CENTRAL UNIVERSITY OF RAJASTHAN
DEPARTMENT OF PHYSICS
Two Year M.Sc. Program

We envisage that imparting quality education is essential for the all-round growth of the students. Therefore, in the M.Sc. Physics (2Y) program, prime emphasis is to provide education of advanced topics along with the everlasting fundamental laws of Physics. During the two years consisting of four semesters, the students are taught various basic and advanced topics of Physics. Besides, the students can opt for the discipline specific elective courses on advanced topics. They can also take open elective courses form other departments as a part of choice based credit system. Online elective courses as approved can also be considered for fulfilling the credit requirement. In the final year, the students are required to do a major project or elective courses of equivalent credits which prepares them for higher studies.

PROGRAM OUTCOMES (PO)

- Understanding the basic concepts of physics to appreciate how diverse phenomena observed in nature follow from a small set of fundamental laws through logical and mathematical reasoning (PO-1)
- Learn to carry out experiments in basic as well as in certain advanced areas of physics and to gain hands-on experience to work in applied fields (PO-2)
- Able to communicate topics of physics to peers, experts from other disciplines and the general public essential for collaborative work with a diverse team (PO-3)
- Building foundation for higher studies as well as enhancing capabilities to get science jobs (PO-4)
- Development of scientific attitude, analytical and rational thinking, positive attitudes to realize the importance of hard work, commitment, ethics and excellence (PO-5)
- Confident for independent pursuit of projects, start-ups and entrepreneurship (PO-6)

M.Sc. Physics (2Y) – Proposed Programme Structure

SEMESTER I (20C)	SEMESTER II (20C)	SEMESTER III (20C)	SEMESTER IV (20C)
Mathematical Methods in Physics: PHY 401 (4 Credit)	Statistical Mechanics PHY 406 (4 Credit)	Condensed Matter Physics PHY 501 (4 Credit)	DSE II PHY 60Y (3 Credit)
Classical Mechanics PHY 402 (4 Credit)	Atomic and Molecular Physics: PHY 407 (4 Credit)	DSE I PHY 60X (3 Credit)	Open Elective II XYZ (3 Credit)
Quantum Mechanics PHY 403 (4 Credit)	Nuclear and Particle Physics PHY 408 (4 Credit)	Open Elective I XYZ (3 Credit)	Project II PHY 504 (12 Credit)
Classical Electrodynamics PHY 404 (4 Credit)	Computational Physics PHY 409 (4 Credit)	Project I PHY 502 (6 Credit)	Seminar PHY 505 (2 Credit)
Electronics PHY 405 (4 Credit)	Physics Lab PHY 410 (4 Credit)	Internship PHY 503 (4 Credit)	

Internship (PHY 503) – 4 Credits (6-8 weeks)

Fitness / Societal – 2 Credits Audit course

Minimum Credits for Award of Degree: 80 Credits
Core (Theory + Lab): 44C, DSEs / Electives: 12C, Project: 18C, Internship + Seminar: 6C, Fitness + Societal: 2C

A student has the choice of either opting for Project or equivalent credit of additional Discipline Specific Elective/Electives

	Year, Semester	Course Name	Course Code	Credit
1	1Y 1Sem.	Mathematical Methods in Physics	PHY 401	4
2		Classical Mechanics	PHY 402	4
3		Quantum Mechanics	PHY 403	4
4		Classical Electrodynamics	PHY 404	4
5		Electronics	PHY 405	4
	1Y 2Sem.	Statistical Mechanics	PHY 406	4
		Atomic and Molecular Physics	PHY 407	4
		Nuclear and Particle Physics	PHY 408	4
		Computational Physics	PHY 409	4
		Physics Lab	PHY 410	4
	2Y 3Sem.	Condensed Matter Physics	PHY 501	4
		DSE I	PHY 60X	3
		Open Elective I	XYZ	3
		Project I	PHY 502	6
		Internship	PHY 503	4
	2Y 4Sem	DSE II	PHY 60Y	3
		Open Elective II	XYZ	3
		Project II	PHY 504	12
		Seminar	PHY 505	2
			Total	**80**

PHY 401: MATHEMATICAL METHODS IN PHYSICS [Credits 4, (L-T-P: 3-1-0]

Course description:

Mathematics, as the saying goes, is the queen of all sciences. For a physicist, mathematics provides his mother tongue. Of late, we have realized that thorough knowledge of mathematics is a must not only in physics discipline but also in all other disciplines like chemistry, biology, economics *etc*. The mathematical physics course is so designed that a student learns mathematics and acquires enough practice and skills to apply what he has learnt to problems in all other subjects in physical sciences. More importantly this course trains a student into a mathematical way of thinking involving rigour and precision. What a student learns in this course will stand him in good stead in whatever vocation the student takes up in future, be it research, or teaching or science jobs.

Prerequisites:

Students must have some familiarity with differentiation, integrations, infinite series, differential vector calculus, matrices and complex numbers.

Syllabus:

• Brief Introduction to Vectors and Tensors

Review of the properties of scalars, vectors and tensors, vector multiplication and geometrical Applications, Linear independence and orthogonality of vectors, Equations of lines and planes, Kronecker delta symbol, Levi-Civita symbol, Physical interpretation of 'div' and 'curl', Integrals over Fields, Coordinate transformations, simple applications of tensors in non-relativistic physics, Ohm's law in an anisotropic medium, Angular momentum and the inertia tensor, Transformation properties of tensors, Directional derivative, electrical conductivity, tensors, stress and strain tensors, generalized Hook's law.

• Vector Spaces

Linear vector spaces, subspaces, Bases and dimension, Gram-Schmidt orthogonalisation procedure. Linear operators. Matrix representation.

• Matrices

The algebra of matrices, Special matrices, Rank of a matrix, Elementary transformations, Elementary matrices, Equivalent matrices, Solution of linear equations, Linear transformations, Change of basis, Eigenvalues and eigenvectors of matrices, The Cayley-Hamilton theorem, Diagonalization of matrices, Principal axis transformation, Functions of matrices.

• Analysis of Complex Variables

Geometrical representation of complex numbers, Functions of complex variables, Properties of elementary trigonometric and hyperbolic functions of a complex variable, Differentiation, Cauchy-Riemann equations, Properties of analytical functions, Contours in complex plane, Integration in complex plane, Cauchy theorem, Deformation of contours, Cauchy integral representation, Taylor series representation, Isolated and essential singular points, Branch Point and branch Cut, Riemann sheets, Laurent expansion theorem, Poles, Residues at an isolated singular point, Cauchy residue theorem, Application of residue theorem to the evaluation of definite integrals and the summation of infinite series, Integrals involving branch point singularity.

• Ordinary and Partial Differential Equation
Ordinary differential equations, separation of variables, Laplace and Poisson's equation in cartesian, cylindrical and spherical polar coordinates, wave equations, heat equation and diffusion equation, boundary value problems.

• Frobenius Method and Special Functions
Singular points of second order linear differential equations and their importance, Frobenius method, Legendre differential equations, properties of Legendre polynomials, orthogonality, recurrence relations, Rodrigues formula, generating function. Bessel functions of first and second kind, Hermite and Laguerre differential equations and their generating functions.

Course Outcomes (CO):

At the end of this course, the students will be able to
- explain the basic concepts of tensors (CO-1)
- develop understanding of complex analysis (CO-2)
- learn about special functions (CO-3)
- solve various physical phenomena using differential equations (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	3	3	1
CO-2	3	1	3	3	3	1
CO-3	3	1	3	3	3	2
CO-4	3	1	3	3	3	3

Text Books:

1. K. F. Riley, M. P. Hobson and S. J. Bence. Mathematical Methods for Physics and Engineering. 3rd edition, Cambridge University Press India,.
2. George B. Arfken, Hans J. Weber and Frank E. Harris. Mathematical Methods for Physicists, Academic Press, 7th edition.
3. Mary Boas. Mathematical Methods in the Physical Sciences, 3rd edition, Wiley India.
4. V. Balakrishnan, Mathematical Physics with Applications, Problems and Solutions, Ane Books.
5. Robert W. Fuller, The mathematics of classical and quantum physics, Dover publications.
6. R. K. Jain and S. R. K. Iyengar. Advanced engineering mathematics, 5th edition, New age international.
7. A. W. Joshi. Elements of group theory for physicists, New age international.
8. A. W. Joshi. Matrices and Tensors, New Age International, Daryaganj, New Delhi.
9. P K. Chattopadhyay, Mathematical Physics, 3rd edition, New Age International, Daryaganj, New Delhi.
10. Jon Mathews and Robert L. Walker. Mathematical Methods of Physics, Pearson Education (US).

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 402: CLASSICAL MECHANICS [Credits 4, 3-1-0]

Course description:

How and why things move the way they do? For a long time, we believed that for an object to move we require an agent. For example, our ancestors told us that the sun's chariot was drawn by seven horses tied by snakes. However, now we know that things moving with a constant velocity are natural and do not require any external agent. We call it inertia. One needs the help of a force when one wants to change the velocity. Inertia is enshrined in the first law of Newton.

Prerequisites:

B.Sc. with Mathematics and Physics papers

Syllabus:

• Lagrangian and Hamiltonian Formulations of Mechanics
Calculus of variations, Hamilton's principle of least action, Lagrange's equations of motion, conservation laws, systems with a single degree of freedom, rigid body dynamics, symmetrical top, Hamilton's equations of motion, phase plots, fixed points and their stabilities.

• Two-Body Central Force Problem
Equation of motion and first integrals, classification of orbits, Kepler problem, scattering in the central force field.

• Small Oscillations
Linearization of equations of motion, free vibrations and normal coordinates, forced oscillations.

• Hamiltonian Mechanics and Chaos
Canonical transformations, Poisson brackets, Hamilton-Jacobi theory, action-angle variables, perturbation theory, integrable systems, introduction to chaotic dynamics.

Course Outcomes (CO):

At the end of this course, the students will be able to

- understand Lagrangian and Hamiltonian formulations (CO-1)
- learn the problems of central force (CO-2)
- understand small oscillations in various natural systems (CO-3)
- understand integrable and nonlinear systems (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	3	1
CO-2	3	3	3	3	3	1
CO-3	3	3	3	3	3	3
CO-4	3	2	3	3	3	3

Text Books:

1. Classical Mechanics (3rd Edition), Herbert Goldstein, Poole Jr., Charles P., and John L. Safko, Pearson (2001).
2. Mechanics (3rd edition, Course of Theoretical Physics), L. D. Landau and E. M. Lifshitz, Butterworth-Heinemann (1976).
3. Introduction to Dynamics, I. C. Percival and D. Richards, Cambridge University Press (1983).
4. Classical Dynamics: A Contemporary Approach, Eugene J. Saletan and Jorge V. José, Cambridge University Press (1998).
5. A Treatise on the Analytical Dynamics of Particles and Rigid Bodies (4th edition), E. T. Whittaker, Cambridge University Press (1989).
6. Mechanics: From Newton's Laws to Deterministic Chaos (6th Edition), Florian Scheck, Springer (2018).
7. Theoretical Mechanics of Particles and Continua, Alexander L. Fetter and John Dirk Walecka, Dover (2003).
8. Analytical Mechanics, Louis N. Hand and Janet D. Finch, Cambridge University Press (1998).
9. Classical. Mechanics, N. C. Rana and P. S. Joag, Tata-McGraw Hill(1994).
10. Foundations of Classical Mechanics, P. C. Deshmukh, Cambridge University Press (2019).

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 403: QUANTUM MECHANICS [Credits 4, 3-1-0]

Course description:

In the beginning few years of the last century, it was realized that the well profound classical mechanics fails to explain many experimental outcomes. To overcome such limitations and difficulties, an alternative theory of what we call Quantum Mechanics was proposed. This theory is essential to study a variety of modern physics subjects such as atomic, molecular, nuclear, particle physics. It has broad and rich applicability in condensed matter physics and also in chemistry.

Prerequisites:

B.Sc level knowledge of quantum mechanics is required.

Syllabus:

• **Formalism of Quantum Mechanics**

Dirac notation, Hilbert space in context of quantum mechanics, Operators in quantum mechanics, Matrix representations, Eigenvalues and Eigenvectors, Discrete and continuous basis of Hilbert space with special reference to eigenvectors of position, momentum and energy operators.

• **Postulates of Quantum Mechanism**

Concepts of physical observables and measurements in quantum mechanics. Probabilistic outcome of measurements and determinate states, Compatible and non-compatible observables, Uncertainty relation.

• **Schrodinger Equation in time-independent potentials**

One-dimensional problems: Particle in a box, Harmonic oscillator, Infinite and finite square wells, Three-dimensional problems: Central potentials, Spherical harmonics, Hydrogen atom, Two-particle systems: Distinguishable vs indistinguishable particles, Bosons and Fermions, Pauli exclusion principle.

• **Theory of Angular Momentum**

Angular momentum operators, eigenvalues and eigenstates. Orbital and Spin angular momenta, spin half and Pauli matrices, Addition of angular momenta and Clebsch-Gordon coefficients.

• **Applications of quantum mechanics and Approximation Methods**

Time-independent perturbation theory: non-degenerate and degenerate cases and its applications, Variational principle and its applications, WKB Approximation and its applications, Time-dependent perturbation theory and its applications, Scattering theory.

Course Outcomes (CO):

At the end of this course, the students will be able to

- understand the formalism and concepts of quantum mechanics (CO-1)
- understand the measurement process in quantum mechanics (CO-2)
- learn approximation methods in explaining certain physical phenomena (CO-3)
- understand the theory of angular momenta (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	**3**	**1**	**3**	**3**	**3**	**2**
CO-2	**3**	**1**	**3**	**3**	**3**	**2**
CO-3	**3**	**1**	**3**	**3**	**3**	**2**
CO-4	**3**	**1**	**3**	**3**	**3**	**2**

Text Books:

1. J. J. Sakurai, Modern Quantum Mechanics, Second Edition, Pearson.
2. R. Shankar, Principles of Quantum Mechanics, Second Edition, Springer.
3. E. Merzbacher, Quantum Mechanics, Third Edition, Wiley.
4. K. Gottfried, Quantum Mechanics, Second Edition, Springer.
5. A. Messiah, Quantum Mechanics (Vol. I & II), Dover Publications Inc.
6. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics (Vol. I & II), Wiley.
7. Richard P. Feynman, The Feynman Lectures on Physics (Vol. III), Pearson.
8. L. D. Landau and E.M. Lifshitz, Quantum Mechanics, Third Edition, Butterworth-Heinemann.
9. Leonard I. Schiff, Quantum Mechanics, Fourth Edition, McGraw Hill Education.
10. David J. Griffiths, Introduction to Quantum Mechanics, Pearson Press.

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 404: CLASSICAL ELECTRODYNAMICS [Credits 4, 3-1-0]

Course description:

This course covers the basic principles and phenomenon involved of electric and magnetic fields and their combined time varying effects. The equations of Maxwell that condense elegantly the vast experimental findings of Michael Faraday, his predecessors, and contemporaries, on electricity and magnetism constitute the course on electrodynamics. Further, it covers the propagation of electromagnetic waves under different media such as dielectric, metal, etc. and study their behavior during reflection and refraction coefficients at the interface and waveguides. The invariance of Maxwell's equations under Lorenz transformation provided the key to the special theory of relativity of Albert Einstein.

Prerequisites:

Knowledge about Vector Algebra, Differential equations, Optics.

Syllabus:

• **Review of Electrostatics and Magnetostatics:**
Coulomb's law, concept of fields, electrostatic energy, Poisson and Laplace equations, formal solution for potential with image method and Green's function method, boundary value problems, multipole expansion, Biot-Savart law, differential equation for static magnetic field,vector potential, magnetic field from localized current distributions, Faraday's law of induction, energy densities of electric and magnetic fields.

• **Maxwell's Equations**
Maxwell's equations in different mediums, Vector and Scalar potentials in electrodynamics, gauge invariance and gauge fixing, Coulomb and Lorenz gauges. Displacement current. Electromagnetic energy and momentum, Poynting Theorem. Conservation laws.

• **Electromagnetic Waves**
Plane waves in a dielectric medium, reflection and refraction at dielectric interfaces. Fresnel's Formula, Change of phase on reflection, Polarization on reflection and Brewster's law, Total Internal reflection. Wave equation in conducting medium, reflection and transmission at metallic surface, skin effect and skin depth. Frequency dispersion in dielectrics and metals. Dielectric constant and anomalous dispersion. Wave propagation in one dimension, group velocity. Wave guides, propagation modes in waveguides, resonant modes in cavities. Dielectric waveguides.

• **Radiation**
EM Field of a localized oscillating source. Fields and radiation in dipole and quadrupole approximations. Antenna; Radiation by moving charges, Lienard-Wiechert potentials, total power radiated by an accelerated charge, Lorentz formula.

Course Outcomes (CO):

At the end of this course, the students will be able to

- explain the basic laws of electrostatics and magnetostatics (CO-1)
- explain Maxwell's equations in vacuum and matter (CO-2)
- understand the propagation of electromagnetic waves through waveguides (CO-3)
- understand the electromagnetic radiation (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	**3**	**2**	**3**	**3**	**3**	**3**
CO-2	**3**	**2**	**3**	**3**	**3**	**3**
CO-3	**3**	**2**	**3**	**3**	**3**	**3**
CO-4	**3**	**2**	**3**	**3**	**3**	**3**

Text Books:

1. Classical Electrodynamics, by J.D. Jackson, Wiley India Pvt. Ltd (2007)
2. Introduction to Electrodynamics, byD.J. Griffiths, Cambridge University Press, Fourth Edition (2017)
3. Electromagnetic Fields and Waves, by P. Lorrain, and D. Corson, CBS Publishers (2003)
4. Principles of Electromagnetics, by Matthew N. O. Sadiku, S.V. Kulkarni, Oxford University Press;Sixth edition
5. Electromagnetic Waves, by R K Shevgaonkar, McGraw Hill Education; first Edition
6. Foundations of Electromagnetic Theory, by J.R. Reitz, F.J. Milford and R.W. Christy, Addison Wesley Publisher; 4 edition (1992)

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 405 ELECTRONICS [Credit 4 (L T P: 2-0-2)]

Course description:

This course has been designed keeping in mind the importance of ever increasing usage of electronic devices in our day-to-day life. The course will impart knowledge of the fundamental components and parts used in the electronic devices. This is an ability enhancement (AE) or skill development (SD) course to cater the need of skill India, a flagship program of the Government of India.

Prerequisites:

Graduation level knowledge of electronics.

Syllabus:

Bipolar Junction transistor: transistor as an amplifier, stability factor, different gain stabilizing circuits, emitter follower, switching action of a transistor, multivibrators using transistors: a stable, monostable and bistable multivibrators, Differential amplifier: its structure and working, common mode- and differential-gain, common mode rejection ratio, Operational amplifier (OP-amp): OP-amp characteristics, inverting and non-inverting amplifiers, OP-amp feedback parameters, OP-amp applications including summer, subtractor, multiplier, divider, integrating and differential circuits, voltage follower, Instrumentation amplifier, log and antilog amplifiers, op-amp as comparator, Schmitt trigger, voltage to current and current to voltage conversions, filters using OP-amp. Boolean algebra, de-Morgan's theorem, Karnaugh mapping, multiplexers, combinational and sequential circuits, flip-flops, Counters, Registers.

Experimental learning of Transistor as a feedback amplifier, Learning of various OP-amp applications, Learning of various Flip flops, Learning of counters, Learning of registers, Multiplexers and demultiplexers, Multivibrators using transistor and 555 timer IC, Learning operation of multimeter, digital oscilloscope etc.

Course Outcomes (CO):

At the end of this course, the students will be able to

- understand the fundamentals of analog and digital devices (CO-1)
- understand the basic characteristics of transistors and amplifiers (CO-2)
- design and analyze different electronic circuits (CO-3)
- use electronic devices for various applications (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	2	2
CO-2	3	3	3	3	2	2
CO-3	3	3	3	3	2	3
CO-4	3	3	3	3	2	3

Text Books:

1. Electronic Devices and Circuit theory, R. L. Boylestad, L. Nashelsky, Pearson publication
2. Electronic Devices Electron flow version, T. L. Floyd, Pearson publication
3. Principles of electronic materials and devices, S. O. Kasap, McGraw Hill publication
4. Electronic Principles, A. P. Malvino, McGraw Hill
5. Physics of Semiconductor Devices, S. M. Sze, Wiley publication
6. Digital Principles and Applications, A. P. Malvino, D. P. Leach, McGraw Hill publication
7. Digital fundamentals, T. L. Floyd, Pearson publication
8. Digital Electronics: Principles and Integrated Circuits, A. K. Maini, Wiley publication

Assessment Method:

The course consists of two continuous internal assessments (C.I.A.) and one end of semester examination (EoSE). Each C.I.A. would be of 20 marks and the EoSE would be of 60 marks. First C. I.A. will be in the form of written examination while the second C.I.A. will be in the form of a surprise test, quiz or classroom presentation as decided by the course instructor. The end semester examination will be lab based examination.

PHY 406: STATISTICAL MECHANICS [Credits 4, 3-1-0]

Course description:

The time asymmetry in the behavior of macroscopic bodies is captured in thermodynamics by the property called entropy; we have the inevitable entropic arrow of time. Contrast this with the time reversal invariance of microscopic laws be it classical or quantum mechanics, or electrodynamics. In the synthesis of macroscopic objects from its microscopic ingredients when and how does time asymmetry emerge? Ludwig Eduard Boltzmann answered this question by interpreting entropy, completely in terms of probabilities. After all, irreversibility is natural to a probabilistic evolution. Thus was born the subject of statistical mechanics which developed quickly and acquired certain robustness with the work of Josiah Willard Gibbs, James Clerk Maxwell and Albert Einstein.

Prerequisites:

B.Sc. with Physics as one of the subjects.

Syllabus:

• **Brief review of thermal Physics**

Extensive and intensive variables, laws of thermodynamics, entropy and Gibbs paradox, Legendre transformation, thermodynamic potentials, chemical potential, Jacobian determinant, Maxwell's relations and their applications.

• **Statistical description of many-particle systems**

Binomial, Gaussian, and Poisson distributions, central limit theorem. Phase space, Liouville's theorem. Microstates and macrostates, statistical ensemble, statistical postulates, probability calculations, accessible states, constraint, equilibrium, irreversibility.

• **Equilibrium statistical mechanics**

Microcanonical ensemble. Canonical ensemble: Boltzmann factor, Boltzmann distribution, canonical partition function and thermodynamic quantities, energy fluctuations, applications of canonical ensemble. Grand canonical ensemble: Gibbs factor, Gibbs distribution, grand partition function and thermodynamic quantities, particle number fluctuations, applications of grand canonical ensemble. Equipartition theorem: proof of the theorem, applications, specific heat of solids. Maxwell–Boltzmann statistics.

• **Quantum statistics**

Bosons: occupation number, Bose-Einstein statistics, specific heat of solids (Einstein model and Debye theory), black-body radiation, Bose-Einstein condensation. Fermions: occupation number, Fermi-Dirac statistics, degenerate Fermi gas.

• **Phase equilibria and phase transitions (Qualitative treatment)**

Equilibrium condition, phase diagrams of some simple systems, Clausius-Clapeyron equation, critical point, first order and second order phase transitions, Ising model.

Course Outcomes (CO):

At the end of this course, the students will be able to

- explain the laws of thermodynamics (CO-1)
- understand the statistical distributions of many-particle systems (CO-2)
- understand various statistical ensembles and equilibrium statistics (CO-3)
- understand different types of quantum statistics and phase transition phenomena (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	**3**	**1**	**3**	**3**	**3**	**3**
CO-2	**3**	**1**	**3**	**3**	**3**	**3**
CO-3	**3**	**1**	**3**	**3**	**3**	**3**
CO-4	**3**	**1**	**3**	**3**	**3**	**3**

Text Books:

1. Frederick Reif, Fundamentals of Statistical and Thermal Physics, McGraw-Hill (1965).
2. Mehran Kardar, Statistical Physics of Particles, Cambridge University Press (2007).
3. Daniel V. Schroeder, An Introduction to Thermal Physics, Addison Wesley Longman (2000).
4. R. K. Pathria and Paul D. Beale, Statistical Mechanics, Academic Press (2011).
5. L. D. Landau and E. M. Lifshitz, Statistical Physics, Third Edition, Part 1: Volume 5, Pergamon Press (1980).
6. Kerson Huang, Statistical Mechanics (Second Edition), Wiley India (2011).
7. Harvey Gould and Jan Tobochnik, Statistical and Thermal Physics: With Computer Applications, Princeton University Press (2010).
8. James P. Sethna, Statistical Mechanics: Entropy, Order Parameters and Complexity,Oxford University Press (2006) .
9. S. K. Ma, Statistical Physics, World Scientific Publishing, Singapore, (1985).

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 407: ATOMIC AND MOLECULAR PHYSICS [Credits 4, 3-1-0]

Course description:

This course has been divided in two parts: (i) Atomic Physics and (ii) Molecular Physics. The first part deals principle of atomic structure, different energy levels in single and multi-electron atoms, coupling based atomic transitions, interaction of atomic spectra under the presence of different fields, while second parts deals with different degrees of freedom that includes rotational, vibrational and electronic, selection rules, Raman spectra and Einstein A and B coefficients.

Prerequisites:

B.Sc. with Physics as one of the subjects.

Syllabus:

• **Atomic structure**
Bohr's model, Bohr's correspondence principle, Wilson - Sommerfeld's quantization rules, energy level & spectra, Stern-Gerlach experiment for electron spin, Revision of quantum numbers, Pauli exclusion principle, electron configuration, Hund's rule.

• **Many-electron Atoms**
Spin –orbit interaction- Hydrogen fine structure, Review of He atom, ground state and first excited state, quantum virial theorem, Thomas-Fermi method, determinantal wave function, Hartree and Hartree-Fock method, Periodic table and atomic properties: ionization potential, electron affinity.

• **Atomic spectra**
Spectroscopic terms: L-S and J-J couplings, Spectra of Alkali and Alkaline earth elements, Hyperfine structure of spectral lines, selection rules, Zeeman effect, Stark effect, X-ray Spectra.

• **Molecular Spectroscopy**
Types of molecular energy states, pure rotational spectra: rigid rotator, non-rigid rotator, vibrational-rotational spectra for diatomic molecules: harmonic oscillator, anharmonic oscillator, vibrating rotator, role of symmetry, Raman spectra, Electronic spectra- Franck Condon principle.

• **Interaction of Atoms with Radiation**
Atoms in an electromagnetic field, absorption and induced emission, spontaneous emission and line-width, Einstein A and B coefficients, two-level atoms in a radiation field.

Course Outcomes (CO):

At the end of this course, the students will be able to

- understand quantum mechanical phenomenon at the atomic and molecular level (CO-1)
- understand the effect of electric and magnetic fields on energy levels (CO-2)
- understand the spontaneous, stimulated emission and absorption (CO-3)
- understand various spectroscopic techniques and selection rules (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	**3**	**2**	**3**	**3**	**3**	**2**
CO-2	**3**	**2**	**3**	**3**	**3**	**2**
CO-3	**3**	**2**	**3**	**3**	**3**	**2**
CO-4	**3**	**2**	**3**	**3**	**3**	**3**

Text Books:

1. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, by Robert Eisberg &Robert Resnick, Wiley India, 2nd Edition
2. Introduction to Atomic Spectra,by H. E. White, McGraw Hill.
3. PerspectivesofModern Physics,by ArthurBeiser,McGraw Hill.
4. MolecularSpectra andMolecularStructure, byGerhard Herzberg, KriegerPub Co.
5. Fundamentals ofMolecularSpectroscopy, byC. N. Banwell,TataMcGraw Hill, Fourth Edition (2017)
6. Physics of Atoms and Molecules, byB.H. Bransden and C.J. Joachain, Pearson, Second Edition, (2003)
7. Quantum Chemistry, byI.N. Levine, Pearson, Seventh Edition (2013)
8. Atoms and Molecules: An Introduction for Students ofPhysical Chemistry, byM. Karplus and R.N. Porter,
9. Quantum Theory of Many-Particle Systems, byL. Fetter and J. D. Walecka

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 408: NUCLEAR AND PARTICLE PHYSICS [Credits 4, 3-1-0]

Course description:

The nuclear and particle physics course is the fundamental course of physics. In the quest of knowing about the fundamental building blocks of the matter, scientists have gone through a sequence from atoms to nuclei, from nuclei to hadrons and from hadrons to quarks. The course, designed here for the M.Sc. Physics students incorporate several properties of the nucleus and their detailed deliberations.

Prerequisites:

It is expected from the students that they should have done a basic course on Atomic Physics, Quantum Physics/Modern Physics at undergraduate level.

Syllabus:

Size, shape, charge distribution, spin and parity, magnetic moments, Nuclear binding energy, Semi empirical mass formula, Liquid drop model, collective model, shell model, magic numbers and the independent particle model, Fermi gas model.

Characteristics of the force between two nucleons, Deuteron Problem, Nucleon Nucleon interaction, Meson theory of nuclear forces, Nucleon nucleon scattering, spin dependence of the nuclear forces, charge independence and charge symmetry of the nuclear forces,O-values and thresholds, nuclear reaction cross sections, examples of different types of reactions and their characteristics.

Alpha decay, Gamow theory of alpha decay, range of alpha particles, alpha spectra, Beta Decay, Pauli's neutrino hypothesis, Fermi theory of beta decay, Detection and properties of neutrino, Gamma decay, Multipole Transition in nuclei- angular momentum and parity selection rules.

Classification of fundamental forces, Elementary particles (quarks, baryons, mesons, leptons); Spin and parity assignments, iso spin, strangeness; Gell Mann-Nishijima formula;negative energy solution and the concept of antiparticle. quark model,quark model interpretation, colour quantum number, C, P, and T invariance and applications of symmetry arguments to particle reactions, parity non conservation in weak interaction standard model.

Course Outcomes (CO):

At the end of this course, the students will be able to

- understand the nucleus and its properties (CO-1)
- understand various nuclear models and nuclear forces (CO-2)
- understand radioactivity and nuclear decays (CO-3)
- explain the basics of particle physics (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	3	3	1
CO-2	3	1	3	3	3	1
CO-3	3	1	3	3	3	2
CO-4	3	1	3	3	3	2

Text Books:

1. Introduction to nuclear physics by K.S. Krane, John Wiley and Sons Publication, II Edition
2. Nuclear Physics by S. N. Ghoshal, S. Chand Limited Reprint Edition 2008
3. Nuclear physics by R Prasad Pearson, Pearson Edition India 2014
4. G.D. Coughlan and J.E. Dodd, The Ideas of Particle Physics, Cambridge University Press
5. D. Griffiths, Introduction to Elementary Particles, 3rd Edition, Wiley VCH
6. D.H. Perkins, Introduction to High Energy Physics Cambridge University Press 4th Edition 2000
7. R.R. Roy and B.P. Nigam, Nuclear Physics New Age Publishers 1996
8. M.A. Preston and R.K. Bhaduri, Structure of the Nucleus Avalon Publishing 1993
9. M.G. Bowler, Nuclear Physics, Elsevier, 1st Edition 1993

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 409: COMPUTATIONAL PHYSICS [Credits 4, 0-0-4]

Course description:

To make the students learn essential aspects of a programming language, numerical techniques and their applications in a variety of Physics problems.

Prerequisites:

Knowledge of any computer languages.

Syllabus:

• **An essential introduction to a programming language**
Introduction to any one of the programming languages in Fortran/C/C++/Python.

• **Root-finding and numerical integration**
Root-finding methods: bisection method, Newton's method, Newton's method and shooting, steepest descent. Basic integration schemes, stochastic methods for multi-dimensional integrals.

• **Numerical solutions of differential equations**
The Verlet method, Runge–Kutta methods, classical equation of motion, systems with chaotic dynamics.

• **Monte-Carlo simulations and Molecular Dynamics in statistical mechanics**
The Metropolis algorithm for equilibrium statistical mechanics, studies of the phase transition in the Ising model of magnetism, cluster algorithms, molecular dynamics.

• **Numerical solutions of quantum mechanical problems**
Eigenstates of the Schrodinger equation, time-evolution of wave-packets, quantum spin systems (ground state and finite-temperature properties).

Course Outcomes (CO):

At the end of this course, the students will be able to

- acquire the proficiency in using various operating system and software (CO-1)
- learn various computer languages (Fortran/C/C++/Python) (CO-2)
- learn various numerical methods and algorithms (CO-3)
- develop hands on training on problem solving through computational techniques (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	**1**	**1**	**2**	**3**	**3**	**3**
CO-2	**1**	**1**	**2**	**3**	**3**	**3**
CO-3	**3**	**2**	**2**	**3**	**3**	**3**
CO-4	**3**	**2**	**2**	**3**	**3**	**3**

Text Books:

1. Michael Metcalf, John Reid, and Malcolm Cohen, Modern Fortran Explained: Incorporating Fortran 2018, Oxford University Press.
2. Bjarne Stroustrup, The C++ Programming Language (4th Edition), Addison-Wesley.
3. John M. Stewart, Python for Scientists (2nd Edition), Cambridge University Press
4. W. H. Press and S. A. Teukolsky, Numerical Recipes (3rd Edition), Cambridge University Press.
5. Werner Krauth, Statistical Mechanics: Algorithms and Computations, Oxford University Press.
6. J. M. Thijssen, Computational Physics (2nd Edition), Cambridge University Press.
7. Joel Franklin, Computational Methods for Physics, Cambridge University Press.
8. N. J. Giordano and H. Nakanishi, Computational Physics (2nd Edition), Addison-Wesley.
9. R. H. Landau et al., Computational Physics: Problem Solving with Computers, Wiley-VCH.
10. D. P. Landau and K. Binder, A Guide to Monte Carlo Simulations in Statistical Physics (4th edition), Cambridge University Press.

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 410: PHYSICS LAB [Credits 4, 0-0-4]

Course description:

The aim of this laboratory course is to make the students perceive some of the fundamental laws of Physics through experiments and gain knowledge regarding the underlying Physics to pursue solutions for various problems. This course introduces some advanced experiments related to Optics, Condensed Matter, Atomic and Nuclear Physics.

Prerequisites:

B.Sc. with Physics as one of the subjects.

Syllabus:

The students will perform experiments based on the various concepts learned in the theory courses. The exhaustive list of experiments is given below:

- To determine the wavelength of sodium light using Michelson Interferometer .
- Solar cell
  - Recording the current-voltage characteristic point by point and measuring the open-circuit voltage U_o and the short circuit IS for various values of the irradiance
  - Determine the power P supplied as a function of the load resistance R for various values of the irradiance
  - Determine the maximum power P_{max}, the associated load resistance R_{max} and the fill factor
- Study of Hall Effect in a semiconductor and determination of all its parameters
- Curie-Weiss Law Experiment
  - Temperature dependence of the capacitance of a ceramic capacitor
  - Verification of Curie-Weiss Law for the Electrical susceptibility of a Ferroelectric material
- Dielectric Constant & Dipole Moment
  - To determine dielectric constant of a nonpolar liquid
  - Dipole moment of an organic molecule Acetone
- Electron diffraction
- Measurement of magnetic susceptibility of paramagnetic solution by Quincke's method.
- Resistivity and energy band gap of Si semiconductor using four probe method
- Determination of Lande-g factor of a paramagnetic sample using electron spin resonance

- To calculate Verdet's constant using Faraday's effect

- Solar (V-I)
  - To demonstrate the I-V and P-V characteristics of PV modules with varying radiation and temperature levels.
  - To demonstrate the I-V and P-V characteristics of series and parallel combination PV modules.
  - To demonstrate the working of diode as bypass diode and blocking diode.

- Zeeman Effect
  - Using the Fabry–Perot interferometer and a self-made telescope and the splitting up of the central line into two sigma lines is measured in wavenumber as a function of the magnetic flux density.
  - Bohr magneton

Course Outcomes (CO):

At the end of this course, the students will be able to

- understand the fundamental concepts of physics through experiments (CO-1)
- develop the skills to design experiments (CO-2)
- develop analytical thinking and scientific temper (CO-3)
- communicate the scientific ideas clearly and effectively (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	**3**	**3**	**3**	**2**	**3**	**2**
CO-2	**3**	**3**	**3**	**3**	**3**	**3**
CO-3	**3**	**3**	**3**	**3**	**3**	**3**
CO-4	**3**	**3**	**3**	**2**	**3**	**2**

Text Books:

1. A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Ed., 2011, Kitab Mahal
2. Advanced Practical Physics for Students, B.L. Worsnop, H.T. Flint
3. BSc Practical Physics, GeetaSanon, R. Chand & Co.
4. Advanced Practical Physics vol.1 – SP Singh (Pragati prakashan).

Assessment Method:

The course consists of two continuous internal assessments (C.I.A.) and one end of semester examination (EoSE). Each C.I.A. would be of 20 marks and the EoSE would be of 60 marks. First and Second C.I.A.s will be in the form of assessment of lab experiments record and viva. The end semester examination will be lab based examination.

PHY 501: CONDENSED MATTER PHYSICS [Credits 4, (L-T-P: 3-1-0)]

Course description:

Condensed matter physics (CMP) is undoubtedly the most important area of research which often uncover the phenomena that are converted to technology, in particular solid-state device technology used in various fields of sciences. The theoretical basis for CMP comes from quantum mechanics and statistical mechanics. This course introduces the basic concepts of crystal structure analysis and how X-ray diffraction patterns helps us to determine the lattice structure of various crystalline materials. It also discusses how the electrons move in these crystalline solids to give rise to the metallic, semiconducting and insulating behavior. Moreover, the dynamic behaviour of the electron and lattice is presented.

Prerequisites:

Knowledge of basic quantum mechanics.

Syllabus:

• **Metals**
Drude theory, DC conductivity, Hall effect and magneto-resistance, AC conductivity, thermal conductivity, thermo-electric effects, Fermi-Dirac distribution, thermal properties of an electron gas, Wiedemann-Franz law, critique of free-electron model.
• **Crystal Lattices**
Bravais lattice, symmetry operations and classification of Bravais lattices, common crystal structures, reciprocal lattice, Brillouin zone, X-ray diffraction, Bragg's law, Von Laue's formulation, diffraction from non-crystalline systems.
• **Classification of Solids**
Band classifications, covalent, molecular and ionic crystals, nature of bonding, cohesive energies, hydrogen bonding.
• **Electron States in Crystals**
Periodic potential and Bloch's theorem, weak potential approximation, energy gaps, Fermi surface and Brillouin zones, Harrison construction, level density.
• **Electron Dynamics**
Wave packets of Bloch electrons, semi-classical equations of motion, motion in static electric and magnetic fields, theory of holes.
• **Lattice Dynamics**
Failure of the static lattice model, harmonic approximation, vibrations of a one-dimensional lattice, one-dimensional lattice with basis, models of three-dimensional lattices, quantization of vibrations, Einstein and Debye theories of specific heat, phonon density of states, neutron scattering.
• **Semiconductors**
General properties and band structure, carrier statistics, impurities, intrinsic and extrinsic semiconductors, p-n junctions, equilibrium fields and densities in junctions, drift and diffusion currents.

Course Outcomes (CO):

At the end of this course, the students will be able to

- learn about crystal structures and to determine them using diffraction techniques (CO-1)
- explain the thermal properties of solids, specifically the heat capacity (CO-2)
- explain general mechanisms to study electronic properties in crystalline materials (CO-3)
- explain various type of bonding in solids (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3	3	3	2
CO-2	3	1	3	3	3	2
CO-3	3	1	3	3	3	2
CO-4	3	2	3	3	3	2

Text Books:

1. C. Kittel, Introduction to Solid State Physics, Wiley; Eighth Edition (2012), Rs. 750/-
2. N.W. Ashcroft and N.D. Mermin, Solid State Physics, Brooks/Cole, New Edition (1976), Rs. 719/-
3. J.M. Ziman, Principles of the Theory of Solids, Cambridge University Press; Second Edition (2018), Rs. 528/-
4. A.J. Dekker, Solid State Physics, Laxmi Publications (2008), Rs. 250/-
5. G. Burns, Solid State Physics, Academic Press Inc; Illustrated Edition (1985), Rs. 7000/-
6. M. P. Marder, Condensed Matter Physics, Wiley; 2nd Edition (2015), Rs. 11,900/-

Assessment Method:

First CIA (20%), Second CIA (20%) and ESE (60%).

PHY 503: INTERNSHIP [4 credits]

Course description:

The internship enables the students to use the theoretical knowledge /concepts to solve the real world problems. The internship enables the students to learn new ideas and research methodologies in a particular field. The technical writing skills can be improved by doing an internship.

Prerequisites:

Students must have completed the first two semesters.

Course Outcomes (CO):

At the end of this course, the students will be able to

- conduct a literature survey and to understand research methodology (CO-1)
- develop analytical skill and critical thinking (CO-2)
- develop independent thinking as well as participative learning (CO-3)
- explain basic concepts of experimental and computational techniques (CO-4)

Mapping of Course Outcomes (COs) with Program Outcomes (POs)

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	**3**	**3**	**1**	**3**	**3**	**3**
CO-2	**3**	**3**	**3**	**3**	**3**	**3**
CO-3	**1**	**2**	**3**	**3**	**3**	**3**
CO-4	**3**	**3**	**1**	**3**	**2**	**3**

Assessment Method:

The assessment will be based on the internship report and presentation.