORE/PHY/PR(C)/501	Computational Lab	50 (2)
		PG/SC/CORE/PHY/PR(C)/502	Core Lab I	50 (4)
		Total		200 (14)
II	CORE	PG/SC/CORE/PHY/TH/103	Quantum Mechanics (I)	50 (4)
		PG/SC/CORE/PHY/TH/104	Statistical Mechanics	50 (4)
		PG/SC/CORE/PHY/PR(F)/501	Computational Lab	50 (2)
		PG/SC/CORE/PHY/PR(C)/503	Core Lab II	50 (2)
Total Marks				200 (12)
III	CORE	PG/SC/CORE/PHY/TH/105	Quantum Mechanics (II)	50 (4)
		PG/SC/CORE/PHY/TH/106	Electrodynamics	50 (4)
		PG/SC/CORE/PHY/PR(F)/503	Core Lab II	50 (2)
		PG/SC/CORE/PHY/PR(C)/504	Core Lab III	50 (2)
Total Marks				200 (12)
IV		PG/SC/CORE/PHY/TH/107	Solid State Physics	50 (4)
		PG/SC/CORE/PHY/TH/108	Electronics	50 (4)
		PG/SC/CORE/PHY/PR(F)/504	Core Lab III	50 (2)
		PG/SC/CORE/PHY/PR(C)/505	Core Lab IV	50(2)
Total Marks				200 (12)
V	CORE	PG/SC/CORE/PHY/TH/109	Atomic and Molecular Physics	50 (4)
		PG/SC/CORE/PHY/TH/110	Nuclear & Particle Physics	50 (4)
		PG/SC/CORE/PHY/PR(F)/505	Core Lab IV	50 (2)
	CBS (Any one)	PG/SC/CBS/PHY/TH/201	Biophysics (I)	50 (4)
		PG/SC/CBS/PHY/TH/202	High Energy Physics	
		PG/SC/CBS/PHY/TH/203	X-Ray Crystallography (I)	
		PG/SC/CBS/PHY/TH/204	General Relativity & Cosmology (I)	
		PG/SC/CBS/PHY/TH/205	Physics of Semiconductor Devices	
		PG/SC/CBS/PHY/TH/206	Optoelectronics	
		PG/SC/CBS/PHY/TH/207	Condensed Matter Physics (I)	
		PG/SC/CBS/PHY/TH/208	Atomic, Molecular &Optical Physics (I)	

		PG/SC/CBS/PHY/PR(C) /506	Advanced Common Lab	50 (2)
		PG/SC/CBS/PHY/PR(C) /507	Advanced Elective Lab I	50 (2)
		PG/SC/PHY/GV/601	Comprehensive Viva	50 (4)
Total marks				350 (22)
VI	CBS (Any one)	PG/SC/CBS/PHY/TH/301	Plasma Physics	50 (4)
		PG/SC/CBS/PHY/TH/302	Dynamical Systems	
		PG/SC/CBS/PHY/TH/303	Quantum Field Theory	
		PG/SC/CBS/PHY/TH/304	Computational Physics**	
		PG/SC/CBS /PHY/TH/305	Soft Condensed Matter Physics	
		PG/SC/CBS/PHY/TH/306	Differential Geometry and Radio Astrophysics	
	CBS (Any one)	PG/SC/CBS/PHY/TH /401	Biophysics (II)	50(4)
		PG/SC/CBS/PHY/TH /402	Nucleus under Different Conditions	
		PG/SC/CBS/PHY/TH /403	X-Rays Crystallography (II)	
		PG/SC/CBS/PHY/TH /404	General Relativity &Cosmology (II)	
		PG/SC/CBS/PHY/TH/405	Advanced Electronic Circuit, Microprocessor and Microcontroller	
		PG/SC/CBS/PHY/TH /406	Microwave Electronics	
		PG/SC/CBS/PHY/TH /407	Condensed Matter Physics (II)	
		PG/SC/CBS/PHY/TH /408	Atomic, molecular & optical physics	
		PG/SC/CBS/PHY/PR(C+F)/508	Advanced Elective Laboratory II	100 (4)
		PG/SC/PHY/PROJ/701	Project	50 (4)
Total marks				250 (16)
Grand Total				1400 (88)

PG/SC/CORE/PHY/TH/101	Classical Mechanics

Marks (Credit) : 50 (4) **60 lecture hours**

1. **Lagrangian Formalism**: Concepts of degrees of freedom, generalized coordinates, generalized forces, constraints, virtual displacement and virtual work. The d'Alembert's principle, derivation of Lagrange's equations using variational principle and using Lagrange's undetermined multipliers. Cyclic coordinates. Simple examples of Lagrangian mechanics. The central-force problem. Symmetry principles and conservation of energy, linear and angular momenta.
   (**12 Lectures**)
2. **Small Oscillations**: Concept of normal modes for two coupled linear oscillators. General problem of determining eigenfrequencies, orthogonality of eigenvectors. Simple examples involving two degrees of freedom. Linear triatomic molecule. Loaded string of several connected masses.
   (**10 lectures**)
3. **Rigid Body Dynamics**: Inertia tensor with examples. Principle axes of inertia. Space and body systems of coordinates. Eulerian angles. Euler's equations for rigid body motion. Torque free motion of a symmetric top. Heavy symmetric top.
   (**12 Lectures**)
4. **Hamiltonian Formalism**: Legendre transformations and the connection between Lagrangian and Hamiltonian. The Hamilton's equations of motion. Concept of phase space and Liouville's theorem. Poisson brackets. Canonical transformations and generating functions. Infinitesimal canonical transformations and conservation theorems using Poisson brackets. Examples. The Hamilton-Jacobi equation. Solution of the HJ equation for simple systems using the method of separation of variables.
   (**10 Lectures**)
5. **Special Relativity**: Recapitulations (Lorentz transformations of coordinates and velocities and their consequences; The mass-energy relation; Doppler effect). Concept

of four-vectors. Conservation of four-energy and four-momentum for simple relativistic collisions. Compton effect.

(**10 Lectures**)

6. **Concepts of nonlinear dynamics**: Fixed points of simple differential equations. Linear stability analysis about fixed points. Saddle-node, transcritical and pitchfork bifurcations for systems having one spatial dimension. Concept of mapping using one-dimensional maps. (**6 Lectures)**

Books:

1. Classical Mechanics – Goldstein, Poole & Safko
2. Classical Mechanics: Systems of Particles and Hamiltonian Dynamics – Greiner
3. Classical Mechanics – Taylor
4. Analytical mechanics – Hand & Finch

Course Outcomes

CO1: To identify the limitation of Newtonian mechanics in constrained systems, and provide alternative methods for solving dynamical problems.
CO2: Analyze equations of motion in accelerated frames, compute pseudo forces, and verify the direction of circulation of sea currents in two hemispheres.
CO3: To understand rigid body motion in terms of Eulerian angles.
CO4: To understand the basic physics of small oscillation and its application in lattice and molecular vibration.
CO5: Study and classify bifurcations, and apply to different physical and social science problems. Recognize the ubiquity of nonlinear systems.
CO6: Applying four vectors in understanding the concept of special theory of relativity.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	2	1	2							
CO2	3	2	1	1	2							
CO3	3	2	1	1	2							
CO4	3	1	2	1	1							
CO5	3	1	1	1	1	2						
CO6	3	3	1	2	1							

PG/SC/CORE/PHY/TH/102	Mathematical Methods

Marks (Credit) : 50 (4) **60 lecture hours**

1. **<u>Ordinary Differential Equations & Special Functions in Physics:</u>**
   Fuchsian system of ODE and recapitulation of Frobenius method, and discussions of Hermite, Legendre and Bessel equations.
   Associated Legendre equation and spherical harmonics, properties of cylindrical and spherical Bessel functions, the hypergeometric (HG) and confluent HG equations and their solutions, orthogonal polynomials and completeness theorems, Sturm-Liouville Problem -- statement only, Gram-Schmidt orthogonalization, regular Sturm-Liouville problems with examples.
   (10 Lectures)
2. **<u>Complex Analysis:</u>**
   Review of basic operations (Cauchy's Theorem and Residue Calculus, Taylor & Laurent expansions, evaluation of residues, evaluating integrals using semi-circular, pie-shaped and rectangular contours).
   Multiple-valued functions, analytic continuation; integrals involving branch-cuts, Bromwich contours, summation of certain series using Mittag-Lefler theorem; steepest decent methods, integral representations & asymptotic expansions of special functions, Introduction and uses of conformal mappings and transformations.
   Cauchy's Theorem and Residue Calculus (10 Lectures)
3. **Linear vector spaces:**
   Axiomatic definition, scalar product, dual spaces, real and complex vector spaces, inner product, metric space, algebra of linear transformations, matrices, characteristic roots and associated properties, canonical form of matrices, function spaces; Euclidean and unitary spaces; Hilbert space, Schwarz inequality.
   (5 Lectures)
4. **<u>Elements of Group Theory:</u>** Why Groups ? Symmetry and Group Theory in Physics, Finite, discrete and continuous groups, crystallographic point groups, Abstract Group Theory and introduction to Representation theory, Continuous Groups -- (only examples) -- rotation, and Lorentz groups, Generators of the rotation group and the theory of Angular Momentum in quantum MECHANICS
   Lie groups: Generators, examples of U(1), U(N), SU(N), O(N) and SO(N) groups, Lie algebra in context of SU(2).
   (8 Lectures)
5. **<u>Integral Transforms:</u>**
   General definitions and properties, Fourier transforms; Laplace transforms; evaluation of inverse transforms using Bromwich contours, partial fractions and convolution Theorems, application to differential equations.
   (6 Lectures)
6. **<u>Green's Functions:</u>**
   Inhomogeneous ordinary second order differential equations with various boundary conditions; solution of boundary value problems with eigenfunction expansions and their relationship with Green's functions, applications with physical examples.
   (8 Lectures)
7. **<u>Partial Differential equations:</u>**
   Solving diffusion and wave equations under infinite, semi-infinite and finite boundary conditions using integral transform techniques and separation of variables, solving

inhomogeneous equations involving the Laplacian operator using Green's functions (Poisson equation & Helmohltz equation).

(7 Lectures)

8. **<u>Tensors:</u>**
Cartesian tensors with examples, definitions of contravariant, covariant and mixed tensors, tensor densities, metric tensor, linear operations with tensors.

(6 Lectures)

<u>Reference Books:</u>

Arfken & Weber – Mathematical Methods for Physicists.
Riley, Hobson & Bence – Mathematical Methods for Physics & Engineering
Boas – Mathematical Methods in the Physical Sciences
Dennery & Krzywicki – Mathematical Methods for Physicists
Physical Applications: Mathematical Physics, V.Balakrishnan,

Sokolnikoff & Redheffer – Mathematics for Physics & Modern Engineering Introduction to Linear Algebra by Gilbert Strang

Groups and Structures, Representations: Lectures on Advanced Mathematical Methods for Physicists, Sunil Mukhi and N. Mukunda

S. Sternberg, Group theory and physics, Cambridge University Press (1994).

R. Gilmore, Lie groups, Lie algebras, and some of their applications, John Wiley and Sons, New York

Lie Algebras and Lie groups: Lie Groups and Lie Algebras for Physicists, Ashok Das, Susumu Okubo,

Irreducible tensor representation and Young tableau: Lie Groups and Lie Algebras for Physicists, Ashok Das, Susumu Okubo,

Course Outcomes

CO1. Applications of ordinary differential equations and special functions in solving problems.

CO2.To solve complex functions, frequently occurring physical systems

CO3. To address the physical problems in quantum mechanics from fundamental concepts of linear vector space.

CO4. To Introduce group theory in the application of quantum mechanics, crystallography, molecular physics and biophysics.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	2	2							
CO2	3	2	1	2	2							
CO3	3	2	1	2	2							
CO4	3	2	1	2	3							

PG/SC/CORE/PHY/TH/103	Quantum Mechanics (I)

Marks (Credit) : 50 (4) **60 lecture hours**

Basic elements: Schrodinger equation, hydrogen atom, delta-function potential, linear vector space, orthogonality, completeness, Dirac notations, kets, bras, raising and lowering operators, harmonic oscillator by operator method, coherent states.

[12 Lectures]

Quantum theory of measurement and time evolution: sequential Stern-Gerlach experiments, Schrodinger, Heisenberg and interaction pictures, equation of motions.

[5 Lectures]

Theory of angular momentum: rotation and angular momentum commutation relations, spin ½ systems and finite rotations, SO(3), SU(2) and Euler rotations, orbital angular momentum as rotation generator, addition of angular momentum,
Clebsch-Gordan coefficients **[11 Lectures]**

Time independent perturbation theory: general description, non-degenerate and degenerate systems, spectra of hydrogen atom and its fine structure, Zeeman effect

[10 Lectures]

Time dependent perturbation theory: two level system, Dyson series, sinusoidal time-dependent perturbations, transition probability, Fermi's golden rule, nuclear magnetic resonance, microwave amplification, interaction of atoms with radiation, absorption and stimulated emission, selection rules of transitions

[10 Lectures]

WKB approximation: position dependent potentials and WKB formulation, classical region, tunneling, connection formulae, concept of quantization and applications

[8 Lectures]

Adiabatic approximation: adiabatic theorem, Pancharatnam-Berry phase, Aharonov-Bohm Effect. **[4 Lectures]**

<u>REFERENCE BOOKS:</u>

1. D. J. Griffiths: Introduction to Quantum Mechanics,
2. J. J. Sakurai and J. Napolitano : Modern Quantum Mechanics
3. C. Cohen-Tannoudji, B. Diu and F. Laloe: Quantum Mechanics
4. P. M. Mathews and K. Venkatesan: A Text Book of Quantum Mechanics
5. E. Merzbacher: Quantum Mechanics
6. R. Shankar: Principles of Quantum Mechanics

7. N. Zettili, Quantum Mechanics Concepts and Applications

Course Outcomes

CO 1: learn the mathematical tool as pre-requisite of quantum mechanics: linear vector space, Dirac formulation, representation of discrete and continuous basis etc.

CO 2: solve the Dirac delta function potential, Hydrogen atom and linear harmonic oscillator problem

CO 3: demonstrate the angular momentum operators as rotation generator, addition of angular momentum, Clebsch-Gordan coefficients

CO 4: learn different approximation methods for stationary states like time independent perturbation and Wentzel-Kramers-Brillouin approximation method.

CO 5: solve the problem having time dependent perturbation and its application in interaction of atoms with radiation, absorption and stimulated emission, selection rules of transitions.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	2	2							
CO2	3	2	2	1	2							
CO3	3	2	1	1	2							
CO4	3	1	1	1	1							

PG/SC/CORE/PHY/TH/104	**Statistical Mechanics**

Marks (Credit) : 50 (4) **60 lecture hours**

1**. Principles**

(a) Phase space and phase space density. Liouville's theorem. Statistical ensembles, Microcanonical, Canonical and Grand-canonical ensembles. (physical examples, e.g., non-relativistic and relativistic ideal gas, system of harmonic oscillators, system of spins are suggested). **[12 Lectures]**

(b) Boltzmann transport equation, H theorem, statistical approach to H theorem.

[2 Lecture hours]

(c) Formulation of quantum statistics, the density matrix and its properties. Statistics of various quantum ensembles and examples. **[6 Lectures]**

(d) Brownian motion, Langevin theory, power spectrum of fluctuations, fluctuation dissipation theorem, Fokker Planck equation **[7 Lectures]**

(e) Dynamical theory of fluids, time dependent correlation functions, fluctuations of thermodynamic functions, correlation of fluctuations, Relations among structure, correlations and scattering experiment. **[3 Lectures]**

2. Applications

(a) Classical interacting systems: Real gases, mean field and cluster expansion

approaches and equation of state. **[5 Lectures]**

(b) Phase transitions and Critical Phenomena: **[25 Lectures]**

i. Critical phenomena in the context of liquid gas and magnetic system, phase

diagram, critical exponents and their calculation for van der Waals gas.

ii. Introduction to Ising system, Bragg-Williams approximation, one dimensional

Ising model and its exact solution using transfer matrix method, Peierls argument, discussion on two-dimensional Ising model.

iii. Landau Mean Field Theory. Ginzburg Landau Hamiltonian.

iv. Critical exponents inequality, correlation length and correlation functions,

The Ornstein Zernike form.

v. Scaling hypothesis, Universality, Kadanoffs theory of decimation for one dimensional and two dimensional Ising system, Renormalization Group.

<u>Books (Texts and References)</u>

1. Huang, Introduction to Statistical Mechanics (Wiley)

2. Pathria, Statistical Mechanics (Elsevier)

3. Greiner, Neise, Ludwig and Stcker, Thermodynamics and Statistical Mechanics (Springer)

4. Schwabl, Statistical Mechanics (Springer)

5. Kardar, Statistical Physics of Particles (Cambridge)

6. Kardar, Statistical Physics of Fields (Cambridge)

7. Landau and Lifshitz, Statistical Physics (Elsevier)

8. Salinas, Introduction to Statistical Mechanics (Springer)

Course Outcomes

CO1: Formulation and principle of statistical mechanics

CO2: Addressing statistical mechanics in classical and quantum mechanical systems.

CO3: Study interacting system and hence explain the existence of different phases of matter.

CO4: To understand behavior of system near the critical point, and formulate the Renormalization Group transformations in statistical mechanics

CO5: To understand the importance of fluctuations in dynamical fluid.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	2	2							
CO2	3	2	1	1	2							
CO3	3	2	1	1	2							
CO4	3	2	2	2	2							
CO5	3	1	1	1	1							

PG/SC/CORE/PHY/TH/105	**Quantum Mechanics (II)**

Marks(Credit) 50 (4) **60 lecture hours**

Variational method: Ritz theorem, trial functions, determination of energy of the ground state and lower excites states, comparison with exact results, ground and first excited states of harmonic oscillator, ground state and first excited state of helium atom

(10 Lectures)

Identical particles: permutation operators, properties of permutation operators related to two particle systems and three particle systems, symmetrizer and antisymmetrizer, symmetrization postulate, Permutation operator and particle occupancy, Pauli's exclusion principle, quantum states of boson and fermions using the concept of permutation operators, Slater determinant and state functions

(10 Lectures)

Theory of scattering: scattering as a time-dependent perturbation, Lippmann-Schwinger equation, Born approximation, optical theorem, Eikonal approximation, method of partial waves, low energy scattering and bound states, identical particle and scattering, symmetry and scattering amplitude, inelastic electron-atom scattering

(12 Lectures)

Basics of second quantization: second quantization formalisms, occupation number representation, second quantization for boson and fermion, two body interaction and extension in different systems, mean-field theory, Hartree and Hartree-Fock formulations

(12 Lectures)

Quantum information: quantum bits, Bloch sphere representation of a qubit, entanglement of composite system, entanglement measurements (4 Lectures)

Relativistic quantum mechanics: single particle relativistic wave equation, Klein-Gordon equation, Dirac equation, prediction of antiparticles, non-relativistic limit and electron magnetic moment (12 Lectures)

Books

1. D. J. Griffiths: Introduction to Quantum Mechanics
2. J. J. Sakurai and J. Napolitano : Modern Quantum Mechanics
3. C. Cohen-Tannoudji, B. Diu and F. Laloe: Quantum Mechanics
4. J. J. Sakurai, Advanced Quantum Mechanics
5. J. D. Bjorken and S. D. Drell, Relativistic Quantum Mechanics
6. W. Gerner, Relativistic Quantum Mechanics
7. A. Fetter and J. D. Walecka, Quantum Theory of Many-Particle Systems
8. H. Bruus and K. Flensberg, Many-body Quantum Theory in Condensed Matter Physics
9. M. A. Nielsen, Quantum Computation and Quantum Information
10. N. D. Mermin, Quantum Computer Science: An Introduction

Course Outcome

CO 1: solve quantum mechanical problem by an approximation method like Variational method.

CO 2: gain concepts of permutation operators, Pauli's exclusion principle,
Construction of wave function of many particle system, Slater determinant,

CO 3: have a clear concept on scattering theory.

CO 4: learn the basics of second quantization

CO 5: gain the insight of relativistic quantum mechanics**.**

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	2	2							
CO2	3	2	2	2	2							
CO3	3	2	2	2	2							
CO4	3	2	2	2	2							

PG/SC/CORE/PHY/TH/106	Electrodynamics

Marks (Credit): 50 (4) **60 Lecture hours**

1. Revisions of basics of electrodynamics; Review of solutions of various boundary value problems in electrostatics and magnetostatics, Green's function technique to solve image problems, multipole expansions and evaluation of dipole and quadrupole moments for static charge and current distributions, Maxwell's equations; Potential formulations in electrodynamics; Gauge transformations and its usefulness; Energy and momentum in electrodynamics; Maxwell's stress tensor

(16)

2. Electromagnetic waves; wave equations; EM waves in nonconducting media; EM wave in conducting media; Dispersion of EM waves; Wave guides: TE, TM and TEM modes. Rectangular and cylindrical waveguides. Resonant cavities.

(12)

3. Electromagnetic radiation; concept of retarded potential; Inhomogeneous wave equations, Solution of inhomogeneous wave equations; Electric dipole radiation; Radiation from linear (thin-wire) antenna. Half-wave antenna. Antenna arrays.

(10)

4. Radiation from a point charge; Lienard-Wiechert potentials; Field of a point charge in motion; Power radiated by a point charge; Radiation reaction; Abraham-Lorentz Formula; Bremsstrahlung, Cerenkov radiation.

(12)

5. **Relativistic Electrodynamics:** Four vector representations of relativistic mechanics; Relativistic momentum and energy of a particle; Relativistic dynamics; Dynamics of relativistic particles and electromagnetic fields; Lagrangian and Hamiltonian for relativistic charged particle in external electromagnetic fields; Magnetism as a relativistic phenomenon; Invariance of Electric charge; covariance of electrodynamics; Transformation of Electric and magnetic fields; The Electromagnetic Field tensor; Electrodynamics in Tensor notations; Invariance of Maxwell's equations, Potential formulation of relativistic electrodynamics.

(10)

Suggested Reference books:

1. Classical Electrodynamics, John David Jackson, Wiley
2. Introduction to Electrodynamics, David J. Griffiths, Pearson
3. Classical Electricity and Magnetism, Panofsky and Phillips, Dover Publications

CO1: Use of mathematical tools to understand the pre-requisite of electrodynamics

CO2:To gain insights into various modes in waveguides.

CO3: Understanding the basics of radiations and it's implementation in the field of communications.

CO4: To acquire knowledge of electrodynamics in the domain of relativity.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	2							
CO2	3	2	2	2	2							
CO3	3	2	2	2	2							
CO4	3	2	2	2	1							

PG/SC/CORE/PHY/TH/107	Solid State Physics

Marks (Credit) : 50 (4) **60 Lecture hours**

SYMMETRIES OF CRYSTAL STRUCTERS: Inter-atomic Forces and Crystal Binding, Translational Symmetry in Crystals, Bravais Lattices, Unit Cells, Primitive Cells, Wigner–Seitz Cell, Reciprocal Lattices, Brillouin Zone, Rotations and Reflection Symmetries, Crystallographic Point Groups, Symmetries of Two and Three Dimensional Bravais Lattices. Classification of Bravais Lattices, X-ray Diffraction by Crystal, Von Laue Formulation and Bragg's Law, Scattering Amplitudes, Methods of Scattering Experiments. **[14 lecture hours]**

LATTICE VIBRATIONS: Inter-Atomic Potential, Harmonic Approximation**,** Vibrations of Monoatomic and Diatomic Chains, Phonon Dispersion Relations, Density of Normal Modes, Specific Heat, Anharmonic Potential, Thermal Expansion of Solid.

[6 lecture hours]

ELECTRON WITHIN CRYSTAL: Born–von Karman Boundary Condition, Bloch's Theorem, Schrödinger Equation in Reciprocal Space, Crystal Momentum, Symmetry

Properties of Energy Eigenstates, Kronig-Penney Model in Reciprocal Space, Electrons in a Weak Periodic Potential, Tight-Binding Method, Wannier Functions, Band Structures, Equation of Motion of Electron Under External Force Field, Concept of Holes, Effective Mass, Symmetry Breaking and Goldstone's Theorem.

[10 lecture hours]

FREE ELECTRON PROPERTIES: Drude Model, Sommerfeld model, Fermi-Dirac Distribution, Fermi Sphere, Fermi Energy, Density of States, Sommerfeld Expansion, Fermi Level at Non-zero Temperatures, Electronic Specific Heat, Pauli Paramagnetism, Electronic Transport, Boltzmann Transport Equation for Electrons, DC, AC and Optical Conductivity, Transport Coefficients, Thermal Conductivity, Wiedemann-Franz Law, Hall effect, Hall Coefficient, Quantum Hall Effect, Landau Levels, Landau Diamagnetism.

[10 lecture hours]

MAGNETIC PROPERTIES: Bohr-Van Leeuwen Theorem, Larmor Diamagnetism, Van Vleck Paramagnetism, Magnetic Orders, Ferromagnet, Antiferromagnet, Ferrimagnet, Coulomb and Exchange Integrals for Diatomic Molecules, Heisenberg Exchange Hamiltonians, Classical Ground States for Ferromagnet and Antiferromagnet, Direct Exchange, Indirect Exchange, Superexchange, Double Exchange, Mean-field Results of Ferromagnetic Heisenberg Systems, Curie-Weiss law, Ferromagnetic Spin-wave Excitation, Magnon Dispersion Relation, Bloch-$T^{3/2}$ Law, Magnetic Specific Heat.

[10 lecture hours]

DIELECTRIC PROPERTIES: Polarizations, Dielectric Constants, Absorption of Electromagnetic Radiation, Dielectric Function for a Harmonic Oscillator, Debye Equations, Ferroelectricity, Landau Theory of Phase Transition.

[**6 lecture hours]**

SUPERCONDUCTIVITY: Properties of Superconductors, Meissner Effect, London Equations, Thermodynamics of Superconductors, Cooper Pair, BCS Theory, Classification of Superconductors.

[4 lecture hours]

References:

1. Introduction to Solid State Physics, C. Kittel, John Wiley and Sons

2. Quantum Theory of Solids, C. Kittel, John Wiley and Sons

3. Solid State Physics, N.W. Ashcroft and N.D. Mermin, Cengage Learning

4. Fundamentals of the Physics of Solids: Volume 1, 2 and 3: by A. Piróth and J. Sólyom, Springer

5. The Physics of Solids, E. N. Economu, Springer

6. Solid-state Physics, H. Ibach and H. Luth, Springer

7. Quantum Theory of the Solid State: An Introduction, L. Kantorovich, Springer

8. Condensed Matter Physics, M. P. Marder, Wiley

9. Principles of the Theory of Solids, J. M. Ziman, Cambridge University Press

10. Magnetism in Condensed Matter, S. Blundell, Oxford University Press

11. The Oxford Solid State Basics, S. H.Simon, Oxford University Press

Course Outcomes:

CO1: To gain knowledge of symmetry and concept of reciprocal lattice to understand the crystal structure, and its experimental determination by X-Ray diffraction.

CO2: Knowledge of lattice vibration to get insight into the thermal properties of solids.

CO3: Knowledge of band theory to understand the electronic properties of solids.

CO4: To acquire theoretical and experimental knowledge of magnetic and dielectric properties of solids.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	2	2							
CO2	3	2	1	2	2							
CO3	3	2	2	2	2							
CO4	3	1	1	1	1							

PG/SC/CORE/PHY/TH/108	Electronics

Marks (Credit) : 50 (4) **60 Lecture hours**

Metal semiconductor junctions: Schottky barrier, Rectifying contact, Ohmic contact; Opto-electronic devices: Photodiodes, LEDs, Solar cells, photo-detectors.

(8 lectures)

Network Analysis

Frequency domain analysis: Solving problems on steady state AC response of circuits (having independent/dependent sources) by Mesh method, Node, KVL, KCL, Thevenin's and Norton's theorems; Complex frequency domain analysis: Application of Laplace transform to network analysis. (10 lectures)

Analog Systems and Applications

Operational Amplifier: Linear applications: Problems on linear applications of op-amp, constant current source, instrumentation amplifier, op-amp as negative resistance and inductor simulator, capacitance multiplier, analog computation, Active Filters: Transfer function and basics of filters, low pass, high pass, band pass, band reject, notch filter, different topology of filters, Butterworth polynomials, Butterworth filter, realization of 1^{st} and 2^{nd} order filters; Nonlinear applications: Comparator, Schmitt trigger, multivibrator, function generator, problems on nonlinear applications of op-amp.

(12 lectures)

Power Supply: Regulated power supply: Characteristics, series and shunt voltage regulators, series voltage regulate using discrete components; Linear voltage regulator ICs: Fixed voltage (78XX and 79XX series) and adjustable voltage regulator (IC 317) ICs, constant current source; Switching voltage regulators: Characteristics of SMPS, buck, boost, buck-boost regulators. (10 lectures)

Digital Systems and Applications

Combinational logic circuit: Problems on combinational logic circuit, encoder, decoder, MUX, DEMUX ICs and their cascading, MUX and Decoder as logic function generator.

(5 lectures)

Sequential logic circuit: Flip flop (FF): Applications, characteristic equation, excitation table, conversion of FF, time diagram, problems on FFs. Registers: Buffer register, shift registers, bidirectional shift registers, universal shift registers and their applications. Counters: Difference between asynchronous and synchronous counters, ripple Up, Down, Up/Down counters, decade counter with time diagram.

(10 lectures)

Data Convertor

DAC and ADC: A/D signal conversion, quantization, sampling, weighted resistor, R-2R ladder type D/A convertors, S/H circuit, block diagram and working of ramp type, dual slope type, SAR type, flash type A/D converter, microprocessor compatibility, problems on DAC and ADC.

(5 lectures)

Recommended readings:

1. Physics of Semiconductor Devices: S.M. Sze
2. Solid State Electronic Devices: B. G. Streetman and S. K. Banerjee
3. Theory and problems of electric circuits: M. Nahvi and Joseph A. Edminister
4. Electronic Devices and Circuit Theory: Boylestad and Nashelski
5. OP-Amps and Linear Integrated Circuit: R. A. Gayakwad
6. Digital Fundamentals: Thomas L. Floyd
7. Digital Circuits, Volume I & II: D. Ray Chaudhuri
8. Fundamentals of Digital Electronics: Anand Kumar
9. Digital Designee: Mano
10. Modern Electronic Instrumentation and Measurement Techniques: A. D. Helfrick and W. D. Cooper

Course Outcome:

CO1: To understand the Metal-Semiconductor theory, Barrier potential and charge transport mechanism. To understand the basic idea of different Opto devices such as LED, Photo Detector and Solar Cell.

CO2: To get idea of Network analysis, KCL and KVL, Complex frequency domain analysis and its application of Laplace Transform of Network analysis

CO3: To understand on analog systems and applications such as electronics OP-AMP, Power Supply.

CO4: To know about the digital systems and its applications such as Flip-Flop, Registrar, Counters and also digital to analog (DAC0 and Analog to digital (ADC) converter.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	2							
CO2	3	2	2	1	2							
CO3	3	2	2	1	2							
CO4	3	1	2	2	1							

PG/SC/CORE/PHY/TH/109	Atomic and Molecular Physics

Marks (Credit): 50 (4) **60 Lecture hours**

1. One electron systems: Fine structure and hyperfine structure of one electron atoms.

(3 Lectures)

2. Lamb-Rutherford experiment, Lamb shift (qualitative explanation) (2 Lectures)
3. H-atom in external electromagnetic field: absorption, stimulated and spontaneous emissions, Einstein's A and B coefficients, Selection rules for electric and magnetic multipole transitions. (5 Lectures
4. Interaction with static external electric and magnetic fields, normal and anomalous Zeeman effect, Paschen-Bach effect and Stark effect for one electron atoms. (5 Lectures)
5. Two electron atoms, construction of ortho and para states, role of Pauli exclusion principle, Slater Determinant, Independent particle model, Modification due to screening. (5 Lectures)
6. Many electron atoms, The central field approximation and corrections to it. L-S / Russel-Saunders and J-J coupling, Introduction to Hartree-Fock Self consistent field method. Spectra of the alkali atoms. (5 Lectures)
7. Rotational spectra of a diatomic molecule, Stark effect in molecular rotational spectra, Spectra of symmetric top molecules, asymmetric molecules. (5 Lectures)
8. Vibrational spectra - Anharmonic molecular vibration, Idea of Fourier transform Infrared (FTIR) Spectroscopy Vibration of polyatomic molecules, Normal vibrations and normal coordinates, symmetry properties of molecular vibrations. Rotation vibration spectra of diatomic molecules, linear molecules and symmetric molecules, parallel and perpendicular bands. (10 Lectures)
9. Raman spectroscopy, Classical & Quantum theory, Concept of polarizability ellipsoid , pure rotational Raman spectra, vibrational Raman Spectra, Depolarization ratio (ρ) of Raman lines. (5 Lectures)
10. Lasers: Population inversion, three level laser, He-Ne laser-principle of operation, tunable lasers, laser induced reactions and isotope separation, laser as a probe for studying excited states of atoms. (5 Lectures)
11. Electronic spectra of diatomic molecules, Fortrat Parabola Deslandres table, B.O. approximation (Qualitative idea), vibrational structure of electronic transition. Franck-Condon principle. (5 Lectures)
12. Introduction to spin resonance spectroscopy, spin and applied fields, NMR and ESR spectroscopy. Elements of Mossbauer effect. (5 Lectures)

Course Outcomes

CO 1: To determine fine and hyperfine structures of one electron atoms.

CO 2: Interaction of external electric and magnetic fields with matter

CO 3: To understand the physics of two-electron and many electron atoms.

CO 4: To explore the rotational, vibrational and electronic spectra of diatomic and polyatomic molecules.

CO 5: To understand the basic principles of LASERs and their applications.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	1	2							
CO2	3	2	2	1	2							
CO3	3	2	1	1	2							
CO4	3	1	1	2	1							

PG/SC/CORE/PHY/TH/110	Nuclear & Particle Physics

Marks (Credit): 50 (4) **60 Lecture hours**

1. **General Properties of Atomic Nuclei:** [7 Lectures]
Nuclear composition, Nuclear size and its determination, Rutherford scattering, Nuclear radius and charge distribution, Nuclear shape- electric quadrupole moment, Nuclear stability- mass and binding energy, Mass spectrometers, Nuclear spin and magnetic moment.

2. **Radioactive Decays:** [14 Lectures]
Alpha decay:
The main features, Mass and energy consideration, Systematics, Gamow theory of alpha decay – consideration of actual barrier – hindrance and formation factor

Beta decay:
Beta-decay and electron capture, Pouli’s neutrino hypothesis and detection of neutrino, Fermi's theory for allowed beta-decay, Comparative half-life and classification of beta emitters, Selection rules for Fermi and Gamow-Teller transitions, Elementary ideas about the gauge theory of weak interaction, Parity non-conservation, Wu's experiment.
Gamma decay:
The modes of gamma-transition, Isomers, Change of parity, Selection rules, Probability of emission, Internal conversion, Conversion coefficients, Auger electrons, Interaction of nuclear radiation with matter, Passage of gamma rays through matter-absorption and scattering.

3. **Nuclear reactions** [7 Lectures]
Types of reactions, Conservation laws, Kinematics of nuclear reactions, Q value, Reaction cross section, Concept of compound and direct reactions, Reaction channels, Nuclear energy levels, Resonance in nuclear reactions, Breit-Wigner formula, S. N.

Ghoshal's experiment for verification of compound nuclear hypothesis, High energy reactions, Nuclear fission and fusion Reactions, Nucleosynthesis.

4. **Nuclear force** [7 Lectures]

Possibilities of two nucleon bound state, Properties of deuteron, Deuteron-square well potential, Schrodinger equation and its solution for ground state of deuteron, Deuteron radius, Spin dependence of nuclear forces, Electric quadrupole moment and magnetic dipole moment of deuteron.

Low energy n-p and p-p scattering, Nature of nuclear forces.

5. **Nuclear models** [7 Lectures]

Elementary ideas of Fermi gas models, The liquid drop model, The shell model and Collective model.

6. **Accelerators and detectors:** [6 Lectures]

Linear accelerator, Cyclotron and betatron, Gas detectors, Scintillation detectors and photo-multiplier tube (PMT), Semiconductor detectors (Si and Ge).

7. **Elementary particles** [12 Lectures]

Elementary particles and classification, Leptons: family members, generations, discovery of positron, solar neutrino problem, neutrino oscillation. Hadrons: production and decay, lifetime, spin, discovery of pion.

Interactions of elementary particles, Quantum numbers, Symmetry and conservation laws, Symmetry classification of hadrons, Quark model, Color quantum number and gluons, Quark structure of hadrons.

Reference Books:

1. Introductory nuclear Physics, Kenneth S. Krane, Wiley India Pvt. Ltd., 2008.
2. Concepts of nuclear physics, Bernard L. Cohen, Tata Mcgraw Hill, 1998.
3. Nuclear Physics, Irving Kaplan, Narosa Publishing House, 2002.
4. Nuclear Physics, R.R. Roy and B.P. Nigam, New Age Publishers,1996.
5. Nuclear and particle Physics, W.E. Burcham and M. Jobes, Prentice Hall,1994.
6. Nuclear Physics, S. N. Ghoshal, S. Chand and Co. Ltd., 2018.
7. Introduction to Elementary Particles, D. Griffith, John Wiley & Sons, 2008.
8. Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi, 2008.
9. Basic ideas and concepts in Nuclear Physics - An Introductory Approach by K. Heyde, IOP Publishing, 2004.
10. Theoretical Nuclear Physics, J.M. Blatt & V.F.Weisskopf, Dover Pub. Inc., 1991.

Course Outcomes

CO1: Recapitulate the basic nuclear properties, Accelerator and Detector Physics

CO2: Grow detailed understanding about the radioactive decays

CO3: Develop the concept of nuclear force by studying deuteron problem & nucleon-nucleon scattering

CO4: Learn about the basic concepts of elementary particle physics

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1								
CO2	3	1	1	1			1					
CO3	3	2	2	1	2							
CO4	3	1	1	1								

CHOICE BASED COURSES:

PG/SC/CBS/PHY/TH/201	Biophysics (I)

Marks (Credit) : 50 (4) **60 Lecture hours**

1. **Introduction to biological molecules [8 lectures]**
   Proteins - Primary - Secondary - Tertiary - Quaternary structures.
   Nucleic acids: DNA - Basic genetic concept - Double helical model of DNA - Replication - Recombination - Repair
   RNA - Types - Functions.
   Lipids and sterols– Structure, nomenclature and Physiological properties.
   Carbohydrates - Structure and Physiological properties.

2. **Physics of Bio-molecules [10 lectures]**
   Intermolecular forces: van der Waal forces, electrostatic double layer, DLVO forces, repulsive entropic (Thermal fluctuations and steric hydration), hydrophobic and hydrophilic interaction.
   Molecular Mechanism of Genetic Information Transfer - Griffith's Experiment Hersey and Chase experiment.
   DNA Replication - Meselson and Stahl experiment.
   Genetic Code
   Transfer of Genetic Information-
   Molecular Mechanism of Protein Synthesis.
   Motor proteins and transport proteins

3. Bio-membrane: [12 lectures]
   Structure and properties of biological membranes. Model system of bio-membrane..

Thermodynamics of self assemble of amphiphilic molecules. Critical micellar concentration.

Uni-lamellar vesicles as a model system of biological membrane and their characterisation.

Elastic properties of the membrane and its free energy. Phase transition in lipid bilayer and characteristics of different phases.

Effect of cholesterol on the membranes phases and structures and its implications in cellular system.Raft hypothesis.

Protein induced phase transition and its implications. Understanding the role of different on the infectious disease.

Antimicrobial peptides as an alternatives of antibiotics, Physics of pore formation on the phospholipid membranes anditsimplications.

Electrostatics of membranes: Concept of zeta potential and GouyChapman theory.

4. Signal transduction [10 lectures]

The Nervous Systems, Electrical Signals of Nerve Cells, Channels and Transporters,

Synaptic Transmission: Electrical Synapses, Neurotransmitters and Their Receptors, Pain, Brain and spinal cord.

Functions of cerebrum, cerebellum and medulla oblongata, Peripheral nervous system.

Structure of neuron, Neuroglia.

Myelinated and unmyelinated nerve fibers.

Polarisation and depolarisation of the cell, Conduction velocity of nerve impulse in relation to various factors.

Properties of nerve fibers –excitability, conductivity, all-or none law, accommodation, adaptation, summation, refractory period, synaptic potentials, synaptic transmission of the impulse, neurotransmitters. Motor unit.

Injury to peripheral nerves-degeneration and regeneration-brief idea and associated diseases.The neuromuscular junctions – structure, events in transmission

Sense organs- Physiology of Vision, The Auditory System, The Chemical Senses: The Olfactory System, The Taste System.

5. Thermodynamics of living system [10 lectures]

Equilibrium and Near Equilibrium of Thermodynamics

Phase Equilibrium

Gibbs Free energy, Enthalpy and energy changes in reaction

Chemical potential.

Reaction kinetics -First order - Second order reaction

Open system - Conservation of mass and energy principle in open system.

Entropy production in open system.

6. Applications of Physico-chemical techniques in Biology [10 lectures]

Diffusion - Fick's laws of diffusion; Osmosis; Centrifugation; Column Chromatographic techniques; Radioactive tracer technique; Uses of Radio-isotope in biomedical system; PCR - RTPCR techniques; ELISA technique.

Reference books:

1. Intermolecular and surface forces, Jacob N. Israelachvili
2. Introduction to Cellular Biophysics, Volume 1 — Membrane transport mechanisms, Kargol, A
3. Handbook of Biological Physics: Structure and dynamics of membranes Edited by R. Lipowsky, E. Sackmann

Course Outcomes

CO1: Understand how the structures of different biological molecules are related with its function to maintain normalcy of the living system.

CO2: Explain, different biological phenomena at the molecular level with the laws of physics.

CO3: Analysis critically various problems of living system and learn to find out the remedies.

CO4: Adopting different physico-chemical techniques to characterize the problem and search solution for sustaining the living system.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	3	1	1							
CO3	3	2	3	1	1							
CO4	3	2	3	1	1							

PG/SC/CBS/PHY/TH/202	High Energy Physics

Marks (Credit): 50 (4) **60 Lecture hours**

1. Scope of Particle Physics

Elementary particles and fundamental interactions, experimental aspects of particle physics.

2. Relativistic Kinematics

Mandelsam variables, phase space, calculation of cross section and decay width.

3. Symmetries in Particle Physics

Isospin and SU(2), quark model and SU(3), C, P, T, CP and CPT.

4. **Quantum Electrodynamics**

Calculation of cross section for Rutherford, Bhabha, Moller, Compton scattering.

5. Hadron Structure and Quantum Chromodynamics

Deep inelastic scattering, form factors, Bjorken scaling, parton model, scaling violation.

6. Flavor Physics

Quark mixing, CKM matrix, FCNC, neutrino masses and mixing, neutrino oscillation.

7. Electroweak Theory

Higgs Mechanism, Generation of fermion and gauge boson masses, Decay width of W and Z boson. Reasons for looking beyond the electroweak theory.

8. Overview of High Energy Experiments

Introduction, Modern particle detectors and accelerators, Data analysis framework and ROOT, Error analysis for high energy experiments, simulation studies of high energy interactions, Aim of LHC and particle physics experiments for the next 25 years.

Recommended Readings

1. F. Halzen and A.D. Martin: Quarks and Leptons
2. T.-P. Cheng and L.-F. Li: Gauge Theories in Particle Physics
3. W. R. Leo, **Techniques for Nuclear and Particle Physics Experiments** (2nd edition), Springer-Verlag Berlin Heidelberg, 1994.
4. J. R. Taylor, **An Introduction to Error Analysis** (2nd edition), University Science Books, 1997.

Course Outcomes

CO1: Know the concept of Symmetries in Particle Physics

CO2: Gain knowledge about the Hadron structures using the framework of Quantum Chromodynamics

CO3: Develop basic concepts of Electroweak theory

CO4: Be acquainted with high energy experiments

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	2							
CO2	3	2	1		2							
CO3	3	2	1	1	2							
CO4	3	1	1	1	1				2	1		

PG/SC/CBS/PHY/TH/203	X-Ray Crystallography (I)

Marks (Credit) : 50 (4) **60 Lecture hours**

1. Symmetry of crystals: crystal lattice, symmetry elements, combination of rotational symmetries, point groups, matrix representation, crystal system, Bravais lattice, zones and forms, spherical, stereographic and gnomonic projections, space groups, equivalent points and diagrammatic representation.

(12)

2. X-ray diffraction and reciprocal lattice: concept of reciprocal lattice, geometrical interpretation of Bragg's law, Laue diffraction condition, equivalence of Bragg's law and Laue equations, Ewald's construction, Brillouin zones.

(8)

3. Experimental techniques: Laue method, rotating crystal method, Debye-Scherrer powder method, interpretation of x-ray diffraction photographs, Weissenberg method, zero layer Weissenberg photograph, measurement of intensities, photographic methods, x-ray diffractometers. (10)

4. Crystal structure determination: Geometrical and physical factors affecting intensity of x-ray diffraction, temperature factor and Wilson plot, absolute scale, theory of use of intensity statistics, space group determination, Atomic scattering factor, Geometrical structure factor, Fourier series for electron density in crystals, useful forms of Fourier series, electron density sections and projections. (15)

5. Methods for structure determination: Phase problem in crystallography, Patterson function and its properties, Harker section and Harker lines, heavy atom method for structure solution, unitary structure factor, isomorphous replacement and anomalous scattering methods for phase determination, direct methods, Harker-Kasper inequality, other inequality relationships and their practical applications, sign relationships, Sayre's equation. (15)

Books:

1. X-Ray Diffraction by B. E. Warren

2. An introduction to crystallography by M. M. Woolfson.

3. Introduction to Solids by L. V. Azaroff.

4. A Basic Course in Crystallography by T.R.N. Kutty.

5. The Basics of Crystallography and Diffraction by C. Hammond.

6. A Practical Guide to Structure Determination by G. Stout and L. Jensen.

7. Crystal Structure Analysis: A Primer by J. P. Glusker, K. N. Trueblood.

8. Structure Determination by X-ray Crystallography by M. F. C. Ladd and R.A. Palmer.

9. X-ray Analysis and the Structure of Organic Molecules by Jack Dunitz.

Course Outcomes

CO1: To gain knowledge of symmetries of crystals.

CO2: Understanding crystal diffraction.

CO3: Analyzing lattice parameters from powder X-ray diffraction.

CO4: Knowledge of electron density map and structure solution from laboratory X-ray data.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	2							
CO2	3	2	1	1	2							
CO3	3	2	1	1	2							
CO4	3	2	1	1	1				2	1		

PG/SC/CBS/PHY/TH/204	**General Relativity & Cosmology (I)**

Marks (Credit): 50 (4) **60 Lecture hours**

1. Review of (i) Special Theory Relativity(STR) and Flat Minkowski Space-Time
(ii) Manifolds and Tensor Algebra [10 Lectures]

2. Riemanian Geometry The Riemanian curvature tensor, Symmetries of the Riemanian tensor, The Bianchi identity, The Ricci and Einstein tensor, Weyl tensor– simple examples and explicit calculations. The Lie derivative for scalars, The lie derivative of the metric and killing vectors, Maximally symmetric spaces and conservation laws.
Curvature and parallel transport, Round trips, Vanishing Riemanian tensor and the existence of flat connections, Riemannian normal co-ordinates, The geodesic deviation equation. [10 Lectures]

3. The Principle of Equivalence and The Einstein Field Equations Equivalence of gravitation and inertia, The weak and strong principle of equivalence. General covariance, Gravitation versus inertial and non-inertial co-ordinates. Einstein Field Equations, The weak field limit and the derivative of Einstein equation, The Cosmological Constant. The Einstein-Hilbert action, The matter Lagrangian and the gravitational field equations [10 Lectures]

4. Introduction to Cosmology: Our Place in the Universe, Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms, Cosmological principles, Observational basis for cosmological theories, the redshifts, Hubble's law, Distances at small redshift , Cosmic Distance Ladder.
[6 Lectures]

5. Dynamics of expanding Universe: Basics of Friedman -Roberson Walker cosmology, Flat.Open and Closed universe, Constituents of the universe; Galaxies rotation curv es, Dark matter, Dark energy, Luminosity distance, Angular diameter distance, Source counts
[12 Lectures]

6. High redshit Universe : Accelerated expansion, Discovery of accelerated expansion, Newtonian interpretation, Dark energy, Deceleration parameter, Jerk & snap, Discovery of early deceleration, Equation of state w parameter, The cosmological constant problems . Different dark energy models [8 Lectures]

7. Reionization of the Universe: The first stars, the reionization process, 21 cm line.
[4 Lectures]

Reference Books:

Weinberg, S., Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity

Peebles, P. J. E. 1993 Principles of Physical Cosmology. Princeton University Press, Princeton, NJ.

Peacock, John A., 1999. Cosmological Physics. Cambridge: Cambridge University Press.

Weinberg, S. , 2008, Cosmology, OUP Oxford.

Narlikar, J.V. Introduction to Cosmology, Cambridge university press, 1993.

Raychaudhuri, A. K. Theoretical Cosmology, Oxford press, 1979.

Course Outcomes:

CO1: Learn the equivalence principle and acquire a good knowledge of how this leads to a geometric description of gravity, in the form of the general theory of gravity using Einstein's Field equations

CO2: Know about methods used in modern differential geometry and tensor calculus on Riemannian manifolds.

CO3: Use an understanding of our galaxy to contrast and compare it with other galaxies as to type, contents, age, luminosity, motion, and size and learn Hubble's law.

CO4: Learn modern cosmological concepts, such as dark energy, dark matter and Cosmic Microwave Background in the context of the Big Bang theory and have a basic understanding on dynamics of the expanding Universe.

CO5:Understand links between theoretical concepts of cosmology and the observable properties of the universe.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	2	2	2	1	1							
CO3	3	2	2	1	1							
CO4	2	2	2	1	1							
CO5	2	2	2	1	1							

PG/SC/CBS/PHY/TH/205	Physics of Semiconductor Devices

Marks (Credit): 50 (4) **60 Lecture hours**

Semiconducting materials: Energy band, direct and indirect band gap semiconductor, charge carriers in semiconductors, effective mass, conductivity and mobility, drift velocity, carrier concentration and its temperature dependence. (2 lectures)
Junction: p-n junction diode, depletion region and barrier formation in p-n junction diode, band structure of p-n junction at equilibrium, forward and reverse, I-V characteristics of semiconductor diode, Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current Flow Mechanism in Forward and Reverse Biased Diode, avalanche and Zener breakdown; p-n junction in transient and AC condition: time variation of stored charge, reverse recovery transient, junction capacitance, Varactor diode, switching diode, metal semiconductor junction: Schottky barrier, Rectifying contact, Ohmic contact, heterojunctions, Charge Coupled Device (CCD). (8 lectures)

Bipolar Junction Transistor: majority carrier distribution and thermal current, Static characteristics: current voltage relationship, output characteristic, device modeling, Embers-Moll model, Gummel-Poon model, Frequency limitation: capacitance and charging effect,transit time effect, high frequency transistor (microwave characteristic, cutoff frequency), switching transistor. (8 lectures)

Field effect transistors: Basics characteristics of JFET and MOSFET, FET: uniform charge distribution, arbitrary charge distribution, normally off FET, field dependent mobility, two-region model, saturation velocity model, pinch-off, saturation, gate control, I-V characteristic, MESFET and related field effect device, short channel effect, microwave performance;
(5 lectures)
MOSFET: nonequilibrium condition, linear and saturation region, subthreshold characteristic, mobility behavior and models, temperature dependence, output characteristic, transfer characteristic, control of threshold voltage, substrate bias effects, equivalent circuit, drain induced barrier lowering, short channel effect, narrow width effect, gate induced drain leakage, MOS capacitance.
(5 lectures)

Tunnel devices: Basic idea of tunneling phenomena, nondegenerate and degenerate semiconductor, band structure of degenerate semiconductor; band structure, I–V characteristic and principle of operation, tunneling probability, I–V relationship, microwave performance: equivalent circuit, cutoff frequency, self-resonance frequency, series and parallel loading.

(8 lectures)

Gunn Diode: Bulk negative resistance, Gunn effect, transferred electron mechanism, RWH theory, modes of operation. (7 lectures)

Avalanche Transit-time Devices: Physical description, structure, working of IMPATT, TRAPATT and BARITT diodes. (5 lectures)

Opto-electronic Devices: LED: Radiative transitions, emission spectra, luminescent efficiency, light emitting materials, working of LED, visible and infrared LEDs, Photo detectors: general features, gain, band width and signal to noise ratio, principle of operation: photodiode, p-i-n, meta-semiconductor photo diode, Solar cells: current and voltage in illuminated junction, p-n junction solar cells, I-V characteristics, solar radiation, conversion efficiency and spectral response, applications, Semiconductor Laser: Basics of laser physics, population invasion, stimulated emission and lasing action in p-n junction, spectral response of p-n junction Laser.

(8 lectures)

Heterojunction: Basics, isotype and anisotype heterojunctions, hetrojunction transistor, FET, photodiode, solar cell, laser. (4 lectures)

Suggested Books:

1. Physics of Semiconductor Devices: S.M. Sze
2. Solid State Electronic Devices: B. G. Streetman and S. K. Banerjee
3. Semiconductor Optoelectronic Devices: Pallab Bhattacharyya
4. Microwave Devices and Circuits: Samuel Y Liao
5. Optical Electronics : A. Ghatak and K. Thyagrajan

After completion of the course students should

CO1: Understand the concepts of energy bands and their role in electric conduction in metals, intrinsic and extrinsic semiconductors and their temperature dependendece.

CO2: Explain the band structure of pn-junctions in unbiased and biased conditions and would apply this to explain its rectifying properties.

CO3: Understand junction capacitance both for dopant charges and mobile charges.

CO4: Understand structure of bipolar junction transistor. Define and calculate base transport ratio and emitter injection efficiency. Analyze the the role of doping and and geometry in optimizing this parameters and should develop different strategies to overcome shortcomings in conventional BJTs.

CO5: Understand the pinch off effect in JFET and should be able to derive its I-V characteristics. Also understand MOSFET band diagram its linear and saturaion behavior.

CO6: Understand the physics and high frequency applications of negative resistance devices of tunnel diode, Gunn diode and different transit time devices.

CO7: understand the physics and applications of optoelectronic semiconducting devices LED, Photo diode, p-i-n diode, LASER diode and solar cells etc.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	2	2	2	1	1							
CO3	3	2	2	1	1							
CO4	2	2	2	1	1							
CO5	2	2	2	1	1							
CO6	1	1	1	1	1							
CO7	1	1	1	1	1							

PG/SC/CBS/PHY/TH/206	Optoelectronics

Marks (Credit) : 50 (4) **60 lecture hours**

1. Optical fibre waveguides: Review on optical processes in solids, Optical fibre, numerical aperture, different modes in optical fibres, dispersion, Single and Multimode fibres, Losses in optical fibres, Cables, Splices and connectors, Splice loss. (10 lectures)

2. Integrated optics : Modes in an asymmetric planar waveguide, Ray analysis of planar waveguides; WKB = analysis of inhomogeneous planar waveguides, strip waveguides, Guided wave devices phase modulator, Mach-Zehnder interferometer modulator and switch optical directions coupler, bulk and integrated optical modulators. (10 lectures)

3. Electro Optic Effect : Electro optic effect in KDP crystals, phase modulation, amplitude modulation, Electro optic effect in lithium niobate and lithium tantalate crystals modulator design. (10 lectures)

4. Acoustic Optic Effect: Raman Nath and Braggs regimes of diffraction, application to periodic media, Acousto Optic Device — : Acousto optic modulation, Bragg modulator, Acousto optic deflectors.

(10 lectures)

5. Optical sources and detectors : LED, Lasers, Photodetectors, PN junction photodiode, PIN , APD photodetectors. (10 lectures)

6. Optical fibre communication systems: LED and Laser diode transmitter design, PIN and APD receiver design, Modulation schemes, Design of digital and analog communication systems, Modulation and line coding schemes, Optical amplifiers. (10 lectures)

Text Books :

1. Optical Electronics	: A. Ghatak and K. Thyagrajan
2. Optical Electronics	: A. Yariv
3. An introduction to optical Waveguides	: M. J. Adams
4. Integrated Optics	: T. Tamir
5. An Introduction to Electro—optic Device	: I. P. Kaminow
6. Optoelectronics and Fiber Optics Communications	: C.K. Sarkar and D.C. Sarkar

Course Outcomes

CO1: To know about the basics of Optical Fibre wave guides, different types of optical fibres, concept of different modes, different loss mechanism of optical fibres.

CO2: To understand Integrated optics, modes in an asymmetric planar waveguide, ray analysis of different planar waveguides and optical modulators.

CO3: To understand about electro optic effect, phase modulator and amplitude modulators, Electro optic effect on KDP crystals, Lithium Niobate Crystals etc.

CO4: To understand the acousto optic effect , Raman Nath and Braggs regimes of diffraction, application to periodic media, Acousto Optic Device — : Acousto optic modulation.

CO5: To know about different optical sources and detectors like LEDs, LASER, Photo detectors. To understand about the optical communication system.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	2	2	2	1	1							
CO3	3	2	2	1	1							
CO4	2	2	2	1	1							
CO5	2	2	2	1	1							

PG/SC/CBS/PHY/TH/207	Condensed Matter Physics (I)

Marks (Credit): 50 (4) **60 Lecture hours**

FORMULATION OF MANY-PARTICLE SYSTEMS IN SECOND QUANTIZATION: Identical Particles, Permutation Symmetry, Indistinguishablity, Fermionic and Bosonic Systems, Symmetric and Anti-Symmetric Wave Functions, Occupation Number Representation, Creation and Annihilation Operators, One and Two-Particle Operators in Second Quantization, Quantum Field Operators, Second Quantized Formulation of Coulomb Interaction, Harmonic Oscillator, Electron in Two-Dimension under Magnetic Field (Landau levels) and Tight-Binding Hamiltonian for Graphene (Dirac Points), Interacting Electron System, Hubbard Hamiltonian.

MEAN FIELD THEORY: Basic Concept of Mean Field Theory. Hartree-Fock Approximation, Electrons in Metal, Exchange Energy, Total Energy of Electron Gas, Mean Field Theory of Heisenberg Spin Model, Mean Field Theory of Hubbard Model, Stoner Model of Metallic Ferromagnetism.

LINEAR RESPONSE THEORY: The General Kubo Formula, Kubo Formula for Conductivity, Dielectric Functions, Hall Conductivity, Thouless-Kohomoto-Nightingale-Nijs (TKNN) invariant, Chern Numbers.

ELEMENTARY EXCITATIONS IN MAGNETIC SYSTEMS: Second Quantization of Heisenberg Spin Model, Holstein-Primakoff Transformation, Spin-Wave Theory of Ferromagnet and Antiferromagnet, Specific Heat due to Magnon, Jordan-WignerTransformation and Exciatations of Antiferromagnetic Heisenberg Chain, Bethe Ansatz Formulation.

SUPERCONDUCTIVITY: Cooper Pair, Second Quantized Formulation of BCS Theory, Bogoliubov Transformation, Gap Function, Expression of Critical Temperature, Energy of Superconducting State, Bogoliubov-de Gennes Equation, Josephson Tunneling.

TOPOLOGY OF ENERGY BANDS: Adiabatic Theorem, Pancharatnam–Berry phase, Berry Curvature, Time-Reversal Symmetry, Su-Schreiffer-Heeger (SSH) Model, Zak Phase, Edge States, Topological Phase Transition.

Books:

1. Many-Body Quantum Theory in Condensed Matter Physics, H. Bruss and K Flensberg, Oxford University Press

2. Quantum Theory of Many-Particle Systems, A. L. Fetter and J. D. Walecka, Dover Publications

3. Quantum Theory of Solids, C. Kittel, John Wiley and Sons

4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, Cengage Learning

5. Fundamentals of the Physics of Solids: Volume 1, 2 and 3: by A. Piróth and J. Sólyom, Springer

6. The Physics of Solids, E. N. Economu, Springer

7. Quantum Theory of the Solid State: An Introduction, L. Kantorovich, Springer

8. Theory of Superconductivity, J. R. Schrieffer, W. A. Benjamin

9. Many-Electron Theory, S. Raimes, North-Holland Publishing Company

10. Magnetism in Condensed Matter, S. Blundell, Oxford University Press

11. A Short Course on Topological Insulators, J L Asboth, L Oroszlany and A Palyi, Springer

Course Outcomes

CO1: Learn second quantization theory in order to study the properties of quantum many particle systems.

CO2: Students will understand the mean-field approximation in order to explain Hartree-Fock theory, Stoner model etc.

CO3: How to obtain elementary excitations of Heisenberg ferromagnet and antiferromagnetic systems and their thermodynamic properties.

CO4: Students will understand the idea of topological insulator and topological supercondutors and how to study the topological phases of matter.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1											
CO2	2	2	1	1											
CO3	2	2	1	1											
CO4	3	1	1	1											

PG/SC/CBS/PHY/TH/208	Atomic, Molecular & Optical Physics (I)

Marks (Credit): 50 (4) **60 Lecture hours**

Atomic Physics

1. Spectra of hydrogen atom. Radial and angular wave functions, Special hydrogenic atoms: Positronium, Muonium, antihydrogen, mounic and hadronic atoms, Rydberg atoms. Problems.

[03 Lectures]

2. Fine structure of one-electron atoms: Relativistic effect; Spin-orbit interaction; splitting of spectral lines of hydrogen atom; Lamb shift and its physical explanation; experimental observation. Spectra of alkali metals, Screening constants, Penetrating and non-penetrating orbits

[09 Lectures]

3. Interaction with external electric and magnetic field: (a) Stark effects in one-electron atoms (linear and quadratic), (b) Magnetic field effect in one-electron atoms: Strong field (Normal Zeeman effect), The Paschen-Back effect, Weak field (anomalous Zeeman effect). Splitting of spectral lines, g-factor and its determination. [09 Lectures]

4. **Hyperfine structure and Isotope shift:**

Isotope effect due to reduced mass effect; Magnetic dipole hyperfine structure; Electric quadrupole hyperfine structure

[04 Lectures]

Laser Physics

(a) Spontaneous and stimulated emissions, Einstein A and B coefficients, Properties of laser. (b) Three-level laser system, laser rate equations, variation of pump power, photon numbers in a cavity, threshold condition (c) Line width and line shape function of spectral lines. Natural, pressure and Doppler broadening [12 Lectures]

Molecular Physics

1. Microwave and far infrared spectroscopy: Energy level determination from semi classical approach; Wave equation of nuclear motion (diatomic molecule). Rigid rotator model and determination of energy levels and wave functions; Selection rules. Non rigid rotator; Spectral structure; Structure determination; Rotational spectra of polyatomic molecules

[09 Lectures]

2. Born-Oppenheimer (BO) approximation and separation of electronic and nuclear motion in molecules; Estimation of electronic, vibrational and rotational energies [02 Lectures]

3. Infrared spectroscopy; Wave equation for pure vibrational motion, energy levels of diatomic molecule under simple harmonic oscillator model. Selection rules. Idea of non-rigidity and rotational –vibrational coupling. Drawbacks of linear harmonic oscillator model. Anharmonicity and Morse potential; Energy levels and spectral structures; Dissociation energy. Rotational-vibrational spectra; P- and R-branches

[09 Lectures]

4. Vibrational spectra of molecules: Normal modes [03 Lectures]

Recommended Books:

1. Physics of Atoms and Molecules **--** BH Bransden and CJ Joachain

2. Quantum Mechanics **--** Eugen Merzbacher

3. Introduction to Atomic Spectra **--** HE White

4. Molecular Spectra and Molecular Structure I – Spectra of Diatomic Molecule **--** G Herzberg

5. Molecular Spectra and Molecular Structure II – Infrared Raman Spectra of Polyatomic Molecules **--** G Herzberg

6. Laser Fundamentals – William T Silfvast

7. LASERS – Fundamentals and Applications – A Ghatak and K Thyagarajan

Course Outcomes

CO 1: To understand the spectra of hydrogen and hydrogen like atoms.

CO 2: Interaction of external electric and magnetic fields with matter

CO 3: To explore fine and hyperfine structures of one electron atoms.

CO 4: To understand the rotational (microwave), vibrational (IR) and electronic spectra of diatomic and polyatomic molecules.

CO 5: To understand the basic principles of LASERs and their applications

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1											
CO2	2	2	1	1											
CO3	2	2	1	1											
CO4	3	1	1	1											

CHOICE BASED SUBJECTS (NON PRACTICAL)

PG/SC/CBS/PHY/TH/301	Plasma Physics

Marks (Credit): 50 (4) **60 Lecture hours**

1. Introduction

Introduction to plasma, Orbit theory of drift motions in plasma. Pinch effect. Bennett's relation, Plasma oscillations, Short wavelength of plasma oscillation. Debye shielding and different characteristic parameter of plasma. (10 Lectures)

2. Single particle motion

Propagation of EM waves through plasma. Effect of external magnetic field on wave propagations: ordinary and extraordinary rays. Adiabatic invariants. (5 Lectures)

3. Waves in a fluid plasma

Fluid picture of plasma, Waves in cold unmagnetized plasma, Electrostatic wave, Electromagnetic waves. Effects of finite temperature on waves in fluid picture. Ion-acoustic wave. (10 Lectures)

4. Magnetohydrodynamics

MHD equations, Magnetic Reynold's number, MHD waves-Alfven wave and magnetosonic wave (5 Lectures)

5. Kinetic description of plasma

Boltzmann-Vlasov equation, Derivation of fluid equations, Vlasov theory of electrostatic plasma waves, Landau damping, Fokker-Planck equation (10 Lectures)

6. Non-linear effects

Plasma sheath, Ponderomotive force, Non-linear wave propagation in plasma, KDV equation, NLS equation. Modulational instability. (5 Lectures)

7. **Plasma production and diagnostics**

Conduction and breakdown in gases. Townsend's current growth equation. Paschen's law. Capacitive and Inductive coupling of plasma. Production of plasma in the laboratory. DC and RF glow discharge plasma. Application of plasma for semiconductor device fabrication. RF plasma enhanced chemical vapour deposition method.

Plasma diagnostics: Estimation of different plasma parameters by Langmuir single and double probe methods, Optical emissions spectroscopy (OES), Mass Spectrometry, Inductively coupled plasma optical emission spectroscopy. (15 Lectures)

Course Outcomes

CO1: Understand different types of plasma and their characteristics. (PO1)

CO2: Understand the motion of charge particles within the plasma with the influence of electric and magnetic field. (PO2, PO3)

CO3: Understand plasma waves and their propagation. (PO4, PO5)

CO4: Understand generation of plasma in laboratory and industry. (PO5)

CO5: Apply their knowledge in the production of plasma for semiconductor devices fabrication. (PO5, PO6)

CO6: Understand different plasma diagnostic techniques. (PO5)

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	2	1	1							
CO3	3	1	1	2	1							
CO4	3	1	1	1	2							
CO5	1	1	1	1	1	1						
CO6	1	1	1	1	1							

PG/SC/CBS/PHY/TH/302	**Dynamical Systems**

Marks (Credit): 50 (4) **60 Lecture hours**

Differential equations describing dynamical systems. Examples from atmospheric physics. Lorenz system. Van der Pol oscillator. Duffing oscillator. Continuous and discrete systems, Mapping. Logistic map. Standard map, Derivation of a simple ode from the physical equation**.** **[16 Lectures]**

Stability of a dynamical system, Fixed points. Nature of fixed points, eigen values. Parabolic, hyperbolic and elliptic fixed points. Nodes. Saddle nodes, centre, focus, limit cycles.

[14 Lectures]

Phenomenon of bifurcation. Hopf bifurcation. Bifurcation in logistic map. Cycles Period doubling bifurcation. **[06 Lectures]**

Transition to chaos. Chaos and stochasticity. Deterministic chaos. Other route to chaos. Intermittency. Analysis of chaos and its characteristic features. Lyapunov exponents. Fractal dimension. Computer assisted calculation of Lyapunov exponents, Correlation dimension.

[20 Lectures]

Idea of Hamiltonian systems. Formation of islands. Chaos in Hamiltonian systems. Derivation of standard map. **[04 Lectures]**

CO1: Construct and solve nonlinear differential equations (henceforth NLD).

CO2: Use graphical methods to generate phase space trajectories.

CO3: Analyze NLD to study and classify bifurcations.

CO4: Learn perturbation methods ascertain their validity or limitation in different problems.

CO5: Understanding of Chaos in simplest systems.

CO6: Formulate different applications of dynamical systems in physical, biological and social problems.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	2	1	1							
CO3	3	1	1	2	1							
CO4	3	1	1	1	2							
CO5	1	1	1	1	1	1						
CO6	1	1	1	1	1							

PG/SC/CBS/PHY/TH/303	**Quantum Field Theory**

Marks (Credit): 50 (4) **60 Lecture hours**

Introduction (6 Lectures)

Continuous systems, Necessity of field viewpoints, second quantization

The Klein-Gordon Field (12 Lectures)

Classical field theory, Noether's theorem, Quantization of fields, Fields as operators, Propagators, Particle creation by a classical source, The Casimir effect.

The Dirac Field (12 Lectures)

Dirac Equation, Dirac bilinear operators, Lorentz transformations for spin-½ particles and fields, discrete symmetries of the Dirac field (Parity (P), Time reversal (T), and Charge conjugation (C)), CP, CPT, CPT theorem.

Interacting Fields (12 Lectures)

Perturbation theory, Wick's theorem, Feynman diagrams, Cross sections and decay rates, Wigner's theorem

Quantum Electrodynamics (10 Lectures)
Some elementary processes, Radiative corrections, Introduction to infrared and ultraviolet divergences, Introduction to renormalization of fields and of the electric charge, Ward identities

Functional Methods (8 Lectures)
Introduction to Path integrals in quantum mechanics, Path integrals in field theory, functional quantization of scalar fields, functional quantization of spinor fields

1. *An Introduction to Quantum Field Theory* by M. Peskin and D. Schroeder
2. Quantum Field Theory by L. H. Ryder
3. Quantum Field Theory by Pal & Lahiri
4. The Quantum Theory of Fields by S. Wienberg

Course Outcomes

CO1: to introduce the basic ideas of quantum field theory;

CO2: to understand how quantum mechanics and special relativity combine to produce realistic theories of particle creation and annihilation;

CO3: to develop calculational techniques to at least the level of tree-level Feynman diagrams for quantum electrodynamics;

CO4: to provide the foundation for more advanced studies in quantum field theory.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	2	1	1							
CO3	3	1	1	2	1							
CO4	3	1	1	1	2							

PG/SC/CBS/PHY/TH/304	**Computational Physics**

Marks (Credit) : 50 (4) **60 Lecture hours**

1. Molecular dynamics: Classical molecular dynamics simulations with Lennard-Jones potential using Verlet algorithm under different initial configurations, demonstration of Maxwell-Boltzmann distribution. [2]

2. Random walk, Wiener process and Brownian motion. [4]

3. Monte-Carlo methods: Basic theory; Metropolis algorithm. Ising model in two- and three- dimension; classical XY-model in two-dimension; quantum Monte-Carlo for the hydrogen molecule. [8]

4. Numerical studies of partial differential equations: Classical wave equation; hydro-dynamical equations in two dimension; time-dependent Schrodinger equation. [6]

5. Classical scattering of a particle by a central potential; partial-wave solution of quantum scattering; dispersion relation of Kronig-Penney model; Hartree-Fock solutions of small atomic systems. [10]

Books:

1) J. M. Thijssen, Computational Physics, Cambridge University Press, Cambridge, 1999.

2) S. E. Koonin and D. C. Meredith, Computational physics: Fortran Version, CRC Press, 2018.

3) T. Pang, An Introduction to Computational Physics, Second Edition, Cambridge University Press, 2006.

4) B. A. Stickler and E. Schachinger, Basic Concepts in Computational Physics, Second Edition, Springer, 2016.

5) M. Razavi, Quantum Theory of Tunneling, Second Edition, World Scientific, 2014.

Course Outcomes

CO1: Students will understand the Metropolis and Wang-Landau algorithms along with their applications.

CO2: Students will devise quantum Monte-Carlo method on the hydrogen molecule.

CO3: Students will learn how to solve scattering by central potential problem numerically.

CO4: Students will obtain the numerical solution for Hartree-Fock equations for small atomic systems.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3

CO1	1	2	1	1	1										
CO2	1	2	1	1	1										
CO3	1	2	1	1	1										
CO4	1	2	1	1	1										

PG/SC/CBS/PHY/TH/305	Soft Condensed Matter Physics

Marks (Credit) : 50 (4) **60 Lecture hours**

1. Introduction to soft materials. Basic experimental techniques to characterize soft materials, concept of broken symmetry, order parameter, basic molecular forces and structure of soft materials. (10 Lectures)

2. **Liquid Crystals:**

   Thermotropic liquid crystals: Classifications and examples, Viscoelastic properties, Elastic deformations and free energy. Thermal fluctuations and stability. Phase transitions, identification of phases. Experimental determination of different liquid crystalline phases. Response to electric and magnetic field. Liquid crystal display. (10 Lectures)

   Lyotropic liquid crystals: Definition and examples. Thermodynamics of self-assembly. Monolayer and critical micellar concentration. Micelles and vesicles and their applications. Phase behavior of some ionic and non-ionic surfactants: simple model. Lipid membranes as a model system of biological membranes. Structure and phase behavior of lipid-water system. (10 Lectures)

3. **Colloids*:*** Poisson-Boltzmann theory, DLVO theory, Depletion interactions, Electro-kinetic effects, Structures and stability. Charge colloids and forces. Scattering techniques, Structure factor, form factor and correlation functions. X-ray and dynamic light scattering technique, rheology.

   (10 Lectures)

4. **Polymers:** Definition and examples. Characterization of polymer materials. Glass transition temperature, Elastic energy of polymer chain, bead-spring model, ideal polymer chain and finite extension models, radius of gyration, pair correlation function, scattering experiments. Diffusion of polymers; reptation. Polymer blends, block copolymer-

homopolymer blends, Polymer electrolytes or polyelectrolytes: structure and properties. Mechanical and electrical properties of polymers.

(10 Lectures)

Reference Books:

4. Principles of Condensed Matter Physics by P. M. Chaikin and T. C. Lubensky
5. Intermolecular and surface forces, Jacob N. Israelachvili
6. The Physics of liquid crystals, P. G. de Gennes and J. Prost
7. Soft Condensed Matter by R. A. L. Jones
8. Structured Fluids: Polymers, Colloids, Surfactants by T. Witten
9. Introduction to Soft Matter: Polymers, Colloids, Amphiphiles and Liquid Crystals by I. W. Hamley
10. Soft Matter Physics by M. Klemanand and O. D. Lavrentovich
11. Colloidal Dispersions by W. B. Russel, D. A. Saville and W. R. Showalter

Course Outcomes

CO1: to learn basics of soft materials and its applications

CO2: Introduce various soft materials, such as liquid crystal, polymer, colloids etc

CO3: Know the viscoelastic properties of liquid crystal and other soft materials and to study different molecular interactions present in soft materials

CO4: Gain insights into the structure of soft materials and to learn physics of phase transition in these systems.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12
CO1	3	2	1	1	1							
CO2	3	1	1	1	1							
CO3	3	2	1	1	1							
CO4	3	1	1	1	1							

PG/SC/CBS/PHY/TH/306	Differential Geometry and Radio Astrophysics

Marks (Credit) : 50 (4) **60 Lecture hours**

1. Smooth Manifolds: Topological manifolds, Differentiable manifolds, and local coordinates.

Smooth Maps: Smooth functions, partitions of unity.

Tangent Bundle: Tangent vectors, tangent and cotangent spaces (one forms), tensors and tensor product spaces. computation in local coordinates, tangent and cotangent bundle.

Submanifolds: Submersions, immersions, embeddings; submanifolds; inverse function theorem. **[10 lectures]**

2. Vector Fields: Vector fields and integral curves, Lie derivative and Lie bracket, basic properties.

Calculus of forms- Differential Forms: Wedge product, Exterior algebra, differential forms on manifolds, exterior derivatives; closed and exact forms, Poincare lemma; symplectic forms.

Integration on Manifolds: Orientations, integration of differential forms, Stokes' theorem.

[10 lectures]

3. Tensors: Algebra of tensors, tensor fields on manifolds, Co-variant derivatives, parallel displacements and geodesics. Torsion and curvature. Cartan's equations of structure and metric tensor. Elementary theories of fibre bundles and connection between gravity and gauge theories. **[10 lectures]**

4. Telescopes: Information content of radiation, focusing systems – focal length and plate scale, aperture and deposited energy, telescope configurations, non-focusing systems, antenna beams, point spread function, radio resolution – optical resolution – X-ray resolution, resolution enhancement; interferometry. **[10 lectures]**

5. Hyperfine transition at 1420 MHz: Role of Radio Astrophyics, the radio window, origin of spin flip 21 cm line transition, radiative transfer, brightness temperature, emission and absorption at 21-cm from z ~ 1100 to z~ 6, cosmic dawn and epoch of reionization and first generation stars, current 21-cm detection experiments : global and ststistical detection, system noise, 21 cm HI signal in the post-reionization epoch. **[14 lectures]**

6. Radio foregrounds: Synchrotron emission, Bremsstrahlung (free-free) emission, extra-galactic point souces, source counts, foregtound contributions in low frequecy radio observations. **[6 lectures]**

Reference Books.

i. Guillemin, V. and Pollack, A., Differential Topology, AMS Chelsea.

ii. Spivak, M., A comprehensive Introduction to Differential Geometry, Vol. I, 3rd Edition, Publish or Perish.
iii. S. Mukhi & N. Mukunda, Introduction to topology, and differential geometry and group theory for physicists.
iv. Kumaresan, S., A Course in Differential Geometry and Lie Groups, Hindustan Book Agency.
v. Radiative Processes in Astophysics , George B.~Rybicki, Alan P.~Lightman, Wiley-VCH , 1986.
vi. H. Karttunen, P. Kroger, H. Oja, M. Poutanen and K. J. Donner, Fundamental Astronomy, Springer-Verlag (1984).
vii. Loeb, Abraham, Ferrara, Andrea, Ellis, Richard S., First Light in the Universe Saas-Fee Advanced Course 36. Swiss Society for Astrophysics and Astronom

CO2: Learn about the basic components of radio telescopes and how they work in practice to explore our universe.

CO3: Understand the importance of redshifted 21 cm HI hyperfine transition in radio astronomy.

CO4: Explain the emission mechanisms that produce radio waves and characterize of continuum radio emission as foreground in the 21 cm cosmology.

CO5: Explore the concepts of an aperture synthesis interferometer synthesis which make use of many small telescopes to synthesize a single, much larger aperture.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1										
CO2	2	2	1									
CO3	2	2	1									
CO4	2	2	1									
CO5	2	2	2									

PG/SC/CBS/PHY/TH/401	Biophysics (II)

Marks (Credit): 50 (4) **60 Lecture hours**

1. **Fluorescence Spectroscopy (10 L)**:
   Jablonski diagram; Stokes shift; fluorescence emission parameters; biomolecules that have fluorescence; protein fluorescence; instrumentation forfluorescence spectroscopy;

fluorescence quenching; Hill equation, polarization and anisotropy, effect of solvent onfluorescence emission, fluorescence resonance energy transfer (FRET), Fluorescence correlation spectroscopy.

2. **Optical Microscopy (10 L):**
   Design and fundamental principles of light and fluorescence microscopes, diffraction-limited resolution of light microscopy; point spread function and its utility. Structure and function of a confocal laser scanning microscope; two-photon fluorescence microscopy, the principle and use of deconvolution in fluorescence microscopy.
3. **Electron Microscopy (5 L):**
   The fundamental principles of transmission and scanning electron microscopy; sample preparation.
4. **Study of interaction and binding among bio-molecules (5 L):**

Isothermal titration calorimetry (ITC). Binding model and thermodynamics of binding kinetics**.**

5. Gene Technology (10 L):

Gene - Structure - Function - Variation; Mutation - Mutagenic factors - Types-Restriction endonucleases - Linkers and Adapters. Gene Cloning- Vectors, Cloning Vehicles - Plasmid - Bacteriophase - Cosmid. Isolation of Plasmid - Transformation - Applications in genetic engineering. Application of Gene technology in Pharmaceuticals - Diagnosis - Insect control - Crop production - Gene therapy etc.

6. **Radiation Biology (10 L):**
   Types of ionizing radiations - Electromagnetic radiations – X-rays and Gamma-rays Particulate radiations – Electrons, protons, a-particles, heavy charged particles – Neutrons .Linear Energy Transfer (LET)- Relative Biological Effectiveness (RBE)Biological effect of Radiation absorption (in DNA) - Mutations The 4 Rs of Radio-biology. Development of Radio-Biological Damages -Tissue Response to Radiation Damage; Dose -Response Relationship. Radiation Therapy (Cancer) [10L]
7. **Quantum Chemistry in Biology (10 L)**
   Chemical Bonding and Hybridization; Molecular Orbitals - Linear Combination of Atomic Orbitals (LCAO); Simple Huckel Theory of the Linear Conjugated Systems and Calculations. Simple Huckel Theory of the Cyclic Conjugated Systems and Calculations; Quantum Mechanical Approach for Absorption Maxima of Vitamin - A Molecule Quantum Mechanical Approach for determination of Eigen Wave function - Energy levels etc. of Linear and Cyclic Conjugated Molecules.

Books: Refer to books in Biophysics (I)

Course Outcomes

CO1: Learn various biophysical techniques to understand physics and chemistry of biological system**.**

CO2**:** Know different experimental techniques, such as fluorescence spectroscopy, optical microscopy and electron microscopy etc

CO3: Understand radiation biology by knowing various radiation based experimental techniques.
CO4: Gain insights into the quantum chemistry in Biology.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1										
CO2	3	2	2									
CO3	3			2	1							
CO4	3				2							

PG/SC/CBS/PHY/TH/402	Nucleus under Different Conditions

Marks (Credit): 50 (4) **60 Lecture hours**

Nuclear Models **[30 lectures]**

Nuclear shell model: Single particle level and magic number; Ground state spin of nuclei; Static electromagnetic moment of nuclei; Electromagnetic Transition probability; Exact treatment of two nucleons by shell model; More than two nucleons in unfilled shell; Nordheim's rules; Many particle shell model.

Phenomenological Collective and Unified model: Collective model and rotation of deformed nuclei; Collective model Hamiltonian; Deformed nucleus with a spin j; Spherical vibrational nuclei, Rotation and vibration of even nuclei, Odd mass nuclei: coupling of particle to even – even core, Nilsson model for deformed single particle wave function, Electromagnetic properties in Unified model: spherical vibrational nuclei, deformed rotational nuclei.

Nuclear Force and Two-body Scattering:
Introduction, n-p scattering, Partial wave analysis and phase shifts, Scattering length, Strength of scattering, Effective range theory, Low energy p-p scattering, Nature of nuclear forces: charge independence, charge symmetry and isospin invariance of nuclear forces.
Nuclear Reactions:

Reaction kinematics, Reaction cross section, Coulomb scattering, Nuclear Scattering, The optical Model: cross sections for elastic scattering; Partial waves, Phase shifts, Scattering amplitudes, Angular distributions.

Nuclear Techniques for Material Studies:

Positron Annihilation Technique (Principles, Systems, Applications); Mössbauer Spectroscopy (Principle, Systems, Applications); Nuclear Magnetic Resonance (Principles, Systems, Applications).

Nucleus Under Extreme Condition **[30 lectures]**

Overview of High Energy Heavy Ion Collisions: Introduction, Classifications of reactions and products, Relativistic and ultra-relativistic nuclear collisions, Phase diagram of nuclear matter: quark-hadron phase transition and critical point.

Relativistic Kinematics: Two-body and three-body decays, Kinematic variables in the lab-frame and CM-frame, Lorentz Transformations; concept of four vectors, proper time, transformation from lab-frame to CM-frame.

Particle Detectors and Accelerators: Modern detection techniques, Energy resolution, Fano factor, Detector efficiency etc. Detector arrangement in high energy heavy ion experiments.

Modern accelerators - Storage ring, Energy, Cross-section, Luminosity, Event rate, Beam parameters.

Experimental Studies on Heavy-Ion Collisions: Fixed-target experiments, Experiments at colliders, Global observables: Multiplicity, (pseudo)rapidity distributions, invariant yields, Centrality of events: Glauber model, Quark-gluon-plasma formation and its detection - Elementary ideas of correlations and fluctuations, Collective flow, J/ψ suppression, strangeness enhancement, high p_T suppression studies.

Data Analysis Techniques: Error analysis in high energy experiments, Analysis framework and ROOT.

Reference Books:

1. M.K. Pal, **Theory of Nuclear Structure,** East -West Press Pvt Ltd, 1932
2. R.R. Roy and B.P. Nigam, **Nuclear Physics**, New Age Publishers,1996.
3. S. N. Ghoshal, **Nuclear Physics**, S. Chand and Co. Ltd., 2018.
4. K. S. Krane : **Introductory Nuclear Physics,** JOHN WlLEY & SONS, 1987
5. M.A. Preston and R.K. Bhaduri: Structure of the Nucleus, CRC Press, Taylor & Francis group, 2018
6. C. Y. Wong, **Introduction to High Energy Heavy-Ion Collisions**, World Scientific publishing, 1994.

7. A. K. Chaudhuri, **A short Course on Relativistic Heavy Ion Collisions,** IOP Publishing, 2014.
8. R. Vogt, **Ultra-Relativistic Heavy Ion Collisions** (1st edition), Elsevier Publishing, 2007.
9. W. R. Leo, **Techniques for Nuclear and Particle Physics Experiments** (2nd edition), Springer-Verlag Berlin Heidelberg, 1994.
10. G. F. Knoll, **Radiation Detection and Measurement** (3rd edition), John-Wiely and Sons, 2000.
11. Nuclear Radiation Detectors, S.S. Kapoor and V. Ramamurthy, New Age International (P) Ltd., 2005.
12. S. Sarkar, **The Physics of the Quark-Gluon Plasma**, Springer, 2010.
13. J. R. Taylor, **An Introduction to Error Analysis** (2nd edition), University Science Books, 1997.

CO1: Learn the technique of estimating different nuclear properties using Nuclear models

CO2: Acquire knowledge about nuclear reactions and Two-body scattering

CO3: Be introduced to the arena of heavy ion physics at relativistic and ultrarelativistic energies

CO4: Gain expertise in experimental methodologies and data analysis techniques in heavy ion collisions at high energies.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1									
CO2	3	1			2							
CO3	3	1			2							
CO4	3								2	1		

PG/SC/CBS/PHY/TH/403	**X-Ray Crystallography (II)**

Marks (Credit): 50 (4) **60 Lecture hours**

1. Scattering of X-rays: Thomson’s scattering, scattering by atom, atomic scattering factor, classical definition, wave mechanical treatment, numerical methods, scattering by monatomic molecules, monoatomic molecules of infinite size, monoatomic liquids and polyatomic

molecules for gases, scattering by liquids with complex molecules, effect of pressure, small angle scattering, Guinier's law. (12)

2. Imperfections in crystals: point defects, line and planar defects, surface imperfections, effect of imperfections on physical properties of crystalline solids. (7)

3. X-ray diffraction by crystals: Kinematical theory, Diffraction by a small crystal, Laue equations, Crystal structure factor, width of diffraction maxima, Integrated intensity and reflecting power, Diffraction by polycrystalline aggregate, multiplicity factor, Effect of absorption, Dynamical theory, abnormal absorption, Darwin's theory, Extinction correction, Ewald's dynamical theory. (12)

4. X-ray spectroscopy: Energy level diagram, spin doublet, Relative intensities of spectral lines, Burger-Dangelo law, Non-diagram lines. Absorption edges, chemical effect on emission and absorption spectra, Fluorescent spectra, soft x-ray spectroscopy, x-ray spectrometers, Curved crystal spectrometer, Double crystal spectrometer. (10)

5. Refraction of X-rays: Dispersion, Index of refraction, Modification of Bragg's law, Total refraction. (3)

6. Refinement of crystal structure determinations: Successive Fourier methods, difference Fourier method, least- squares method. (4)

7. Some applications of X-ray powder diffraction: Identification of crystalline phase using powder method, accurate lattice parameter determination, line broadening and particle size determination, residual stress analysis, X-ray line profile analysis, Rietveld's method. Characterization of defects using X-ray diffraction. (12)

Books:

1. X-Ray Diffraction by B. E. Warren

2. An introduction to crystallography by M. M. Woolfson.

3. Introduction to Solids by L. V. Azaroff.

4. A Basic Course in Crystallography by T.R.N. Kutty.

5. The Basics of Crystallography and Diffraction by C. Hammond.

6. A Practical Guide to Structure Determination by G. Stout and L. Jensen.

7. Crystal Structure Analysis: A Primer by J. P. Glusker, K. N. Trueblood.

8. Structure Determination by X-ray Crystallography by M. F. C. Ladd and R.A. Palmer.

9. X-ray Analysis and the Structure of Organic Molecules by Jack Dunitz.

Course Outcomes

CO1: Learn advance theory of x-ray scattering including small angle scattering

CO2: Understand the structure of single crystal and polycrystalline materials from the analysis of x-ray diffraction

CO3: Know the applications of x-ray powder diffraction

CO4: Gain knowledge of xray spectroscopy and refraction of x-rays.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	2	1	1							
CO3	3	1	1	2	1							
CO4	3	1	1	1	2							

PG/SC/CBS/PHY/TH/404	General Relativity & Cosmology (II)

Marks (Credit): 50 (4) **60 Lecture hours**

1. Selected Applications and Raychaudhuri equation:The Schwarzchild solution and metric, Spherically symmetric metric and singularity, Birkoff's theorems, Oppenheimer–Volkoff equation and limit,Oppenheimer–Snydder non-static dust model, gravitational collapse, Motion of a test particle in curved space time. Perihelion precession, Gravitational red Shift, Penrose diagrams -conformal infinity, Area theorem and Black hole Evaporation. Cogruence of nonintersecting world lines, Raychaudhuri equation **[10 Lectures]**

2. Gravitational Radiations: The Linearized Einstein Equations with Sources, General Solution and production of weak Gravitational waves, Gravitational Radiations from Binary sources, Binary Pulsar Slow down. Quadrupole radiation formula for energy loss, Power emitted by a periodic source, Detection of Gravitational Radiations-Present and Future Missions: e.g. LIGO, LISA, SKA etc. **[10 Lectures]**

3. Relativistic Hydrodynamics: Covariant divergence of the Energy -Momentum Tensor, Ideal gas, Energy momentum tensor of a perfect fluids, The conservation laws, Hydrostatic equilibrium. Pressure and proper energy density, The particle current, The Relativistic Euler equation, The Relativistic Entropy equation, 4-velocity distribution function, The Relativistic Equation of State, Relativistic viscous Accretion **[10 Lectures]**

4. Relics of the big bang:Thermal history of the universe; Entropy density, BoseEinstein distributions ,Time vs. temperature, Effective number of species, Neutrino decoupling, Heating by electron-positron annihilation, Neutrino masses,cosmological nucleosynthesis, the cosmic microwave background radiation (CMBR), Anisotropy in the CMBR.
[10 Lectures]

5. Linear perturbations after recombination: Inhomogeneities in the universe, gravitational instability, linear perturbations theory for description and evolution of density fluctuations, Power Spectrum P(k), correlation function, Baryon acoustic oscillations. **[10 Lectures]**

6. Nonlinear growth: Spherically symmetric collapse, Calculation of Rms fluctuation, Press Schechter mass function ,Collapse of baryonic matter, Jeans mass, Critical wave number for baryon collapse.
[4 Lectures]
7. The Reionization of Cosmic Hydrogen: Metal-free stars, Properties of the first stars, The frontier of 21 cm Cosmology. **[6 Lectures]**

Reference Books:

Weinberg, S., Gravitation and Cosmology: Principles and Applications of the General Theory of Relativit
Peebles, P. J. E. 1993 Principles of Physical Cosmology. Princeton University Press, Princeton, NJ.
Weinberg, S. , 2008, Cosmology, OUP Oxford.
Narlikar, J.V. Introduction to Cosmology, Cambridge university press, 1993.
Raychaudhuri, A. K. Theoretical Cosmology, Oxford press, 1979.
CO1: Learn the basic mathematical and analytical skills needed to find out black hole solutions using Schwarzchild metric and and understand the Raychaudhuri equations and its application in general relativity.

CO2: Understand the basics of gravitational waves and learn how they can unveil the properties of the most extreme astrophysical objects in the universe.

CO3: Understand and gain knowledge on thermal history of the universe and related processes.

CO4: Learn linear perturbations theory to understand the large scale structure formation in the Universe and to describe evolution of density fluctuations and its Power Spectrum P(k),

CO5: Learn possible sources for the cosmic reionization and the impact of the redshifted 21 cm HI line in modern cosmology.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	1	1	1							
CO3	3	2	1	1	1							
CO4	2	2	2	1	1							
CO5	2	2	2	1	1							

PG/SC/CBS/PHY/TH/405	Advanced Electronic Circuit, Microprocessor and Microcontroller

Marks (Credit): 50 (4) **60 Lecture hours**

Analog Multiplier: Gilbert Cell multiplier, block diagram and working principle of analog multiplier ICs, Applications: Multiplication, Squaring, frequency doubling, phase angle detector, divider, square root extractor, amplitude modulation, demodulation, frequency shifting.

(5 lectures)

Phase Looked Loop (PLL): Block diagram, voltage controlled oscillator (VCO), phase angle detector (analog and digital), operating principles, capture and tracking, PLL ICs, Application: frequency multiplier, frequency synthesizer. (5 lectures)

Synchronous Counters: Synthesis of truncated counters: MOD-N counters with initial rest state and $N_1 - N_2$ counter, arbitrary count sequence generator, pulse train generator.

(10 lectures)

Sequential Circuit: State table, state diagram, Mealy and Moore model, state assignment, state reduction, equivalence of Mealy and Moore model, excitation table, excitation equation of FFs, problems on sequential circuit: synthesis of sequential circuit from state diagram, state table, obtaining state diagram and sate table from circuit diagram.

(10 lectures)

Programmable Logic Devices: RAM, ROM, PROM, EPROM, EEPROM, PLA. (5 lectures)

Microprocessor and Microcontroller

Introduction: Microprocessors, microcomputer and microcontrollers. Address bus, data bus and Control bus, Control unit, Arithmetic and logic unit, Flags, Registers, Memories, Tristate logics, memory and I/O interfaces, Memory spaces, ROM and RAM, Schematic connection on bus, Clock,T-state and bus cycle. (5 lectures)

8086 microprocessor: Registers, memories:- Physical address and logical addresses, Representation of data and addresses by hexadecimal numbers. (5 lectures)

Instruction set: Data movement instructions, Arithmetic and logic instructions, Branching instructions, String instructions and Miscellaneous instructions, Syntax and operation with illustrative examples, Stacks and its uses, software and hardware interrupts with timing diagrams. (10 lectures)

Interfacing: Input and output instructions, Memory mapped I/O and I/O mapped memory, Programmable Peripheral Interface (PPI) 8255, Programmable timer counter 8253/8254, Programmable Interrupt Controller (PIC) 8259. (5 lectures)

Recommended readings:

1. Operational Amplifiers and Linear Integrated Circuits: Robert F. Coughlin and Frederick F. Driscoll
2. Opamps and Linear Integrated Circuits: R. A. Gayakwad
3. Design With Operational Amplifiers and Analog Integrated Circuits: Sergio Franco

4. Phaselock Techniques: Floyd M. Gardner
5. Digital Circuits, Volume I & II: D. Ray Chaudhuri
6. Fundamentals of Digital Electronics: Anand Kumar
7. Microprocessors and Interfacing: Douglas V Hall
8. Microcomputers and Microprocessors: J. Uffenbeck
9. Microprocessor Architecture, Programming and Applications with the 8085: R. Gaonkar

CO1: Understand and be able to explain the different techniques of multiply two analog voltages

CO2: Learn to use analog multiplier ICs and be able to design various analog modulation and demodulation process of analog signals using these ICs.

CO3: develop the concept Phase locked loop, locking amplifiers and frequency multiplier using PLL.

CO4: learn general techniques of designing sequential circuits and apply them to produce state table and state diagram from circuits and vice versa.

CO5: learn about the general building blocks of microprocessors to execute stored program. Microprocessors development in different generation at least upto 4th generation.

CO6: learn about the registers and memory addressing techniques of 8086 microprocessor.

CO7: learn the 8086 microprocessors instruction set and be able to write assembly language program for 8086 microprocessor using macros and procedures

CO8: develop the concept of hardware and software compatibility in interfacing I/O devices

CO9: be able to develop and implement program optimization process and real time programming.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	1	1	1							
CO3	3	2	1	1	1							
CO4	2	2	2	1	1							
CO5	2	2	2	1	1							
CO6	3	1	1	1	1							
CO7	1	1	1	1	1							
CO8	3	1	1	1	1							

CO9	**2**	**2**	**2**	**1**	**1**							

PG/SC/CBS/PHY/TH/406	**Microwave Electronics**

Marks (Credit) : 50 (4) **60 lecture hours**

1. Basic Idea : Microwave frequency, Difficulties of conventional devices at microwave frequencies, Microwave devices and systems, Ground wave, sky wave, Line of sight propagation. Applications of microwaves.

(4)

2. Microwave transmission lines : Primary parameters *RLGC,* Transmission line equation and its solution, Characteristic impedance and propagation constant, Low loss transmission line, Line impedance under load, Reflection and Transmission coefficient, Standing wave Ratio, Smith Chart, Impedance matching, Stub matching.

(8)

3. Microwave waveguides : Rectangular waveguides, TE and TM modes, solutions, velocities of propagation and losses, Dominant mode, Circular waveguides and solutions for TE and TM modes, Microwave cavities, Q-factors, Waveguide circuits, S-Parameteters, Tees, rings,circulators, isolators and direction couplers.

(12)

4. Klystrons: Velocity modulation and bunching, Output powers, Reflex klystron, multicavity klystron (qualitative).

Travelling Wave Tube: Slow wave structures, Amplification process, Axial electric field, wave modes , gain consideration, Coupled cavity TWT.

(16)

5. Magnetron : Cylindrical magnetron, linear magnetron, coaxial magnetron, Voltage tunable magnetron, Inverted coaxial magnetron, Forward cross field and backward cross field magnetron.

(8)

6. Gunn diode: Gunn effect, Differential negative resistance, High field domain, Gunn oscillation mode, LSA mode, stable amplification mode.

Tunnel diode : Principle of operation, microwave characteristics.

Qualitative discussion on Read diode, IMPATT diodes, Parametric devices.

(12)

Books:

Microwave Devices and circuits: S.Y. Liao. PHI

Microwave and Radar Engineering 3rd edition: M. Kulkarni. Umesh Publication, New Delhi Microwaves : Introduction to Circuits Devices and Antennas: M.L. Sisodia and Vijay Laxmi gupta. New Age Publications

Microwave electronics : A.D. Grigoriev, V.A. Ivanov, S.I. Molokov. Springer

Microwave electronic devices : T.G. Roer. Springer

Microwave Electronics: Measurement and Materials Characterization: L.F. Chen, C.K. Ong, C.P. Neo, V.V. Varadan and V.K. Varadan. Wiley

CO1 : To have basic idea about microwave frequencies, devices and systems

CO2: To know the basics of plane electromagnetic wave propagation in different media, attenuation and transmittance

CO3: To know about microwave cavities, hybrid circuits, waveguide tees and directional couplers

CO4: To know ferrite materials and its properties and have some idea about different ferrite devices like circulators, gyrators, isolators, switches and filters

CO5: To know about microwave crossed-filled tubes and microwave strip lines

CO6: To know how to detect microwave signal and how to measure power, attenuation, VSWR, impedance, frequency, phase and noise factor

CO7: Finally, to know about the application of microwave in communication, in industry and in devices based on dielectric heating.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO11	PO12
CO1	3	1	1	1	1							
CO2	3	2	1	1	1							
CO3	3	2	1	1	1							
CO4	2	2	2	1	1							
CO5	2	2	2	1	1							

PG/SC/CBS/PHY/TH/407	Condensed Matter Physics (II)

Marks (Credit): 50 (4) **60 Lecture hours**

1. Liquid Crystal (lc): Introduction, different types of lc, Thermotropic, Lyotropic etc. Structure wise and property wise division (Nematic, Smectic, Cholesteric); Structure of the Cholesteric lc;
   Physical properties: Optical, Electrical (dielectric), X-ray structural and Magnetic properties.Order parameter (OP) and to find out OP theoretically and experimentally; Maiyer- Saupe mean field theory. Elastic properties and distortion of lc: splay, bend and twist; stress and strain due to the different distortion. Mixing of different Smectic lc and their new properties. Application and utilisation of lc (over solid state system).
   [10 lectures]

2. (a) Optical and dielectric properties: Optical and dielectric properties of solid from simple atomic theory. Metal Optics: Optical properties of metals and Plasma. Dispersion relation of electro- magnetic wave in plasma.
   (b) Defects of crystals and colour centers: F- centres and V- centres; Vacancy defects, Frenkel defects and Schottky defects; Calculation of number of colour centers for different defects. Optical density and determination of order of colour centers from experiment; Thermoluminescence.
   (c) Optical properties of Semi- conductors: Photoconductivity with and without traps; Response time; Measurement of mobility (of holes and electrons) and recombination coefficient from experiment. Exciton and its different properties; Crystal counter.
   [20 lectures]

3. Magnetic Properties
   Heisenberg Hamilton, Spin wave, itinerant ferromagnetism, antiferromagnetism and superexchange, Neutron diffraction, helimagnetism, ferromagnetic and antiferromagnetic resonance, Ising model (Two dimension), NMR bloch's equation. ESR [10 lectures]

4. Superconductivity and superfluidity
   Electrodynamics and superconductor – London's equation and Pippard's non local equation, BCS theory, Ginzburg –Landau Theory, magnetic properties of type II superconductors, Josephson's effect, superconducting quantum interference devices (SQUID), fluctuation effect in superconductors, High Tc superconsuctor

Superfludity: London's argument, Liquid He 3 as a dilute Fermi gas, qualitative features of London's theory, phase transition in He 3 and nuclear magnetism.

[20 lectures]

Course Outcomes

CO1: Students will learn how to study the properties of different liquid crystals phases in detail.

CO2: Students will learn the optical and dielectric properties of matter and thier utility.

CO3: Understand the mechanisms behind various phenomena involved in semiconductors

CO4: Students will learn the quantum phenomena like superconductivity and superfluidity in great details.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3
CO1	1	2	1	2	1										
CO2	1	1	1	1	1										
CO3	1	2	1	1	1										
CO4	2	2	1	2	1										

PG/SC/CBS/PHY/TH/408	Atomic, Molecular & Optical Physics (II)

Marks (Credit): 50 (4) **60 Lecture hours**

Atomic Physics

1. Schrödinger equation for two-electron atoms: Para and ortho states; Spin wave functions and the role of Pauli exclusion principle; The independent particle model . [06 Lectures]

2. Many Electron atoms: Central field approximation for many-electron atoms; Spin, the Pauli exclusion principle and Slater determinant; Electron states in a central field, The Thomas-Fermi model of atom; Outline of Hartree-Fock and self-consistent field; Correction to the Central field approximation: L-S and j-j coupling; Equivalent and non-equivalent electron; Determination of spectroscopic terms; Hund's rules.
[14 Lectures]

3. Application of Atomic physics: Magnetic resonance [02 Lectures]

Laser Physics

1.(a) Principal of holography and characteristics, Recording and reconstruction, classification of hologram and application, non-destructing testing, (b) Q-switching, Kerr and Pockels cells, (c) Origin of non-linearity, susceptibility tensor, phase matching, 2nd harmonic generation, methods of enhancement, frequency mixing processes, (d) Multi-photon spectroscopy, Doppler free spectroscopy etc. (e) Pulsed and tunable lasers; Types of lasers: CO_2, N_2 and Ar^+ etc; Solid state lasers; Nd-YAG, Nd-Glass, Excimer lasers, Free electron laser. Masers

[09 Lectures]

Molecular Physics

1. Raman spectroscopy: Raman Effect. Classical treatment, Stokes and anti-stokes lines. Polarizability ellipsoid and intensity of Raman bands, Drawbacks of the classical explanation, Quantum theoretical explanation. Selection (derivation) rules for both rotational and vibrational Raman spectra of diatomic molecule and their spectral features, Rotational-vibrational Raman spectra and O- and S-branches. , Resonance Raman Spectroscopy, Elementary idea of Surface Enhanced Raman spectroscopy and Non-linear Raman effect.

[07 Lectures]

2. Electronic spectra of diatomic molecules: (a) Vibrational structure of electronic spectra, Progression and sequence, Emission and absorption spectra, Idea of zero-zero band, Isotope shifts, Deslandres tables, Molecular constants in ground and excited electronic states, Molecular bonding – elementary idea, (b) Rotational structure of electronic spectra, P-, O- and R-branches, Formation of band heads and shading of bands, (c) Intensity distribution in the vibrational structure of electronic spectra (both absorption and emission) of diatomic molecule, Frank-Condon Principle, Fortrat parabolae, (d) Hund's coupling cases. [06 Lectures]

3. (a) Hydrogen molecule ion and molecular orbitals. Coulomb and exchange integrals, Electronic structures of simple molecules, n-, σ- and π-orbitals and chemical bonding, (b) Photophysics: Absorption, Beer-Lambert's Law, Jablonski diagram, Decay mechanisms, Kasha's rule, Fluorescence, Quenching of Fluorescence, Dynamic & Static quenching , Stern-Volmer Plots and Phosphorescence, Basic principle of TCSPC (c) Types of Spectroscopy: NMR spectroscopy, ESR Spectroscopy and Photoelectron spectroscopy. [10 Lectures]

4. Group theory in molecular spectroscopy: Order, class and representation of a group; Characters; First and second orthogonal theorem of characters (statements only); Character table; Construction of C_{2v}, C_{3v} etc. character tables. Transformation properties of translational, rotational vectors and polarizability components, Selection rules of Infrared and Raman spectra, Examples [06 Lectures]

Recommended Books:

1. Quantum Mechanics -- Eugen Merzbacher
2. Physics of Atoms and Molecules -- BH Bransden and CJ Joachin
3. Atomic and Laser Spectroscopy - Alan Corney
4. Holography: A Practical Approach-Gerhard K. Ackermann and Jürgen Eichler
5. Atomic and Molecular Spectroscopy: Basic Aspects and Practical Applications-S Svanberg

6. Molecular Spectra and Molecular Structure I – Spectra of Diatomic Molecules – G Herzberg
7. Molecular Spectra and Molecular Structure II – Infrared and Raman Spectra of Polyatomic Molecules -- G Herzberg

8. Principles of Fluorescence Spectroscopy -- Joseph R Lakowicz

9. Chemical Application of Group Theory - F Albert Cotton

PG laboratory: Please see attached list of experiments and computations

Course Outcomes

CO1: To explore Schrödinger equation for two-electron atoms

CO2: To understand the Many Electron atoms from Central field approximation.

CO3: To understand the basic principles of holography and their application

CO4: To explore the basic physics of Raman spectroscopy and their applications.

CO5: To explore the chemical applications of group theory

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1	1										
CO2	3	1	1	1	1										
CO3	3	2	1	1	1										
CO4	3	2	1	1	2										
CO5	3	1	2	1	1										

Core Laboratory

PG/SC/CORE/PHY/PR/501	**Computational Lab**
PG/SC/CORE/PHY/PR/502	**Core Lab I**
PG/SC/CORE/PHY/PR503	**Core Lab II**
PG/SC/CORE/PHY/PR/504	**Core Lab III**
PG/SC/CORE/PHY/PR/505	**Core Lab IV**

Advance laboratory (for choice based subjects)

PG/SC/CBS/PHY/PR/506	Advanced Common Lab
PG/SC/CBS/PHY/PR/507	Advanced Elective Lab I

PG/SC/PHY/GV/601	COMPREHENSIVE VIVA
PHY/PR/701	Project

Computational Lab (PG/SC/CORE/PHY/PR/501)

CO1: learn how to obtain numerical solutions of various nonlinear oscillators for the understanding of their phase space behaviour.

CO2: learn the matrix diagonalization algorithms and their applications.

CO3: Understand the Numerov method in order to obtain the bound states for various potential wells.

CO4: learn the numerical computation of transmission probability across various potential junctions.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

UG/SC/CORE/PHY/PR/11 Quantum Mechanics and applications		PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3
	CO1	3	3	1	3	1										
	CO2	3	3	1	2	1										
	CO3	3	3	1	1	1										
	CO4	3	2	1	1	1										

LIST OF PRACTICAL

Computational lab

1. Simulation of coupled harmonic oscillators. Finding normal modes and obtaining phase portraits numerically.

2. Computational study of motion in an accelerated frame. Motion of freely falling body in northern hemisphere.

3. Computational study of a heavy symmetric top.

4. Obtaining phase plots for linear systems and their classification.

5. Computational study of simple non-linear systems showing existence of limit cycles.

6. Computational study of Saddle-Node, Pitchfork, and Transcritical bifurcations.

7. Computational study of a non-linear system (one example of instructor's choice from Duffing oscillator, van der Pol oscillator, glycolysis cycle, predator-prey model)

8. Ideas of High Performance Computing Mathematica, Python, Octave, AWK, shell script. Introduction to Parallel computing:

9. Solving Linear Equations: Vectors and Linear Equations, The idea of Elimination, Elimination using Matrices, Transposes and permutations. Factorization: A=LU, Inverse Matrix.

10. Complete solution to AX=b, solving AX=0, The Null space of A. Idea of the Four Subspaces and Dimensions.

11. Projections; Orthogonal Bases and Gram-Schmidt.

12. Eigen values and Eigenvectors: Commuting matrices with degenerate eigenvalues, Cayley-Hamilton Theorem

13. Matrix diagonalization and its applications.

14. On given manifolds calculate volumes, Christaffel connection, curvatures.

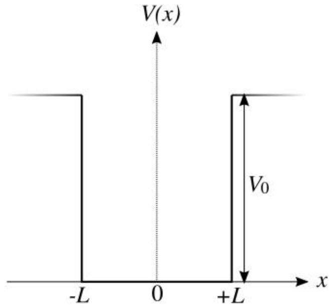
15. Calculate the normal and geodesic curvatures of a curve on a surface, and decide whether the curve is a geodesic;

16. Obtain eigen values and eigen functions numerically for the one-dimensional

(a) finite and (b) infinite potential wells by using separately

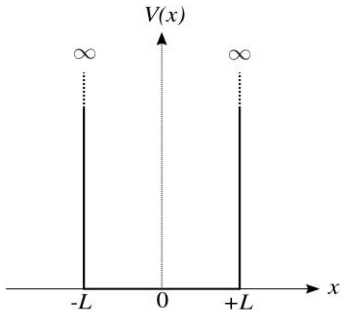
(i) combined Numerov and bisection algorithms, (ii) finite difference method.

Draw the wave functions.



Finite potential well.

$$V(x) = \begin{cases} 0, & \text{when } -L \le x \le +L, \\ V_0, & \text{elsewhere.} \end{cases}$$



Infinite potential well.

$$V(x) = \begin{cases} 0, & \text{when } -L \le x \le +L, \\ \infty, & \text{elsewhere.} \end{cases}$$

17. Determine the eigen values numerically and draw the eigen functions by using (i) combined Numerov and shooting algorithms, (ii) finite difference method, separately, for the one-dimensional

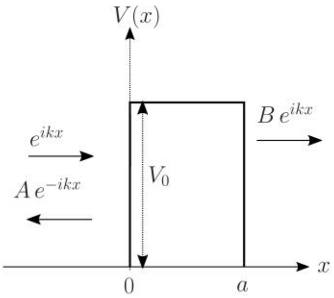
(a) harmonic oscillator,

$$V(x) = \frac{1}{2} m\omega^2 x^2,$$

(b) half-harmonic oscillator,

$$V(x) = \begin{cases} \frac{1}{2} m\,\omega^2 x^2, & \text{when } x \geq 0, \\ \infty, & \text{elsewhere.} \end{cases}$$

18. Solve potential barrier numerically and draw the variation of transmission probability with the barrier width, *a*, and the energy of incoming particle, *E*.



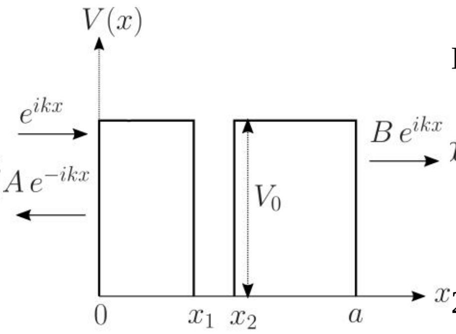
Potential barrier.

$$V(x) = \begin{cases} V_0, & \text{when } 0 \leq x \leq a, \\ 0, & \text{elsewhere.} \end{cases}$$

19. Solve the following double barrier numerically by using Numerov and

steepest-decent algorithms and obtain the variation of transmission probability with the energy of incoming particle.

$V(x$



Double-barrier

x_1 and $x_2 \leq x \leq a,$

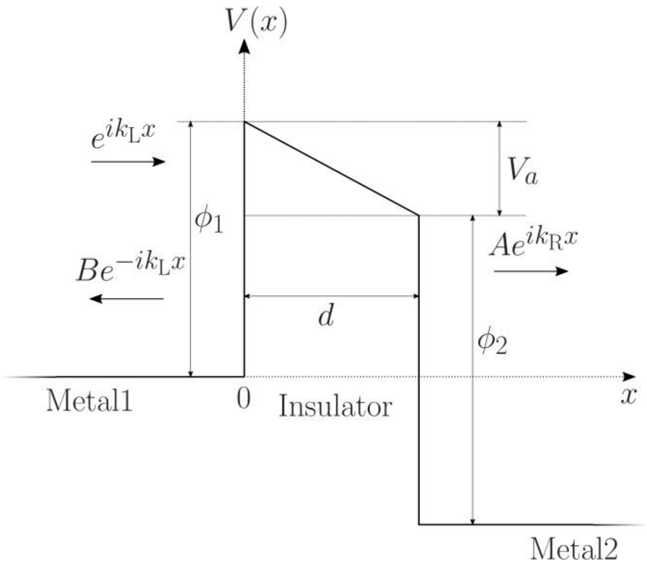
20. Obtain numerical solution of the eigenvalue problem for the one-dimensional Schrodinger equation with potential *V(x)* using combined secant and Numerov algorithms.

$$V(x) = \frac{1}{2}\alpha^2 \lambda (\lambda - 1) \left(\frac{1}{2} - \frac{1}{\cosh^2(\alpha x)} \right).$$

Draw the eigen functions and compare numerical eigen values with the exact values,

$$E_n = \frac{1}{2}\alpha^2 \left(\frac{\lambda(\lambda-1)}{2} - (\lambda - 1 - n)^2 \right), n = 0, 1, 2, \cdots .$$

21. Compute the transmission (tunneling) probability through Metal1-Insulator-Metal2 junction by (i) finite difference, (ii) transfer matrix and (iii) WKB methods. Compare the results.



Metal1-Insulator-Metal 2 junction:

$$V(x) = \begin{cases} 0, & \text{when } x < 0, \text{ metal1}, \\ \phi_1 - eEx, & \text{when } 0 \le x \le d, \text{ insulator}, \\ \phi_1 - \phi_2 - V_a, & \text{when } x > d, \text{ metal2}. \end{cases}$$

d: width of insulator,
ϕ_1 (ϕ_2): berrier height of metal1 (metal2),
$E = V_a/d$: applied electric field.

22. Find numerical solution for the radial part of Schrodinger equation in the presenc of Coulomb potential (hydrogen like atoms) by using Numerov algorithm,

$$\left[-\frac{\hbar^2}{2m}\frac{d^2}{dr^2} - \frac{Ze^2}{4\pi\epsilon_0 r} + \frac{l(l+1)\hbar^2}{2mr^2} - E\right]\chi(r) = 0.$$

23. Compute Clebesch-Gordon (CG) coefficients for the following combinations of (i) j_1=1/2 and j_2 =1/2, (ii) j_1=1 and j_2 =1/2 and (iii) j_1=1 and j_2 =1.

24. Numerical calculation of the probability of transition P (□) as a function of the driving frequency of a sinusoidal time dependent perturbation following the Fermi-Golden rule in a two level system.

Course Outcomes

CO1: Students will learn how to obtain numerical solutions of various nonlinear oscillators for the understanding of their phase space behaviour.

CO2: Students will learn the matrix diagonalization algorithms and their applications.

CO3: Understand the Numerov method in order to obtain the bound states for various potential wells.

CO4: Students will learn the numerical computation of transmission probability across various potential junctions.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12
CO1	**1**	**2**	**1**	**1**	**1**							
CO2	1	**2**	1	**1**	**1**							
CO3	1	**2**	1	**1**	**1**							
CO4	1	**2**	1	**1**	**1**							

Core lab

LIST OF EXPERIMENTS FOR CORE I, II, III, IV:

1. **Study of P N Junction:**
   i. Determination of reverse saturation current I_0 and material constant
   ii. Determination of Temperature Coefficient of junction voltage and Energy band gap
   iii. Study of Junction Capacitance of diode

2. **Study of Hall effect**:
   i. To find out the Hall Coefficient
   ii. To calibrate an unknown magnetic field
   iii. To find out the carrier concentration and mobility of the carrier

3. Four Probe Method:Determination of Band gap of a semi conducting sample by studying temperature variation of resistivity

4. Lattice Dynamics: Dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibration

5. **Study of Magnetic Property:**
    i. Magnetic parameters of a magnetic material by hysteresis loop tracer
    ii. Study of para-ferromagnetic phase transition

6. **Study of Dielectric Property**:
    i. Temperature dependence of Dielectric Constant of ferroelectric ceramics and evaluation of Curie temperature
    ii. Frequency Dependence of Dielectric Constant Barium Titanate at different temperatures

7. **Experiments on Operational Amplifier**:
    i. Inverting Amplifier
    ii. Non-Inverting Amplifier
    iii. Unity Gain Buffer
    iv. Constant Current Source
    v. Summing Amplifier
    vi. Differential Amplifier
    vii. AC Inverting and Non-inverting Amplifiers and their Frequency Response
    viii. Integrator and Differentiator
    ix. Voltage Comparator, Zero Cross Detector
    x. Schmitt Trigger

8. **Study on Logic Gates**:
    i. .Design of Combinational Logic Circuits Using basic Logic Gates
    ii. Design of Combinational Logic Circuits Using NAND and NOR gates
    iii. Coincidence Circuit
    iv. Full Adder Circuit
    v. Majority Logic Circuit
    vi. Even Parity check
    vii. Odd parity check
    viii. Clock Pulse Generator
    ix. 12. De Bouncer Clock
    x. Study of Binary storage elements: S-R. D, J-K and Master Slave J-K Flip Flop using NAND gates

9. Study of Counter Circuit: Generation of suitable clock pulse using 555 Timer 3 bit Asynchronous Up and Down counter Decade Counter

10. **Study of Power Supply:**
    Load Regulation, Line Regulation and Ripple Factor of Unregulated
    Design and characteristics of Series and Linear IC Voltage Regulator:
    i. Study of Load Regulation
    ii. Stud of Line Regulation
    iii. Study of Ripple Factor

11. **Study of frequency response of RC Coupled Amplifier**:
    i. Without Feedback
    ii. Negative Feedback

12. Study on Modulation and Demodulation Circuit

13. **Study of DAC and ADC**
    i. To design weighted resistor and R-2R ladder type digital to analog converter (DAC) of given specifications.
    ii. To study the analog to digital convertor (ADC) IC

14. **Study of Oscillator Circuits using op-amp:**
To design astable multivibrator of given specifications
To design a Wien bridge oscillator of given frequency
To design a function generator of given specifications

15. **Active Filter circuits:**
Design and study of frequency response of Low Pass, High Pass, Band Pass, Band Reject and Notch filters

16. **Study of different characteristics of a Transformer:**
    i. Secondary Voltage vs. Primary Voltage
    ii. Secondary Voltage vs. Number of turns in Primary
    iii. Secondary Voltage vs. Number of turns in Secondary
    iv. Secondary Current vs. Primary Current
    v. Secondary Current vs. Number of turns in Primary
    vi. Secondary Current vs. Number of turns in Secondary
    vii. Power vs. Secondary Current
    viii. Phase Diagram of the Transformer

17. **Ultrasonic Interferometer**:
    i. Determination of Velocity of ultrasonic wave at different concentration of Liquid
    ii. Determination of compressibility of the liquid mixer at different Concentration

18 **Diffraction at slit by LASER:**
    i. Study of the single slit diffraction pattern
    ii. Intensity ratio of different secondary maximum
    iii. Determination of wavelength/slit width

19 **FEBRY PEROT Interferometer**:
Measurement of the wavelength of a diode Laser
Determination of difference in wavelengths of sodium doublet (D_1 and D_2 lines)

20 Experiments with optical fibers:
Determination of power Distribution within the beam of given diode Laser and Calculation of Spot Size

21. **Frank Hertz Experiment :**
Verification of Bohr's Atomic Theory

22. **UV-Vis spectroscopy**:

Measurement of UV-Vis absorption of a solution for different solution and to find the unknown strength of a given solution

23. **Study of Zeeman effect:**
Determination of e/m, Lande g-factor of electrons

24. **ESR Spectroscopy**:
Determination of Lande g-factor by ESR spectroscopy

25. **Thomson's Method:**
Determination of e/m of electrons

26. **X-ray Diffraction Simulation:**
Identification of Lattice and determination of Lattice Constant

Course Outcomes:

CO1: Learn experiments to understand the characteristics of P-N junction

CO2: Design advance electronics circuit using OP-AMP, transistor and other passive electronic components to study amplifiers, regulated power supply, oscillator etc.

CO3: Learn experimental verification of various electronics properties of materials.

CO4: Gain insights into interference and diffraction phenomena using LASER, Febri Perot interferometry etc.

CO5: Understand Zeeman effect, Lande g factor , specific charge of electron using some spectroscopic experiments

CO6: Learn properties and performance of transformer though some laboratory experiments.

CO7: Identify the type of crystal lattice and analysis of lattice using x-ray diffraction simulation.

CO8: Verify the Bohr's atomic theory using Frank Hertz experiment.

CO9: Study the performance of logic gate and its applications various mathematical operation.

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO12
CO1	**3**	**2**	**2**	**1**	**1**							
CO2	3	**2**	2	**1**	**1**							
CO3	3	**2**	2	**1**	**1**							
CO4	3	**2**	2	**1**	**1**							
CO5	3	**1**	2	**1**	**1**							

CO6	3	**2**	1	**1**	**1**							
CO7	3	**1**	2	**1**	**1**							
CO8	3	**1**	1	**1**	**2**							
CO9	3	**1**	1	**1**	**1**							

Advance Common laboratory

1. Determination of Molecular Weight of an unknown Protein by Gel-Chromatography technique
2. Verification of Beer-Lamberts law and estimation of unknown concentration of organic molecules in solvents from UV-Vis electronic spectroscopy.
3. Recording the FTIR spectra of organic molecules and assignments of prominent vibrational bands.
4. X-ray diffraction experiment — Laue spots — determination of Miller indices by gnomonic projection.
5. Indexing of powder x-ray diffraction pattern of metallic oxides and determination of crystallite size.
6. Study of morphological properties of powder sample and thin film using FESEM.
7. Study of structural and surface properties of thin films using XRD and AFM.
8. Study of potentiostatic electrochemical response and galvanostatic charging discharging profile of energy storage (supercapacitive and pseudocapacitive) materials.
9. Electrochemical Impedance Spectroscopic study of energy storage materials/ semiconductor/ polymers.
10. Determination of phase transition temperatures of a thermotropic liquid crystal.
11. γ spectrometry with scintillation detectors and single/multi-channel analyzers: (a) Recording of Energy spectrum of γ rays (b) Calibration of γ spectrometer (c) Determination absorption coefficient of aluminum.
12. Characterization of dia-, para- and ferro- magnetic materials using VSM.
13. Determination of Raman spectrum of organic molecules and estimation of depolarization ratios of the Raman lines.
14. Determination of Surface enhanced Raman spectrum of organic molecules and estimation of the enhancement factor of the Raman bands.

Advance Laboratory I & II

NUCLEAR & PARTICLE PHYSICS (Practical)

List of experiments:

1. Study of beta absorption curve using GM Counter.
2. Determination of calibration factor for Solid State Nuclear Track Detector.
3. Determination of alpha activity of a distributed source using Solid State Nuclear Track Detector.
4. Calibration of gamma ray spectrometer and hence to find energy of unknown gamma source.
5. To find the gamma ray attenuation coefficient of an absorber.
6. Simple simulation studies of high energy interactions.
7. Study of Mossbauer spectra of some materials.

X-RAY CRYSTALLOGRAPHY I & II

1) Determination of Debye-Scherrer camera radius using X-ray powder diffraction pattern of a given cubic crystal.
2) Determine the lattice constant of a given a bcc crystal from Nelson-Riley extrapolation function using a Debye-Scherrer camera.
3) Determine the lattice constant of a given an fcc crystal from Nelson-Riley extrapolation function using a Debye-Scherrer camera
4) .Determination of lattice parameter of a given cubic crystal using the diffraction pattern obtained from a laboratory X-ray powder diffractometer.
5) Determination of crystal structure of an organic compound from single crystal X-ray diffraction.
6) Determination of structure of a metal-organic complex from single crystal X-ray diffraction.
7) Determination of instrumental broadening parameters of a laboratory X-ray powder diffractometer.
8) Determination of particle size and micro strain in a deformed crystal using Scherrer method.

NUCLEUS UNDER DIFFERENT CONDITIONS

1. Determination of range of beta particles by Feather's method.
2. To compare alpha activity of different samples using SSNTD.
3. Determination of range of α particle using semiconductor detectors.
4. Identification of radioisotopes using gamma ray spectrometer.
5. To find gamma activity of a powder sample using gamma ray spectrometer.
6. To study angular and range distribution of target fragments in relativistic nucleus-nucleus and hadron-nucleus collisions using nuclear emulsion technique.
7. Simulation studies using Glauber model.

8. Two particle correlation study in simulated nucleus-nucleus collision.
9. Study of materials by Mossbauer spectroscopy.

GENERAL RELATIVITY & COSMOLOGY - I : COMPUTATION/NUMERICAL APPLICATIONS)

Following kinds of computationals would be included in future
Perform Five Numericals Exercises.

1. Compute and plot for at least three sets of cosmological parameters of your choice the following
2. quantities as a function of redshift (up to z=10): age of the universe in Gyrs; comoving distance in Gpc, angular
3. diameter distance in Gpc; luminosity distance in Gpc.
4. 2. Using a flat cosmological model, find the numerical solution of the redshift at which the apparent size of an object of
5. given intrinsic size is minimum as a function of cosmological constant.
6. 3. Numerical solutions of deceleration parameter, Jerk & snap as a function of redshift for different cosmological
7. models.
8. 4. Compute the age of the universe for different sets of cosmological parameters of your choice.
9. 5. Compute the evolution of the mean cosmic microwave background radiation (CMBR) and the gas temperature as
10. function of scale factor in the expanding Universe.
11. 6. Computation of Multiplication and contraction of Contra-variant and Co-variant tensors tensors,
12. Derivative of tensor, Covariant differentiation and the notion of a connection, Connection co-efficient, Affine
13. connection. The Christaffel connection (metric is given)
14. 7. Computation of Covariant differentiation along a curve and geodesic equation (metric is given).
15. 8. Computation of the Riemanian and Ricci curvature tensor (metric is given),
16. 9. Computation of Curvature and parallel transport, Round trips (metric is given).
17. 10. Computation of the geodesic deviation equation (metric is given).

Atomic, molecular physics
1. Study of the spectra of atomic hydrogen and determination of Rydberg constant.
2. Study on Zeeman Effect
3. I_2 Absorption spectroscopy

BIOPHYSICS I & II:

1. Isolation of Pure bacterial strain by serial dilution techniques;

Maintenance of bacterial stains through Plate culture; Stab culture etc

2. .Draw the calibration curve of bacterial cell numbers vs. optical density; Determination of bacterial Growth curve;
3. Purification of a protein and determination its molecular weight from a mixture of proteins through column chromatographic technique
4. Isolation of Plasmid DNA by alkali-lysis method and Boiling method.
5. Transformation of plasmid into a bacterial host cells.

HIGH ENERGY PHYSICS

List of experiments:

1. Multiplicity distribution study in high energy hadron-hadron collisions using Bubble Chamber technique.
2. Hands on training in ROOT environment and random number generation.
3. Study of charged particle energy loss in a medium and hence to identify the particle.
4. Study of particle properties in hadronic decay.
5. Event generation using Monte-Carlo models.
6. Study of different observables of high energy interactions and curve fitting using ROOT environment.
7. Study of correlation among produced particles in high energy interactions.

ELECTRONICS ADVANCED PAPER

1. Studies on Diac, Triac and SCR.
2. Unijunction transistors, characteristics and use as saw-tooth generator
3. Characterization of Solar cell
4. Magnetic parameters of a magnetic material by hysteresis loop tracer
5. To Design and study of frequency response of 2nd order Active Filters.
6. Study of magnetoresistance of semiconductor
7. Experiments on applications of analog multiplier IC
8. To design voltage controlled oscillator (VCO) using op-amp and 555 IC
9. Experiments on digital electronics: Combinational Logic circuit design using MUX, Counter, Register and Sequential logic circuit
10. To design a temperature controller circuit of given specification.
11. To design a regulated power supply on Veroboard/PCB
12. Experiments on microprocessor (8085/8086): Assembly Language Programming

ATOMIC, MOLECULAR AND OPTICAL PHYSICS

1. Mach-Zender interferometer
2. Verification of Beer-Lambert's law
3. Raman spectral analysis of organic molecule

CONDENSED MATTER PHYSICS

1. Studies on the magnetoresistance of semiconducting materials
2. Studies on the magnetoresistance of metallic materials
3. Study on the ferroelectric to paraelectric transition and the determination of Curie temperature
4. Studies on thermoluminescence of KCl and CsCl
5. Determination of the Hall-coefficient and its temperature dependence of semiconducting materials
6. Determination of magnetic susceptibility and effective Bohr magneton (p_{eff}) of a paramagnetic solid
7. Experiments on the classification of several magnetic solids (dia, para, ferro, antifferro etc)

Comprehensive viva : PG/SC/PHY/GV/601

Course Outcomes:

After completion of this course student will

CO1: understand the different subject taught in all courses in MSc curriculum.

CO2: be able to prepare for the interview of PhD level.

CO3: be able to increase their ability to answer appropriately all academic questions

CO4: be able to clear doubt in understanding of basic physics and to improve communication skill. .

CO-PO Mapping :(3 – Strong, 2 – Moderate and 1 – Weak)

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CO1	**3**	**3**	**1**	**1**	**3**							
CO2	1											
CO3	1	**2**	1	**1**		**1**						
CO4	1		1	**1**	**1**	**2**						

Project: PHY/PR/701

Course Outcomes

CO1:Get exposure and acquainted with the research environment

CO2: learn to work in community

CO3: Improve communication language skill.

CO4: Help students to think some innovative ideas in their field of interests.