KURUKSHETRA UNIVERSITY, KURUKSHETRA, Haryana (INDIA)

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("A" Grade, NAAC Accredited)

Structure and Syllabi of
M. Sc. PHYSICS (Four Semester) Course

(Effective from the Academic Session 2014-15)

Department of Physics
Kurukshetra University
Kurukshetra - 136 119
Haryana (INDIA)

Structure and Syllabi of
M. Sc. PHYSICS (Four Semester) Course

(Effective from the Academic Session 2014-15)

SEMESTER I

Course Code	**Course Title**	**Teaching Hours per week**	**Maximum Marks**		
			Internal Assessment*	End-semester Examination	Total
PHY 101	Mathematical Physics	4	20	60	80
PHY 102	Classical Mechanics	4	20	60	80
PHY 103	Quantum Mechanics-I	4	20	60	80
PHY 104	Electronic Devices and Circuits-I	4	20	60	80
PHY 105	Physics Laboratory-I	20	40	120	160
Total Marks					**480**

SEMESTER II

Course Code	**Course Title**	**Teaching Hours per week**	**Maximum Marks**		
			Internal Assessment*	End-semester Examination	Total
PHY 201	Quantum Mechanics-II	4	20	60	80
PHY 202	Nuclear and Particle Physics	4	20	60	80
PHY 203	Solid State Physics	4	20	60	80
PHY 204	Electronic Devices and Circuits-II	4	20	60	80
PHY 205	Physics Laboratory-II	20	40	120	160
PHY 206	Seminar**	2[1]			40
Total Marks					**520**

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[1] Seminar will be held once a week during the laboratory hrs.

SEMESTER III

Course Code	**Course Title**	**Teaching Hours per week**	**Maximum Marks**		
			Internal Assessment*	End-semester Examination	Total
PHY 301	Advanced Quantum Mechanics	4	20	60	80
PHY 302	Statistical Mechanics	4	20	60	80
*Any one of the following specializations****		4	20	60	80
PHY 303A	Condensed Matter Physics-I				
PHY 303B	Nuclear Physics-I				
PHY 303C	Particle Physics-I				
*Any one of the following specializations****		4	20	60	80
PHY 304A	Computational Physics-I				
PHY 304B	Electronics-I				
PHY 304C	Material Science-I				
PHY 305	Physics Laboratory-III	20	40	120	160
Total Marks					**480**

SEMESTER IV

Course Code	**Course Title**	**Teaching Hours per week**	**Maximum Marks**		
			Internal Assessment*	End-semester Examination	Total
PHY 401	Electrodynamics and Plasma Physics	4	20	60	80
PHY 402	Atomic and Molecular Physics	4	20	60	80
Same specialization is to be taken as in Semester III		4	20	60	80
PHY 403A	Condensed Matter Physics-II				
PHY 403B	Nuclear Physics-II				
PHY 403C	Particle Physics-II				
Same specialization is to be taken as in Semester III		4	20	60	80
PHY 404A	Computational Physics-II				
PHY 404B	Electronics-II				
PHY 404C	Material Science-II				
PHY 405	Physics Laboratory-IV	20	40	120	160
PHY 406	Seminar**	2[2]			40
Total Marks					**520**

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[2] Seminar will be held once a week during the laboratory hrs.

Total Marks of all Four Semesters

Semester	**Marks**
Semester I	480
Semester II	520
Semester III	480
Semester IV	520
Grand Total	2000

[*]Internal Assessment in theory papers will be made on the basis of sessional test(s) and other parameters as decided by the University from time to time, while in Laboratory papers it will be decided from continuous assessment in internal viva-voce examination of all the experiments performed. Current guidelines for determining Internal Assessment in theory papers are given as Annexure 1.

[**] Each student will deliver one seminar of about 40 minutes duration on the topic to be allotted by the departmental seminar committee in both 1st and 2nd years of the M. Sc. Physics Course as per the schedule drawn in the beginning of each year. The marks will be awarded by the seminar committee on the basis of performance in the seminar and the seminar report submitted by the student.

[***] The special papers will be allotted to students on the basis of their preference cum percentage of marks in the First Semester examination of M. Sc. Physics.

General guidelines:

1. If a course is being taught by two or more teachers, they should coordinate among themselves the coverage of course material as well as the internal assessment of the students to maintain uniformity.
2. Each theory course in a semester has been designed for a period of 48-54 lectures. The total number of actual lectures delivered may vary at most by 10 %.
3. The books indicated as references are suggestive of the level of coverage. However, any other standard book may be followed.
4. In specialization courses, new specializations may be added to the list from time to time keeping in view the expertise available in the Department and/or the emergence of new frontier areas of specialization.
5. New experiments in the Laboratory Courses may be added from time to time.

LEARNING OBJECTIVES OF DIFFERENT COURSES

SEMESTER I

PHY 101: Mathematical Physics

This course has been developed to introduce students to some topics of mathematical physics which are directly relevant in different papers of M. Sc. Physics course. It includes elements of group theory, special functions, functions of a complex variable and calculus of residues. On completion of this course, students would be able to handle the mathematics that appears invariably in other papers such as Classical Mechanics, Quantum Mechanics, Nuclear Physics, Condensed Matter Physics, etc.

PHY 102: Classical Mechanics

The aim and objective of the course on Classical Mechanics is to train the students of M. Sc. class in the Lagrangian and Hamiltonian formalisms so that they can apply these methods to solve real world problems. The multi-disciplinary topic 'Chaos' will enable the students to learn the techniques to handle the problems from the field of non-linear dynamics.

PHY 103: Quantum Mechanics-I

This course aims at providing an elementary introduction to the basic principles of (non-relativistic) Quantum Mechanics, and its wave-mechanical and matrix-mechanics formulations. Starting with the mechanics of a single spin-less particle, formulation is extended to deal with spin and a system of many identical particles. To demonstrate practical importance, simple applications have also been considered. This course would enable students to comprehend the basic structure of Quantum Mechanics and to use it in different branches of Physics like Atomic and Molecular Physics, Nuclear Physics, Condensed Matter Physics etc.

PHY 104: Electronic Devices and Circuits-I

Through this course on electronic devices and circuits, the students are supposed to understand basic physics of semiconductor materials and the construction and operation of pn-diode and BJT under different operating conditions. The students will also be able to learn the importance and consequences of feedback in electronic circuits, the art of designing various biasing circuits, circuit models of BJT under small signal conditions in different frequencies regimes, large signal amplifiers, their classifications and analysis of different circuits associated with this class of amplifiers. Topics on various network analysis theorems will give an edge to students in circuit understanding, analysis and design. The topics on electronic voltage regulators are included, so that students can understand the underlying intricacies of modern IC regulators.

PHY 105: Physics Laboratory-I

The aim of the course on Physics Laboratory is to train students in handling the basic tools of experimental physics, and their use in laboratory demonstration of important physical phenomenon and the underlying principles of physics. In order to have a hands-on illustration of otherwise intricate theoretical concepts, the experiments included in the curriculum have a close link with the syllabi of theory papers. Most of the experiments are designed to be open ended so as to provide a platform to students to see the things actually happening in the laboratory.

SEMESTER II

PHY 201: Quantum Mechanics-II

Having introduced the basic structure of Quantum Mechanics in the course PHY 103, this course has focus on the need and development of variety of approximate methods in Quantum Mechanics (perturbation theory, variational method and WKB approach) and their illustration by way of application to selected atomic and molecular systems. Also, an introduction to the quantum theory of scattering is provided. Training in this course should equip students with the ability to use quantum mechanics in real physical situations and to obtain approximate solutions.

PHY 202: Nuclear and Particle Physics

The course aims to provide the students with an understanding of basic radiation interaction and detection techniques for nuclear physics, radioactive decays, nuclear reactions and elementary particle physics. This syllabus describes the basic interaction mechanisms for charged particles and electromagnetic radiation relevant for radiation detectors and explain their importance for detecting various types of ionizing radiation at different energies, the working principles behind detectors and their characteristic properties with respect to energy resolution, efficiency etc. It also describes the basic features involved in alpha and beta decays, nuclear forces and various kinds of nuclear reactions besides the fundamentals of elementary particle physics.

PHY 203: Solid State Physics

The course on Solid State Physics has focus on the crystalline state of matter and is meant to introduce students to crystal structure, basic concepts and principles underlying structure determination, lattice vibrations, energy band theory and salient features of superconductivity. On accomplishing this course, the students should be able to comprehend how the macroscopic properties (viz. thermal and electrical) of crystalline solids are derived from microscopic considerations. This course will also provide a sound foundation for specialization in Condensed Matter Physics.

PHY 204: Electronic Devices and Circuits-II

The aim of this course is to train students to a host of important electronic device being used in vital practical applications. OPAMPs, the basic building block of analog electronics, is included so that students can grasp the basics of OPAMP and are able to understand and analyze complex practical circuits. The topics of various number systems and their arithmetic, basic logic gates and simplification techniques for Boolean expressions will enable the students to enter into the fascinating world of digital electronics. The students will also be exposed to circuit design of different types of oscillators.

PHY 205: Physics Laboratory-II

The aim of the course on Physics Laboratory is to train students in handling the basic tools of experimental physics, and their use in laboratory demonstration of important physical phenomenon and the underlying principles of physics. In order to have a hands-on illustration of otherwise intricate theoretical concepts, the experiments included in the curriculum have a close link with the syllabi of theory papers. Most of the experiments are designed to be open ended so as to provide a platform to students to see the things actually happening in the laboratory.

PHY 206: Seminar

This course makes a unique component of the curriculum. It is mandatory for every student to deliver a seminar of approximately 40 minutes duration on a topic as decided by the departmental seminar committee. Each and every student would get an opportunity to express his/her level of understanding of various concepts and this, apart from strengthening the subject knowledge, would help students in developing better communication skills and higher level of confidence.

SEMESTER III

PHY 301: Advanced Quantum Mechanics

The aim of the course is to introduce students to the basics of relativistic quantum mechanics, classical and quantum field theories, and quantum theory of radiation. The course is planned as a continuation of Quantum Mechanics courses PHY 103 and PHY 201. After having taken Advanced Quantum Mechanics course, the students will acquire: (i) A working knowledge of relativistic quantum mechanics, second quantization and quantum theory of radiation and (ii) The ability to apply the techniques of quantum field theory in other branches of physics such as condensed matter physics, nuclear physics, particle physics etc.

PHY 302: Statistical Mechanics

This course is intended to provide a firm foundation to students in a very fundamental subject of Statistical Mechanics which aims to derive the macroscopic behaviour of a system in terms of the mechanics of its microscopic constituents, and finds application in almost all branches of Physics. It makes use of the ensemble theory and covers both classical and quantum statistics. Generalization to systems of interacting particles is also considered. To demonstrate practical importance of the course, some simple applications from different branches of Physics are included. On completion of this course, the students would be able to explore the physical behaviour of a variety of statistical systems.

PHY 303A: Condensed Matter Physics-I

The aim of Condensed Matter Physics-I is to expose students to topics like electron dynamics in semiconductors and metals, Fermi surface and its determination, optical properties of solids, dielectrics and ferroelectrics, and quantum-mechanical origin of magnetism. Theoretical formulation of these properties has been brought in direct contact with relevant experiments. The students should be able to learn how these properties can be deduced using the fundamental principles of mechanics (classical/quantum) and statistical mechanics.

PHY 303B: Nuclear Physics-I

This course is designed for students with interest in experimental nuclear physics. The course aims to provide the students with an understanding of basic particle identification and detection techniques, nuclear electronics, ion-solid interaction, ion accelerators and reactor physics. This syllabus describes the various mechanisms of particle identification and the relevant detector telescopes for their detection, basics of nuclear electronics used in pulse processing, process of ion beam penetration and stopping in matter, different ion sources with main emphasis on Pelletron accelerator and basic features of nuclear reactor physics.

PHY 303C: Particle Physics-I

Starting from the fundamental concepts of particle physics, the present course deals with the importance of isospin formalism and various conservation rules and symmetries associated with different fundamental types of interactions.

PHY 304A: Computational Physics-I

In theoretical physics, one comes across very frequently with the situations where the analytical solutions of the equations describing the physical system are not possible. In these situations the numerical methods for solving equations, evaluating differentiation, integration etc. provide a powerful tools to describe the physical phenomenon quantitatively. After completing this course the students will be able to understand the concepts involved in various numerical methods and to apply these methods in various physical situations using computer programming in FORTRAN.

PHY 304B: Electronics-I

The aim of the course is to understand basic operational amplifier characteristics along with its applications in various electronic devices, modulation and communication will give insight of the transmission and reception in communication systems, combinational and sequential digital systems will be used to understand the applications in day to day life, basic structure of the Microprecessor will help the student to understand various controlled application. The course is designed in a manner such that the student after studying this will have strong basic knowledge to design Power Electronic Systems easily.

PHY 304C: Material Science-I

This course aims to provide the students with a basic understanding of different kind of imperfections, deformation, strengthening mechanisms, different phase diagrams and phase transformations in solids. It describes the understanding of fundamentals of ion implantation technique for materials processing besides various ion beam based methods of material characterization.

PHY 305: Physics Laboratory-III

This course is intended to impart hands-on training to students in handling somewhat specialized techniques in their respective chosen fields of specialization, one each from two groups viz. Group 1: Condensed Matter Physics, Nuclear Physics, and Particle Physics; Group 2: Computational Physics, Electronics, and Material Science. There is a close overlap between the experiments offered and the theory course.

SEMESTER IV

PHY 401: Electrodynamics and Plasma Physics

On completion, the students will be able to: (i) Demonstrate an understanding of the use of scalar and vector potentials and of gauge invariance, (ii) Know and use methods of solution of Poisson/Laplace equation, (iii) Know and use principles of Lorentz covariant formalism and tensor analysis, (iv) Demonstrate the compatibility of electrodynamics in special theory of relativity, (v) Know about radiation fields of moving charge, and (vi) Gather basic understanding of Plasma state essential for higher studies.

PHY 402: Atomic and Molecular Physics

The course illustrates the fundamental aspects of atomic and molecular physics, and will use quantum mechanics at different levels to understand the structure and dynamics of both atoms and molecules. On completion of the course, the students shall have basic knowledge of modern atomic and molecular physics in order to (i) master both experimental and theoretical working methods in atomic and molecular physics for making correct evaluations and judgments, (ii) carry out experimental and theoretical studies on atoms and molecules, with focus on the structure and dynamics of atoms and molecules, and (iii) account for theoretical models, terminology and working methods used in atomic and molecular physics.

PHY 403A: Condensed Matter Physics-II

The aim of second course on Condensed Matter Physics is to prepare students for undertaking somewhat advanced studies in Condensed Matter Physics. It emphasizes on the consequences of going beyond the independent electron approximation (central approximation made in the courses PHY 203 & PHY 303A) and an exposure to the language of second quantization- the language in use in condensed matter theory research. Importantly, it also includes an introduction to the emerging field of Nano-structures and electron transport phenomenon in such systems.

PHY 403B: Nuclear Physics-II

One of the primary goal of nuclear physics, since from its inception, is to understand the exact nature of nuclear interaction and hence the structural and behavioral aspects of atomic nucleus. The nuclear scattering and reaction experiments are the most effective tools to achieve this goal. After completing this course the students will acquire the knowledge of various properties of strong nuclear interaction extracted through the scattering and reaction experiments which in turn will help in understanding various nuclear models used to describe observed properties of atomic nuclei.

PHY 403C: Particle Physics-II

This course covers the relativistic kinematics associated with the nuclear reactions at relativistic energies and the decays of fundamental particles. The course will provide the fundamental understanding of charge particle interaction, and the details of particle detectors and accelerators employed in particle physics. The introduction to Higg’s boson and its status are also discussed.

PHY 404A: Computational Physics-II

Theoretically most of the physical systems are described by differential equations, integral equations etc. Some time these equations are not analytically solvable and hence one has to go for numerical solutions of differential and integral equations. After completing this course the students will be able to apply various numerical methods for solving differential and integral equations to physical systems. Further after learning the fundamental concepts involved in simulating simple physical phenomena the students will be able to simulate the complex physical processes also.

PHY 404B: Electronics-II

The course will give insight of IC fabrication. After doing this course, the students will be able to work in fabrication laboratories in India and abroad. It also gives the basic idea about the simulations of various electronic circuits such that the students can handle the simulations problems without any difficulty. Design aspects of digital systems will give a confidence to the students to handle complex problems in this area.

PHY 404C: Material Science-II

This course will provide the students an understanding of basic fundamentals and properties of magnetic, dielectric, optical and ferroelectric materials. The course describes the various mechanical methods for tension, hardness, impact, fatigue and creep testing of materials. It will also provide the understanding of importance of surface and electron, photon and electric field based techniques for surface analysis.

PHY 405: Physics Laboratory-IV

This course is intended to impart hands-on training to students in handling somewhat specialized techniques in their respective chosen fields of specialization, one each from two groups viz. Group 1: Condensed Matter Physics, Nuclear Physics, and Particle Physics; Group 2: Computational Physics, Electronics, and Material Science. There is a close overlap between the experiments offered and the theory course.

PHY 406: Seminar

This course makes a unique component of the curriculum. It is mandatory for every student to deliver a seminar of approximately 40 minutes duration in the field of chosen specialization and on a topic as decided by the departmental seminar committee. Each and every student would get an opportunity to express his/her level of understanding of various concepts and this, apart from strengthening the subject knowledge, would help students in developing better communication skills and higher level of confidence.

DETAILED COURSES OF STUDY

M. Sc. Physics (Semester I)

PHY 101: Mathematical Physics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 40% of total marks.

Unit I: Matrices and Group Theory (12 hrs.)

Matrices: Orthogonal, Unitary and Hermitian Matrices with examples, Independent elements of orthogonal and unitary matrices of order 2, Matrix diagonalization, eigenvalues and eigenvectors; Fundamentals of Group theory: Definition of a group and illustrative examples, Group multiplication table, rearrangement theorem, cyclic groups, sub-groups and cosets, permutation groups, conjugate elements and class structure, normal devisors and factor groups, isomorphism and homomorphism, class multiplication.

Unit II: Group representation (12 hrs.)

Groups representation by matrices, reducible and irreducible representations, great orthogonality theorem and its geometric interpretation, character of a representation, construction of character table with illustrative examples of symmetry groups of equilateral triangle, rectangle and square. Decomposition of reducible representation, the regular representation. The elements of the group of Schrodinger equation.

Unit III: Special Functions (12 hrs.)

Bessel Functions: Bessel functions of the first kind $J_n(x)$, Generating function, Recurrence relations, $J_n(x)$ as solution of Bessel differential equation, Expansion of $J_n(x)$ when n is half an odd integer, Integral representation; Legendre Polynomials $P_n(x)$: Generating function, Recurrence relations and special properties, $P_n(x)$ as solution of Legendre differential equation, Rodrigues' formula, Orthogonality of $P_n(x)$; Associated Legendre polynomials and their orthogonality; Hermite and Laguerre Polynomials: generating function & recurrence relations only.

Unit IV: Functions of a complex variable and calculus of residues (12 hrs.)

Complex algebra, Functions of a complex variable, Cauchy-Riemann conditions, Analytic functions; Cauchy’s intergral theorem, Cauchy's integral formula; Taylor and Laurent expansions; Singularities; Cauchy's residue theorem, Cauchy principle value, Singular points and evaluation of residues, Jordan's Lemma; Evaluation of definite integrals of the type: $\int_0^{2\pi} f(\sin\theta, \cos\theta)\,d\theta$; $\int_{-\infty}^{\infty} f(x)\,dx$; $\int_{-\infty}^{\infty} f(x)\,e^{iax}\,dx$ *. Exercises in this unit are at the level of those given in book at Ref. No. 2.*

Reference Books:

1. Group Theory and Quantum Mechanics by M. Tinkam.
2. Mathematical Methods for Physicists (4th edition) by G. Arfken.
3. Mathematical Physics for Physicists & Engineers by L. Pipes.

PHY 102: Classical Mechanics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Lagrangian and Hamiltonian formulations (12 hrs.)

Hamilton’s principle, Derivation of Lagrange’s equations from Hamilton’s principle, Principle of Least Action and its applications, Canonical Transformation; The Hamiltonian Formalism: Canonical formalism, Hamiltonian equations of motion, The physical significance of the Hamiltonian, Cyclic coordinates, Rauthian procedure and equations, Derivation of Generating functions, examples, properties, Derivation of Hamiltonian equations from variational principle.

Unit II: Poisson bracket and theory of small oscillations (12 hrs.)

Poisson bracket, special cases of Poisson bracket, Poisson theorem, Poisson bracket and canonical transformation, Jacobi identity and its derivation, Lagrange bracket and its properties, the relationship between Poisson and Lagrange brackets and its derivation, the angular momenta and Poisson bracket, Liouville’s theorem and its applications; Theory of small oscillations: Formulation of the problem, Eigenvalue equation and the principle axis transformation, frequencies of free vibrations and normal coordinates, free vibrations of a linear triatomic molecule, beyond small oscillations; the damped driven pendulum.

Unit III: Two-body central force problem and H-J theory (14 hrs.)

Two body central force problem: Reduction to the equivalent one body problem, the equation of motion and first integrals, classification of orbits, the Virial theorem, the differential equation for the orbit, integrable power law in time in the Kepler’s problem, the Laplace-Runge-Lenz vector, scattering in central force field; H-J Theory: H-J equation and their solutions, use of H-J method for the solution of harmonic oscillator problem, Hamilton’s principle function, Hamilton’s characteristic function and their properties, Action angle variables for completely separable systems, the Kepler’s problem in action angle variables.

Unit IV: Introductory non-linear dynamics (12 hrs.)

Classical Chaos: Periodic motion, Perturbation and KAM theorem, dynamics in phase space, phase portraits for conservative systems, attractors, classification and stability of equilibrium points, stability analysis of cubic anharmonic oscillator and undamped pendulum, chaotic trajectories and Liapunov exponent, Poincare Map, Henon-Hiels Hamiltonian, bifurcation, driven-damped harmonic oscillator, the logistic equation, Fractals and dimensionality.

Reference Books:

1. Classical Mechanics (3rd ed., 2002) by H. Goldstein, C. Poole and J. Safko, Pearson Edition
2. Classical Mechanics of particles and rigid bodies by K. C. Gupta
3. Chaos and Integrability in nonlinear dynamics: An introduction (1989) by Michael Tabor
4. Nonlinear dynamics: Integrability, Chaos and patterns (2003) by M. Lakshmanan and S. Rajasekar

PHY 103: Quantum Mechanics-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: General formulation of Quantum Mechanics (14 hrs.)

Recapitulation of basic concepts: Why quantum mechanics? Two-slit experiment with radiation and particles, and wave function, Schrödinger wave equation, Ehrenfest theorem; Interpretative postulates of quantum mechanics: Dynamical variables as Hermitian operators, Eigenvalues and eigenfunctions, Expansion in eigenfunctions; Illustration of postulates for energy and momentum: Orthonormality of eigenfunctions, Reality of eigenvalues, Closure property, Probability function and expectation value, Co-ordinate and momentum representations of wave function, Uncertainty principle for two arbitrary operators; Problems: A charged particle in a uniform static magnetic field, Hydrogen atom (radial wave function and energy eigenvalues).

Unit II: Matrix formulation of Quantum Mechanics (12 hrs.)

Preliminaries: Hermitian and unitary matrices, Transformation and diagonalization of matrices, Matrices of infinite rank, Representation of dynamical variables and wavefunctions as matrices, Choice of basis, Change of basis, Hilbert space representation; Dirac's ket and bra notations; Time-development of quantum system: Schrödinger, Heisenberg and interaction pictures, Link with classical equations of motion, Quantization of a classical system, Application to motion of a particle in an em field; Matrix theory of the harmonic oscillator: Spectrum of eigenvalues and eigenfunctions, Matrices for position, momentum and energy operators (energy representation).

Unit III: Quantum theory of Angular Momentum (12 hrs.)

Orbital angular momentum operator **L**, Cartesian and spherical polar co-ordinate representation, Commutation relations, Orbital angular momentum and spatial rotations, Eigenvalues and eigenfunctions of $\mathbf{L}^2$ and L_z, Spherical harmonics; General angular momentum **J**: Eigenvalues and eigenfunctions of $\mathbf{J}^2$ and J_z, Matrix representation of angular momentum operators, Spin angular momentum, Wave function including spin (Spinor); Spin one-half: Spin eigenfunctions, Pauli spin matrices; Addition of angular momenta, Clebsch-Gordan coefficients and their calculation for $j_1= j_2 =1/2$, $j_1=1$, $j_2 =1/2$ and $j_1= j_2 =1$.

Unit IV: Many-particle systems (12 hrs.)

Many-particle Schrodinger wave equation; Identical particles: Physical meaning of identity, Principle of indistinguishability and its consequences, Exchange operator, Symmetric and anti-symmetric wave functions, Connection between spin, symmetry and statistics, Fermions and bosons; Spin and total wave function for a system of two spin ½ particles, Pauli exclusion principle and Slater determinant; Application to the electronic system of the helium atom (para- and orthohelium).

Reference Books:

1. Quantum Mechanics (3rd edition) by L. I. Schiff
2. Quantum Mechanics (2nd edition) by B. H. Bransden and Joachain
3. Quantum Mechanics (3rd edition) by S. Gasiorowicz
4. Quantum Mechanics (3rd edition) by E. Merzbacher
5. Quantum Mechanics by John L. Powell and B. Crasemann
6. Quantum Mechanics by A. K. Ghatak and S. Loknathan
7. Introductory Quantum Mechanics (4th edition) by Richard L. Liboff

PHY 104: Electronic Devices and Circuits-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Basics of semiconductor electronics (14 hrs.)

Semiconductors: intrinsic and extrinsic semiconductors, charge densities in p and n type semiconductors, conduction by charge drift and diffusion, the pn-junction, energy level diagrams of pn-junction under forward and reverse bias conditions, derivation of pn-diode equation, Zener and avalanche breakdowns, clipping and clamping circuits; The bipolar junction transistor: Basic working principle, configurations and characteristics, voltage breakdowns, the Ebers-Moll's model; Network theorems: node theorem, mesh theorem, Millman's theorem, Thevenin's theorem, Norton's theorem, superposition theorem.

Unit II: Amplifier models, feedback and biasing (12 hrs.)

Two port network analysis: active circuit models, gain in decibels, equivalent circuit for BJT, the transconductance model for BJT, analysis of CE, CB, and CC amplifiers; An amplifier with feedback, effect of negative feedback on gain and its stability, distortions, input and output impedances of amplifiers, Analysis of amplifiers with voltage series, voltage shunt, current series and current shunt negative feedbacks; Location of quiescent (Q) point, biasing circuits for amplifiers: fixed bias, emitter feedback bias & voltage feedback bias, bias sources for integrated circuits, Circuits for stabilization of Q-Point.

Unit III: Frequency response of amplifiers (12 hrs.)

Introduction, the amplifier pass band, mid range response of CE cascade, the high frequency equivalent circuit (Miller effect), the high frequencies response, the frequency response of RC and transformer coupled CE amplifiers, gain-frequency plots of amplifier response, bandwidth of cascaded amplifiers, bandwidth criterion for the transistor, the gain-bandwidth product, composite amplifier designs, bootstrapping in amplifiers, noise in amplifiers, noise figure.

Unit IV: Power amplifiers and regulators (12 hrs.)

Power amplifiers: class A large signal amplifiers, second and higher order harmonic distortions, the transformer coupled power amplifier, impedance matching, efficiency, push-pull amplifiers, class-B amplifiers, complementary stages, cross over distortions, class-AB operation, heat sinks; Electronic voltage regulators: basic introduction, Zener diode voltage regulator, single BJT shunt and series regulators, feedback regulators, overload and short circuit protection circuits.

Reference Books:

1. Electronic fundamentals and applications (5th ed.) by J. D. Ryder
2. Integrated Electronics by J. Millman and C. C. Halkias
3. Network analysis by Van Valkenburg
4. Electronic devices and circuits by Y. N. Bapat
5. Pulse, digital and switching waveforms by J. Millman and H. Taub
6. Millman's Electronic Devices & Circuits by J. Millman, C. C. Halkias & Satyabrata Jit

PHY 105: Physics Laboratory-I

Max. Marks: 120
Time: 5 Hours

Note: Experiments in the First Year Laboratory are grouped into two sections, viz. A and B, with sections A and B containing electronics experiments and general physics experiments, respectively. In this course, students will complete at least nine experiments in a semester from one of the two sections as per allotment by the teacher in-charge of the Laboratory. Experiments pertaining to the remaining section will be undertaken in the second semester. Besides continuous assessment of students through internal viva-voce examination of the experiments performed, there shall be end-semester laboratory examination wherein each student will be required to perform at least one experiment as per paper setting by a duly appointed panel of examiners. The evaluation will be made on the basis of performance of students in (i) experiment, (ii) report and analysis of the experiment and (iii) viva-voce examination.

List of experiments is given as under[3]:

Section A

E1 To study the frequency response of low-pass, high-pass and band-pass filters.

E2 To study the rectifier circuits and to measure the ripple factors of C, L and π-section filters. Also study the stabilization characteristics of a voltage regulator consisting of IC-741.

E3 To study the characteristics of a class-B push-pull amplifier.

E4 To generate and find the frequency of saw-tooth waves using UJT.

E5 To draw frequency response characteristics of a RC-coupled single stage BJT amplifier in all the three configurations.

E6 To design circuits for OR, AND, NOT, NAND and NOR logic gates and verify their truth tables.

E7 To measure (a) phase difference, (b) deflection sensitivity and (c) frequency of an unknown ac signal using CRO.

E8 To study the astable multivibrator.

E9 To study the clipping and clamping circuits.

E10 To study the differentiating and integrating circuits.

E11 To determine various parameters of a pn-junction diode.

E12 To study the modulation and demodulation circuits.

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[3] New experiments may be added to this list from time to time.

Section B

G1 To measure the width of a narrow slit using the diffraction phenomenon.

G2 To determine the ionization potential of mercury.

G3 To determine the value of Planck’s constant using photocell/LED.

G4 To study absorption of β-rays in Aluminum.

G5 Michelson interferometer experiment.

G6 Fabry-Paret interferometer experiment.

G7 To determine the half-life of Indium.

G8 To determine the strength of an α-source using SSNTD.

G9 To study nuclear statistics using SSNTD.

G10 Demonstration of energy quantization using the Frank-Hertz Experiment.

G11 Fourier analysis of complex signals.

G12 To determine band-gap of a semiconductor material.

M. Sc. Physics (Semester II)

PHY 201: Quantum Mechanics-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Approximate methods for bound states-I (13 hrs.)

Stationary perturbation theory: Non-degenerate case- First-order and second-order corrections to energy eigenvalues and eigenfunctions, Perturbation of an oscillator (harmonic and anharmonic perturbations), Fine structure of hydrogen atom (Relativistic and spin-orbit coupling corrections), Ground state of Helium atom; Degenerate case- Removal of degeneracy in second order, Zeeman effect without electron spin, First-order Stark effect in n=2 state of Hydrogen; Rayleigh-Ritz variational method: Ground and excited states, Application to ground state of Helium, Van der Waals interaction using perturbation and variational methods.

Unit II: Approximate methods for bound states-II (12 hrs.)

The WKB approximation: Classical limit, Approximate solutions, Asymptotic nature of solutions, Solution near a turning point, Special case of linear turning point, Connection at the turning point, Asymptotic connection formulae, Application to energy levels of a quantum well, tunneling through a potential barrier and alpha decay; First-order Time-dependent perturbation theory, Transition probability for constant and harmonic perturbations, Transition to a group of final states- The Fermi golden rule, Applications: Ionization of hydrogen atom, Interaction of an atom with em radiation (semi-classical treatment), Transition probability for induced absorption and emission.

Unit III: Selected applications of Quantum Mechanics (12 hrs.)

Atomic structure of many-electron atoms: Central-field approximation, Periodic system of elements, Thomas-Fermi statistical model, Evaluation of the potential, Hartree's self-consistent fields and connection with the variational method, Correction to the central-field approximation (L-S and j-j couplings); Molecular structure: Classification of energy levels, Wave equation; Hydrogen molecule: Potential energy function, The Morse potential, Rotation and vibration of diatomic molecules, Energy levels.

Unit IV: Quantum theory of scattering (12 hrs.)

Scattering experiments and cross-sections, Laboratory and centre-of-mass systems, Scattering amplitude and cross-section; Method of partial waves: Phase shift, Differential and total cross-sections, Relation between phase shift and scattering potential, Convergence of partial-wave series, Scattering by a finite square well, Resonances- Breit-Wigner formula, Scattering by a hard-sphere potential; Green's function method: Lippmann-Schwinger equation, Born series, First Born approximation, Scattering of an electron by a screened Coulomb potential in Born approximation and validity criterion; Scattering of two identical spinless bosons, and spin-1/2 fermions.

Reference Books:

1. Quantum Mechanics (3rd edition) by L. I. Schiff
2. Quantum Mechanics (2nd edition) by B. H. Bransden and Joachain
3. Introduction to Quantum Mechanics (2nd edition) by David J. Griffiths
4. Quantum Mechanics by A. K. Ghatak and S. Loknathan
5. A Textbook of Quantum Mechanics by P. M. Mathews and K. Venkatesan
6. Quantum Mechanics (3rd edition) by S. Gasiorowicz
7. Quantum Mechanics by John L. Powell and B. Crasemann

PHY 202: Nuclear and Particle Physics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Interaction of Radiation with Matter (12 hrs.)

Interaction of Charged Particles with Matter: qualitative description of various energy loss mechanisms, their relative contribution in case of heavy ions and electrons, classical stopping power equation for electronic energy-loss (no derivation) with significance of various terms involved, behavior of electronic energy-loss curve as a function of ion velocity, concept of energy straggling and range straggling and their correlation; Interaction of Gamma Radiation with Matter: features of photoelectric, Compton and pair production processes, interaction cross sections, energy, target and projectile dependence of all three processes; linear and mass attenuation coefficients of gamma rays in matter, positron annihilation in matter.

Unit II: Radiation Detectors (12 hrs.)

G.M. Counter: basic principle, working, Geiger discharge, quenching & mechanism of pulse formation; Gamma Ray Spectrometer: basic principle and working of NaI (Tl) scintilation detector, mechanism of pulse formation, basic idea of pulse processing unit, concept of energy resolution and efficiency of detector and its applications; Semiconductor Detectors: basic principle, construction and working and applications of Si surface barrier, lithium drifted silicon and germanium detectors, high purity germanium detector.

Unit III: Radioactive Decays, Nuclear Forces and Nuclear Reactions (12 hrs.)

Radioactive Decays: energetics of alpha decay, tunnel theory of alpha decay, energetics of beta decay, Fermi theory of allowed beta decay, importance of Fermi-Kurie plot, parity non-conserving property of neutrino; Nuclear Forces: experimental evidence of charge symmetry and charge independence of nuclear forces, concept of isospin, Meson theory of nuclear forces, relationship between the range of the force and mass of the mediating particle; Nuclear Reactions: types of nuclear reactions, Q-value of a nuclear reaction and its determination, definition of cross section and its significance, elementary idea of compound nuclear reactions and direct reactions. concept of neutron reactions, Coulomb excitation, nuclear kinematics.

Unit IV: Particle Physics (12 hrs.)

Units in high energy physics; Classification of particles- fermions and bosons, particles and antiparticles; Strange particles, Basic idea of different fundamental types of interactions with suitable examples; Quark flavors and their quantum numbers, Quarks as constituents of Hadrons, Qualitative idea of Quark confinement and asymptotic freedom, necessity of introducing colour quantum number.

Reference Books:

1. Introduction to Experimental Nuclear Physics by R. M. Singru.
2. Elements of Nuclear Physics by W. E. Meyerhof.
3. Nuclear Radiation Detectors by S. S. Kapoor and V. S. Ramamurthy
4. Introduction to High Energy Physics (2nd edition) by D. H. Perkins.

PHY 203: Solid State Physics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Crystal structure (12 hrs.)

Recapitulation of basic concepts: Bravais lattice, Primitive vectors, Primitive, conventional and Wigner-Seitz unit cells, Crystal structures and lattices with basis, Lattice planes and Miller indices, Simple crystal structures- Sodium chloride, Cesium chloride, Diamond, and Zincblende structures; Determination of crystal structure by diffraction: Reciprocal lattice and Brillouin zones (examples of sc, bcc and fcc lattices), Bragg and Laue formulations of X-ray diffraction by a crystal and their equivalence, Laue equations, Ewald construction, Brillouin interpretation, Crystal and atomic structure factors, Structure factor of the bcc and fcc lattices; Experimental methods of structure analysis: Types of probe beam, the Laue, rotating crystal and powder methods.

Unit II: Lattice dynamics and thermal properties (12 hrs.)

Classical theory of lattice vibration (harmonic approximation): Vibrations of crystals with monatomic basis- Dispersion relation, First Brillouin zone, Group velocity, Two atoms per primitive basis- acoustical and optical modes; Quantization of lattice vibration: Phonons, Phonon momentum, Inelastic scattering of neutrons by phonons; Thermal properties: Lattice (phonon) heat capacity, Normal modes, Density of states in one and three dimensions, Models of Debye and Einstein; Effects due to anharmonic crystal interactions, Thermal expansion.

Unit III: Electronic properties of solids (12 hrs.)

Free electron gas model in three dimensions: Density of states, Fermi energy, Effect of temperature, Heat capacity of the electron gas, Experimental heat capacity of metals, Thermal effective mass, Electrical conductivity and Ohm's law, Hall effect; Failure of the free electron gas model and Band theory of solids: Periodic potential and Block's theorem, Kronig-Penney model, Wave equation of electron in a periodic potential, Solution of the central equation, Approximate solution near a zone boundary, Periodic, extended and reduced zone schemes of energy band representation, Number of orbitals in an energy band, Classification into metals, semiconductors and insulators; Tight binding method and its application to sc and bcc structures.

Unit IV: Superconductivity (12 hrs.)

Experimental survey: Superconductivity and its occurrence, Destruction of superconductivity by magnetic field, Meissner effect, Type I and type II superconductors, Entropy, Free energy, Heat capacity, Energy gap, Microwave and infrared properties, Isotope effect; Theoretical survey: Thermodynamics of the superconducting transition, London equation, Coherence length, Salient features of the BCS theory of superconductivity, BCS ground state; Flux quantization in a superconducting ring; Dc and Ac Josephson effects; Macroscopic long-range quantum interference; High T_c superconductors (introduction only).

Reference Books:

1. Introduction to Solid State Physics (7th edition) by Charles Kittel
2. Solid State Physics by Neil W. Ashcroft and N. David Mermin
3. Applied Solid State Physics by Rajnikant
4. Solid State Physics: An Introduction to Theory and Experiment by H. Ibach and H. Luth
5. Principles of the Theory of Solids (2nd edition) by J. M. Ziman

PHY 204: Electronic Devices and Circuits-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Operational amplifiers and Negative resistance devices (12 hrs.)

The basic OPAMP, inverting and non-inverting OPAMPS, the differential amplifiers, common mode rejection ratio (CMRR), the emitter coupled differential amplifier, the transfer characteristics of differential amplifier, an IC OPAMP (MC 1530 Motorolla) and its dc analysis, offset voltages and currents, universal balancing techniques, measurement of OPAMP parameters; Basic working principles, characteristics and applications of unijuction transistor (UJT), four layer diode (pnpn-diode) and silicon controlled rectifier (SCR).

Unit II: Junction field effect transistors and Oscillators (12 hrs.)

Basic structure and operation of JFET, calculation of pinch off voltage, volt-ampere characteristics of JFET, the FET small signal model, metal oxide semiconductor field effect transistor (MOSFET), physical structure, operation and characteristics, enhancement and depleted modes of operation, metal semiconductor field effect transistor (MESFET), comparison of p and n channel FETS, low frequency common source and common drain FET amplifiers, FET Biasing, FET as a voltage variable resistor (VVR); Feedback sinusoidal oscillators: phase shift oscillators, Wein bridge oscillators, Tuned circuit oscillators, Hartley and Colpitt's oscillators, crystal oscillators; Multivibrators: bistable multivibrators, Schmitt trigger circuit, monostable and astable multivibrators.

Unit III: Digital Circuits (14 hrs.)

Various number systems and their arithmetic: binary number system, 2's compliment, octal number system, hexadecimal number system, BCD codes, Excess-3 codes, Gray codes, Octal codes, Hexadecimal codes and ASCII codes; Digital (binary) operation of a system, Logic systems, the OR gate, the AND gate, the NOT gate, the exclusive OR gate, De Morgan's laws, the NAND and NOR diode- transistor gates, Modified DTL gates, high threshold logic (HTL) gates, transistor- transistor logic (TTL) gates, output stages, resistance-transistor logic (RTL) gates, direct coupled transistor logic (DCTL) gates, emitter coupled logic (ECL) gates, digital MOSFET circuits, complementary MOS (CMOS) logic gates, comparison of logic families, Karnaugh- map (K-map) up to four variable and its applications.

Unit IV: Optoelectronic devices (11 hrs.)

Radiative and nonradiative transitions, solar cells: basic characteristics, radiation effect and fill factor, light dependent resistance (LDR), photodiodes, p-i-n diodes, metal semiconductor photodiodes, avalanche photodiodes, light emitting diodes (LEDs), semiconductor diode lasers, photo transistor; Temperature measurements: resistance thermometers, thermocouples, thermistors.

Reference Books:

1. Integrated Electronics by J. Millman and C. C. Halkias
2. Electronic devices and circuits by Y. N. Bapat
3. Microwave devices and circuits by Samuel Y. Liao
4. Physics of semiconductor Devices by S. M. Sze
5. Electronic instrumentation and measurement techniques by W. D. Cooper and A. D. Helfrick
6. OPAMPs and linear IC circuits by Ramakant A. Gayakwad
7. Pulse, digital and switching waveforms by J. Millman and H. Taub
8. Modern Digital Electronics (3rd Ed.) by R. P. Jain

PHY 205: Physics Laboratory-II

Max. Marks: 120
Time: 5 Hours

Note: Experiments in the First Year Laboratory are grouped into two sections, viz. A and B, with Sections A and B containing electronics experiments and general physics experiments, respectively. In this course, students shall complete at least nine experiments from the section other than the one undertaken in 1st semester. The evaluation pattern and list of experiments is the same as given in the Course PHY 105.

M. Sc. Physics (Semester III)

PHY 301: Advanced Quantum Mechanics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Relativistic Quantum Mechanics (14 hrs.)

Introduction, Klein-Gordan (KG) equation: Plane wave solution, Probability and current densities, KG equation with electromagnetic potentials; Energy levels in a Coulomb field (Hydrogen atom problem). Difficulties of KG equation, Dirac's relativistic equation: Free particle solutions, Dirac matrices and spinors, Probability and current densities, Dirac equation with electromagnetic potentials, Dirac equation for a central field, Existence of spin angular momentum, spin - orbit energy. Energy levels of Hydrogen atom and their classification (Lamb shift).

Unit II: Field Quantization (12 hrs.)

Introduction, Classical and Quantum field equations: Coordinates of the field, Time derivatives, Classical Lagrangian equation, Classical Hamiltonian equations; Quantum equation of the field, Field with more than one component, Complex field, Quantization of the non relativistic Schrödinger equation (Second quantization): Classical Lagrangian and Hamiltonian equations, Quantum field equations, The N representation, Creation, Destruction and Number operators for Bosons and Fermions, Connection with the many particles Schrödinger equation.

Unit III: Quantization of Relativistic Fields and Feynman Diagrams (12 hrs.)

Natural system of units, Quantization of K-G field, Dirac field and Electromagnetic fields (in vacuum); Lagrangian equations, quantum equations, quantized field energy. Interacting fields and Feynman Diagrams: Introduction, Normal product, Dyson and Wick's chronological products, Contraction, Wick's theorem, Electromagnetic Coupling, The Scattering Matrix, Power series expansion of S-matrix, Scattering processes up to second order.

Unit IV: Quantum theory of radiation (12 hrs.)

Classical radiation field, Transversality condition, Fourier decomposition and radiation oscillators, Quantization of radiation oscillators, Creation, Annihilation and Number operators, Photon states, Photon as a quantum mechanical excitations of the radiation field, Fluctuations and the uncertainty relation, Validity of the classical description, Matrix element for emission and absorption, Spontaneous emission in the dipole approximation, Rayleigh scattering, Thomson scattering and Raman effect, Radiation damping and Resonance fluorescence.

Reference Books:

1. Quantum Mechanics by L. I. Schiff (3rd edition)
2 Quantum Mechanics by V. K. Thankappan
3. Advanced Quantum Mechanics by J. J. Sakurai
4. Quantum Mechanics by A. P. Messiah
5. Advanced Quantum Mechanics by B. S. Rajput
6. The principles of Quantum Mechanics by P. A. M. Dirac
7. Relativistic Quantum Mechanics by Schweber

PHY 302: Statistical Mechanics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Classical Statistical Mechanics (14 hrs.)

Foundations of Statistical Mechanics: The macroscopic and microscopic states, Postulate of equal a priori probability, Contact between statistics and thermodynamics; Ensemble theory: Concept of ensemble, Phase space, Density function, Ensemble average, Liouville’s theorem, Stationary ensemble; The microcanonical ensemble, Application to the classical ideal gas; The canonical and grand canonical ensembles, Canonical and grand canonical partition functions, Calculation of statistical quantities; Thermodynamics of a system of non-interacting classical harmonic oscillators using canonical ensemble, and of classical ideal gas using grand canonical ensemble, Energy and density fluctuations; Entropy of mixing and the Gibbs paradox, Sackur-Tetrode equation.

Unit II: Quantum Statistical Mechanics (14 hrs.)

Quantum-mechanical ensemble theory: Density matrix, Equation of motion for density matrix, Quantum-mechanical ensemble average; Statistics of indistinguishable particles, Two types of quantum statistics- Fermi-Dirac and Bose-Einstein statistics, Fermi-Dirac and Bose-Einstein distribution functions using microcanonical and grand canonical ensembles (ideal gas only), Statistics of occupation numbers; Ideal Bose gas: Internal energy, Equation of state, Bose-Einstein Condensation and its critical conditions; Bose-Einstein condensation in ultra-cold atomic gases: its detection and thermodynamic properties; Ideal Fermi gas: Internal energy, Equation of state, Completely degenerate Fermi gas.

Unit III: Non-Ideal Systems (12 hrs.)

Cluster expansion method for a classical gas, Simple cluster integrals, Mayer-Ursell relations, Virial expansion of the equation of state, Van der Waal’s equation, Validity of cluster expansion method; Phase transitions: Construction of Ising model, Solution of Ising model in the Bragg-William approximation, Exact solution of the one-dimensional Ising model; Critical exponents, Landau theory of phase transition, Scaling hypothesis.

Unit IV: Fluctuations (12 hrs.)

Thermodynamic fluctuations and their probability distribution law, Spatial correlations in a fluid, Connection between density fluctuations and spatial correlations; Brownian motion, the Langevin theory of the Brownian motion (derivations of mean square displacement and mean square velocity of Brownian particle), Auto-correlation function and its properties, The fluctuation-dissipation theorem, Diffusion coefficient; the Fokker-Planck equation; Spectral analysis of fluctuations: the Wiener-Khintchine theorem.

Reference Books:

1. Statistical Mechanics by R. K. Pathria (2nd edition)
2. Statistical Mechanics by R. K. Pathria and P. D. Beale (3rd edition)
3. Statistical and Thermal Physics by F. Reif
4. Statistical Mechanics by K. Huang
5. Statistical Mechanics by L. D. Landau and I. M. Lifshitz
6. Statistical Mechanics by R. Kubo

PHY 303A: Condensed Matter Physics-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Semiconductor crystals and Fermi surfaces & metals (12 hrs.)

Semiconductor crystals: Band gap, Direct and indirect absorption processes, Motion of electrons in an energy band, Holes, Effective mass, Physical interpretation of effective mass, Effective masses in semiconductors; Fermi surfaces and metals: Fermi surface and its construction for square lattice (free electrons and nearly free electrons), Electron orbits, Hole orbits, Open orbits; Wigner-Seitz method for energy bands, Cohesive energy; Experimental determination of Fermi surface: Quantization of orbits in a magnetic field, De Hass-van Alphen effect.

Unit II: Optical properties of solids (12 hrs.)

Dielectric function of the free electron gas, Plasma optics, Dispersion relation for em waves, Transverse optical modes in a plasma, Transparency of alkalis in the ultraviolet, Longitudinal plasma oscillations, Plasmons and their measurement; Electrostatic screening, Screened Coulomb potential, Mott metal-insulator transition, Screening and phonons in metals; Optical reflectance, Kramers-Kronig relations, Electronic inter-band transitions, Excitons: Frenkel and Mott-Wannier excitons; Raman effect in crystals; Electron spectroscopy with X-rays.

Unit III: Dielectrics and Ferroelectrics (12 hrs.)

Polarization, Macroscopic electric field, Dielectric susceptibility, Local electric field at an atom, Dielectric constant and polarizability, Clausius-Mossotti relation, Electronic polarizability, Classical theory of electronic polarizability; Structural phase transitions; Ferroelectric crystals and their classification; Landau theory of the phase transition; Anti-ferroelectricity, Ferroelectric domains; Piezoelectricity, Ferroelasticity.

Unit IV: Magnetism (14 hrs.)

Diamagnetism and paramagnetism: Magnetic susceptibility, Langevin diamagnetism equation, Quantum theory of diamagnetism; Quantum theory of paramagnetism- Curie law, Hund's rules, Paramagnetic susceptibility of conduction electrons; Ferromagnetism and antiferromagnetism: Ferromagnetic order, Electrostatic origin of magnetic interactions, Magnetic properties of a two-electron system, Singlet-triplet (exchange) splitting in Heitler-London approximation; Spin Hamiltonian and the Heisenberg model; Mean field theory- Curie-Weiss law; Spin waves- magnons, Bloch $T^{3/2}$ law; Neutron magnetic scattering (principle);Ferromagnetic domains: Magnetization curve, Bloch wall, Origin of domains; Antiferromagnetic order and magnons.

Reference Books:

1. Introduction to Solid State Physics (7th edition) by Charles Kittel
2. Solid State Physics by Neil W. Ashcroft and N. David Mermin
3. Applied Solid State Physics by Rajnikant
4. Solid State Physics: An Introduction to Theory and Experiment by H. Ibach and H. Luth
5. Principles of the Theory of Solids (2nd edition) by J. M. Ziman

PHY 303B: Nuclear Physics-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Particle Identification (12 hrs.)

Basic principle of ΔE-E detector telescopes, short range charged particles ΔE-E telescope, methods of particle identification using semiconductor and gaseous detectors, ΔE-E time of flight spectroscopy; Event by event particle identification system for heavy ion induced reaction analysis; neutron-gamma discrimination; Modem Gas Detectors: basic principle and operation of split anode ionization chamber, position sensitive ionization chamber, position sensitive proportional counter & multi wire proportional counter.

Unit II: Nuclear Electronics (12 hrs.)

Types of preamplifiers: basic idea of voltage sensitive and current sensitive pre-amplifiers, details of charge sensitive preamplifier and its applications; Amplifier Pulse Shaping Circuits: RC, Gaussian, delay-line, bipolar and zero cross-over timing circuits, pole zero cancellation and base line restorer; Coincidence Techniques: basic idea of coincidence circuit and its resolving time, basic principle of slow coincidence, slow fast coincidence and sum coincidence techniques; Single Channel Analyzer; Multi-Channel Analyzer; CAMAC Based Data Acquisition System.

Unit III: Ion Accelerators and Ion Beam Interaction in Solids (12 hrs.)

Ion Accelerators: Ion sources- basic features of RF ion source, direct extraction negative ions source (Duoplasmatron) and source of negative ions by Cs sputtering (SNICS); Basic principle and working of Tandom accelerator and Pelletron accelerator and its applications; Ion Beam Interaction in Soilds: Basic ion bombardment processes in solids- general phenomenon, ion penetration and stopping, ion range parameters, channelling, components of an ion implanter, energy deposition during radiation damage, sputtering process and ion beam mixing.

Unit IV: Nuclear Reactors (12 hrs.)

Nuclear stability, fission, prompt and delayed neutrons, fissile and fertile materials- characteristics and production, classification of neutrons on the basis of their energy, four factor formula, control of reactors, reactors using natural uranium, principle of breeder reactors, fast breeder reactor & doubling time, calculation of critical size and mass of reactor; Basic principle of neutron detection; Basic concept of fusion reactors.

Reference Books:

1. Nuclear Radiation Detectors by S. S. Kapoor and V. S. Ramamurthy
2. Introduction to Experimental Nuclear Physics by R. M. Singru
3. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo
4. Radiation Detection and Measurement by G. F. Knoll
5. The Physics of Nuclear Reactions by W. M. Gibson
6. VLSI Technology by S. M. Sze

PHY 303C: Particle Physics-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Wave Optical Description of Hadron Scattering (12 hrs.)

Partial wave analysis for elastic scattering cross-section (non identical and spin less particles), characteristic S and P wave scattering, reaction cross-section, optical theorem and its significance; Resonanaces: Introduction to resonances, difference between resonances and unstable particles, Δ(1236) resonance, Briet-Wigner resonance formula and its significance, introduction to Dalitz plots with example of $K^{+}\rightarrow 3\pi$ decay, discovery of charm, bottom and top quarks (qualitative description).

Unit II: Isospin Formalism (12 hrs.)

Concept of isospin, assignment of isospin to hadrons, isospin multiplets, generalized Pauli principle, assignment of isospin to deutron in its ground state, isospin wavefuctions for nucleon-nucleon, pion-nucleon and pion-pion systems, isospin invariance in strong interactions through examples like $\sigma_{pn}\rightarrow d\pi^{0}/\sigma_{pp}\rightarrow d\pi^{+\cdot}=1/2$, and $\sigma_{pd}\rightarrow {}^{3}He\pi^{0}/\sigma_{pd}\rightarrow {}^{3}H\pi^{+\cdot}=1/2$, relative cross-sections for $\pi^{+\cdot}-p$ (elastic scattering), $\pi^{-\cdot}-p$ (elastic scattering) and $\pi^{-\cdot}-p$ (charge exchange) processes using isospin analysis.

UNIT III: Conservation Laws (12 hrs.)

The conservation of electric charge and stability of electron, the conservation of baryon number and stability of proton, Lepton number conservation, conservation and violation of isospin in different types of interactions, assignment of strangeness number to hadrons, strangeness conservation in strong and electromagnetic interactions and violation in weak interactions with suitable examples, The Ge11-Mann-Nishijima formula, the baryon $3/2^{+}$ decuplet, $1/2^{+}$ octet and the meson 0^{-} octet, SU(3) classification of hadrons, qualitative idea of Grand Unification theory, prediction of proton decay.

Unit IV: Symmetry Principles (12 hrs.)

Charge conjugation invariance, suppression of $\pi^{0}\rightarrow 3\gamma$ decay w. r. t. $\pi^{0}\rightarrow 2\gamma$ decay, restrictions imposed by C-invariance on the states of positronium annihilating in the modes $e^{+}e^{-}\rightarrow 2\gamma\ 3\gamma$, G-Parity, Ґ-θ puzzle, parity conservation in strong and electromagnetic interactions and violation in weak decays, C and P operations on neutrino states, CPT theorem (statement only) and its consequences.

Reference Books:

1. Introduction to High Energy Physics (2nd and 3rd edition): D. H. Perkins.
2. Intermediate Energy Nuclear Physics: W. O. Lock and D. F. Measday.

PHY 304A: Computational Physics-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Computer Fundamentals and Programming in FORTRAN (12 hrs.)

Basic Computer Organization: Input unit, Output unit, Storage unit, Arithmetic logic unit, Control unit, Central processing unit, The system concept. Fortran Programming: Data types, Arithmetical and logical expressions, Input-Output statements, IF statement, DO statement, Arrays and subscripted variables, Functions and subroutines, Handling of files. Computer programs for arranging numbers in ascending and descending orders, Matrix multiplication.

Unit II: Errors and Solution of Algebraic Equations (12 hrs.)

Errors: Round off error, Truncation error, Machine error, Random error, Propagation of errors. Loss of Significance: Significant Digits, Computer caused loss of significance, Avoiding loss of significance in subtraction. Solutions of algebraic equations: Bisection method, Iteration method, Method of false position, Newton-Raphson method, Muller’s method, Quotient-Difference method, Secant Method.

Unit III: Interpolation and Curve fitting (12 hrs.)

Interpolation and Extrapolation: Finite differences, Forward differences, Backward differences, Central differences, Newton’s formula for interpolation, Gauss central difference formula, Stirling’s formula, Bessel’s formula, Lagrange’s interpolation formula, Hermite’s interpolation formula. Least square curve fitting: The principle of least square fitting, Linear regression, Polynomial regression, Fitting exponential and trigonometric functions, Data fitting with cubic splines.

Unit IV: Systems of Linear Equations and Eigenvalue Problem (12 hrs.)

Solutions of simultaneous linear algebraic equations: Gauss elimination method, Gauss Jordan elimination method, Doolittle method, Matrix inversion method, Ill-conditioned matrix and error correction, Jacobi Method, Gauss seidel iterative method, Matrix eigenvalues and eigenvectors: Polynomial method, Power method.

Reference Books:

1. William E. Mayo and Martin Cwiakala, Programming with Fortran 77, Schaum’s outline serios, McGraw Hill, Inc.
2. Pradeep K Sihna and Priti Sinha, Foundation of Computing, BPB Publication.
3. F B Hildebrand, Introduction to Numerical Analysis, Tata McGraw Hill, New Delhi.
4. R C Desai, Fortran Programming and Numerical methods, Tata McGraw Hill, New Delhi.
5. Suresh Chandra, Computer Applications in Physics, Narosa Publishing House.
6. William H. Press, Saul A Teukolsky, William T Vellerling and Brain P. Flannery, Numerical Recipes in Fortran, Cambridge University Press.
7. S S Sastry Introductory methods of numerical Analysis, Prentice Hall of India Pvt. Ltd.
8. V Rajaraman, Computer Oriented Numerical Method, Prentice Hall of India Pvt. Ltd.
9. C Balachandra Rao and C K Santha, Numerical Methods, University Press
10. K E Atkinson, An introduction to numerical analysis, John Wiley and Sons.
11. P B Patil and U. P. Verma, Numercal Computational Methods, Narosa Publishing House

PHY 304B: Electronics-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Operational Amplifier (12 hrs.)

Differential amplifier, inverting and non-inverting inputs, analysis of inverting and non-inverting amplifier, Effect of negative feedback on input resistance, output resistance, Band width; closed loop gain and offset voltage, Voltage follower, Input bias current, input off-set current, total output offset voltage, CMRR. DC and AC amplifier, Summing, Scaling, instrumentation amplifier, integrator and differentiator, log & antilog Amplifiers, comparators, waveform generators and Regenerative comparator (Schmitt Trigger) using 741 opamp. Oscillator principles, oscillator types, frequency stability, frequency response, Phase shift oscillator.

Unit II: Modulation & Communication (12 hrs.)

PLL using IC, Active Filters (Butter-worth 1st and 2nd order), Amplitude Modulation, generation of AM waves, Demodulation of AM waves. Frequency modulation, Block diagram of transmitter and super hytrodyne receiver, Digital communication, basic idea about delta modulation, PCM and PWM, Block diagram of Radar and radar range equation.

Unit III: Digital electronics (12 hrs.)

Q.M. method for the simplification of Boolean functions (upto 4 variables), Exclusive OR gate, Decoder, Demultiplexer, multiplexer and encoder. Flip-flops RS, JK, MSJK, D Type Flip-flop, Analog computation, Time scaling, Amplitude sealing, ROM and its applications, Random Access Memory, D/A Converters: Weighted resister, R-2R ladder, Specifications for D/A converter, A/D converter: Quantization and Encoding, Parallel Comparator, Successive Approximation, A/D converter using Voltage-to-Frequency conversion and Voltage-to-Time conversion, Sample and Hold circuit, Solution of linear differential equation with constant coefficient using analog computer.

Unit IV: Microprocessor (12 hrs.)

Microcomputer systems and Hardware, Microprocessor architecture and Microprocessor system, instruction and timing diagram, introduction to 8085 basic instructions (Arithmetic operation, logic operation, branch operation), 16 bit arithmetic instructions, arithmetic operation related to memory, Rotate and compare instructions. Stack and subroutines, Programing of 8085 using instructions, Introduction to Microcontroller.

Reference Books:

1. Integrated electronics - MiIlman & Halkias.
2. Microprocessor and Interfacing - D. V Hall.
3. Microprocessor Architecture Prog. & Appls. - S. Gaonkar, Wiley-Estern
4. Micro Electronics - Millman & Grabel.
5. Digital Computer Electronics - AP. Malvino.
6. Advanced Electronic Communication System-Wayne Tomasi Phi. Edn.
7. Electronic communication system by Kennedy.
8. Modern digital electronics by R. P. Jain

PHY 304C: Material Science-I

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Imperfections in Solids (12 hrs.)

Point Defects: vacancy, substitutional, interstitial, Frenkel and Schottky defects, equilibrium concentration of Frenkel and Schottky defects**;** Line Defects: slip planes and slip directions, edge and screw dislocations, Burger’s vector, cross-slip, glide and climb, jogs, dislocation energy, super & partial dislocations, dislocation multiplication, FrankRead sources; Planar Defects: grain boundaries and twin interfaces; Dislocation Theory – experimental observation of dislocation, dislocations in FCC, HCP and BCC lattice.

Unit II: Mechanical Properties (12 hrs.)

Stress Strain Curve; Elastic Deformation: atomic mechanism of elastic deformation and anisotropy of Young's modulus, elastic deformation of an isotropic material; Anelastic and Viscous deformation; Plastic Deformation: Schmid’s law, critically resolved shear stress; Strengthening Mechanisms: work hardening, recovery, recrystallization, strengthening from grain boundaries, low angle grain boundaries. yield point. strain aging, solid solution strengthening, two phase aggregates, strengthening from fine particles; Fracture: ideal fracture stress, brittle fracture-Griffith's theory, ductile fracture.

Unit III: Microstructure (12 hrs.)

Solid Solutions and Intermediate Phases: phase rule, unitary & binary phase diagrams, Lever rule, Hume-Rothery rule; Free Energy and Equilibrium Phase Diagrams: complete solid miscibility, partial solid miscibility-eutectic, peritectic and eutectoid reactions, eutectaid mixture; Nucleation, Growth and Overall Transformation Kinetics; Martenstic Transformation; The Iron-Carbon System: various phases, phase diagram, phase transformations, microstructure and property changes in iron-carbon system; Ceramics: glass transition temperature, glassformers, commercial ceramics, mechanical properties. high temperature properties.

Unit IV: Materials Processing and Characterization (12 hrs.)

Ion Implantation: introduction, ion implantation process, depth profile, radiation damage and annealing effects of trace-impurities, implantation induced alloying and structural phase transformation; Rutherford Backscattering Spectrometry (RBS): principle, kinematics of elastic collision, shape of the backscattering spectrum, depth profiles and concentration analysis, applications; Elastic Recoil Detection Analysis (ERDA): basic principle, kinematics, concentration analysis, depth profiling, depth resolution, applications; Secondary Ion Mass Spectroscopy (SIMS): basic principle, working, yield of secondary ions and applications.

Reference Books:

1. Material Science by J. C. Anderson, K. D. Leaver, J. M. Alexander and R. D. Rawlings
2. Mechanical Metallurgy by G. E. Dieter
3. Ion Implantation by G. Dearnally
4. Fundamentals of Surface and Thin Film Analysis by L. C. Feldman and J. W. Mayer
5. Surface Analysis Methods in Material Science by D. J. O’Connor, B. A. Sexton and R. St. C. Smart (Eds), Springer Series in Surface Sciences 23

PHY 305: Physics Laboratory-III

Max. Marks: 120
Time: 5 Hours

Note: Unlike the M. Sc. First Year Laboratory, experiments in the Final Year Laboratory are based upon six different specializations. In this course, students shall complete at least seven experiments from one of the two allotted specializations. Experiments corresponding to the second specialization will be undertaken in the 4th semester. Besides continuous assessment of students through internal viva-voce examination of the experiments performed, there shall be end-semester laboratory examination wherein each student will be required to perform at least one experiment as per paper setting by a duly appointed panel of examiners. The evaluation will be made on the basis of performance of students in (i) experiment, (ii) report and analysis of the experiment and (iii) viva-voce examination.

List of specialization-wise experiments is given as under[4]:

Condensed Matter Physics

C1 Band Gap of a given semiconductor material using Four-Probe method.
C2 Study of Hall effect for a bulk semiconducting material.
C3 Temperature dependence of Hall coefficient.
C4 Dispersion of lattice vibrations using electrical analogue of real lattice.
C5 Magnetic susceptibility of hydrated copper sulfate.
C6 Lattice parameter and Miller Indices using XRD.
C7 Transition temperature of ferrites.
C8 Study of the phenomenon of magneto-resistance.
C9 Electron paramagnetic resonance experiment.
C10 Thermo-luminescence studies.
C11 High temperature superconductivity experiment.

Nuclear Physics

N1 $\chi2$-Statistics using G. M. Counter
N2 Range of alpha particles in air using Spark Counter.
N3 Resolving Time of G. M. Counter set-up.
N4 Resolving Time of a Fast Coincidence Circuit.
N5 (a) Thickness of Al Sheet using G. M. Counter. (b) Gamma Ray Absorption Experiment.
N6 Study of Energy Resolution of Gamma Ray Detector as a function of $E_{\gamma.}$
N7 Efficiency Determination of NaI (Tl) Detector.
N8 Study of Alpha-Spectrometer.
N9 Compton Scattering Experiment.
N10 Rutherford Back Scattering Experiment.
N11 Finding the wavelength for the characteristic K_α and K_β x-ray radiation of molybdenum using XRD.

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[4] New experiments may be added to this list from time to time.

Particle Physics

P1 Angular distribution of shower tracks.

P2 Mean Multiplicity of shower, grey and black tracks.

P3 In-elasticity of an interaction for shower particles.

P4 Momentum distribution of shower particles.

P5 Classification of Nuclear Interaction Star Tracks and Determination of Excitation energy.

P6 Nuclear Statistics using Solid State Nuclear Track Detector.

P7 To determine the mean free path for relativistic nucleus-nucleus interactions.

P8 To determine fusion to alpha branching ratio in spontaneous emission of ^{252}Cf.

P9 Relativistic Kinematics.

Computational Physics

CP1 Numerical Integration using (a) Simpson 1/3 and (b) Gauss quadrature methods for one and two-dimensional integrals.

Application: Show that the function f(x)

$$f(x) = \frac{n}{\pi} \frac{1}{1+n^2 x^2}$$

behaves like the Dirac delta function for large *n*.

CP2 Least Square fitting (Linear).

CP3 Solution of second-order differential equation using Runge-Kutta method.
Application: Eigenvalues and eigenfunctions of a linear harmonic oscillator using Runge-Kutta method.

CP4 To find roots of an equation of degree 1, 2 and 3 by using Bisection method.

CP5 Solution of Simultaneous Linear Algebraic equations by Gauss-Jordan elimination method.
Application: Illustration of Kirchoffs laws for simple electric circuits.

CP6 Interpretation and Extrapolation by using Lagrangian method.

CP7 Finding eigenvalues and eigenvectors of square matrices.

CP8 Simulation of Nuclear Radioactivity by Monte Carlo Technique.

CP9 Dynamics of logistic equations.

Electronics

E1 Negative feedback Amplifiers: Measurement of gain vs. frequency

E2 Determination of h-parameters of transistor

E3 Monostable Multivibrator: Measurement of pulse width for various time constants

E4 To study Ripple Counter

E5 To study Schmitt Trigger using transistor and OPAMP

E6 FET: Study of static drain characteristics and calculations of various parameters

E7 To study 4 bit Shift Register
E8 Flip-Flops: RS, Choked RS, JK, Master slave JK, D and T types
E9 OPAMP-I: Measurement of various parameters
E10 OPAMP-II: Applications as Adder, Subtracter, differentiator, integrator and voltage follower
E11 To study 8085 Microprocessor and its applications
E12 8 bit A/D converter: Verification of truth table
E13 8 bit D/A converter: Verification of truth table

Material Science

M1 Band Gap of a given semiconductor material using Four-Probe method.
M2 Study of Hall effect.
M3 Lattice parameter and Miller Indices using XRD.
M4 Determination of particle size and lattice strain using XRD.
M5 Magnetic susceptibility of hydrated copper sulfate.
M6 Dielectric constant of a given material.
M7 Solar cell characteristics.
M8 Transition temperature of a ferroelectric material.
M9 Study of the phenomenon of magneto-resistance.
M10 Estimation of effect of sun tracking on energy generation by solar PV module.
M11 Thermo-luminescence studies.
M12 High temperature superconductivity experiment.

M. Sc. Physics (Semester-IV)

PHY 401: Electrodynamics and Plasma Physics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Electrostatics (12 hrs.)

Electric Field, Gauss Law, Differential form of Gauss Law, Electromagnetic scalar and vector potentials, Maxwell’s equations in terms of scalar and vector potentials, Non uniqueness of Electromagnetic potentials and concept of Gauge. Lorentz gauge and coulomb gauge. Boundary value problem, Poisson and Laplace equations, Solution of Laplace equation in Rectangular coordinates, Green’s Theorem, Dirichlet and Neumann boundary conditions, Formal solution of boundary value problem with Green’s function, Electrostatic potential energy and energy density.

Unit II: Method of Images & Special Theory of Relativity (12 hrs.)

Point charge near an infinite good conducting plane, Point charge in the presence of grounded conducting sphere, Point charge in the presence of charged, insulated conducting sphere, Point charge near a conducting sphere at fixed potential, Conducting sphere in a uniform electric field. Review of Four vectors and Lorentz transformation in four dimensional space, Mathematical properties of the space-time of special relativity, Electromagnetic field tensor and covariance of Electrodynamics under Lorentz transformation.

Unit III: Electromagnetic Waves and Radiation by Moving Charges (12 hrs.)

Wave equation, Reflection and Refraction of electromagnetic waves at a plane interface between dielectrics, Wave propagation in a non-conducting and conducting media, Fresnel relations, Brewster's angle, Wave guides: TE and TM modes in rectangular wave guides; Moving point charges, Retarded potentials, Lienard-Wiechart potentials for a point charge, The fields of moving charge particles, Total power radiated by a point charge: Larmor’s formula and its relativistic generalization.

Unit IV: Plasma Physics (12 hrs.)

Elementary concepts, Derivation of moment Equations from Boltzmann Equation, Plasma Oscillation, Theory of simple oscillation, Electron oscillation in a plasma, Electronic oscillations when the motion of ions is also considered. Derivation of plasma oscillation using Maxwell's equation, Propagation of Electro-magnetic waves in plasma containing a magnetic field Quasineutrality of plasma, Debye shielding distance, Plasma production and heating of the plasma, Confinement of plasma, plasma instabilities.

Reference Books:

1. Classical Electrodynamics by J.D. Jackson.
2. Introduction to Electrodynamics by A. Z. Capri and P. V. Panat.
3. Electrodynamics by S. P. Puri.
4. Introduction to Electrodynamics by D. J. Griffiths.
5. Introduction to Plasma Physics by F. F. Chen.
6. Introduction to Plasma Theory by D. R. Nicholson.

PHY 402: Atomic and Molecular Physics

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Atomic Physics (12 hrs.)

Spectrum of He-atom and Heisenberg resonance, Physical interpretation of quantum numbers, Pauli principle and the building-up principle, Terms for equivalent & non-equivalent electron atom, Space Quantization: Stern-Gerlach experiment, Normal & anomalous Zeeman effect, Stark Effect, Paschen – Back effect; Intensities of spectral lines: General selection rule; Hyperfine structure of Spectra lines: Isotope effect and effect of Nuclear Spin.

Unit II: Molecular Physics (12 hrs.)

Rotation of molecules: Classification of molecules, Interaction of radiation with rotating molecules, Rotational spectra of rigid diatomic molecules, Isotope effect in rotational spectra, Intensity of rotational lines, Non rigid rotator, Information derived from rotational spectra; Infrared spectroscopy: The vibrating diatomic molecule, The diatomic vibrating-rotator spectra of diatomic molecules, Infrared spectrophotometer; Raman Spectroscopy: Introduction, Pure rotational Raman spectra, Vibrational Raman Spectra, Nuclear Spin and intensity alternation in Raman spectra, Isotope effect, Raman Spectrometer.

Unit III: Electronic Spectra of diatomic molecules and Fluorescence spectroscopy (12 hrs.)

Born Oppenheimer approximation, Vibrational coarse structure of electronic bands, Progression and sequences, Intensity of electronic bands-Frank Condon Principle, Dissociation and pre-dissociation, Dissociation energy; Rotational fine structure of electronic bands, The Fortrat parabole, Electronic structure of diatomic molecules; Fluorescence spectroscopy: Fluorescence and Phosphorescence, Kasha's rule, Quantum Yield, Nonradiative transition, Jablonski Diagram, Spectrofluorometer, Time resolved fluorescence and determination of excited state lifetime.

Unit IV: Resonance Spectroscopy (12 hrs.)

NMR: Basic principles – Classical and quantum mechanical description – Bloch equations – Spin-spin and spin-lattice relaxation times – Chemical shift and coupling constant -- Experimental methods – Single coil and double coil methods – High resolution methods; ESR: Basic principles – ESR spectrometer – nuclear interaction and hyperfine structure – relaxation effects – g-factor – Characteristics – Free radical studies and biological applications.

Reference Books:

1 Concepts of Modern Physics by Arthur Beiser (McGraw-Hill Book Company, 1987).
2 Atomic spectra & atomic structure, Gerhard Hertzberg: Dover publication, New York.
3 Molecular structure & spectroscopy, G. Aruldhas; Prentice – Hall of India, New Delhi.
4 Fundamentals of molecular spectroscopy, Colin N. Banwell & Elaine M. McCash, Tata McGraw – Hill publishing company limited.
5 Introduction to Atomic spectra by H.E. White
6 Spectra of diatomic molecules by Gerhard Herzberg

PHY 403A: Condensed Matter Physics-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Electron Transport Phenomenon (12 hrs.)

Motion of electrons in bands and the effective mass tensor (semi-classical treatment), Currents in bands and holes, Scattering of electrons in bands (elastic, inelastic and electron-electron scatterings), The Boltzmann equation, Relaxation time *ansatz* and linearized Boltzmann equation; Electrical conductivity of metals, Temperature dependence of resistivity and Matthiesen's rule; Thermoelectric effects, Thermopower, Seebeck effect, Peltier effect, The Wiedemann-Franz law.

Unit II: Nanostructures and Electron Transport (14 hrs.)

Nanostructures; Imaging techniques (principle): Electron microscopy (TEM, SEM), Optical microscopy, Scanning tunneling microscopy, Atomic force microscopy; Electronic structure of 1D systems: 1D subbands, Van Hove singularities; 1D metals- Coulomb interactions and lattice couplings; Electrical transport in 1D: Conductance quantization and the Landauer formula, Two barriers in series- Resonant tunneling, Incoherent addition and Ohm's law, Coherence-Localization; Electronic structure of 0D systems (Quantum dots): Quantized energy levels, Semiconductor and metallic dots, Optical spectra, Discrete charge states and charging energy; Electrical transport in 0D- Coulomb blockade phenomenon.

Unit III: Beyond the independent electron approximation (12 hrs.)

The basic Hamiltonian in a solid: Electronic and ionic parts, One-electron model, The adiabatic approximation; The Hartree equations, Exchange: The Hartree-Fock approximation, Hartree-Fock theory of free electrons- Ground state energy, exchange energy, correlation energy (only concept); Screening in a free electron gas: The Dielectric function, Thomas-Fermi theory of screening, Calculation of Lindhard response function, Lindhard theory of screening, Friedel oscillations, Frequency dependent Lindhard screening (no derivation.

Unit IV: Many-particle physics: Second quantization formulation (14 hrs.)

Many-particle Schrodinger wave equation in first quantization, The single-particle states as basis states, Normalized symmetric and anti-symmetric wave functions; Second quantization: Transformation of Schrodinger equation to occupation number representation (both for bosons and fermions), Many-particle Hilbert space and creation and destruction operators; Field operators, Second-quantized from of number-density operator; Application to degenerate electron gas: First and second-quantized Hamiltonian operators, r_s parameter, Ground-state energy in first-order perturbation theory, Contact with the Hartree-Fock result, Exchange energy.

Reference Books:

1. Solid State Physics: An Introduction to Principles of Materials Science (4th Ed.) by H. Ibach and H. Luth
2. Introduction to Solid State Physics (8th Ed.) by Charles Kittel
3. Solid State Physics by Neil W. Ashcroft and N. David Mermin
4. The Wave Mechanics of Electrons in Metals by Stanley Raimes
5. Quantum Theory of Many-particle Systems by A. L. Fetter and J. D. Walecka
6. Many-body Quantum Theory in Condensed Matter Physics by H. Bruus and K. Flensberg

PHY 403B: Nuclear Physics-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: The Two Nucleon Problem (12 hrs.)

Qualitative features and phenomenological potentials, Exchange forces, generalized Pauli principle. The ground state of deuteron, Range-depth relationship for square well potential. Neutron-Proton scattering at low energies (below 10 Mev), Concept of scattering length and its interpretation, Spin dependence of neutron-proton scattering, Effective range theory of n-p scattering, Coherent scattering of neutrons on ortho and para hydrogen, Magnetic moment and its importance in the determination of exact ground state of deuteron.

Unit II: Nuclear Reaction Theory (12 hrs.)

Nuclear reactions and cross sections, Resonance : Breit-Wigner dispersion formula for $\ell = 0$, Breit-Wigner dispersion formula for all values of ℓ, The compound nucleus, Continuum theory of cross section σ_C, Statistical theory of nuclear reactions, Evaporation probability and cross sections for specific reactions, Kinematics of the stripping and pick-up reactions, Theory of stripping and pick-up reactions.

Unit III: Nuclear Models-I (12 hrs.)

Liquid drop model, Outlines of Bohr and Wheeler theory of nuclear fission, Concept of magic numbers, The properties of magic nucleus, Nuclear Shell Model, Predictions of shell closure on the basis of harmonic oscillator potential, Need of introducing spin-orbit coupling to reproduce magic numbers. Extreme single particle model and its predictions regarding ground state spin parity, magnetic moment and electric quadrupole moments.

Unit IV: Nuclear Models-II (12 hrs.)

Nuclear surface deformations, General parameterization, Types of multipole deformations, Quadrupole deformations, Symmetries in collective space, Surface vibrations, Vibrations of a classical liquid drop, The Harmonic quadrupole oscillator, The collective angular momentum operator, The collective quadrupole operator, Quadrupole vibrational spectrum, Rotating nuclei, The rigid rotor, The symmetric rotor, The asymmetric rotor.

Reference Books:

1. R. R. Roy and B. P. Nigam, “Nuclear Physics: Theory and Experiment”, Wiley Eastern Limited, 1993.
2. M. K. Pal, “Theory of Nuclear Structure”, Affiliated East-West Press, New Delhi.
3. Greiner and Maruhn, “Nuclear Models”, Springer, 1996
4. W. E. Burcham, “Nuclear Physics : An Introduction”, Longman Group Limited, London, 1973.
5. R. G. Sachs, “ Nuclear Theory”, Addison-Wesley Publishing Company, Cambridge, 1955.
6. K. S. Krane, “Introductory Nuclear Physics”, Wiley India Pvt. Ltd., 2008

PHY 403 C: Particle Physics-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Weak Interactions (10 hrs.)

Classification of weak interactions- Leptonic, semi-leptonic and non-leptonic decays; pion and muon decay, helicity of neutrino and anti-neutrino, C-P invariance and violation in K^0 decay, $\pi \rightarrow \mu$ and $\pi \rightarrow e$ branching ratios, weak decay of strange particles- selection rules for non-leptonic and semi-leptonic decays, suppression of $\Delta S=1$ transitions in comparison to $\Delta S=0$ transitions- Cabibbo theory.

Unit II: Relativistic Kinematics (12 hrs.)

Concept of 4-vector notation and its importance, Calculation of centre of mass energy for two particles colliding in lab frame, advantage of colliding beam experiments in comparison to fixed target experiments, derivation of expression to calculate threshold energy of the projectile hitting a stationary target resulting in production of additional particles (examples like $pp \rightarrow pppp$, $pp\pi$, ppk^+k^- ppk^0 k^0, Σ^+k^0 p etc.), calculation of energies of the decay products in the rest frame of the decaying particle from the two body decay like $A \rightarrow B + C$.

Unit III: Passage of Charged Particles Through Matter (12 hrs.)

Ionization loss of charged particles, derivation of stopping power equation for electronic loss based on impact parameter approach, Bethe-Bloch formula (no derivation), concept of effective charge, Shell and Density effect corrections, scaling law and its importance, nuclear energy Loss, radiation loss of electrons- Bremsstrahlung process, emission of Cerenkov radiations at relativistic velocities, stopping power in compounds- Bragg’s additivity rule, concept of energy loss straggling- collisional and charge exchange straggling.

Unit IV: Particle Detectors and Accelerators (14 hrs.)

Nuclear emulsion detector- principle and mechanism for charged particle detection, nuclear emulsion as a 4π detector, advantage of nuclear emulsion in relativistic hadron-nucleus interactions (multiplicity, momentum, energy distributions of produced particles); Solid state nuclear track detectors- principle and mechanism of detection of nuclear charged particles, Ion-explosion spike model and its predictions, restricted energy loss model for organic detectors; Basic principle of working of cloud chamber, bubble chamber, cerenkov counter; Calorimeters- formation of electromagnetic and hadron showers; Principle of neutrino detection Accelerators: Principle and important features of Linear accelerator (LINACs), cyclic accelerator (synchrotrons): electron synchrotron, colliding beam machine, Introduction to Large Hadron collider, Introduction to Higg’s boson and status of experimental discovery.

Reference Books:

1. Introduction to High Energy Physics (2nd and 4th edition): D. H. Perkins.
2. Solid State Nuclear Tracks Detection, 'Principle Methods and Applications: S. A. Durrani and R. K. Bull.
3. Nuclear Tracks in Solids: Principles and Applications (1975): R. L. Fleischer, P. B. Price & R. M. Walker

PHY 404A: Computational Physics-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Differentiation and Integration (12 hrs.)

Differentiation: Taylor series method, Numerical differentiation using Newton's forward difference formula, Backward difference formula, Stirling's formula, Cubic splines method; Integration: Trapezoidal rule, Simpson's 1/3 rule, Gaussian Quadrature, Legendre–Gauss Quadrature, Numerical double integration, Numerical integration of singular integrals.

Unit II: Solution of Differential Equations (12 hrs.)

Numerical solution of ordinary differential equations: Taylor's series method, Euler's method, Forth-order Runge Kutta method, Cubic splines method; Second order differential equations: Initial and boundary value problems, Numeric solution of Radial Schrodinger equation for Hydrogen atom using Forth-order Runge-Kutta method(when eigenvalue is given), Numerical Solutions of Partial Differential Equations Using Finite Difference Method.

Unit III: Random Numbers and Chaos (12 hrs.)

Random numbers: Random number generators, Mid-square methods, Multiplicative congruential method, Mixed multiplicative congruential methods, Modeling radioactive decay. Hit and miss Monte-Carlo methods, Monte-Carlo calculation of π, Monte-Carlo evaluation of integration, Evaluation of multidimensional integrals; Chaotic dynamics: Some definitions, The simple pendulum, Potential energy of a dynamical system. Portraits in phase space: Undamped motion, Damped motion, Driven and damped oscillator.

Unit IV: Simulation of selected physics problems (12 hrs.)

Algorithms to simulate interference and diffraction of light, Simulation of charging and discharging of a capacitor, current in LR and LCR circuits, Computer models of LR and LCR circuits driven by sine and square functions, Computer model of Rutherford scattering experiment, Simulation of electron orbit in H_2 ion.

Reference Books:

1. F B Hildebrand, Introduction to Numerical Analysis, Tata McGraw Hill, New Delhi.
2. R C Desai, Fortran Programming and Numerical methods, Tata McGraw Hill, New Delhi.
3. Suresh Chandra, Computer Applications in Physics, Narosa Publishing House.
4. William H. Press, Saul A Teukolsky, William T Vellerling and Brain P. Flannery, Numerical Recipes in Fortran, Cambridge University Press.
5. M L De Jong, Introduction to Computation Physics, Addison-Wesley publishing company.
6. R C Verma, P K Ahluwalia and K C Sharma, Computational Physics an Introduction, New Age International Publisher.
7. S S Sastry Introductory methods of numerical Analysis, Prentice Hall of India Pvt. Ltd.
8. V Rajaraman, Computer Oriented Numerical Method, Prentice Hall of India Pvt. Ltd.
9. C Balachandra Rao and C K Santha, Numerical Methods, University Press
10. K E Atkinson, An introduction to numerical analysis, John Wiley and Sons.

PHY 404B: Electronics-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: IC Fabrication-I (12 hrs.)

Silicon planar process, crystal growth, wafer production, thermal oxidation, high pressure oxidation, concentration enhanced oxidation, chlorine oxidation, lithography & pattern transfer, etching process, factors affecting the etching process, HF-$HN0_3$ system, dopant addition, ion implantation, diffusion, diffusion in concentration gradient, Fick's Laws, diffusivity variation, Segregation, CVD, epitaxial and non-epitaxial films.

Unit II: IC Fabrication-II (12 hrs.)

Monolithic IC technology, BJT Fabrication, PNP transistor, multi-emitter Schottky transistor, superbeta transistor fabrication, Fabrication of FET/NMOS enhancement as well as depletion transistor, Fabrication of CMOS devices, Monolithic diodes, Clean rooms & their classifications.

Unit III: MOS systems & SPICE (12 hrs.)

Metal semiconductor contacts, ideal MS contacts, Schottky barriers and ohmic contacts, oxide and interface charges, origin of oxide charges, the MOS structure, Effect of bias voltage, capacitance of MOS system, Introduction to electrical computer simulation, SPICE and its evaluations, Electrical circuit specifications, The SPICE DC analysis.

Unit IV: Combinational logic design using IC (12 hrs.)

Adders and their use as Substractors, Ripple counters, Sequential logic design, Shift registers, Application of shift registers as delay line, serial to parallel converter, parallel to serial converter, ring counter, twisted ring counter, sequence generator, synchoronous counter design, up-down counter, Asynchronous versus synchronous sequential circuits, Applications of Asynchronous sequential circuits, Asynchronous sequential machine modes, Asynchronous sequential circuit design.

Reference Books:

1. Integrated electronics - MuIlman & Halkias.
2. Microprocessor and Interfacing - D. V Hall.
3. Theory and Application of Micro Electronics - S.K. Gandhi.
4. Micro Electronics - Millman & Grabel.
5. Digital Computer Electronics - AP. Malvino.
6. Device Electronics for Integrated Circuits - Muller & Kamins.
7. P SPICE -Rashid.
8. VLSI Fabrication Principal & Practice - S.K. Gandhi.
9. Advanced Electronic Communication System-Wayne Tomasi Phi. Edn:
10. Microprocessor Architecture Prog. & Appls.- S. Gaonkar, Wiley-Estern.
11. Electronic Devices & Circuit Theory- Robert Boylested & Louis Nashdky PHI New Delhi.
12. Opamps & Linear Integrated Circuits- RA. Gayakwad, PHI, 1991.
13. Opamps - David A. Bell.
14. Semiconductor Devices Physics & Technology - S.M. Sze.
15. Microcontrollers - Ayala Panram Pub.
16. Modern Digital Electronics – R. P. Jain

PHY 404C: Material Science-II

Max. Marks: 60
Time: 3 Hours

Note: Nine questions will be set and students will attempt five questions. Question No. 1 will be compulsory and will consist of 4-6 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be four units in the question paper with each unit consisting of two questions taken from the corresponding units of the syllabus. Students will select one question from each unit. The question paper is expected to contain problems to the extent of 20% of total marks.

Unit I: Material Testing (12 hrs.)

The Tension Test: engineering stress-strain curve, true stress-strain curve, instability in tension, Considere's construction, ductility measurement, effect of strain rate on flow properties, strain rate sensitivity; notch tensile test; The Hardness Test: Brinell hardness, Meyer hardness, Vicker's hardness number and test, Rockwell hardness test, Knoop hardness number and test; The Impact Test: brittle fracture problem, notched bar impact tests-Carpy and Izod Impact tests; The Fatigue Test: fatigue failures, stress cycles, the S-N curve, fatigue limit; The Creep Test: creep curve, primary, secondary and tertiary creep, effect of temperature and stress on the creep curve.

Unit II: Magnetic Materials (12 hrs.)

Magnetic Processes: Larmor frequency; Diamagnetism, magnetic susceptibility, Langevin's diamagnetism equation; Paramagnetism, Curie constant, density of states curves for a metal; Ferromagnetism, Curie temperature, Curie-Weiss law, exchange interactions, domain structure; Antiferromagnetism and magnetic susceptibility of an antiferromagnetic material; Ferrimagnetism and Ferrites; Paramagnetic, ferromagnetic and cyclotron-resonance.

Unit III: Dielectice, Optical and Ferroelectric Materials (12 hrs.)

Introduction, Energy bands, dielectric constant, complex permittivity, dielectric loss factor, polarization, mechanism of polarization, classification of dielectrics-frequancy dependence of dielectric constant; Optical absorption, transmission and reflection, refractive index, color; Ferro, para and pyro-electric states, transition temperature, classification of ferro electric crystals, polarization catastrophe, Landau theory of first and second-order phase transitions, antiferroelectricity, ferro electric domains.

Unit IV: Solid Surfaces and Analysis (12 hrs.)

Surface and its importance, selvedge depths of surface; Methods of Surface Analysis: Auger Electron spectroscopy (AES)- basic principle, methodology, composition analysis and depth profiling; X-ray photoelectron spectroscopy (XPS) or ESCA: principle, methodology and quantitative analysis; Glancing angle X-ray Diffraction (GXRD), basic concept, methodology and structural analysis; Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM): Principle, methodology and Applications in surface analysis; Atomic Force Microscopy (AFM): Basic principle, Methodology, applications in structural analysis.

Reference Books:

1. Material Science, J.C. Anderson, K.D. Leaver, J. M. Alexander and R. D. Rawlings
2. Mechanical Metallurgy, G.E. Dieter.
3. Electronic Processes in Materials, L. V. Azaroff and J. J. Brophy
4. Fundamentals of Surface and Thin Film Analysis, L.C. Feldman and J. W. Mayer
5. Surface Analysis Methods in Material Science, D. J. O'Connor, B. A. Sexton and R. St. C. Smart (Eds), Springer Series in Surface Sciences 23

PHY 405: Physics Laboratory-IV

Max. Marks: 120
Time: 5 Hours

Note: Unlike the M. Sc. First Year Laboratory, experiments in the Final Year Laboratory are based upon six different specializations. In this course, students shall complete at least seven experiments from the the second specialization. Pattern of evaluation and list of specialization-wise experiments is already given in the course PHY 305.