KURUKSHETRA UNIVERSITY, KURUKSHETRA

(Established by the State Legislature Act XII of 1956)

(“A$^+$” Grade, NAAC Accredited)

Structure and Syllabus of

M. Sc. PHYSICS (Ist to IVth Semesters) Course

Under CBCS-LOCF

(Effective from the Academic Session 2020-21)

In phased manner

Department of Physics

Kurukshetra University

Kurukshetra - 136 119

Haryana (INDIA)

Structure and Syllabus of
M. Sc. PHYSICS (Ist to IVth Semesters) Course
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SEMESTER I

Course Code	**Course Title**	**Credits**	**Teaching Hours per week**	**Maximum Marks**			**Duration of Exam.**
				Internal Assessment*	End-semester Examination	Total	**Hours**
PHY 101	Mathematical Physics	4	4	20	60	80	3
PHY 102	Classical Mechanics	4	4	20	60	80	3
PHY 103	Quantum Mechanics-I	4	4	20	60	80	3
PHY 104	Electronic Devices and Circuits-I	4	4	20	60	80	3
PHY 105	Physics Laboratory-I	8	20	40	120	160	5
Total Credits/Marks		**24**				**480**	

SEMESTER II

Course Code	**Course Title**	**Credits**	**Teaching Hours per week**	**Maximum Marks**			**Duration of Exam.**
				Internal Assessment*	End-semester Examination	Total	**Hours**
PHY 201	Quantum Mechanics-II	4	4	20	60	80	3
PHY 202	Nuclear and Particle Physics	4	4	20	60	80	3
PHY 203	Solid State Physics	4	4	20	60	80	3
PHY 204	Electronic Devices and Circuits-II	4	4	20	60	80	3
PHY 205	Physics Laboratory-II	8	20	40	120	160	5
PHY 206	Seminar**	2[1]	2			40	40 minutes
Open Elective Paper-I (*Course code and course title as per choice made by the student*)		2	2	15	35	50	1.30
Total Credits/Marks		**28**				**570**	

SEMESTER III

Course Code	Course Title	Credits	Teaching Hours per week	Maximum Marks			Duration of Exam. Hours
				Internal Assessment*	End-semester Examination	Total	
PHY 301	Electrodynamics and Plasma Physics	4	4	20	60	80	3
PHY 302	Statistical Mechanics	4	4	20	60	80	3
Any one of the following subject electives/specializations$		4	4	20	60	80	3
PHY 303A	Condensed Matter Physics-I						
PHY 303B	Nuclear Physics-I						
PHY 303C	Particle Physics-I						
Any one of the following subject electives/specializations$		4	4	20	60	80	3
PHY 304A	Computational Physics-I						
PHY 304B	Electronics-I						
PHY 304C	Material Science-I						
PHY 305	Physics Laboratory-III	8	20	40	120	160	5
Open Elective Paper-II (*Course code and course title as per choice made by the student*)		2	2	15	35	50	1.30
Total Credits/Marks		**26**				**530**	

SEMESTER IV

Course Code	Course Title	Credits	Teaching Hours per week	Maximum Marks			Duration of Exam. Hours
				Internal Assessment*	End-semester Examination	Total	
PHY 401	Advanced Quantum Mechanics	4	4	20	60	80	3
PHY 402	Atomic and Molecular Physics	4	4	20	60	80	3
Same electives/specializations are to be taken as in Semester III		4	4	20	60	80	3
PHY 403A	Condensed Matter Physics-II						
PHY 403B	Nuclear Physics-II						
PHY 403C	Particle Physics-II						
Same electives/specializations are to be taken as in Semester III		4	4	20	60	80	3
PHY 404A	Computational Physics-II						
PHY 404B	Electronics-II						
PHY 404C	Material Science-II						
PHY 405	Physics Laboratory-IV/Project***	8	20	40	120	160	5
PHY 406	Seminar**	2	2			40	40 minutes
Total Marks		**26**				**520**	

** Seminar will be held once a week during the laboratory hrs.

Open Elective Papers

For the Students of M.Sc. Physics

A student will earn four credits by way of selecting one open elective paper of two credits in second semester and one more such paper of same credits in third semester, out of the open elective papers offered by the departments/institutes on the campus other than the Department of Physics or MOOCs.

For the Students of Other Departments/Institutes on the campus

The Department of Physics offers the following open elective papers to the students of other departments/institutes on the campus. A paper shall be run only if the number of students opting for it is at least 20. There will be an upper limit of 50 students in each paper. Open elective papers will be allotted by the Chairperson as per university norms.

Course Code	**Course Title**	**Credits**	**Teaching Hours per week**	**Maximum Marks**		
				Internal Assessment*	End-semester Examination	Total
OE-208 (For 2nd Semester)	Elements of nano-science & nano-technology	**2**	**2**	**15**	**35**	**50**
OE-308 (For 3rd Semester)	Radiation Physics	**2**	**2**	**15**	**35**	**50**

Total Marks of all Four Semesters

Semester	**Marks**	**Credits**
Semester I	480	24
Semester II	570	28
Semester III	530	26
Semester IV	520	26
Grand Total	2100	104

*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.

** 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.

***Total number of students' project offered will be one per faculty member per year, and allotment will be made on the basis of merit cum preference of the students. Students opting for project will be exempted from the corresponding laboratory course.

$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.

Program Outcomes (POs) for Post Graduate Programs (CBCS) in the Faculty of Sciences, Kurukshetra University, Kurukshetra

PO1	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge gained during course of study
PO2	Research Aptitude	Capability to ask relevant/appropriate questions for identifying, formulating and analyzing the research problems and to draw conclusion from the analysis
PO3	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large
PO4	Problem Solving	Capability of applying knowledge to solve scientific and other problems
PO5	Individual and Team Work	Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.
PO6	Investigation of Problems	Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions
PO7	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices
PO8	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices
PO9	Life-Long Learning	Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout life
PO10	Ethics	Capability to identify and apply ethical issues related to one's work, avoid unethical behaviour such as fabrication of data, committing plagiarism and unbiased truthful actions in all aspects of work
PO11	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects

Program Specific Outcomes (PSOs)

After successful completion of M. Sc. Physics program, the students will

PSO1	Acquire an in-depth understanding and knowledge of the core areas of Physics encompassing mathematical physics, classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics for explicating physical phenomena covering wide length and time scales.
PSO2	Be capable of applying the core physical laws to unravel multitude of physical properties, processes, and effects involving radiation, nuclei, atoms, molecules, and bulk forms of matter.
PSO3	Develop hands-on skills for carrying out elementary as well as advanced experiments in different sub-fields of Physics viz. condensed matter physics, nuclear physics, particle physics, materials science, computational physics & electronics, along with enhancing their understanding of physical concepts and theories.
PSO4	Attain abilities of critical thinking, problem mapping & solving using fundamental principles of Physics, systematic analysis & interpretation of results, and unambiguous oral & writing/presentation skills.
PSO5	Have robust foundation in basic and practical aspects of Physics enabling them to venture into research in front-line areas of physical sciences, and career as Physics teachers and scientists.

DETAILED COURSES OF STUDY

M. Sc. Physics (Semester I)

PHY 101: Mathematical Physics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Mathematical Physics, a student will be able to:

PHY101.1 *Learn basics of group theory and prepare group multiplication tables*.
PHY101.2 *Understand reducible and irreducible group representations and construct character table of symmetry groups of equilateral triangle, rectangle and square*.
PHY101.3 *Find the Fourier series expansion and develop Fourier integrals.*
PHY101.4 *Learn properties of Fourier and Laplace transforms and evaluate the Fourier and Laplace transforms of functions and derivatives.*
PHY101.5 *Obtain explicit expressions of Bessel and Legendre polynomials by solving the concerned differential equations.*
PHY101.6 *Find explicit expressions of Hermite, Laguerre, Bessel and Legendre polynomials using the corresponding generating functions and derive various recurrence relations among these special functions.*
PHY101.7 *Derive Cauchy integral theorem and Cauchy integral formula and find Taylor and Laurent series expansion of functions of complex variable.*
PHY101.8 *Understand the calculus of residue and evaluate some typical definite integral using the method of contour integration.*

Unit I: Group Theory (14 hrs.)

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.

Group representation: Reducible and irreducible representations, great orthogonality theorem (without proof) 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 II: Fourier Series and Integral Transforms (12 hrs.)

Fourier series, General properties, Advantages and applications, Gibbs phenomenon, Development of the Fourier integral, Inversion theorem, Fourier transform, Fourier transform of derivatives, Momentum representation, Laplace transform, Laplace transform of derivative, Properties of Laplace transforms, Faltungs theorem, Inverse Laplace transformation.

Unit III: Special Functions (12 hrs.)

Bessel Functions: Bessel functions of the first kind $J_n(x)$, Generating function, Recurrence relations, 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, Rodrigues' formula, Orthogonality of $P_n(x)$; Associated Legendre polynomials, Spherical harmonics, Addition theorem for spherical harmonics, Hermite and Laguerre Polynomials: generating function & recurrence relations only.

Unit IV: Functions of a complex variable and calculus of residues (10 hrs.)

Complex algebra, Functions of a complex variable, Cauchy’s integral 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: $\int_0^{2\pi} f(\sin\theta, \cos\theta)\, d\theta$; $\int_{-\infty}^{\infty} f(x)dx$; $\int_{-\infty}^{\infty} f(x)e^{iax}dx$ using Cauchy’s residue theorem.

Exercises in this unit are at the level of those given in book at Ref. No. 2.

References:

1. Group Theory and Quantum Mechanics by M. Tinkam.
2. Mathematical Methods for Physicists (4th edition) by G. Arfken.
3. Mathematical Methods for Physicists (6th edition) by Arfken and Weber.
4. Mathematical Physics for Physicists & Engineers by L. Pipes.
5. Introduction to Mathematical Physics by C. Harper

PHY 102: Classical Mechanics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Classical Mechanics, a student will be able to:

PHY102.1 *Demonstrate a basic and advanced knowledge of Lagrangian and Hamiltonian Formulations and solve related problems.*
PHY102.2 *Identify the cyclic coordinates and understand their importance in Hamiltonian formulation.*
PHY102.3 *Acquire knowledge of canonical Transformation and various generating functions for this transformation.*
PHY102.4 *Develop a deep understanding to tackle the problems of classical mechanics under small oscillations.*
PHY102.5 *Demonstrate the concept of motion of a particle under central force and apply advanced methods to deal with central force problems.*
PHY102.6 *Use Hamilton-Jacobi theory for finding the solutions of various Classical systems.*
PHY102.7 *Understand the foundations of nonlinear dynamics in general, and chaotic motion and fractals, in particular.*
PHY102.8 *Perform stability analysis of cubic anharmonic oscillator and undamped pendulum, and find chaotic trajectories.*

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

Mechanics of a system of particles, Constraints of motion, Generalized coordinates, D'Alembert's Principle and Lagrange's Equations, Simple applications of Lagrangian formulation, Hamilton's Principle, Lagrange's equations from Hamilton's Principle. Extending Hamilton's Principle to systems with constraints, Advantages of variational principle formulation, Legendre Transformation and Hamilton's Equations of Motion, Cyclic Coordinates, Routh's Procedure, Conservation theorems using Hamiltonian, Simple applications of Hamiltonian formulation.

Unit II: Canonical Transformation and Small Oscillations (12 hrs.)

Equations of Canonical Transformation and Generating Functions, Examples of canonical Transformations, Poisson bracket and its properties, Angular momenta and Poisson bracket, Jacobi identity, Invariance of Poisson Bracket using Canonical Transformation, Lagrange bracket and its properties, Relation between Poisson and Lagrange brackets, Formulation of the problem under small oscillations, Eigenvalue equation and the principle axis transformation, Frequencies of free vibrations and Normal coordinates, Free vibrations of a linear triatomic molecule.

Unit III: Central Force problem and Hamilton-Jacobi theory (14 hrs.)

Reduction to equivalent one body problem, Equations of motion and first integrals, Classification of Orbits, Virial theorem, Differential equation for the orbit and integrable power law Potentials, The Kepler Problem, Deduction of Kepler's laws, Scattering in Central Force Field, Hamilton-Jacobi Equation for Hamilton's Principle Function, Harmonic Oscillator Problem as an example of Hamilton-Jacobi Method, Hamilton-Jacobi Equation for Hamilton's Characteristic Function, Separation of variables in Hamilton-Jacobi Equation, Action Angle Variables, Kepler Problem using Hamilton-Jacobi Equation.

Unit IV: Introductory Nonlinear Dynamics (12 hrs.)

Classical Chaos: Linear and nonlinear systems, 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.

References:

1. Classical Mechanics (3rd Edition) by H. Goldstein, C. P. Poole and J. Safko
2. Classical Mechanics by John R. Taylor
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 Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering by S. Strogatz

PHY 103: Quantum Mechanics-I

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Quantum Mechanics-I, a student will be able to:

PHY103.1 *Realize the basic quantum-mechanical view point, and learn its wave mechanical and matrix formulations for a non-relativistic situation*

PHY103.2 *Solve the Schrödinger wave equation for eigenfunctions and eigenvalues for simple interaction potentials, including harmonic and central potentials.*

PHY103.3 *Construct matrices for observables and wave functions in different representations, and apply the matrix theory for calculating eigenvalues and eigenfunctions of linear harmonic oscillator.*

PHY103.4 *Describe the time-development of a quantum system in Schrödinger, Heisenberg and Interaction pictures, and to envisage the same in Hilbert space.*

PHY103.5 *Calculate the eigenvalues and eigenfunctions for the orbital and general angular momenta, along with the matrix representation of angular momentum.*

PHY103.6 *Perform quantum-mechanical addition of two general angular momenta, and calculate Clebsch-Gordan coefficients for some simple situations.*

PHY103.7 *Grasp the concepts of identity, indistinguishability, and see how eigenstates of a system of identical particles bifurcate into totally symmetric and anti-symmetric ones.*

PHY103.8 *Find the spin and total wave functions for a system of two identical spin ½ particles, and comprehend connection among spin, symmetry and statistics of identical particles.*

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

Recapitulation of basic concepts: Why quantum mechanics? Two-slit experiment with *em* radiation and matter particles, Quantum-mechanical view point, The Schrödinger wave equation, Expectation values, 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 observables; Problems: A charged particle in a uniform static magnetic field (eigenfunctions and Landau levels); The Hydrogen atom (reduced mass, radial wave functions 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 observables and wave functions as matrices, Transformation theory, choice of basis, change of basis, unitary transformations, Hilbert space representation; Dirac's ket and bra notation; 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 two angular momenta, Clebsch-Gordan coefficients and their calculation for $j_1= j_2 =1/2$, $j_1=1$, $j_2 =1/2$ and $j_1= j_2 =1$; The Wigner-Eckart theorem.

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

Many-particle Schrödinger wave equation, Stationary-state solutions; Systems of identical particles, Physical meaning of identity, Principle of indistinguishability, Exchange and transposition operators, Totally symmetric and anti-symmetric wave functions, Time-invariance of symmetry, Construction of symmetric and anti-symmetric wave functions, Connection among spin, symmetry and statistics of identical particles, Fermions and bosons; Spin and total wave functions 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 *ortho*-helium); Limit of distinguishability of identical particles.

References:

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 (4rd edition) by Richard L. Liboff
8. Quantum Mechanics: Concepts and Applications (2nd edition) by N. Zettili

PHY 104: Electronic Devices and Circuits-I

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Electronic Devices and Circuits-I, a student will be able to:

PHY104.1 *Be aware of the general characteristics of important semiconductor materials.*
PHY104.2 *Develop a deep understanding of the basic design, operation and characteristics of a pn-junction and a BJT along with knowledge of the basic network theorems and their applications in electronic circuit analysis.*
PHY104.3 *Learn to devise and analyze various transistor amplifier models.*
PHY104.4 *Understand the concept of negative feedback and its importance in amplifiers.*
PHY104.5 *Perform a load-line analysis and design of various biasing schemes in amplifiers.*
PHY104.6 *Acquaint with the frequency response of variously coupled amplifiers and sources of noise in electronic devices.*
PHY104.7 *Gain knowledge of classification, sources of distortions and their estimation, operation and determination of efficiency of power amplifiers.*
PHY104.8 *Clearly understand the need of regulation, operation and circuit analysis of different voltage and current regulators.*

Unit I: Basics of pn-junction, BJT and Network Theorems (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 diode, Zener and avalanche breakdowns, clipping and clamping circuits; The bipolar junction transistor: basic working principle, configurations and characteristics, voltage breakdowns, Network theorems: node theorem, mesh theorem, superposition theorem, Miller’s theorem, Thevenin’s theorem and Norton’s 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, Location of quiescent (Q) point, biasing circuits for amplifiers: fixed bias, emitter feedback bias & voltage feedback bias, bias compensation, bias techniques for linear integrated circuits, thermal runaway and thermal stability.

Unit III: Frequency Response of Amplifiers (12 hrs.)

The amplifier pass band, mid frequency range response of a direct coupled CE cascade, the high frequency equivalent circuit (Miller effect), the high frequency response of a direct coupled CE cascade, the frequency response of RC and transformer coupled CE amplifiers, gain-frequency plots of amplifier response (Bode plots), 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 amplifier, 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, derating curve; Electronic voltage regulators: basic operation and analysis of Zener diode voltage regulator, single BJT shunt and series regulators, feedback series BJT regulator and current regulator, overload and short circuit protection circuits.

References:

1. Electronic fundamentals and applications (5th ed.) by J. D. Ryder
2. Integrated Electronics by J. Millman and C. C. Halkias
3. Circuits and Networks: Analysis and Synthesis by A Sudhakar and S.S. Palli
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
7. Electronic Devices & Circuit Theory by Robert L Boylestad & Louis Nashelsky
8. Solid state Electronic Devices by B.G. Streetman and S.K. Banerjee

PHY 105: Physics Laboratory-I

Credit: 8
Max. Marks: 120+40
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.

Section A (Electronics)

Course Outcomes (COs)

After successful completion of the course on Physics Laboratory-I (electronics), a student will be able to:

PHY105.1 *Draw and understand the frequency response of different Filter circuits and a RC-coupled amplifier in its three configurations.*
PHY105.2 *Design and measure important parameters of rectifier, filter, voltage regulator and pn-junction circuits.*
PHY105.3 *Design and draw load characteristics of a push-pull amplifier and generate and determine the frequency of saw-tooth waves using UJT.*
PHY105.4 *Design and verify truth tables of the basic logic gates.*
PHY105.5 *Design and understand the operations of astable multivibrator, clipping and clamping circuits.*
PHY105.6 *Design and understand the operations of differentiating, integrating, modulation and demodulation circuits.*
PHY105.7 *Measure the sensitivities of X and Y plates of a CRO and determine frequency and phase-difference using CRO.*
PHY105.8 *Draw the characteristics of various opto-electronic devices and determine high resistance by leakage and k/e using a transistor.*

List of experiments[2]

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 load characteristics of a class-B push-pull amplifier.
E4 To generate saw-tooth waves using UJT and find its frequency.
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 sensitivities 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.
E13 To draw characteristics of opto-electronic devices.
E14 To determine high resistance by leakage and k/e using a transistor.

Section B (General Physics)

Course Outcomes (COs)

After successful completion of the course on Physics Laboratory-I (general physics), a student will be able to:

PHY105.1 *Measure the width of a narrow slit using diffraction phenomenon and ionization potential of mercury.*
PHY105.2 *Calculate the Planck's constant using a suitable light source and half life of Indium.*
PHY105.3 *Measure the mass absorption coefficient of β-rays in Aluminum and the band gap of a semiconductor.*
PHY105.4 *Set Michelson and Fabry-Parot interferometers for various practical measurements.*
PHY105.5 *Determine the strength of α-source and verify nuclear statistics using SSNTD.*
PHY105.6 *Verify the energy quantization using the Frank-Hertz Experiment.*
PHY105.7 *Demonstrate different harmonics present in complex signals using Fourier Analysis.*
PHY105.8 *Understand the underlying dynamics mimicked by the Feigenbaum and the Chua' circuits.*

List of experiments[2]

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-Parot 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.
G13 To study nonlinear dynamics using Feigenbaum circuit.
G14 To study nonlinear dynamics using Chua' circuit.

M. Sc. Physics (Semester II)

PHY 201: Quantum Mechanics-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Quantum Mechanics-II, a student will be able to:

PHY201.1 *Formulate perturbation, variational and WKB methods for obtaining approximate solutions of the Schrödinger equation, and apply these to simple physical situations.*
PHY201.2 *Comprehend on how perturbation can remove the degeneracy, particularly explanation of the Zeeman and Stark effects.*
PHY201.3 *Use the WKB method to understand tunneling through a barrier and the alpha decay process.*
PHY201.4 *Apply the time-dependent perturbation theory to deal with atom-em radiation interaction and calculate explicitly the transition probability for the induced absorption and emission processes.*
PHY201.5 *Explicate the electronic structure of many-electron atoms in central-field approximation, and estimate the central potential using the Thomas-Fermi and Hartree methods.*
PHY201.6 *Have an understanding of the nature of molecular energy levels, and calculate these for diatomic molecules.*
PHY201.7 *Grasp the basics of non-relativistic quantum scattering theory, and learn the partial waves and Green's function methods for deriving scattering cross-sections.*
PHY201.8 *Calculate and analyze scattering cross-sections for finite square well, hard sphere and screened Coulomb potentials.*

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 ($ax^3 + bx^4$) perturbations), Ground state of Helium atom; Degenerate case- Removal of degeneracy in first and second order, Zeeman effect without electron spin, First-order Stark effect in n=2 state of Hydrogen, Fine structure of hydrogen atom (Relativistic and spin-orbit coupling corrections); 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 the solutions, Solution near a turning point, 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 a hydrogen atom, Ionization probability, Interaction of an atom with *em* radiation (semi-classical treatment), Transition probability for induced absorption and emission, perturbation theory in scattering problems.

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, Corrections to the central-field approximation, L-S and j-j couplings; Molecular structure: Classification of energy levels, Wave equation; The 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, The laboratory and centre-of-mass systems, Scattering amplitude and cross-section; The method of partial waves: Phase shift, Differential and total cross-sections, Relation between phase shift and scattering potential, Convergence of the 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, The Born series, The 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.

References:

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 by John L. Powell and B. Crasemann
7. Quantum Mechanics: Concepts and Applications (2nd edition) by N. Zettili

PHY 202: Nuclear and Particle Physics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Nuclear and Particle Physics, a student will be able to:

PHY202.1 *Understand the energy loss processes of different energetic particles in a medium and mechanisms of interaction of gamma photon with matter.*
PHY202.2 *Learn about the basic properties and characteristics of Nuclear forces, and their mediating particle.*
PHY202.3 *Know and learn about various type of detectors used in nuclear physics experiments, unique properties of different detectors and their applications in the field of nuclear physics.*
PHY202.4 *Differentiate between different type of nuclear reactions, relevant aspects associated with nuclear reactions and kinematics of such reactions.*
PHY202.5 *Describe certain properties associated with nuclei, models governing different aspects of nuclear behaviour and detailed understanding of deuteron problem.*
PHY202.6 *Understand the phenomenon of radioactive decays of alpha and beta particles, their detailed formalism.*
PHY202.7 *Know about different elementary particles, their quark content and quark model.*
PHY202.8 *Learn about decay of some elementary particles and laws governing such decays.*

Unit I: Radiation Interaction and Nuclear Forces (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, 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.

Unit II: Radiation Detectors and Nuclear Reactions (12 hrs.)

Gamma Ray Spectrometer: basic principle and working of NaI (Tl) scintillation 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 detector, high purity germanium detector. 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 detection, Coulomb excitation, nuclear kinematics.

Unit III: Nuclear Properties and Radioactive Decays

Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model, Deuteron problem; Ground state of deuteron, Magnetic moment and its importance in the determination of exact ground state of deuteron. 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;

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 the Color quantum no., Quark model, decay of pion and muon, Gell-Mann Nishijima formula, conservation laws.

References:

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.
5. Radiation Detection and Measurement by G. F. Knoll.
6. Nuclear Physics Theory and Experiment, by R. R. Roy and B. P. Nigam.

PHY 203: Solid State Physics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Solid State Physics, a student will be able to:

PHY203.1 *Analyze the structure of a crystalline solid in terms of lattice, basis and unit cell, and of a non-crystalline solid on the basis of pair-distribution function.*
PHY203.2 *Deduce the structure of a crystalline solid from an analysis of the XRD pattern and the theoretically calculated crystal structure factor.*
PHY203.3 *Calculate the dispersion of lattice waves for crystals with mono- and diatomic basis, and understand the principle underlying its experimental measurement using neutron scattering.*
PHY203.4 *Acquire an understanding of the concept of phonon and use it to determine the lattice heat capacity in the Einstein and Debye models.*
PHY203.5 *Learn the Bloch's theorem, its application to the KP model, solve the one-electron Schrödinger equation for a periodic potential to see the emergence of energy bands, and classify materials into conductors, semiconductors and insulators.*
PHY203.6 *Learn and apply the tight binding and Wigner-Seitz methods for calculating the energy bands.*
PHY203.7 *Grasp important characteristics of superconductors, along with qualitative aspects of the BCS theory of superconductivity.*
PHY203.8 *Explain the flux quantization in a superconducting ring, and the DC and AC Josephson effects.*

Unit I: Crystal structure (12 hrs.)

Recapitulation of basic concepts: Bravais lattice and Primitive vectors; Primitive, Conventional and Wigner-Seitz unit cells; Crystal structures and lattices with bases; Symmetry operations and fundamental types of lattices; Index system for crystal planes. 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, Examples of NaCl and diamond; Experimental methods of structure analysis: Types of probe beam, The Laue, rotating crystal and powder methods. Non-crystalline solids: Diffraction pattern; Monatomic amorphous materials; Pair-distribution function.

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

Binding in solids: Crystals of inert gases, Lennard-Jones potential; Qualitative idea of Ionic, Covalent and Metallic binding. Classical theory of lattice vibration (in harmonic approximation): Vibrations of crystals with monatomic basis- Dispersion relation, First Brillouin zone, Group velocity; Two atoms per primitive basis- dispersion of acoustical and optical modes. Quantization of lattice waves: 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; Thermal conductivity.

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

Failure of the free electron gas model; Band theory of solids: Nearly free electron model, Energy gap; Periodic potential and Bloch's theorem; Kronig-Penney model; Wave equation of electron in a periodic potential, Solution of the central equation, Approximate solution at and near a zone boundary; Periodic, extended and reduced zone schemes of energy band representation; Number of orbitals in a band; Classification into metals, semiconductors and insulators. Calculation of energy bands: Tight binding method and its application to *sc* and *bcc* structures; Wigner-Seitz method, Cohesive energy; Pseudo-potential methods (qualitative idea).

Unit IV: Superconductivity (12 hrs.)

Experimental survey: Superconductivity and its occurrence, Destruction of superconductivity by magnetic fields, 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; Microscopic theory: Qualitative features of the BCS theory, BCS ground state wave function; Quantitative predictions of the BCS theory, critical temperature, energy gap, critical field, specific heat; Flux quantization in a superconducting ring; Dc and Ac Josephson effects; Macroscopic long-range quantum interference; High T_c superconductors (introduction only).

References:

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

PHY 204: Electronic Devices and Circuits-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Electronic Devices and Circuits-II, a student will be able to

PHY204.1 *Well acquainted with the basic structures, operations, characteristics and biasing schemes of various field effect transistors.*
PHY204.2 *Understand the operations of different multivibrator circuits.*
PHY204.3 *Develop a clear understanding of the basics of OPAMPS, its operating modes, internal structure of an IC OPAMP and its vital design parameters.*
PHY204.4 *Become familiar with the basic structure, operation, characteristics and important applications of negative resistance devices.*
PHY204.5 *Design and describe the operations of various families of logic gates.*
PHY204.6 *Simplify involved Boolean expressions with the help of Boolean algebra and K-map*
PHY204.7 *Explain the construction, operation, characteristics and important technological applications of various photonic devices.*
PHY204.8 *Explain the construction, operation, characteristics and important technological applications of different temperature sensitive devices.*

Unit I: Field Effect Transistors and Multivibrators (12 hrs.)

Basic structure and operation of JFET, calculation of pinch off voltage, V-I 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), low frequency common source and common drain FET amplifiers, FET biasing, FET as a voltage variable resistor (VVR); Multivibrators: a fixed biased transistor, a self-biased transistor and a direct connected bistable multivibrator circuits, Schmitt trigger circuit, triggering techniques for bistable multivibrators, collector-coupled and emitter-coupled monostable and astable multivibrators.

Unit II: OPAMPs and Negative Resistance Devices (12 hrs.)

The basic OPAMP, inverting and non-inverting mode of operation of OPAMP, effect of negative feedback on input and output resistances of OPAMPs, the differential amplifier, common mode rejection ratio (CMRR), the emitter coupled differential amplifier, the transfer characteristics of a differential amplifier, an IC OPAMP (MC-1530 Motorola) and its dc analysis, offset voltages and currents, universal balancing techniques, measurement of OPAMP parameters; basic working principles, characteristics and applications of uni-junction transistor (UJT), four layer diode (pnpn-diode), tunnel diode and silicon controlled rectifier (SCR).

Unit III: Digital Circuits (14 hrs.)

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, Boolean algebra, the NAND and NOR diode-transistor gates, Modified DTL gates, fan-in and fan-out, wired logics, high threshold logic (HTL) gates, transistor- transistor logic (TTL) gates, output stages for TTL gates, 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 and Temperature Sensing Devices (11 hrs.)

Radiative and nonradiative transitions, basic construction, operation, characteristics and applications of solar cells, light dependent resistance (LDR), photodiodes, p-i-n diodes, metal semiconductor photodiodes, avalanche photodiodes, light emitting diodes (LEDs), semiconductor diode lasers, photo transistors, resistance thermometers, thermocouples and thermistors.

References:

1. Integrated Electronics by J. Millman and C. C. Halkias
2. Pulse, digital and switching waveforms by J. Millman and H. Taub
3. Electronic devices and circuits by Y. N. Bapat
4. Microwave devices and circuits by Samuel Y. Liao
5. Physics of semiconductor Devices by S. M. Sze
6. Electronic instrumentation and measurement techniques by W. D. Cooper and A. D. Helfrick
7. OPAMPs and linear IC circuits by Ramakant A. Gayakwad
8. Electronics for Scientists and Engineers: Devices, Circuits and Systems by TV Viswanathan, GK Mehta and V Rajaraman

PHY 205: Physics Laboratory-II

Credit: 8
Max. Marks: 120+40
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 1^{st} semester. The course outcomes, evaluation pattern and list of experiments are the same as given in the Course PHY 105.

PHY 206: Seminar

Credit:2
Max. Marks: 40
Time: 40 Minutes

Note: Each student will deliver one seminar 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.

Course Outcomes (COs)

After successful completion of the course on seminar a student will be able to:

PHY206.1 *Achieve effective communication skills.*
PHY206.2 *Understand the concepts involved in the topic of seminar.*
PHY206.3 *Acquire skills for working in team.*
PHY206.4 *Develop confidence for facing audience.*
PHY206.5 *Learn to write effectively a report on a particular topic.*
PHY206.6 *Know the techniques of responding to the questions posed by audience.*
PHY206.7 *Enhance the presentation abilities.*
PHY206.8 *Improve interpersonal skills.*

M. Sc. Physics (Semester III)

PHY 301: Electrodynamics and Plasma Physics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Advanced Quantum Mechanics a student will be able to:

PHY301.1	*Have sound knowledge of basic concepts of electrostatics and find solution of Poisson's and Laplace's equations.*
PHY301.2	*Enhance skills for solving Boundary value problems especially using Method of images.*
PHY301.3	*Understand basic concepts of magnetostatics and apply them for solving the related problems.*
PHY301.4	*Recognize various 4-vecters and develop understanding of Minkowski space in context with special theory of relativity.*
PHY301.5	*Describe the propagation of electromagnetic wave through different media and rectangular waveguide.*
PHY301.6	*Get familiarize with concept of retarded time for charges undergoing acceleration and evaluate Lienard-Wiechert Potentials.*
PHY301.7	*Understand the basic concepts of Plasma Physics and find validity of plasma approximation.*
PHY301.8	*Realize the mechanism of plasma oscillations and have knowledge of plasma instabilities.*

Unit I: Electrostatics and Method of Images (12 hrs.)

Electric Field, Gauss's Law, Differential Form of Gauss Law, Poisson's and Laplace's equations, Solution of Laplace's equation in various coordinates, Green's Theorem, Dirichlet and Neumann boundary conditions, Formal solution of boundary value problem with Green Function, Method of Images, Point charge near an infinite Grounded 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 held at Fixed Potential, Conducting sphere in a Uniform Electric Field.

Unit II: Magnetostatics, Maxwell Equations and Special Theory of Relativity (12 hrs.)

Magnetostatics: Biot-Savart Law: Steady Currents, The magnetic field of a Steady Current, Ampere's Law, Comparison of Magnetostatics and Electrostatics, Maxwell's Displacement Current; Maxwell's Equations, Scalar and Vector potentials, Maxwell's equations in terms of scalar and vector potentials, Non uniqueness of Electromagnetic potentials, Gauge Transformation, Lorentz gauge and Coulomb gauge. Minkowski Space and Four vectors, Mathematical Properties of the Space-Time of Special Relativity, Electromagnetic field strength tensors, Covariance of Maxwell's and Lorentz force equations.

Unit III: Electromagnetic Waves and Radiation by Moving Charges (14 hrs.)

Electromagnetic Waves in Vacuum: The Wave Equation for E and B, Monochromatic Plane Waves, Energy and Momentum in Electromagnetic Waves. Electromagnetic Waves in Matter: Propagation in Linear Media, Reflection and Transmission at Normal Incidence, Reflection and Transmission at Oblique Incidence. Electromagnetic Waves in Conductors, Reflection at a Conducting Surface. Wave Guides, TE and TM Waves in a Rectangular Wave Guide, Retarded Time, Lienard-Wiechert Potentials for a point charge, Total power radiated by a point charge: Larmor's formula and its relativistic generalization.

Unit IV: Plasma Physics (12 hrs.)

Occurrence of Plasmas in Nature, Quasineutrality of plasma, Debye Shielding, The Plasma Parameter, Criteria for Plasmas, Representation of Waves in Plasma, Group Velocity, Plasma Oscillations, Electron Plasma Waves, Sound Waves, Ion Waves, Validity of the Plasma Approximation, Comparison of Ion and Electron Waves, Electrostatic Electron Oscillations Perpendicular to B. Introduction to plasma Instabilities: Streaming instabilities, Rayleigh–Taylor instabilities, Universal instabilities, Kinetic instabilities. Velocity Distribution Function in Plasma, Derivation of the Fluid Equations as moments of the Boltzmann equation.

References:

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

PHY 302: Statistical Mechanics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Statistical Mechanics, a student will be able to:

PHY302.1 *Realize the fundamental connection between statistical mechanics and thermodynamics.*
PHY302.2 *Learn the ensemble formulation of statistical mechanics, and apply these to calculate important thermodynamical quantities for simple systems.*
PHY302.3 *Formulate the quantum mechanical ensemble theory and use it to derive the laws of quantum statistics, viz. Fermi-Dirac (FD) and Bose-Einstein (BE) statistics.*
PHY302.4 *Apply the laws of quantum statistics to determine the equation of state for ideal Bose and Fermi gases, and understand the origin of Bose-Einstein condensation.*
PHY302.5 *Grasp the basics of cluster expansion method for a classical real gas to obtain its equation of state and simple cluster integrals.*
PHY302.6 *Construct and solve the Ising model, along with the Landau theory of phase transition.*
PHY302.7 *Understand fluctuations, their spectral analysis and connection with spatial correlations.*
PHY302.8 *Describe the theoretical basis of Brownian motion on the basis of Enistein-Smoluchowski, and Langevin approaches.*

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; Entropy of mixing and the Gibbs paradox, Sackur-Tetrode equation, Ensemble theory: Concept of ensemble, Phase space, Density function, Ensemble average, Liouville"s theorem, Stationary ensemble; The microcanonical ensemble, The canonical and grand canonical ensembles, Application to the classical ideal gas; 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.

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, 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, qualitative description of ferromagnetism, Lattice gas and Binary alloy, 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. The role of correlation and fluctuation

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, Enistein-Smoluchowski theory of Brownian Motion, 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.

References:

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

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Condensed Matter Physics-I, a student will be able to:

PHY303A.1 *Have an understanding of basic physical concepts (like band gap, holes, effective mass, etc.) related to semiconductors.*

PHY303A.2 *Appreciate the concept and importance of Fermi surface of metals and its experimental determination through De Hass-van Alphen effect, along with magneto-transport in a 2D channel.*

PHY303A.3 *Learn the description of collective excitations of the Fermi Sea (plasmons) and the electrostatic screening of electron-impurity interaction, in terms of the dielectric function of the electron gas.*

PHY303A.4 *Understand different physical quantities (reflectivity coefficient, reflectance, real & imaginary parts of response etc.) related to the optical response of solids, and Raman Effect in crystals.*

PHY303A.5 *Relate the dielectric polarization with the macroscopic electric field and the local electric field acting on an atom in the dielectric, along with frequency dependence of polarizability.*

PHY303A.6 *Comprehend ferroelectricity and the Landau theory of phase transition.*

PHY303A.7 *Calculate magnetic susceptibility for atoms, insulating solids and conduction electrons, and have an understanding of the microscopic origin of ferromagnetism and anti-ferromagnetism.*

PHY303A.8 *Determine the low-energy excitations (spin waves/magnons) for ferromagnetic and antiferromagnetic systems, understand principle underlying their experimental measurement, and learn about ferromagnetic domains.*

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

Semiconductor crystals: Band gap, Direct and indirect absorption processes; Equations of motion in an energy band, Concept and properties of holes, Effective mass and its physical interpretation, Effective masses in semiconductors, Examples of Silicon and Germanium; Intrinsic carrier concentration, Law of mass action, Intrinsic mobility. Fermi surfaces and metals: Fermi surface and its construction for square lattice (free electrons and nearly free electrons); Electron orbits, Hole orbits, Open orbits; Experimental determination of Fermi surface: Quantization of orbits in a magnetic field, De Hass-van Alphen effect, Extremal orbits. Magnetoresistance in a two-dimensional channel, Integral Quantized Hall 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; Displacive transitions; Landau theory of the phase transition; Anti-ferroelectricity, Ferroelectric domains; Piezoelectricity, Ferroelasticity.

Unit IV: Magnetism (14 hrs.)

Diamagnetism and paramagnetism: Magnetization density and susceptibility, Calculation of atomic susceptibilities, Larmor diamagnetism; Quantum theory of paramagnetism- Curie law; Hund's rules; Paramagnetic susceptibility of conduction electrons. Ferromagnetism and anti-ferromagnetism: Ferromagnetic order, Mean field theory- Curie-Weiss law; Electrostatic origins of magnetic interactions, Magnetic properties of a two-electron system, Singlet-triplet (exchange) splitting in Heitler-London approximation, Exchange interaction; Spin Hamiltonian and the Heisenberg model; Spin waves and their dispersion; Quantization of spin waves, Magnons, Thermal excitation of magnons and Bloch $T^{3/2}$ law; Neutron magnetic scattering (principle); Ferromagnetic domains: Magnetization curve, Bloch wall, Origin of domains; Antiferromagnetic order and magnons.

References:

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

PHY 303B: Nuclear Physics-I

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Nuclear Physics-I, a student will be able to:

PHY303B.1 *Do Particle identification using solid state and gaseous detectors using the formalism of particle energy in two slices of the detectors.*
PHY303B.2 *Learn about the concept, working and properties of various gas filled detectors.*
PHY303B.3 *Describe the mechanisms adopted for processing a pulse through nuclear electronics, optimization of signal processing and techniques of coincidence for nuclear experiments.*
PHY303B.4 *Understand the concept of pulse processing and data acquisition using different methods.*
PHY303B.5 *Grasp the concept and working of different ion accelerators used in modern day nuclear/material research.*
PHY303B.6 *Describe the mechanisms such as ion range, channelling and sputtering etc. associated with study of material properties.*
PHY303B.7 *Understand about various type of fission reactors used in different branches of research and energy production.*
PHY303B.8 *Understand the concept of fusion reactor and process of breeding in fission reactors.*

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, electronic considerations for pulse processing, device impedance, pulse attenuator, pulse splitter, linear and logic pulses, 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 Solids: 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.

References:

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

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Particle Physics-I, a student will be able to:

PHY303C.1 *Realize the Fundamental constituents of matter, their origination*
PHY303C.2 *Understand qualitative and quantitative analysis of Resonance and Dalitz plots.*
PHY303C.3 *Formulate Quantum mechanical scattering theory leading to understand origination of field particles.*
PHY303C.4 *Understand three major interactions viz strong, electromagnetic and weak are in existence.*
PHY303C.5 *Understand Isospin formulation and its fundamentals.*
PHY303C.6 *Invariance and violation of various conservation laws and symmetries in these interactions.*
PHY303C.7 *Understand fundamental knowledge of the subject matter leading to the attempt for grand unification.*
PHY303C.8 *Formulate Parity conservation, violation and Charge conjugation invariance.*

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

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 $e_+ e_- \rightarrow 2\gamma$ 3γ, G-Parity, Γ-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.

References:

1. Introduction to High Energy Physics (2nd, 3rd and 4th edition): D. H. Perkins.
2. Intermediate Energy Nuclear Physics: W. O. Lock and D. F. Measday.
3. Introduction to Particle Physics: M. P. Khanna.
4. Elementary Particle Physics: Yorikiyo Nagashima.
5. Symmetry Principles in Elementary Particle Physics: W. M. Gibson and B. R. Pollard.

PHY 304A: Computational Physics-I

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Computational Physics-I, a student will be able to:

PHY304A.1 *Understand the working of FORTRAN statements and tracing of FORTRAN programs.*
PHY304A.2 *Implement algorithms in developing FORTRAN programs and learn shell based plotting using Gnuplot.*
PHY304A.3 *Understand different type of errors, their propagation, and to minimize errors while writing a program.*
PHY304A.4 *Find roots of algebraic equations using various iterative methods.*
PHY304A.5 *Solve numerical problems involving interpolation and/or extrapolation using different methods.*
PHY304A.6 *Fit a given data set with a best fit curve using principle of least square fitting and learn about fitting of different non-linear functions.*
PHY304A.7 *Solve a set of simultaneous linear algebraic equations numerically.*
PHY304A.8 *Find numerically the eigenvalues and eigenvectors of matrices using polynomial and power methods.*

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, Linux operating system; distributions, linux shell, basic commands, Introduction to compilers, Fortran Programming: Data types, Data handling, Arithmetical and logical expressions, Intrinsic functions, Input-Output statements, Format statements, IF statement, DO statement, While loop, Common blocks, Arrays and subscripted variables, Functions and subroutines, Handling of files. Plotting using Gunuplot, Computer programs for arranging numbers in ascending and descending orders, Matrix multiplication, Program debugging.

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, Convergence conditions, Muller’s 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, error of interpolation, Least square

curve fitting: The principle of least square fitting, Linear regression, Polynomial regression, Fitting exponential and trigonometric functions, Data fitting with cubic splines, Data fitting using Gnuplot.

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.

References:

1. William E. Mayo and Martin Cwiakala, Programming with Fortran 77, Schaum's outline serios, McGraw Hill, Inc.
2. R C Desai, Fortran Programming and Numerical methods, Tata McGraw Hill, New Delhi.
3. S S Sastry Introductory methods of numerical Analysis, Prentice Hall of India Pvt. Ltd.
4. V Rajaraman, Computer Oriented Numerical Method, Prentice Hall of India Pvt. Ltd.
5. P B Patil and U. P. Verma, Numercal Computational Methods, Narosa Publishing House

PHY 304B: Electronics-I

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Electronics-I, a student will be able to:

PHY304B.1 *Design and comprehend a host of OPAMP based linear analog electronic circuits.*
PHY304B.2 *Design and understand various nonlinear analog electronic circuits with the help of OPAMPs.*
PHY304B.3 *Gain a fair understanding of the operation and underlying circuitry of amplitude and frequency modulations.*
PHY304B.4 *Understand the necessary circuitry of digital modulation techniques and Radars.*
PHY304B.5 *Explain the principle of optical fibers, their various types & fabrication techniques.*
PHY304B.6 *Comprehend connectors, splices and amplifiers in fiber optics communication.*
PHY304B.7 *Become familiar with the ideal MS contacts, their classification, surface effects and their important applications.*
PHY304B.8 *Describe the basics of ideal and non-ideal MOS systems, MOS capacitance, MOS memories and charged-coupled devices.*

Unit I: Applications of Operational Amplifiers (12 hrs.)

Linear analog systems: inverters, scale changers, phase shifters, adders, subtractors, voltage to current and current to voltage convertors, dc voltage follower, differential dc amplifier, bridge amplifier, ac coupled amplifier, instrumentation amplifier, integrator and differentiator, analog computer to solve linear differential equations with constant coefficients; non-linear analog systems: comparators, sample and hold circuits, precision ac/dc convertors, log & antilog amplifiers, logarithmic multipliers and dividers, square, pulse and triangular waveform generators, regenerative comparator (Schmitt-trigger circuit).

Unit II: Modulation and Communication (12 hrs.)

Basic operation and internal circuitry of PLL, active filters (Butter-Worth 1st and 2nd order), amplitude modulation, frequency spectrum and power in the AM wave, generation of AM waves, demodulation of AM waves. frequency modulation, block diagram of transmitter and super heterodyne receiver, digital communication, basic idea about delta modulation, PCM and PWM, block diagram of Radar, radar range equation and applications of Radars.

Unit III: Introduction to Fiber Optics (12 hrs)

Optical fibers, basic principle, numerical aperture, V-parameter, types of optical fibers: single mode step index fiber, multimode step index fiber, multimode graded index fiber, material dispersion, signal degradation, fiber losses, fiber materials, fabrication methods for fiber cables: liquid-phase techniques, vapor-phase deposition techniques, fiber connectors and splices, applications of fiber cables, an introduction to semiconductor optical amplifiers.

Unit IV: MS contacts and MOS systems (12 hrs.)

Metal semiconductor contacts, ideal MS contacts, Schottky barriers and ohmic contacts, surface effects on

MS contacts, applications of MS contacts, the ideal MOS structure and its analysis, capacitance of MOS system, non-ideal MOS system: oxide and interface charges, origin of oxide charges, effect of bias voltage, MOS memories, and charge-coupled devices.

References:

1. Integrated electronics by J Millman & CC Halkias.
2. Micro Electronics by J Millman & A Grabel.
3. Electronic communications by D Roddy and J Coolen.
4. Electronic Communications: Modulation and Transmission by RJ Schoenbeck
5. OPAMPs and linear IC circuits by Ramakant A. Gayakwad
6. Electronic fundamentals and applications (5th ed.) by J D Ryder
7. Electronic Devices & Circuit Theory by Robert L Boylestad & Louis Nashelsky
8. Microelectronic Circuits: Theory and Applications (6th ed.) by Adel S Sedra and Kenneth C Smith

PHY 304C: Material Science-I

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Material Science-I, a student will be able to:

PHY304C.1 *Understand the basic concepts and properties of Materials*
PHY304C.2 *Describe how and why defects (point, line and planar) in materials greatly affect engineering properties and limit their use in service*
PHY304C.3 *Understand strengthening and grasp the importance of various strengthening mechanisms.*
PHY304C.4 *Describe various parameters involved in elastic deformation, plastic deformation, anelastic deformation etc.*
PHY304C.5 *Grasp the concept of phase diagrams and be able to predict microstructures and understand transformation mechanisms (nucleation and growth, martensitic).*
PHY304C.6 *Comprehend Iron-Carbon system and ceramics.*
PHY304C.7 *Elucidate the kinematics of elastic collisions and have in depth understanding energetic ion beam based techniques (given in the syllabus) for analysis of materials*
PHY304C.8 *Perform computations of depth profiles and concentration analysis using these techniques, Choose the most appropriate technique for characterization*

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, Frank Read 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.

References:

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

Credit:8
Max. Marks: 120+40
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.

Condensed Matter Physics

Course Outcomes (COs)

After successful completion of the course on Physics Laboratory-III (Condensed Matter Physics), a student will be able to:

PHY305.1 *Measure the variation in potential drop with temperature for a semiconductor using the four probe method, and use it to determine the band gap of semiconductor.*
PHY305.2 *Establish the type of semiconductor by measuring the Hall coefficient, explore temperature dependence of Hall coefficient, and measure the magneto-resistance.*
PHY305.3 *Ascertain the magnetic nature of a given material by measuring its magnetic susceptibility.*
PHY305.4 *Observe the electron paramagnetic resonance phenomenon and use it to determine the Lande g-factor.*
PHY305.5 *Understand the change in magnetization of ferrites with heating by tracing the B-H loops, and determine the Curie temperature.*
PHY305.6 *Record and analyze the XRD pattern of a crystalline substance using a table-top X-ray diffractometer, and find the lattice parameter and Miller indices.*
PHY305.7 *Simulate the dispersion of lattice vibrations using an electrical analogue of real lattice.*
PHY305.8 *Learn and measure the characteristics of a thermo-luminescent material.*

List of experiments[2]

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.

C12 Dielectric constant of benzene and dipole moment of acetone.

Nuclear Physics

Course Outcomes (COs)

After successful completion of the course on Physics Laboratory-III (Nuclear Physics), a student will be able to:

PHY305.1 *Understand the working of GM Counter and measure its resolving time and hence determine the nuclear statistics of source and thickness of given sample.*
PHY305.2 *Measure the resolving power and efficiency of scintillation detector*
PHY305.3 *Ascertain range of alpha particles in air using Spark Counter.*
PHY305.4 *Understand the concept of signal to noise ratio and solid angle in nuclear experiments.*
PHY305.5 *Understand the working of alpha ray spectrometer.*
PHY305.6 *Realize the particle nature of radiation through Compton scattering experiment.*
PHY305.7 *Observe large angle scattering of alpha particles and analyze the data.*
PHY305.8 *Calculate wavelength for the characteristic* K_α *and* K_β *x-ray radiation of molybdenum using the data obtained from a table-top X-ray diffractometer.*

List of experiments[2]

N1 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 Signal to noise ratio using Scintillation detector.

N5 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_γ.

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.

N12 Solid angle dependence of nuclear counting.

Particle Physics

After successful completion of the course on Physics Laboratory-III (Particle Physics) a student will be able to:

PHY305.1 *Learn and realize the concept of high energy (GeV) interaction and production of field particles*
PHY305.2 *Understand the mechanism of nuclear emulsion as a detector and target both.*
PHY305.3 *Learn the concept of internuclear cascading, concept of slow and fast reaction involve in the high energy interaction*
PHY305.4 *Analyze the various interaction parameters qualitatively as well as quantitatively.*
PHY305.5 *Mechanism of energy transfer of incident ion in material medium.*
PHY305.6 *Learn aspects in radiation exposure to material for the preparation of SSNTD.*
PHY305.7 *Understand etching mechanism and statistics involve in nuclear charge particle interaction with material medium.*
PHY305.8 *Understand the relativistic kinematics in high energy interaction.*

List of experiments[2]

PP1 Angular distribution of shower tracks.

PP2 Mean Multiplicity of shower, grey and black tracks.

PP3 In-elasticity of an interaction for shower particles.

PP4 Momentum distribution of shower particles.

PP5 Classification of Nuclear Interaction Star Tracks and Determination of Excitation energy.

PP6 Nuclear Statistics using Solid State Nuclear Track Detector.

PP7 To determine the mean free path for relativistic nucleus-nucleus interactions.

PP8 To determine fusion to alpha branching ratio in spontaneous emission of ^{252}Cf.

PP9 Relativistic Kinematics.

PP10 Exposure and etching of polymeric sample for the preparation of Solid State Nuclear Track Detector (SSNTD).

Computational Physics

Course Outcomes (COs)

After successful completion of the course on Physics Laboratory-III (Computational Physics), a student will be able to:

PHY305.1 *Develop FORTRAN programs to evaluate definite integrals by employing Simpson and Gauss quadrature methods.*

PHY305.2 *Write FORTRAN programs for interpolation and extrapolation by Lagrangian method and curve fitting through least square method.*

PHY305.3 *Construct FORTRAN program to solve second order differential equations using Runge-Kutta method and apply the program to find Eigenvalues and eigen functions of a linear harmonic oscillator.*

PHY305.4 *Develop FORTRAN programs to find roots of an equation of degree 1, 2 and 3 by using Bisection method.*

PHY305.5 *Write FORTAN program to solve set of Simultaneous Linear Algebraic equations by Gauss-Jordan elimination method and Illustrate Kirchhoff's laws for simple electric circuits.*

PHY305.6 *Develop FORTRAN program to find eigenvalues and eigenvectors of square matrices using power method.*

PHY305.7 *Simulate the process of nuclear radioactivity through Monte Carto method by developing a FORTRAN program.*

PHY305.8 *Simulate the chaotic phenomena like damped and driven oscillator and logistic equation through FORTRAN programs.*

List of experiments[2]

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

Application: Show that the function $f(x) = \frac{n}{\pi}\frac{1}{1+n^2x^2}$

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 Kirchhoff's 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.

CP10 Dynamics of damped driven pendulum

Electronics

Course Outcomes (COs)

After successful completion of the course on Physics Laboratory-III (Electronics), a student will be able to

PHY305.1	*Draw and understand the effect of negative feedbacks on frequency response of a RC-coupled amplifier.*
PHY305.2	*Design and measure h-parameters of an amplifier and pulse width of a mono-stable multivibrator circuit.*
PHY305.3	*Design and draw V-I characteristics of a FET and determine its important parameters.*
PHY305.4	*Design and verify truth tables of the 8 bits D/A and A/D converters.*
PHY305.5	*Design and understand the operations of ripple counter, 4 bit shift resistor, various flip-flops and the Schmitt trigger circuit.*
PHY305.6	*Measure the important parameters of an OPAMP.*
PHY305.7	*Design different OPAMP based circuits for various practical applications.*
PHY305.8	*Understand the operation of 8085 microprocessor and its arithmetic applications.*

List of experiments[2]

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

After successful completion of the course on Physics Laboratory-III (Material Science), a student will be able to:

PHY305.1 *Understand four probe method for determining band gap of materials and use it to compute band gap of semiconductor material by measuring the variation in potential drop with temperature.*
PHY305.2 *Comprehend the concept of Hall Effect and magnetoresistance. Measure Hall coefficient and establish the type of semiconductor and measure the magneto-resistance.*
PHY305.3 *Have understanding of X-ray diffractometer and use it to record and analyze the XRD pattern of a crystalline substance using it. Further use of this technique to compute lattice parameter and Miller indices.*
PHY305.4 *Ascertain the magnetic nature of a given material by measuring its magnetic susceptibility.*
PHY305.5 *Understand dielectric materials and measure dielectric constant of given material.*
PHY305.6 *Grasp the concept of ferroelectricity and study the variation of dielectric constant with temperature for given ferroelectric material.*
PHY305.7 *Learn about solar cell and measure its I-V characteristics..*
PHY305.8 *Learn and measure the characteristics of a thermo-luminescent material.*

List of experiments[2]

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: Advanced Quantum Mechanics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Electrodynamics and Plasma Physics, a student will be able to:

PHY401.1	*Have knowledge of basic laws of relativistic quantum mechanics and ability to solve Klein-Gordan equation and Dirac equation.*
PHY401.2	*Understand the concept of Dirac matrices and their properties for spin half relativistic particles.*
PHY401.3	*Acquire understanding of Classical field and develop Lagrangian and Hamiltonian formulations for the same.*
PHY401.4	*Perform second quantization of a nonrelativistic field to find quantized energy and understand the matrix formulation of related operators.*
PHY401.5	*Implement second quantization of various relativistic fields to determine quantized energy.*
PHY401.6	*Establish scattering matrix using operators and represent various scattering processes on Feynman Diagrams.*
PHY401.7	*Have sound understanding of semi classical theory of radiation and check the validity of classical description.*
PHY401.8	*Develop theoretical understanding of emission and absorption of photons by atoms and find basic matrix elements for both processes.*

Unit I: Relativistic Wave Equations (14 hrs.)

Klein-Gordan equation: Free particle, Charge and Current Densities, Electromagnetic potentials. Energy levels in a Coulomb Field (Hydrogen atom problem). Difficulties of Klein-Gordan equation. Dirac equation: Properties of the Dirac Matrices, Free particle solutions, Charge and Current Densities, Electromagnetic potentials. Dirac equation for a central field: Spin Angular Momentum, Approximate reduction; Spin-Orbit energy, Separation of the equation, The Hydrogen atom, Classification of energy levels, Negative energy States.

Unit II: Field Quantization (12 hrs.)

Lagrangian Field Theory: Canonical Quantization, Coordinates of the Field, The Classical Field Equations, Functional Derivative, Hamiltonian Formulation, Quantization of the Field, Field with more than One component, Complex Field. Non-relativistic field: Lagrangian and Hamiltonian Equations, Quantization for system of Bosons and Fermions, The N representation, Matrix representation of Creation, Annihilation and Number operators for Bosons and Fermions, Commutators and Anticommutators at Unequal Times.

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

Relativistic Fields, Natural system of units, Quantization of Klein-Gordan field, Quantization of Dirac field, Quantization of Electromagnetic fields (in vacuum): Lagrangian and Hamiltonian Equations, Quantization Procedure, Quantized field energy. Interacting fields: Feynman Diagrams, Normal product, Dyson and Wick's chronological products, Contraction of field operators, Wick's theorem, Electromagnetic Coupling, The Scattering Matrix, Representation of various Scattering processes on Feynman diagrams up to second order.

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

Classical radiation field: Transversality Condition, Fourier decomposition and radiation oscillators. Creation, Annihilation and Number operators: Quantization of radiation oscillators, Photon states. Quantized Radiation Field: Photons as quantum mechanical excitations of the radiation field, Fluctuations and the uncertainty relation, Validity of the classical description. Emission and Absorption of Photons by Atoms: Basic matrix elements for emission and absorption, Time dependent perturbation theory, Spontaneous emission in dipole approximation.

References:

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. The principles of Quantum Mechanics by P. A. M. Dirac
6. Relativistic Quantum Mechanics by Schweber

PHY 402: Atomic and Molecular Physics

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Atomic and Molecular Physics, a student will be able to:

PHY402.1	*Have Qualitative as well as Quantitative understanding of origination of atomic physics, analysis of spectral lines*
PHY402.2	*Capable to understand the change in behavior of atoms in external applied electric and magnetic field on atomic spectral lines, their selection rule.*
PHY402.3	*Construct and Analysis the rotational, vibrational and Raman spectra of molecules.*
PHY402.4	*Describe the basic principle and instrumentation of IR and Raman spectrometer.*
PHY402.5	*Understand electronic energy spectroscopy, its rule, spectral range, application in understanding the characteristic feature molecular transition.*
PHY402.6	*Grasp intensive knowledge of equipment and their working used to analyze the electronic transitions in molecule.*
PHY402.7	*Understand the theory and description of the nucleus interaction with external field and effect on their spectrum to understand the molecule.*
PHY402.8	*Understand basic principle and instrumentation of NMR and ESR spectroscopy and formulation used in these spectroscopy.*

Unit I: Atomic Physics (12 hrs.)

Qualitative description of H-atom Spectrum, Physical interpretation of quantum numbers, Pauli principle and the building-up principle, Space Quantization: Stern-Gerlach experiment, spectrum of He-atom: its quantum mechanical description and Heisenberg resonance, LS and jj Coupling, Terms for equivalent & non-equivalent electron atom, Branching rule, 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; UV-Visible Absorption spectroscopy, Lambert-Beer law, Absorption spectrometer, Fluorescence spectroscopy: Fluorescence and Phosphorescence, Kasha‟s rule, Quantum Yield, Non-radiative 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, isotropy and anisotropy in chemical shift and coupling constant, NMR spectrometer, 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.

References:

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
7. Principles of fluorescence spectroscopy by Joseph R. Lakowicz

PHY 403A: Condensed Matter Physics-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Condensed Matter Physics-II, a student will be able to:

PHY403A.1 *Explicate response of band electrons to an external electric field and their scattering, and calculate currents in bands.*
PHY403A.2 *Develop a semi-classical description of electrical and thermal transport in metals using the Boltzmann approach, and explain different thermoelectric effects.*
PHY403A.3 *Distinguish nanostructures from bulk materials and learn principle of different imagining techniques for nanostructures.*
PHY403A.4 *Calculate the electronic structure of nano-scale 1D, 0D solids in effective mass approximation, and use it to explain the electrical transport in these solids.*
PHY403A.5 *Treat the electron-electron interactions in Hartree and Hartree-Fock approximations using the variational principle and apply these to calculate electronic properties of simple metals.*
PHY403A.6 *Learn the concept of screening and calculate the screened potential using the Thomas-Fermi and Lindhard approaches.*
PHY403A.7 *Transform the Schrodinger equation for a many-particle system (bosons as well as fermions) to the second quantized form, and construct field operators for one- and two-body operators.*
PHY403A.8 *Apply the second-quantized method to a degenerate homogenous electron gas for calculating the first-order ground-state energy.*

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, Thomson effect, The Wiedemann-Franz law.

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

Nanostructures; Imaging techniques for nanostructures (principle): Electron microscopy (TEM, SEM), Optical microscopy, Scanning tunneling microscopy, Atomic force microscopy; Electronic structure of 1D systems: 1D sub-bands, 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, The Born-Oppenheimer Approximation; The Hartree method, Connection with variational principle; Exchange: The Hartree-Fock approximation, Koopmans' theorem; Application of Hartree and Hartree-Fock methods to homogeneous electron gas- One-electron energy, Band width, DOS, Effective mass, Ground-state energy, Exchange energy; Concept of correlation energy; 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 systems; The Schrodinger equation in first quantization, Expansion of wave function in basis of single-particle wave functions, Symmetry of expansion coefficients, Normalized symmetric and anti-symmetric wave functions; Second quantization: Transformation of Schrodinger equation to occupation number representation for bosons and fermions, Many-particle Hilbert space, and creation and destruction operators, Second-quantized Hamiltonian; Fields, Hamiltonian and number-density operators in terms of field operators; Application to degenerate homogeneous 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.

References:

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. Electronic Structure of Materials by Rajendra Prasad
5. The Wave Mechanics of Electrons in Metals by Stanley Raimes
6. Electronic Structure: Basic Theory and Practical Methods by Richard M. Martin
7. Quantum Theory of Many-particle Systems by A. L. Fetter and J. D. Walecka
8. Many-body Quantum Theory in Condensed Matter Physics by H. Bruus and K. Flensberg

PHY 403B: Nuclear Physics-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After completing the course on Nuclear Physics-II, a student will be able to:

PHY403B.1 *Learn basics of nuclear liquid drop model, nuclear fission process and nuclear shell model.*
PHY403B.2 *Predict ground state properties like spin, parity, magnetic dipole moment, electric quadrupole moment of nuclei by employing nuclear shell model.*
PHY403B.3 *Understand types of multipole deformations and surface vibrations in heavy nuclei.*
PHY403B.4 *Apply nuclear collective model in predicting low lying rotational and vibrational excited states of nuclei.*
PHY403B.5 *Acquire conceptual understanding of the general theory of nuclear scattering and reactions.*
PHY403B.6 *Analyze the cross sections for compound and direct nuclear reactions.*
PHY403B.7 *Understand the key features of nuclear reactions involving weakly bound nuclei and heavy induced ion reactions.*
PHY403B.8 *Appreciate the importance of recent research activities being carried out by using beams of rare isotopes.*

Unit I: 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 II: 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.

Unit III: 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 , 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 IV: Heavy Ion Reactions and Exotic Nuclei (12 hrs.)

Nuclear phenomena in heavy ion collisions: Coulomb excitation, Quasielastic reactions, fusion reactions, Deep inelastic reactions.

Semi classical description of scattering: Role of classical deflection function, Special features: Interference, Rainbow scattering, Glory effect, Spiral scattering, Elastic scattering of alpha particles by atomic nuclei.

Exotic nuclei: Production of rare isotopes, Breakup mechanisms of weakly bound nuclei, Halo and Borromean nuclei. Fusion mechanisms of weakly bound nuclei, Single channel description of fusion, Hill-Wheeler formula, Wong formula, barrier distribution, threshold anomaly.

References:

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. W. Greiner and J. A. Maruhn, "Nuclear Models", Springer, 1996
4. R. A. Broglia and A. Winther, "Heavy Ion Reactions (Lecture Notes)", Benjamin/Cummings Publishing Company, Inc., 1981
5. Ford and Wheeler, Annals of Physics, Vol. 7 (1959) 259.
6. C. A. Bertulani, M. Hussein and G Muenzenberg, " Physics of Radioactive Beams", Nova Science, NY, 2002.
7. L. F. Canto et al., Physics Reports, Vol. 424 (2006) 1.

PHY 403 C: Particle Physics-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Particle Physics-II, a student will be able to:

PHY403C.1 *Realize the Weak interaction, Leptons fundamentals their decay.*
PHY403C.2 *Understand the concept of Helicity, Higgs field and existence of Higgs Bosons.*
PHY403C.3 *Understand of the relativistic kinematics and its importance in calculations at relativistic energies.*
PHY403C.4 *Construct Analysis of the decay energy in various high energy reactions.*
PHY403C.5 *Understand the interaction of charge particles with matter and will be able to calculate the dynamics of high energy particles.*
PHY403C.6 *Learn the quantitative and qualitative analysis of Energy loss and Straggling mechanism.*
PHY403C.7 *Understand radiations mechanism at relativistic velocities.*
PHY403C.8 *Grasp details of particle accelerators for the creation of high energy particles will be provided.*

Unit I: Weak Interactions (10 hrs.)

Classification of weak interactions- Leptonic, semi-leptonic and non-leptonic decays; Concept of Helicity. Helicity conservation, Helicity assigned to neutrino and antineutrino, Helicity assigned to other particles involved in these decays, helicity of neutrino and anti-neutrino, C-P invariance and violation in K_0 decay, $\pi\rightarrow\mu$ and $\pi\rightarrow e$ branching ratios and its outcome, 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, Introduction to Higg‟s boson.

Unit II: Relativistic Kinematics (12 hrs.)

Lorentz transformation, 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,

References:

1. Introduction to High Energy Physics (2_{nd} and 4_{th} edition): D. H. Perkins.
2. Solid State Nuclear Tracks Detection, 'Principle Methods and Applications: S. A. Durrani and
3. R. K. Bull.
4. Nuclear Tracks in Solids: Principles and Applications (1975): R. L. Fleischer, P. B. Price and R. M. Walker.
5. Introduction to Particle Physics: M. P. Khanna.
6. Elementary Particle Physics: Yorikiyo Nagashima.
7. Symmetry Principles in Elementary Particle Physics: W. M. Gibson and B. R. Pollard.
8. Particle Physics: Anwar Kamal
9. Nuclear Physics and Interaction of Particles with Matter: Academician D. V. Skobel'tsyn

PHY 404A: Computational Physics-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Computation Physics-II, a student will be able to:

PHY404A.1 *Apply various numerical methods for finding differentiation and integration appearing in physical problems.*
PHY404A.2 *Find numerically double integration and integration of singular integrals.*
PHY404A.3 *Solve ordinary and partial differential equations using numerical methods.*
PHY404A.4 *Understand hydrogen atom problem more conspicuously by solving the concerned Schrodinger equation numerically.*
PHY404A.5 *Understand the concept of random numbers and generate sequence of random numbers by employing various methods.*
PHY404A.6 *Apply random number sequences in the simulation of random processes like nuclear radioactivity and chaotic systems.*
PHY404A.7 *Learn the fundamental concepts involved in simulation of simple physical phenomena.*
PHY404A.8 *Develop algorithms to simulate physical processes like LR, LC, LCR circuits, Rutherford scattering etc.*

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, Drawbacks of numerical differentiation, Integration: Trapezoidal rule, Trapezoidal rule from Lagrange linear interpolation, Simpson's 1/3 rule, Simpson's 3/8th rule, error in integration (Simpson and Trapezoidal), Gaussian Quadrature, Legendre–Gauss Quadrature, Numerical double integration, Numerical integration of singular integrals, Debye model.

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

Numerical solution of ordinary differential equations: Single step method, multi-step method, Taylor's series method, Euler's method, Modified Euler's method, Fourth-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 Fourth-order Runge-Kutta method (when eigenvalue is given), Numerical Solutions of Partial Differential Equations using Finite Difference Method, Stability of numerical methods.

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

Random numbers: Random sequences, Random number generators, Seeding, 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.
Elementary probability theory, Binomial, Poisson and normal distributions, Central limit theorem.

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

Algorithms and programs 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.

References:

1. R C Desai, Fortran Programming and Numerical methods, Tata McGraw Hill, New Delhi.
2. P B Patil and U. P. Verma, Numercal Computational Methods, Narosa Publishing House
3. M L De Jong, Introduction to Computation Physics, Addison-Wesley publishing company.
4. R C Verma, P K Ahluwalia and K C Sharma, Computational Physics an Introduction, New Age International Publisher.
5. S S Sastry Introductory methods of numerical Analysis, Prentice Hall of India Pvt. Ltd.
6. C Balachandra Rao and C K Santha, Numerical Methods, University Press
7. K E Atkinson, An introduction to numerical analysis, John Wiley and Sons.

PHY 404B: Electronics-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Electronics-II, a student will be able to:

PHY404B.1 *Understand the fabrication processes for devices and ICs like crystal growth, Oxidation, pattern transfer, diffusion, etching, ion-implantation and epitaxial growth.*

PHY404B.2 *Gain knowledge of inter-connections, packaging and the processing of compound semiconductors.*

PHY404B.3 *Obtain a fair understanding of the steps involved in the fabrication of electronic devices like BJT, MOSFET, FET, CMOS, Schottky diodes, IC diodes, capacitors and resistances.*

PHY404B.4 *Know the need of Clean rooms & their classifications.*

PHY404B.5 *Gain a fair understanding of the operation and applications of decoders, demultiplexers, multiplexers, encoders and flip-flops.*

PHY404B.6 *Comprehend the operation and applications of RAMs, ROMs, 555 IC timer, D/A and A/D converters.*

PHY404B.7 *Describe the operation and important applications of half and full adders, and shift-resistors.*

PHY404B.8 *Explain operation and important applications of asynchronous and synchronous counters.*

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, chemical vapor deposition techniques.

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

Epitaxial and non-epitaxial films, inter connection and packaging, compound semiconductors processing, monolithic IC technology, BJT fabrication, PNP transistor, multi-emitter Schottky transistor, superbeta transistor fabrication, fabrication of FET/NMOS enhancement as well as depletion transistors, fabrication of CMOS devices, monolithic diodes, IC resistors and capacitors, Clean rooms & their classifications.

Unit III: Digital electronics (12 hrs.)

QM method for the simplification of Boolean functions (upto 4 variables), Decoder, Demultiplexer, Multiplexer and Encoder. Flip-flops: RS, JK, master-slave-JK, D-Type and T-type flip-flops, ROM and its applications in look-up tables, sequence generator, seven-segment display, character generator and combinational logic, programmable ROM (PROM) and erasable PROM (EPROM), random access memory (RAM), D/A Converters: weighted resister, R-2R ladder, A/D converter; the 555 IC timer as mono and astable multivibrators.

Unit IV: Combinational logic design (12 hrs.)

Half adders, full adders and their use as substractors, shift resistor, applications of shift registers as digital delay line, serial-to-parallel converter, parallel-to-serial converter, ring counter, twisted ring counter, sequence generator; ripple (asynchronous) counters: up-down counter, divided-by-N counter, synchronous counter design, up-down synchronous counter with parallel carry, Asynchronous versus synchronous sequential circuits, Applications of counters.

References:

1. Integrated Electronics by J Millman & CC Halkias.
2. Theory and Application of Micro Electronics by SK Gandhi.
3. Micro Electronics by J Millman & A Grabel.
4. Digital Computer Electronics by AP Malvino.
5. Device Electronics for Integrated Circuits by RS Muller & TI Kamins.
6. VLSI Fabrication Principal & Practice by SK Gandhi.
7. Semiconductor Devices Physics & Technology by SM Sze.
8. Modern Digital Electronics by RP Jain
9. Introduction to semiconductor Materials and Devices by MS Tyagi

PHY 404C: Material Science-II

Credit: 4
Max. Marks: 60+20
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. Each question will carry 12 marks.

Course Outcomes (COs)

After successful completion of the course on Material Science-II, a student will be able to:

PHY404C.1 *Comprehend various tests (Tension test, hardness tests, Impact test, fatigue test, creep test) used for measuring the mechanical properties of materials*

PHY404C.2 *Realize the difference between strength and hardness of materials. Compute various strength and ductility measures from engineering stress-strain curve and true stress-strain curves*

PHY404C.3 *Understand magnetic processes, Diamagnetism, Paramagnetism, density of states curves for a metal;*

PHY404C.4 *Grasp the concepts of Ferromagnetism, exchange interactions, domain structure; Antiferromagnetism, Ferrimagnetism and Ferrites*

PHY404C.5 *Elucidate the physics describing dielectrics and ferroelectric materials, with focus on the functionality.*

PHY404C.6 *Describe the optical properties of insulators*

PHY404C.7 *Understanding of the surface and concepts of salvage depth.*

PHY404C.8 *Grasp the concept, working and applications of different electron and photon based surface analysis techniques.*

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: Dielectric, Optical and Ferroelectric Materials (12 hrs.)

Introduction, Energy bands, dielectric constant, complex permittivity, dielectric loss factor, polarization, mechanism of polarization, classification of dielectrics-frequency dependence of dielectric constant; Optical Phenomena in Insulators Colour of crystals - Excitons - weakly bound and tightly bound excitons. Colour centers – F-centers and other electronic centers in alkali halides. Ferroelectrics: General characteristics - piezoelectric, pyroelectric and ferroelectric materials . Classification of ferroelectrics and representative materials. Ferroelectric domains. polarization catastrophe, Landau theory of first and second-order phase transitions, Antiferroelectric materials .

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.

References:

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
6. Solid State Physics – A J Dekker (McMillan, 1971)
7. Materials Science and Engineering by William D. Callister

PHY 405: Physics Laboratory-IV

Credit:8
Max. Marks: 120+40
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 second specialization. Course outcomes, pattern of evaluation and list of specialization-wise experiments is already given in the course PHY 305. Students opting for project will be evaluated on the basis of project report (60 marks) and Project Presentation cum viva-voce (60 marks) by a committee consisting of project supervisor, one internal faculty member as nominated by the Chairperson and an external expert as nominated by PGBOS while the component of internal assessment (40 marks) in the project shall be assessed by the respective project supervisor.

PHY 406: Seminar

Credit:2
Max. Marks: 40
Time: 40 Minutes

Note: Each student will deliver one seminar on the topic to be allotted by the departmental seminar committee in both 1st and 2nd year 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.

Course Outcomes (COs)

After successful completion of the course on seminar a student will be able to:

PHY406.1 *Achieve effective communication skills.*
PHY406.2 *Understand the concepts involved in the topic of seminar.*
PHY406.3 *Acquire skills for working in team.*
PHY406.4 *Develop confidence for facing audience.*
PHY406.5 *Learn to write effectively a report on a particular topic.*
PHY406.6 *Know the techniques of responding to the questions posed by audience.*
PHY406.7 *Enhance the presentation abilities.*
PHY406.8 *Improve interpersonal skills.*

OE-208: Elements of Nano Science and Nano Technology

Credit:2
Max. Marks: 35+15
Time: 1:30 Hours

Note: Five questions will be set and students will attempt three questions. Question No. 1 will be compulsory and comprise 7 marks; it will consist of 3-5 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be two units in the question paper with each unit consisting of two questions of 14 marks each 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.

Course Outcomes (COs)

After successful completion of the course on Elements of Nano Science and Nano Technology, a student will be able to:

OE208.1 *Understand the basics of nanoscience.*
OE208.2 *Describe the various techniques to fabricate nanostructure.*
OE208.3 *Comprehend the principles and working of characterization tools for analyses of*
OE208.4 *Grasp the concepts of various physical properties of nanostructures.*

UNIT I

Introduction to Nanomaterials: Bottom up and Top Down approach, Classification of nanostructures: Zero dimension, one dimension and two dimensional nanostructures, Smart materials.
Nanostructure fabrication by Physical Methods: Physical Vapor deposition: evaporation, Molecular beam epitaxy, sputtering, comparison of evaporation and sputtering, Lithography: Photolithography, Electron Beam Lithography, X-ray lithography

UNIT II

Structural characterization: X-ray diffraction, small angle X-ray scattering, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunneling Microscopy, Spectroscopic Techniques: UV-Visible Spectroscopy, Photo-luminescence spectroscopy, Infra-red spectroscopy, Raman Spectroscopy,
Physical properties of nanomaterials: Melting points and lattice constants, Mechanical properties, Optical properties, Electrical conductivity, Superparamagnetism

References:

1. Introduction to Nanotechnology – Charles P. Poole Jr. and Frank J. Owens, Wiley India Pvt. Ltd., 2007.
2. Nanomaterials – Guozhong Cao, Imperial College Press, 2004.

OE-308: Radiation Physics

Credit:2
Max. Marks: 35+15
Time: 1:30 Hours

Note: Five questions will be set and students will attempt three questions. Question No. 1 will be compulsory and of 7 marks; it will consist of 3-5 conceptual questions uniformly distributed over the whole syllabus. In addition to Question No. 1, there will be two units in the question paper with each unit consisting of two questions of 14 marks each 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.

After successful completion of the course on Radiation Physics, a student will be able to:

OE308.1 *Understand about various sources of radiation.*
OE308.2 *Describe units used for measuring radiation.*
OE308.3 *Comprehend the biological effects of radiation exposure.*
OE308.4 *Realize the importance of radiation protection and safe disposal of radioactive*

UNIT – I

Radiation and need for its measurement, Physical features of radiation, Conventional sources of radiation.
Exposure to natural radiation: external to the body, Radiation from cosmic rays and solar radiation, Internal exposure to the body, Radioactivity arising from technological development: Possible health hazards from nuclear and laser radiations
Maximum permissible level of radiation. Radiation quantities and units of energy flux, energy fluence, cross-section.

UNIT – II

Biological effects of radiation: Dose - response characteristics, Direct and indirect action, Acute effects, Delayed effects, Cumulative effect, Accidental exposure, Radiation induced chemical changes in tissues, Radiation protection procedures (diagnostics and therapy).

Basic radiation safety criteria, Protection from direct radiation, Energy deposition, Effect of distance and shielding, Protection from contamination, Preparation of a safe radiation area,

Radioactive waste disposal and management: Type of radioactive waste, Airborne waste, Solid and liquid waste, Assessment of Hazard.

References:

1. Introduction to Radiobiology and Radiation Dosimetery - F.H. Aurix, John Wiley.
2. Techniques of Radiation Dosimetery - Eds K. Mahesh and DR Vij Wiley Eastern Limited.
3. Nuclear Energy - Raymond L. Murray Pergamon Press, N.Y.

Mapping: Mapping is a process of representing the correlation between COs and POs, Cos and PSOs in the scale of 1 to 3 as follows (Table-1)

Table -1: Scale of mapping between COs and POs

Scale	
1	If the content of the course have low correlation (i.e. in agreement with the particular PO to a small extent) with the particular program outcome.
2	If the contents of course have medium correlation (i.e. in agreement with the particular PO to a reasonable extent) with the particular program outcome.
3	If the contents of course have strong correlation (i.e. in agreement with the particular PO to a large extent) with the particular program outcome.

Same scale has been used to define the correlation between COs and PSOs

CO-PO mapping Matrices

CO-PO matrix for the course PHY101 (Mathematical Physics)

COs #	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
PHY101.1	3	2	2	3	2	2	2	2	3	3	2
PHY101.2	3	2	2	3	2	2	2	2	3	3	2
PHY101.3	3	2	2	3	2	2	2	2	3	3	2
PHY101.4	3	2	2	3	2	2	2	2	3	3	2
PHY101.5	3	2	2	3	2	2	2	2	3	3	2
PHY101.6	3	2	2	3	2	2	2	2	3	3	2
PHY101.7	3	2	2	3	2	2	2	2	3	3	2
PHY101.8	3	2	2	3	2	2	2	2	3	3	2
Average	3	2	2	3	2	2	2	2	3	3	2

CO-PO matrix for the course PHY102 (Classical Mechanics)

COs #	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
PHY102.1	3	2	3	3	2	2	2	2	3	3	3
PHY102.2	3	2	3	3	2	2	2	2	3	3	3
PHY102.3	3	2	3	3	2	2	2	2	3	3	3
PHY102.4	3	2	3	3	2	2	2	2	3	3	3
PHY102.5	3	2	3	3	2	2	2	2	3	3	3
PHY102.6	3	2	3	3	2	2	2	2	3	3	3
PHY102.7	3	2	3	3	2	2	2	2	3	3	3
PHY102.8	3	2	3	3	2	2	2	2	3	3	3
Average	3	2	3	3	2	2	2	2	3	3	3

CO-PO matrix for the course PHY 103 (Quantum Mechanics-I)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY103.1	3	3	2	3	2	2	2	1	2	2	1
PHY103.2	3	2	2	3	2	2	2	1	2	2	1
PHY103.3	3	2	2	3	2	2	2	1	2	2	1
PHY103.4	3	3	2	3	2	1	2	1	2	2	1
PHY103.5	3	2	2	3	2	1	2	1	2	2	1
PHY103.6	3	2	2	3	2	1	2	1	2	2	1
PHY103.7	3	3	2	3	2	2	2	1	2	2	1
PHY103.8	3	2	2	3	2	2	2	1	2	2	1
Average	3	2.38	2	3	2	1.63	2	1	2	2	1

CO-PO matrix for the course PHY:104 (Electronics Devices and Circuits-I)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY104.1	3	2	3	3	2	3	3	3	3	2	3
PHY104.2	3	2	3	3	2	3	3	3	3	2	3
PHY104.3	3	2	3	3	2	3	3	3	3	2	3
PHY104.4	3	2	3	3	2	3	3	3	3	2	3
PHY104.5	3	2	3	3	2	3	3	3	3	2	3
PHY104.6	3	2	3	3	2	3	3	3	3	2	3
PHY104.7	3	2	3	3	2	3	3	3	3	2	3
PHY104.8	3	2	3	3	2	3	3	3	3	2	3
Average	3	2	3	3	2	3	3	3	3	2	3

CO-PO matrix for the course PHY:105 (Physics Laboratory-I)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY105.1	3	2	3	3	2	3	3	3	3	2	3
PHY105.2	3	2	3	3	2	3	3	3	3	2	3
PHY105.3	3	2	3	3	2	3	3	3	3	2	3
PHY105.4	3	2	3	3	2	3	3	3	3	2	3
PHY105.5	3	2	3	3	2	3	3	3	3	2	3
PHY105.6	3	2	3	3	2	3	3	3	3	2	3
PHY105.7	3	2	3	3	2	3	3	3	3	2	3
PHY105.8	3	2	3	3	2	3	3	3	3	2	3
Average	3	2	3	3	2	3	3	3	3	2	3

CO-PO matrix for the course PHY 201 (Quantum Mechanics-II)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY201.1	3	3	2	3	2	2	3	1	2	2	2
PHY201.2	3	2	2	3	2	1	2	1	2	2	2
PHY201.3	3	2	2	3	2	1	2	1	2	2	2
PHY201.4	3	3	2	3	2	2	3	1	2	2	2
PHY201.5	3	3	2	3	2	2	3	1	2	2	2
PHY201.6	3	2	2	3	2	2	2	1	2	2	2
PHY201.7	3	3	2	3	2	2	3	1	2	2	2
PHY201.8	3	2	2	3	2	1	1	1	2	2	2
Average	3	2.5	2	3	2	1.63	2.38	1	2	2	2

CO-PO matrix for the course PHY202 (Nuclear and Particle Physics)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY202.1	3	3	3	2	2	3	3	3	3	2	2
PHY202.2	3	3	3	3	2	3	3	3	3	2	2
PHY202.3	3	3	2	2	2	3	2	2	3	2	2
PHY202.4	3	3	2	3	2	3	3	2	3	2	1
PHY202.5	3	3	3	2	2	3	2	2	3	2	2
PHY202.6	3	3	3	3	2	3	2	3	3	2	2
PHY202.7	3	3	3	3	2	3	2	2	3	-	-
PHY202.8	3	3	2	3	2	3	2	2	3	-	-
Average	3	3	2.62	2.62	2	3	2.37	2.38	3	2	1.83

CO-PO matrix for the course PHY 203 (Solid State Physics)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY203.1	3	3	2	3	2	3	2	1	1	2	2
PHY203.2	3	3	2	3	2	3	2	1	1	2	2
PHY203.3	3	3	2	2	2	3	2	1	1	2	2
PHY203.4	3	2	2	2	2	2	2	1	1	2	2
PHY203.5	3	3	2	3	2	3	2	1	1	2	2
PHY203.6	3	2	2	2	2	2	2	1	1	2	2
PHY203.7	3	2	2	2	2	2	2	1	1	2	2
PHY203.8	3	2	2	2	2	2	2	1	1	2	2
Average	3	2.5	2	2.38	2	2.5	2	1	1	2	2

CO-PO matrix for the course PHY:204 (Electronics Devices and Circuits-II)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY204.1	3	2	3	3	2	3	3	3	3	2	3
PHY204.2	3	2	3	3	2	3	3	3	3	2	3
PHY204.3	3	2	3	3	2	3	3	3	3	2	3
PHY204.4	3	2	3	3	2	3	3	3	3	2	3
PHY204.5	3	2	3	3	2	3	3	3	3	2	3
PHY204.6	3	2	3	3	2	3	3	3	3	2	3
PHY204.7	3	2	3	3	2	3	3	3	3	2	3
PHY204.8	3	2	3	3	2	3	3	3	3	2	3
Average	3	2	3	3	2	3	3	3	3	2	3

CO-PO matrix for the course PHY:205(Physics Laboratory-II)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY205.1	3	2	3	3	2	3	3	3	3	2	3
PHY205.2	3	2	3	3	2	3	3	3	3	2	3
PHY205.3	3	2	3	3	2	3	3	3	3	2	3
PHY205.4	3	2	3	3	2	3	3	3	3	2	3
PHY205.5	3	2	3	3	2	3	3	3	3	2	3
PHY205.6	3	2	3	3	2	3	3	3	3	2	3
PHY205.7	3	2	3	3	2	3	3	3	3	2	3
PHY205.8	3	2	3	3	2	3	3	3	3	2	3
Average	3	2	3	3	2	3	3	3	3	2	3

CO-PO matrix for the course PHY 206 (Seminar)

COs #	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
PHY206.1	3	2	3	2	3	2	3	3	3	3	3
PHY206.2	3	2	3	2	3	2	3	3	3	3	3
PHY206.3	3	2	3	2	3	2	3	3	3	3	3
PHY206.4	3	2	3	2	3	2	3	3	3	3	3
PHY206.5	3	2	3	2	3	2	3	3	3	3	3
PHY206.6	3	2	3	2	3	2	3	3	3	3	3
PHY206.7	3	2	3	2	3	2	3	3	3	3	3
PHY206.8	3	2	3	2	3	2	3	3	3	3	3
Average	3	2	3	2	3	2	3	3	3	3	3

CO-PO matrix for the course PHY301 (Electrodynamics and Plasma Physics)

COs#.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY301.1	3	2	3	3	2	2	3	2	3	3	3
PHY301.2	3	2	3	3	2	2	3	2	3	3	3
PHY301.3	3	2	3	3	2	2	3	2	3	3	3
PHY301.4	3	2	3	3	2	2	3	2	3	3	3
PHY301.5	3	2	3	3	2	2	3	2	3	3	3
PHY301.6	3	2	3	3	2	2	3	2	3	3	3
PHY301.7	3	2	3	3	2	2	3	2	3	3	3
PHY301.8	3	2	3	3	2	2	3	2	3	3	3
Average	3	2	3	3	2	2	3	2	3	3	3

CO-PO matrix for the course PHY 302 (Statistical Mechanics)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY302.1	3	3	3	3	3	3	2	3	3	2	3
PHY302.2	3	3	3	3	2	3	2	3	3	2	3
PHY302.3	3	3	3	3	2	3	2	2	3	2	2
PHY302.4	3	3	3	3	2	3	2	2	3	2	2
PHY302.5	3	3	2	3	2	3	2	2	3	2	3
PHY302.6	3	3	2	3	2	3	2	2	3	2	2
PHY302.7	3	3	2	3	2	3	2	2	3	2	2
PHY302.8	3	3	2	3	1	3	2	2	3	2	1
Average	3	3	2.5	3	2	3	2	2.25	3	2	2.25

CO-PO matrix for the course PHY 303A (Condensed Matter Physics-I)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY303A.1	3	2	2	2	2	2	2	1	1	2	2
PHY303A.2	3	3	2	2	2	3	2	1	1	2	2
PHY303A.3	3	2	2	3	2	2	2	1	1	2	2
PHY303A.4	3	3	2	2	2	3	2	1	1	2	2
PHY303A.5	3	2	2	2	2	2	2	1	1	2	2
PHY303A.6	3	2	2	2	2	2	2	1	1	2	2
PHY303A.7	3	3	2	3	2	2	2	1	1	2	2
PHY303A.8	3	2	2	3	2	2	2	1	1	2	2
Average	3	2.38	2	2.38	2	2.25	2	1	1	2	2

CO-PO matrix for the course PHY303B (Nuclear Physics-I)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY303B.1	3	3	3	2	2	3	3	3	3	2	3
PHY303B.2	3	3	3	3	2	3	3	3	3	2	3
PHY303B.3	3	3	2	2	2	3	3	3	3	2	3
PHY303B.4	3	3	2	3	2	3	3	2	3	2	3
PHY303B.5	3	3	3	2	2	3	3	3	3	2	3
PHY303B.6	3	3	3	3	2	3	3	3	3	2	3
PHY303B.7	3	3	3	3	2	3	1	2	3	2	2
PHY303B.8	3	3	2	3	2	3	1	2	3	2	1
Average	3	3	2.62	2.62	2	3	2.5	2.67	3	2	2.67

CO-PO matrix for the course PHY 303C (Particle Physics-I)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY303C.1	3	3	3	3	3	3	3	3	2	2	3
PHY303C.2	3	3	3	3	2	3	2	2	2	2	3
PHY303C.3	3	3	3	3	2	3	2	2	2	2	3
PHY303C.4	3	3	3	3	2	3	2	2	3	2	3
PHY303C.5	3	3	3	3	2	3	2	2	2	2	3
PHY303C.6	3	3	3	3	2	3	2	2	2	2	3
PHY303C.7	3	3	3	3	2	3	2	2	2	2	3
PHY303C.8	3	3	3	3	2	3	1	1	2	2	3
Average	3	3	3	3	2.17	3	2	2.17	2.17	2	3

CO-PO matrix for the course PHY304A (Computational Physics-I)

COs#.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY304A.1	3	2	2	3	2	2	2	2	3	3	1
PHY304A.2	3	2	2	3	2	2	2	2	3	3	1
PHY304A.3	3	2	2	3	2	2	2	2	3	3	1
PHY304A.4	3	2	2	3	2	2	2	2	3	3	1
PHY304A.5	3	2	2	3	2	2	2	2	3	3	1
PHY304A.6	3	2	2	3	2	2	2	2	3	3	1
PHY304A.7	3	2	2	3	2	2	2	2	3	3	1
PHY304A.8	3	2	2	3	2	2	2	2	3	3	1
Average	3	2	2	3	2	2	2	2	3	3	1

CO-PO matrix for the course PHY304B (Electronics-I)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY304B.1	3	2	3	3	2	3	3	3	3	2	3
PHY304B.2	3	2	3	3	2	3	3	3	3	2	3
PHY304B.3	3	2	3	3	2	3	3	3	3	2	3
PHY304B.4	3	2	3	3	2	3	3	3	3	2	3
PHY304B.5	3	2	3	3	2	3	3	3	3	2	3
PHY304B.6	3	2	3	3	2	3	3	3	3	2	3
PHY304B.7	3	2	3	3	2	3	3	3	3	2	3
PHY304B.8	3	2	3	3	2	3	3	3	3	2	3
Average	3	2	3	3	2	3	3	3	3	2	3

CO-PO matrix for the course PHY 304C (Material Science-I)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY304C.1	3	3	3	3	3	3	3	3	3	2	3
PHY304C.2	3	3	3	3	3	3	3	3	3	2	3
PHY304C.3	3	2	3	3	2	3	3	3	3	2	3
PHY304C.4	3	2	3	3	2	3	3	3	3	2	3
PHY304C.5	3	2	3	2	2	3	3	3	3	2	2
PHY304C.6	3	2	3	2	2	3	3	3	3	2	2
PHY304C.7	3	3	3	3	3	3	3	3	3	2	3
PHY304C.8	3	3	3	3	3	3	3	3	3	2	3
Average	3	2.5	3	2.75	2.5	3	3	3	3	2	2.75

<u>CO-PO matrix for the course PHY 305 (Physics Laboratory-III)</u>

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY305.1	3	3	2	2	2	3	3	2	2	2	1
PHY305.2	3	3	2	2	2	3	3	2	2	2	1
PHY305.3	3	3	2	2	2	3	3	2	2	2	1
PHY305.4	3	3	2	2	2	3	3	2	2	2	1
PHY305.5	3	3	2	2	2	3	3	2	2	2	1
PHY305.6	3	3	2	2	2	3	3	2	2	2	1
PHY305.7	3	3	2	2	2	3	3	2	2	2	1
PHY305.8	3	3	2	2	2	3	3	2	2	2	1
Average	3	3	2	2	2	3	3	2	2	2	1

CO-PO matrix for the course PHY401 (Advanced Quantum Mechanics)

COs #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY401.1	3	2	3	3	2	2	3	2	3	3	2
PHY401.2	3	2	3	3	2	2	3	2	3	3	2
PHY401.3	3	2	3	3	2	2	3	2	3	3	2
PHY401.4	3	2	3	3	2	2	3	2	3	3	2
PHY401.5	3	2	3	3	2	2	3	2	3	3	2
PHY401.6	3	2	3	3	2	2	3	2	3	3	2
PHY401.7	3	2	3	3	2	2	3	2	3	3	2
PHY401.8	3	2	3	3	2	2	3	2	3	3	2
Average	3	2	3	3	2	2	3	2	3	3	2

CO-PO matrix for the course PHY 402 (Atomic and Molecular Physics)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY402.1	3	3	3	3	3	3	2	3	2	3	3
PHY402.2	3	3	3	3	3	3	2	3	2	3	3
PHY402.3	3	3	3	3	3	3	2	3	2	3	2
PHY402.4	3	3	3	3	3	3	3	3	2	2	2
PHY402.5	3	3	3	3	3	3	3	3	2	2	2
PHY402.6	3	3	3	3	3	3	2	3	2	2	3
PHY402.7	3	3	3	3	3	3	2	3	2	2	2
PHY402.8	3	3	3	3	3	3	2	3	2	2	2
Average	3	3	3	3	3	3	2.25	3	2	2.37	2.37

CO-PO matrix for the course PHY 403A (Condensed Matter Physics-II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY403A.1	3	3	2	3	2	3	2	1	1	2	2
PHY403A.2	3	3	2	3	2	3	2	1	1	2	2
PHY403A.3	3	3	2	2	2	3	2	1	1	2	2
PHY403A.4	3	3	2	3	2	2	2	1	1	2	2
PHY403A.5	3	3	2	3	2	3	2	1	1	2	2
PHY403A.6	3	2	2	2	2	2	2	1	1	2	2
PHY403A.7	3	3	2	3	2	2	2	1	1	2	2
PHY403A.8	3	2	2	2	2	2	2	1	1	2	2
Average	3	2.75	2	2.63	2	2.5	2	1	1	2	2

CO-PO matrix for the course PHY403B (Nuclear Physics-II)

COs#.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY403B.1	3	3	2	3	2	3	2	2	3	3	1
PHY403B.2	3	3	2	3	2	3	2	2	3	3	1
PHY403B.3	3	3	2	3	2	3	2	2	3	3	1
PHY403B.4	3	3	2	3	2	3	2	2	3	3	1
PHY403B.5	3	3	2	3	2	3	2	2	3	3	1
PHY403B.6	3	3	2	3	2	3	2	2	3	3	1
PHY403B.7	3	3	2	3	2	3	2	2	3	3	1
PHY403B.8	3	3	2	3	2	3	2	2	3	3	1
Average	3	3	2	3	2	3	2	2	3	3	1

CO-PO matrix for the course PHY403C (Particle Physics-II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY403C.1	3	3	3	3	3	3	3	3	2	2	2
PHY403C.2	3	3	3	3	3	3	3	3	2	2	2
PHY403C.3	3	3	3	3	3	2	3	2	2	2	2
PHY403C.4	3	3	3	3	3	2	2	2	2	2	2
PHY403C.5	3	3	3	3	3	2	2	2	2	2	2
PHY403C.6	3	3	3	3	3	2	2	2	2	2	2
PHY403C.7	3	3	3	3	3	2	2	2	2	2	2
PHY403C.8	3	3	3	3	3	1	2	2	2	2	2
Average	3	3	3	3	3	2.12	2.37	2.25	2	2	2

CO-PO matrix for the course PHY404A (Computational Physics-II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY404A.1	3	2	2	3	2	2	2	1	3	3	1
PHY404A.2	3	2	2	3	2	2	2	1	3	3	1
PHY404A.3	3	2	2	3	2	2	2	1	3	3	1
PHY404A.4	3	2	2	3	2	2	2	1	3	3	1
PHY404A.5	3	2	2	3	2	2	2	1	3	3	1
PHY404A.6	3	2	2	3	2	2	2	1	3	3	1
PHY404A.7	3	2	2	3	2	2	2	1	3	3	1
PHY404A.8	3	2	2	3	2	2	2	1	3	3	1
Average	3	2	2	3	2	2	2	1	3	3	1

CO-PO matrix for the course PHY:404B (Electronics-II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY404B.1	3	2	3	3	2	3	3	3	3	2	3
PHY404B.2	3	2	3	3	2	3	3	3	3	2	3
PHY404B.3	3	2	3	3	2	3	3	3	3	2	3
PHY404B.4	3	2	3	3	2	3	3	3	3	2	3
PHY404B.5	3	2	3	3	2	3	3	3	3	2	3
PHY404B.6	3	2	3	3	2	3	3	3	3	2	3
PHY404B.7	3	2	3	3	2	3	3	3	3	2	3
PHY404B.8	3	2	3	3	2	3	3	3	3	2	3
Average	3	2	3	3	2	3	3	3	3	2	3

CO-PO matrix for the course PHY404C (Material Science-II)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY404C.1	3	3	3	3	3	3	3	3	3	2	3
PHY404C.2	3	3	3	3	3	3	3	3	3	2	3
PHY404C.3	3	2	3	3	2	3	3	3	3	2	3
PHY404C.4	3	2	3	3	2	3	3	3	3	2	3
PHY404C.5	3	2	3	2	2	3	3	3	3	2	3
PHY404C.6	3	2	3	2	2	3	3	3	3	2	3
PHY404C.7	3	3	3	3	3	3	3	3	3	2	3
PHY404C.8	3	3	3	3	3	3	3	3	3	2	3
Average	3	2.5	3	2.75	2.5	3	3	3	3	2	3

CO-PO matrix for the course PHY 405 (Physics Laboratory-III)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY405.1	3	3	2	2	2	3	3	2	2	2	1
PHY405.2	3	3	2	2	2	3	3	2	2	2	1
PHY405.3	3	3	2	2	2	3	3	2	2	2	1
PHY405.4	3	3	2	2	2	3	3	2	2	2	1
PHY405.5	3	3	2	2	2	3	3	2	2	2	1
PHY405.6	3	3	2	2	2	3	3	2	2	2	1
PHY405.7	3	3	2	2	2	3	3	2	2	2	1
PHY405.8	3	3	2	2	2	3	3	2	2	2	1
Average	3	3	2	2	2	3	3	2	2	2	1

CO-PO matrix for the course PHY 406 (Seminar)

COs#	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY406.1	3	2	3	2	3	2	3	3	3	3	3
PHY406.2	3	2	3	2	3	2	3	3	3	3	3
PHY406.3	3	2	3	2	3	2	3	3	3	3	3
PHY406.4	3	2	3	2	3	2	3	3	3	3	3
PHY406.5	3	2	3	2	3	2	3	3	3	3	3
PHY406.6	3	2	3	2	3	2	3	3	3	3	3
PHY406.7	3	2	3	2	3	2	3	3	3	3	3
PHY406.8	3	2	3	2	3	2	3	3	3	3	3
Average	3	2	3	2	3	2	3	3	3	3	3

CO-PSO Mapping Matrices

CO-PSO matrix for the course PHY101 (Mathematical Physics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY101.1	3	2	2	2	3
PHY101.2	3	2	2	2	3
PHY101.3	3	2	2	2	3
PHY101.4	3	2	2	2	3
PHY101.5	3	2	2	2	3
PHY101.6	3	2	2	2	3
PHY101.7	3	2	2	2	3
PHY101.8	3	2	2	2	3
Average	3	2	2	2	3

CO-PSO matrix for the course PHY102 (Classical Mechanics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY102.1	3	2	2	3	3
PHY102.2	3	2	2	3	3
PHY102.3	3	2	2	3	3
PHY102.4	3	2	2	3	3
PHY102.5	3	2	2	3	3
PHY102.6	3	2	2	3	3
PHY102.7	3	2	2	3	3
PHY102.8	3	2	2	3	3
Average	3	2	2	3	3

CO-PSO matrix for the course PHY 103 (Quantum Mechanics-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY103.1	3	3	1	3	3
PHY103.2	3	3	1	2	2
PHY103.3	3	3	1	2	3
PHY103.4	3	3	1	2	3
PHY103.5	3	3	1	2	2
PHY103.6	3	3	1	2	2
PHY103.7	3	3	1	3	3
PHY103.8	3	3	1	2	2
Average	3	3	1	2.25	2.5

CO-PSO matrix for the course PHY:104 (Electronics Devices and Circuits-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY104.1	2	2	3	3	3
PHY104.2	2	2	3	3	3
PHY104.3	2	2	3	3	3
PHY104.4	2	2	3	3	3
PHY104.5	2	2	3	3	3
PHY104.6	2	2	3	3	3
PHY104.7	2	2	3	3	3
PHY104.8	2	2	3	3	3
Average	2	2	3	3	3

CO-PSO matrix for the course PHY:105 (Physics Laboratory-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY105.1	2	2	3	3	3
PHY105.2	2	2	3	3	3
PHY105.3	2	2	3	3	3
PHY105.4	2	2	3	3	3
PHY105.5	2	2	3	3	3
PHY105.6	2	2	3	3	3
PHY105.7	2	2	3	3	3
PHY105.8	2	2	3	3	3
Average	2	2	3	3	3

CO-PSO matrix for the course PHY 201(Quantum Mechanics-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY201.1	3	3	1	3	3
PHY201.2	3	2	2	2	2
PHY201.3	3	2	1	2	2
PHY201.4	3	2	1	2	2
PHY201.5	3	3	1	3	3
PHY201.6	3	3	1	2	2
PHY201.7	3	3	2	2	3
PHY201.8	3	2	1	2	2
Average	3	2.5	1.25	2.25	2.38

CO-PSO matrix for the course PHY 202(Nuclear and Particle Physics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY202.1	3	3	2	2	3
PHY202.2	3	3	2	2	3
PHY202.3	3	3	2	2	3
PHY202.4	3	3	2	2	3
PHY202.5	3	3	2	2	3
PHY202.6	3	3	2	2	3
PHY202.7	3	3	2	2	3
PHY202.8	3	3	2	2	3
Average	3	3	2	2	3

CO-PSO matrix for the course PHY 203 (Solid State Physics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY203.1	3	3	1	3	3
PHY203.2	3	3	3	3	3
PHY203.3	2	3	2	3	3
PHY203.4	2	3	1	2	2
PHY203.5	3	3	1	3	3
PHY203.6	2	3	1	2	2
PHY203.7	2	3	2	2	2
PHY203.8	2	3	2	2	2
Average	2.38	3	1.63	2.5	2.5

CO-PSO matrix for the course PHY:204(Electronics Devices and Circuits-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY204.1	2	2	3	3	3
PHY204.2	2	2	3	3	3
PHY204.3	2	2	3	3	3
PHY204.4	2	2	3	3	3
PHY204.5	2	2	3	3	3
PHY204.6	2	2	3	3	3
PHY204.7	2	2	3	3	3
PHY204.8	2	2	3	3	3
Average	2	2	3	3	3

CO-PSO matrix for the course PHY:205(Physics Laboratory-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY205.1	2	2	3	3	3
PHY205.2	2	2	3	3	3
PHY205.3	2	2	3	3	3
PHY205.4	2	2	3	3	3
PHY205.5	2	2	3	3	3
PHY205.6	2	2	3	3	3
PHY205.7	2	2	3	3	3
PHY205.8	2	2	3	3	3
Average	2	2	3	3	3

CO-PSO matrix for the course PHY:206(Seminar)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY206.1	3	2	2	3	3
PHY206.2	3	2	2	3	3
PHY206.3	3	2	2	3	3
PHY206.4	3	2	2	3	3
PHY206.5	3	2	2	3	3
PHY206.6	3	2	2	3	3
PHY206.7	3	2	2	3	3
PHY206.8	3	2	2	3	3

CO-PSO matrix for the course PHY301 ((Electrodynamics and Plasma Physics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY301.1	3	2	2	3	3
PHY301.2	3	2	2	3	3
PHY301.3	3	2	2	3	3
PHY301.4	3	2	2	3	3
PHY301.5	3	2	2	3	3
PHY301.6	3	2	2	3	3
PHY301.7	3	2	2	3	3
PHY301.8	3	2	2	3	3
Average	3	2	2	3	3

CO-PSO matrix for the course PHY 302 (Statistical Mechanics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY302.1	3	3	2	3	3
PHY302.2	3	3	3	3	3
PHY302.3	3	3	3	3	3
PHY302.4	3	3	3	3	3
PHY302.5	3	3	3	2	2
PHY302.6	3	3	3	2	2
PHY302.7	3	2	2	2	2
PHY302.8	3	2	2	3	2
Average	3	2.75	2.63	2.63	2.5

CO-PSO matrix for the course PHY 303A (Condensed Matter Physics-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY303A.1	2	2	2	3	2
PHY303A.2	3	3	2	3	3
PHY303A.3	3	3	1	2	3
PHY303A.4	3	3	2	2	3
PHY303A.5	2	2	1	3	2
PHY303A.6	2	3	1	3	3
PHY303A.7	3	3	1	3	3
PHY303A.8	2	3	2	3	2
Average	2.5	2.75	1.5	2.75	2.63

CO-PSO matrix for the course PHY 303B (Nuclear Physics-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY303B.1	3	3	3	3	3
PHY303B.2	3	3	3	3	3
PHY303B.3	3	3	3	3	3
PHY303B.4	3	3	3	3	3
PHY303B.5	3	3	3	3	3
PHY303B.6	3	3	3	3	3
PHY303B.7	3	3	1	2	2
PHY303B.8	3	3	1	2	1
Average	3	3	2.5	2.75	2.62

CO-PSO matrix for the course PHY 303C (Particle Physics-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY303C.1	2	3	3	3	2
PHY303C.2	2	3	3	3	2
PHY303C.3	3	3	3	3	2
PHY303C.4	2	3	3	3	2
PHY303C.5	2	3	3	3	2
PHY303C.6	3	3	3	3	2
PHY303C.7	2	3	3	3	2
PHY303C.8	2	3	3	3	2
Average	2.25	3	3	3	2

CO-PSO matrix for the course PHY304A (Computational Physics-I)

COs#.	PSO1	PSO2	PSO3	PSO4	PSO5
PHY304A.1	3	2	3	3	2
PHY304A.2	3	2	3	3	2
PHY304A.3	3	2	3	3	2
PHY304A.4	3	2	3	3	2
PHY304A.5	3	2	3	3	2
PHY304A.6	3	2	3	3	2
PHY304A.7	3	2	3	3	2
PHY304A.8	3	2	3	3	2
Average	3	2	3	3	2

CO-PSO matrix for the course PHY304B (Electronics-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY304B.1	2	2	3	3	3
PHY304B.2	2	2	3	3	3
PHY304B.3	2	2	3	3	3
PHY304B.4	2	2	3	3	3
PHY304B.5	2	2	3	3	3
PHY304B.6	2	2	3	3	3
PHY304B.7	2	2	3	3	3
PHY304B.8	2	2	3	3	3
Average	2	2	3	3	3

CO-PSO matrix for the course PHY304C(Material Science-I)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY304C.1	3	3	3	3	3
PHY304C.2	3	3	3	3	3
PHY304C.3	3	3	3	3	3
PHY304C.4	3	3	3	3	3
PHY304C.5	3	2	2	3	3
PHY304C.6	3	2	2	3	3
PHY304C.7	3	3	3	3	3
PHY304C.8	3	3	3	3	3
Average	3	2.75	2.75	3	3

CO-PSO matrix for the course PHY 305 (Physics Laboratory-III)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY305.1	2	3	3	3	3
PHY305.2	2	3	3	3	3
PHY305.3	2	3	3	3	3
PHY305.4	2	3	3	3	3
PHY305.5	2	3	3	3	3
PHY305.6	2	3	3	3	3
PHY305.7	2	3	3	3	3
PHY305.8	2	3	3	3	3
Average	2	3	3	3	3

CO-PSO matrix for the course PHY401 (Advanced Quantum Mechanics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY401.1	3	3	2	3	3
PHY401.2	3	3	2	3	3
PHY401.3	3	3	2	3	3
PHY401.4	3	3	2	3	3
PHY401.5	3	3	2	3	3
PHY401.6	3	3	2	3	3
PHY401.7	3	3	2	3	3
PHY401.8	3	3	2	3	3
Average	3	3	2	3	3

CO-PSO matrix for the course PHY402 (Atomic and Molecular Physics)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY402.1	2	3	3	3	3
PHY402.2	3	3	3	3	3
PHY402.3	2	3	3	3	3
PHY402.4	2	3	3	2	3
PHY402.5	2	3	3	3	3
PHY402.6	2	3	3	2	3
PHY402.7	2	3	3	3	3
PHY402.8	2	3	3	2	3
Average	2.12	3	3	2.63	3

CO-PSO matrix for the course PHY 403A (Condensed Matter Physics-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY403A.1	2	3	2	3	3
PHY403A.2	3	3	2	3	3
PHY403A.3	2	3	2	3	2
PHY403A.4	3	3	1	3	2
PHY403A.5	3	3	1	3	3
PHY403A.6	2	2	1	2	3
PHY403A.7	3	3	1	3	3
PHY403A.8	3	3	1	2	3
Average	2.63	2.88	1.38	2.75	2.75

CO-PSO matrix for the course PHY403B (Nuclear Physics-II)

COs#.	PSO1	PSO2	PSO3	PSO4	PSO5
PHY403B.1	3	3	2	3	3
PHY403B.2	3	3	2	3	3
PHY403B.3	3	3	2	3	3
PHY403B.4	3	3	2	3	3
PHY403B.5	3	3	2	3	3
PHY403B.6	3	3	2	3	3
PHY403B.7	3	3	2	3	3
PHY403B.8	3	3	2	3	3
Average	3	3	2	3	3

CO-PSO matrix for the course PHY403C (Particle Physics-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY403C.1	3	3	2	3	3
PHY403C.2	3	3	2	3	3
PHY403C.3	3	3	3	3	3
PHY403C.4	3	3	2	3	3
PHY403C.5	3	3	2	3	3
PHY403C.6	3	3	2	3	3
PHY403C.7	3	3	2	3	3
PHY403C.8	3	3	3	3	3
Average	3	3	2.25	3	3

CO-PSO matrix for the course PHY404A (Computational Physics-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY404A.1	3	2	3	3	2
PHY404A.2	3	2	3	3	2
PHY404A.3	3	2	3	3	2
PHY404A.4	3	2	3	3	2
PHY404A.5	3	2	3	3	2
PHY404A.6	3	2	3	3	2
PHY404A.7	3	2	3	3	2
PHY404A.8	3	2	3	3	2
Average	3	2	3	3	2

CO-PSO matrix for the course PHY404B (Electronics-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY404B.1	2	2	3	3	3
PHY404B.2	2	2	3	3	3
PHY404B.3	2	2	3	3	3
PHY404B.4	2	2	3	3	3
PHY404B.5	2	2	3	3	3
PHY404B.6	2	2	3	3	3
PHY404B.7	2	2	3	3	3
PHY404B.8	2	2	3	3	3
Average	2	2	3	3	3

CO-PSO matrix for the course PHY404C (Material Science-II)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY404C.1	3	3	3	3	3
PHY404C.2	3	3	3	3	3
PHY404C.3	3	3	3	3	3
PHY404C.4	3	3	3	3	3
PHY404C.5	3	2	2	3	3
PHY404C.6	3	2	2	3	3
PHY404C.7	3	3	3	3	3
PHY404C.8	3	3	3	3	3
Average	3	2.75	2.75	3	3

CO-PSO matrix for the course PHY 405 (Physics Laboratory-III)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY405.1	2	3	3	3	3
PHY405.2	2	3	3	3	3
PHY405.3	2	3	3	3	3
PHY405.4	2	3	3	3	3
PHY405.5	2	3	3	3	3
PHY405.6	2	3	3	3	3
PHY405.7	2	3	3	3	3
PHY405.8	2	3	3	3	3
Average	2	3	3	3	3

CO-PSO matrix for the course PHY 406 (Seminar)

COs#	PSO1	PSO2	PSO3	PSO4	PSO5
PHY406.1	3	2	2	3	3
PHY406.2	3	2	2	3	3
PHY406.3	3	2	2	3	3
PHY406.4	3	2	2	3	3
PHY406.5	3	2	2	3	3
PHY406.6	3	2	2	3	3
PHY406.7	3	2	2	3	3
PHY406.8	3	2	2	3	3
Average	3	2	2	3	3

CO-PO-PSO mapping Matrix

CO-PO-PSO mapping matrix for all courses of M.Sc. Physics

Course code	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
PHY101	3	2	2	3	2	2	2	2	3	3	2	3	2	2	2	3
PHY102	3	2	3	3	2	2	2	2	3	3	3	3	2	2	3	3
PHY103	3	2.38	2	3	2	1.63	2	1	2	2	1	3	3	1	2.25	2.5
PHY104	3	2	3	3	2	3	3	3	3	2	3	2	2	3	3	3
PHY105	3	2	3	3	2	3	3	3	3	2	3	2	2	3	3	3
PHY201	3	2.5	2	3	2	1.63	2.38	1	2	2	2	3	2.5	1.25	2.25	2.38
PHY202	3	3	2.62	2.62	2	3	2.37	2.38	3	2	1.83	3	3	2	2	3
PHY203	3	2.5	2	2.38	2	2.5	2	1	1	2	2	2.38	3	1.63	2.5	2.5
PHY204	3	2	3	3	2	3	3	3	3	2	3	2	2	3	3	3
PHY205	3	2	3	3	2	3	3	3	3	2	3	2	2	3	3	3
PHY206	3	2	3	2	3	2	3	3	3	3	3	3	2	2	3	3
PHY301	3	2	3	3	2	2	3	2	3	3	2	3	3	2	3	3
PHY302	3	3	2.5	3	2	3	2	2.25	3	2	2.25	3	2.75	2.63	2.63	2.5
PHY303A	3	2.38	2	2.38	2	2.25	2	1	1	2	2	2.5	2.75	1.5	2.75	2.63
PHY303B	3	3	2.62	2.62	2	3	2.5	2.67	3	2	2.67	3	3	2.5	2.75	2.62
PHY303C	3	3	3	3	2.17	3	2	2.17	2.17	2	3	2.25	3	3	3	2
PHY304A	3	2	2	3	2	2	2	2	3	3	1	3	2	3	3	2
PHY304B	3	2	3	3	2	3	3	3	3	2	3	2	2	3	3	3
PHY304C	3	2.5	3	2.75	2.5	3	3	3	3	2	2.75	3	2.75	2.75	3	3
PHY305	3	3	2	2	2	3	3	2	2	2	1	2	3	3	3	3
PHY401	3	2	3	3	2	2	3	2	3	3	3	3	2	2	3	3
PHY402	3	3	3	3	3	3	2.25	3	2	2.37	2.37	2.12	2	2	3	3
PHY403A	3	2.75	2	2.63	2	2.5	2	1	1	2	2	2.63	2.88	1.38	2.75	2.75
PHY403B	3	3	2	3	2	3	2	2	3	3	1	3	3	2	3	3
PHY403C	3	3	3	3	3	2.12	2.37	2.25	2	2	2	3	3	2.25	3	3
PHY404A	3	2	2	3	2	2	2	1	3	3	1	3	2	3	3	2
PHY404B	3	2	3	3	2	3	3	3	3	2	3	2	2	3	3	3

PHY404C	3	2.5	3	2.75	2.5	3	3	3	3	2	3	3	2.75	2.75	3	3
PHY405	3	3	2	2	2	3	3	2	2	2	1	2	3	3	3	3
PHY406	3	2	3	2	3	2	3	3	3	3	3	3	2	2	3	3
Average	**3**	**2.42**	**2.59**	**2.77**	**2.17**	**2.55**	**2.529**	**2.224**	**2.57**	**2.31**	**2.26**	**2.63**	**2.48**	**2.35**	**2.83**	**2.79**

Attainment of COs

The attainments of COs can be measured on the basis of the results of internal assessment and semester examination. The attainment is measured on scale of 3 after setting the target for COs attainment as shown in the following table.

CO Attainment levels for internal assessment

Attainment level	
1 (Low level of attainment)	60% of students score more than 60% of marks in class tests of a course.
2 (Medium level of attainment)	70% of students score more than 60% of marks in class tests of a course.
3 (High level of attainment)	80% of students score more than 60% of marks in class tests of a course.

CO Attainment levels for End Semester Examination (ESE)

Attainment level	
1 (Low level of attainment)	60% of students obtained grade of A or above (for CBCS programs) or score more than 60% of marks (for non CBCS programs) in ESE of a course.
2 (Medium level of attainment)	70% of students obtained grade of A or above (for CBCS programs) or score more than 60% of marks (for non CBCS programs) in ESE of a course.
3 (High level of attainment)	80% of students obtained grade of A or above (for CBCS programs) or score more than 60% of marks (for non CBCS programs) in ESE of a course.

Overall CO Attainment level of a course

The overall CO attainment level of a course can be obtained as:

Overall CO attainment level=50% of CO attainment level in internal assessment+ 50% of CO attainment level in End Semester Examination.

The overall CO attainment level can be obtained for all the courses of the program in a similar manner.

PO Attainment Values using Direct Methods

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PHY101											
PHY102											
PHY103											
PHY104											
PHY105											
PHY201											
PHY202											
PHY203											
PHY204											
PHY205											
PHY206											
PHY301											
PHY302											
PHY303A											
PHY303B											
PHY303C											
PHY304A											
PHY304B											
PHY304C											
PHY305											
PHY401											
PHY402											
PHY403A											
PHY403B											
PHY403C											
PHY404A											
PHY404B											
PHY404C											
PHY405											
PHY406											
Direct PO attainment											

The PO attainment values to be filled in above table can be obtained as follows:

For PHY101-PO1 Cell:

PO1 attainment value=(Mapping factor for PHY101-PO1 From CO-PO-PSO table x Overall CO attainment value for the course PHY101)/3

Similarly values for each cell of the above table can be obtained. The direct attainment of POs is average of individual PO attainment values.

In order to obtain the PO attainment using indirect method, a student exit survey based on the questionnaire of POs may be conducted at end of last semester of the program. The format for the same is given in the following table. Average of the responses from the outgoing students for each PO is estimated.

The overall PO attainment values are obtained by adding attainment values estimated using direct and indirect methods in the proportion of 80:20 as follows

Overall attainment value for PO1= 0.8 x average attainment value for PO1 using direct method+ 0.2 x average response of outgoing students for PO1

Similarly overall attainment value can be obtained for each PO.

Questionnaire for indirect measurement of PO attainment (for outgoing students)

	Please tick any one		
Capable of demonstrating comprehensive disciplinary knowledge gained during course of study	3	2	1
Capability to ask relevant/appropriate questions for identifying, formulating and analyzing the research problems and to draw conclusion from the analysis	3	2	1
Ability to communicate effectively on general and scientific topics with the scientific community and with society at large	3	2	1
Capability of applying knowledge to solve scientific and other problems	3	2	1
Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.	3	2	1
Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions	3	2	1
Ability to use and learn techniques, skills and modern tools for scientific practices	3	2	1
Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices	3	2	1
Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout life	3	2	1
Capability to identify and apply ethical issues related to one's work, avoid unethical behaviour such as fabrication of data, committing plagiarism and unbiased truthful actions in all aspects of work	3	2	1
Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects	3	2	1
3: Strongly Agree; 2: Agree; 1: Average			

Overall PO attainment values

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
Direct PO attainment											
Indirect PO attainment											
Overall PO attainment											
Target	**2**	**2**	**2**	**2**	**1.5**	**2**	**2**	**2**	**2**	**1.5**	**1.5**