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 basic and advanced quantum mechanics, analog and digital electronics, classical mechanics, condensed matter physics, mathematical Physics, statistical mechanics, Nuclear Physics, Atomic and Molecular Physics etc. Besides, the students can opt for the elective courses in Materials Sciences, Fiber Optics and Lasers etc. They can also take elective courses form other departments as a part of choice based credit system. In the final semester, the students are required to do a major project in Physics 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 (16 C)

- Mathematical Methods in Physics PHY 401 (4 Credit)
- Classical Mechanics PHY 402 (4 Credit)
- Quantum Mechanics I PHY 403 (4 Credit)
- General Physics Lab PHY 404 (4 Credit)

SEMESTER II (23 C)

- Classical Electrodynamics PHY 405 (4 Credit)
- Quantum Mechanics II PHY 406 (4 Credit)
- Condensed Matter Physics PHY 407 (4 Credit)
- Computational Physics Lab (AEC)
- Advance Physics Lab PHY 409 (4 Credit)
- Elective-I (3 Credit)

SEMESTER III (23 C)

- Atomic and Molecular Physics PHY 501 (4 Credit)
- Nuclear and Particle Physics PHY 502 (4 Credit)
- Statistical Mechanics PHY 503 (4 Credit)
- Electronics (AEC) PHY 504 (3 Credit)
- Electronics Lab (AEC) PHY 505 (2 Credit)
- DSE-I PHY 60X (3 Credit)
- Elective-II (3 Credit)

SEMESTER IV (18

- DSE-II PHY 60Y (3 Credit)
- DSE-III PHY 607 (3 Credit)
- Dissertation/DSEs PHY 506 (12 Credit)

A student has the choice of either opting for dissertation or equivalent credit of additional DSEs.

Internship/PBL (PHY 507) – at least 2 Credits in two Years (2-4 weeks duration)

Fitness – at least 2 Credits in two Years

Societal – at least 2 Credits in two Years

Minimum Credits for Award of Degree: 80+6 (audit courses) = 86 Credits
Core (Theory + Lab): 44 C, AEC (Theory + Lab): 9 C, DSE + Electives+ Dissertation: 27 C, Internship + Fitness +Societal: 6 C
AEC: Ability Enhancement Course, DSE: Discipline Specific Elective, PBL: Project Based Learning

S.No.	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 I	PHY 403	4
4.		General Physics Lab	PHY 404	4
5.	1Y 2Sem.	Classical Electrodynamics	PHY 405	4
6.		Quantum Mechanics II	PHY 406	4
7.		Condensed Matter Physics	PHY 407	4
8.		Computational Physics Lab	PHY 408	4
9.		Advanced Physics Lab	PHY 409	4
10.		Elective-I		3
11.	2Y 3Sem.	Atomic and Molecular Physics	PHY 501	4
12.		Nuclear and Particle Physics	PHY 502	4
13.		Statistical Mechanics	PHY 503	4
14.		Electronics	PHY 504	3
15.		Electronics Lab	PHY 505	2
16.		DSE-I	PHY 60X	3
17.		Elective-II		3
18.	2Y 4Sem	DSE-II	PHY 60Y	3
19.		DSE-III	PHY 60Z	3
20.		Dissertation	PHY 506	12
21.		**Total**		**80**
22.		**Internship (PHY 507), Fitness, Societal (Audit Courses of 2C reach)**		**6**
23.		**Degree Requirement**		**86**

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

Course Outcomes (CO):

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

- To use the fundamental concepts of complex analysis and their role in physics, engineering and mathematics.
- To define continuity and differentiability for complex functions
- To compute determinants, eigenvalue problems, diagonalization of matrices in several areas of physics, Taylor, power, Laurent series, singularities and poles, residues, complex integrals.

Program Outcomes (PO): The course covers the program outcomes from PO-1, PO-2 and PO5 to -PO6.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**1**	**1**	**3**	**3**
CO2	**3**	**1**	**1**	**1**	**3**	**3**
CO3	**3**	**1**	**1**	**1**	**3**	**3**

Course Level: Mastery

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.

Course Objectives:

- To explain the basic concepts of vectors, scalars and tensors
- To expose the students to the fascinating world of real and complex numbers
- To introduce the special functions essential in solving physics problems
- To model and solve physical phenomena using differential equations
- To find power series solutions of differential equations

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.

Prerequisites:

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

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.

A. W. Joshi. Elements of group theory for physicists, New age international.

A. W. Joshi. Matrices and Tensors, New Age International, Daryaganj, New Delhi.

7. P K. Chattopadhyay, Mathematical Physics, 3rd edition, New Age International, Daryaganj, New Delhi.
8. Jon Mathews and Robert L. Walker. Mathematical Methods of Physics, Pearson Education.

Assessment Method: First CIA (20 %), second CIA/assignments (20 %) and EOSE (60 %).

Any need for revision of existing rules: No

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

Course Outcomes:
Student has developed the knowledge of modern mechanics like Langaraangian and Hamiltonian formulations and their applications in appropriate physical problems (CO-1).
Learn the problems of Central force and Small oscillations (CO-2).
This course prepares the students for taking up work in nonlinear dynamics and chaos (CO-3).

Program Outcomes (PO): The course covers the program outcomes from PO-3 to PO-4.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**1**	**1**
CO2	**3**	**1**	**3**	**3**	**1**	**1**
CO3	**3**	**1**	**3**	**3**	**1**	**1**

Course Level: Mastery

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.

Course Objectives

The course on classical mechanics deals with Newton's laws of motion and several of its later metamorphoses like Euler Lagrange formulations, Hamilton Jacobi equations, Poisson brackets *etc*. It imparts knowledge on different formulations of mechanics; more importantly the Hamiltonian formulation with Poisson bracket prepares the students for quantum mechanics which is taught in two courses each of four credits. Besides, knowledge of classical mechanics is a must for studying nonlinear dynamics and chaos. The subject of nonlinear dynamics and chaos has enormous scope for both basic and applied research.

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.

Prerequisites: B.Sc with Mathematics and Physics papers

Text Books and Reference 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: Written examination and assignments

Any need for revision of existing rules: No

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

Course Outcomes:

After completing this course, students will

- Feel comfortable in the process of solving the quantum mechanical eigenvalue problems (CO-1).
- Digest the connection between measurement results and the uncertainty relation (CO-2).
- Realize the meaning of wave function in quantum mechanics (CO-3).
- Appreciate the amazing power and surprises of quantum mechanics in problems like free particle and particle in a potential (CO-4).
- Recognize the applicability of angular momenta in several branches of physics (CO-5).

Program Outcomes (PO): The course covers the program outcomes from PO-1 to PO-5.

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

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.

Course Objectives:

This course facilitates students to

- Learn mathematical tools needed to develop the formal theory of quantum mechanics.
- Understand the measurement process in quantum mechanics.
- Study time-independent and time-dependent Schrodinger wave equations.
- Solve a one-dimensional Schrodinger equation for simple problems.
- Develop theory of angular momenta and to learn to add them.

Syllabus

Vector Spaces in Quantum Mechanics

Dirac notation, Vector Spaces, Bases, Dimension, Subspaces, Dual spaces, Inner product spaces, Orthonormality and Completeness. Linear operators, Matrix representations, Change of basis, Eigenvalues and Eigenkets, Degeneracy, Complete sets of commuting observables.

Fundamental Concepts

Measurement, compatible and incompatible observables, uncertainty relation. Position operator and position eigenkets, momentum operator and momentum eigenkets. Wave functions in position and momentum space. Wave packets.

Quantum Dynamics

Time-Evolution and the Schrodinger Equation, the Schrodinger versus the Heisenberg Picture. Simple harmonic oscillator—energy eigenkets and energy values, time development, coherent state. Schrodinger's Wave Equation, interpretations of the wave function, the classical limit.

Solutions to Schrodinger Wave Equation

Free Particles, Piecewise Constant Potentials in One Dimension (one-dimensional box, square-well potential, potential barrier, potential step, symmetrical double-well potential, periodic potentials), Transmission and Reflection, Central potential: spherical harmonics, radial solution, hydrogen-like atoms.

Theory of Angular Momentum

Rotations and angular momentum, eigenvalues and eigenstates of angular momentum, spin and orbital angular momenta, addition of angular momenta, Tensor operators and Wigner-Eckart theorem, Pauli matrices and spinors.

Prerequisites: B.Sc level knowledge of quantum mechanics is required.

Text Books and Reference Books:

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

Assessment Method: Written examination and assignments.

Any need for revision of existing rules: No

PHY 404: General Physics Lab [Credits 4, 0-0-4]

Course Outcomes:

At the end of this laboratory course, the students will be capable of handling sophisticated instruments besides learning the Physics concepts behind these experiments

Program Outcomes: PO1-PO5

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**3**	**3**	**3**	**3**	**1**

Course level: Introductory

Course Description:

The aim of this laboratory course is to make the students understand the usage of basic laws and theories to determine various properties of the materials and gain knowledge regarding the underlying Physics to pursue solutions for various problems.

Course Objectives

The aim of this laboratory course is to make the students perceive some of the fundamental laws of Physics through experiments.

Syllabus:

1. To determine the wavelength of sodium light using Michelson Interferometer.
2. Solar cell
   a. 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
   b. Determine the power P supplied as a function of the load resistance R for various values of the irradiance
   c. Determine the maximum power P_{max}, the associated load resistance R_{max} and the fill factor.
3. Study of Hall Effect in a semiconductor and determination of all its parameters.
4. Curie-Weiss Law Experiment
   a. Temperature dependence of the capacitance of a ceramic capacitor
   b. Verification of Curie-Weiss Law for the Electrical susceptibility of a Ferroelectric material.
5. To Study the BH curve in ferromagnetic material.

6. Dielectric Constant & Dipole Moment:
   a. To determine dielectric constant of a nonpolar liquid
   b. Dipole moment of an organic molecule Acetone
7. Electron diffraction
   a. Determine the wavelength of the electrons.
   b. Verification of de Broglie’s equation.

Prerequisite to take the course: BSc with Physics as one of the subjects

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: Record writing, viva and final exam

Any need for revision of existing rules: No

PHY 405: Classical Electrodynamics [Credits 4, 3-1-0]

Course Outcomes:

- The students will be capable of understanding the underlying Physics behind telecommunication
- This course will lay the foundation for the modern optics and photonics, ionosphere
- The students will be able to analyze different radiative systems such as electric dipole, magnetic dipole, electric quadrupole and their importance and dominance over each other.
- The students will havebasic understanding of the covariant formulation of electrodynamics and the concept of retarded time for charges undergoing acceleration.
- Students will be prepared enough to understand advances courses relativistic quantum field theory

Program Outcomes (PO): The course covers the program outcomes from PO-1 to PO-6.

Course Level: Mastery

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**3**
CO2	**3**	**2**	**3**	**3**	**3**	**3**
CO3	**3**	**2**	**3**	**3**	**3**	**3**
CO4	**3**	**2**	**3**	**3**	**3**	**3**
CO5	**3**	**2**	**3**	**3**	**3**	**3**

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.

Course Objectives

- To make the students learn about the unification of forces
- To give students the insights of Maxwell equations and their importance for the development of Electromagnetic theory.
- To make students learn how to solve different complex numerical problems based on Maxwell’s equation and Electromagnetic waves.
- To make the students understand the propagation behavior of electromagnetic radiation in different media

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.

Prerequisites: Knowledge about Vector Algebra, Differential equations, Optics

Text Books and reference 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: Written and Assignments

Any need for revision of existing rules: No

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

Course Outcome:

After completing this course, students will

- Know the connection between symmetries, degeneracies, and conservation laws.
- Differentiate between classical and quantum identical particles.
- Appreciate the profound strength of approximate methods in problems like Stark effect, Zeeman effect, etc.
- Understand the scattering processes that take place in atomic, subatomic, and molecular systems.
- Get basic information needed for advanced courses like quantum field theory.

Program Outcome (PO): The course covers the program outcomes from PO-1 to PO-5.

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**	**1**
CO-4	**3**	**1**	**3**	**3**	**3**	**1**
CO-5	3	1	3	3	3	1

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.

Course Objectives

This course facilitates students to

- Study continuous and discrete symmetries and their consequences.
- Know about identical quantum particles and their wavefunctions.
- Learn various approximation techniques of solving quantum mechanical problems.
- Develop the theory of scattering processes.
- Learn elementary aspects of relativistic -quantum mechanics.

Syllabus

Symmetry in Quantum Mechanics

Symmetries, conservation laws, and degeneracies. Space-translation, Time-translation, Parity (or space inversion), and Time-Reversal symmetries.

Identical Particles

Permutation symmetry, symmetrization postulate, two-electron system, the Helium atom, permutation symmetry and Young tableaux.

Approximation Methods

The variational and WKB methods, time-independent perturbation theory (non-degenerate and degenerate).Dirac-picture, time-dependent perturbation theory. Sudden and Adiabatic approximations.

Scattering Theory

Lippmann-Schwinger equation, Born approximation, optical theorem. Free-particle states: plane wave versus spherical waves. Method of partial waves, low-energy scattering and bound states, resonance scattering.

Relativistic Quantum Mechanics

Klein-Gordon equation, Dirac equation, Symmetries of the Dirac equation, Dirac’s equation for a Central Potential.

Prerequisites: Quantum Mechanics **I**

Text Books and Reference Books:

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

Assessment Method: Written examination and assignments

Any need for revision of existing rules: No

PHY 407: CONDENSED MATTER PHYSICS [Credits 4, (L-T-P: 3-1-0)]

Course Outcome:

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

- learn about various crystal structures and how we determine a crystal structure by X-Ray diffraction experiments
- explain the thermal properties of solids, specifically the heat capacity
- understand general mechanisms to study electronic properties in crystalline materials (metals and semiconductors)

Program Outcomes (PO): PO1, PO3 to PO6

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**2**
CO2	**3**	**1**	**3**	**3**	**3**	**2**
CO3	**3**	**1**	**3**	**3**	**3**	**2**

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.

Course Objectives:

- To use quantum mechanics in explaining the peculiar behaviour of materials
- To describe how X-Ray diffraction experiments help us to determine the crystal structures
- To make the students understand various exotic properties of materials under different length scales
- To give basic formalism of how electrons behave in crystalline materials to give rise various electronic (e.g, conductivity) and thermal properties (e.g, heat capacity)

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.

Prerequisites: Basic quantum mechanics

Reference 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: written, viva, seminar, assignment

Any need for revision of existing rules: No

PHY 408: COMPUTATIONAL PHYSICS LAB [Credits 4, 0-0-4]

Course Outcome:

At the end of this laboratory, the students will be capable to use numerical ideas in diverse areas such as biological systems, economics, nonlinear dynamics

Program Outcome (PO): The course covers the program outcomes from PO-1 to PO-6.

Course Level: Mastery

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	1

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

Course Objectives:

- To acquire the proficiency in effectively using the GUI Windows, the LINUX operating system and also in using the LaTeX software for writing a text file.
- To highlights the use of computational methods to solve physical problems
- Uses of computer languages (Fortran/C/C++/Python)
- Hands on training on Problem solving on Computers.
- To find the roots of a polynomial equation.

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).
Prerequisites: Knowledge of any computer languages

Text Books and Reference 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: Written examinations and assignments

Any need for revision of existing rules: No

PHY 409: ADVANCED PHYSICS LAB [Credits 4, 0-0-4]

Course Outcome:

At the end of this laboratory course, the students will be capable of handling sophisticated instruments besides learning the Physics concepts behind these experiments

Program Outcome: PO1-PO5

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**3**	**3**	**3**	**3**	**1**

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.

Course Objectives

The aim of this laboratory course is to make the students perceive some of the advanced laws of Physics through experiments.

Syllabus

1. Light Runner
   a. To study the length dependence of attenuation in the given optical fiber at different wavelengths.
   b. To determine the relationship between the laser current and output power and hence find out the threshold laser current.
   c. To check the linearity between laser optical power and its monitor diode.
2. Measurement of magnetic susceptibility of paramagnetic solution by Quincke's method.
3. To investigate the attenuation of x-rays as a function of the absorber thickness and absorber material.
4. Solar (V-I)
   a. To demonstrate the I-V and P-V characteristics of PV modules with varying radiation and temperature levels.
   b. To demonstrate the I-V and P-V characteristics of series and parallel combination PV modules.
   c. To demonstrate the working of diode as bypass diode and blocking diode.
5. Zeeman Effect
   a. 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.
   b. Bohr magneton

6. To determine the wavelength of the most intense spectral lines of Helium and calculation of Rydberg Constant.
7. To find the resistivity and energy band gap of silicon semiconductor using four probe method.
8. Frank Hertz Experiment.
9. Radioactivity using Geiger-Muller counter
   a. G.M. Counter - characteristics, Inverse square law.
   b. Measurement of dead time of a Geiger-Muller counter
   c. End point energy and Absorption coefficient using G.M. tube.
   d. G.M. Counter - Absorption coefficient.
10. Determination of Lande-g factor of a paramagnetic sample using electron spin resonance
11. Millikan's oil drop experiment for the determination of specific charge
12. Study the dependence of magneto-resistance on the applied magnetic field for a given sample
13. Calibrate a given thermocouple & determine the melting point of Sn-Pb (60:40) alloy
14. Ionic conductivity

Prerequisite to take the course: B.Sc with Physics as one of the subjects or PHY404 course
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: Record writing, viva and final exam

Any need for revision of existing rules: No

PHY 501: ATOMIC AND MOLECULAR PHYSICS [Credits 4, 3-1-0]

Course Outcome:

- To make the students understand Quantum mechanical phenomenon at the atomic and molecular level
- To make the students understand various couplings effects and selection rules
- To make the students understand about various absorption/emission spectroscopic transitions
- To make the students understand importance of Einstein coefficient for the development of LASER
- Understand the quantum based description of atomic and molecular systems.

- Understand the interaction of atomic and molecular energy level with electric and magnetic fields
- Acquire the basic understanding of ultraviolet-visible-infrared spectroscopy
- Justify the selection rules for various optical spectroscopies in terms of the symmetries of molecular vibrations
- Understand the spectroscopy of non-polar molecules using Raman effect
- Understand the phenomenon of spontaneous, stimulated emission and absorption in the two level system

Program Outcome (PO): The course covers the program outcomes from PO-1 to PO-6.

Course Level: Mastery

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**2**	**3**	**3**	**3**	**3**
CO2	**3**	**2**	**3**	**3**	**3**	**3**
CO3	**3**	**2**	**3**	**3**	**3**	**3**
CO4	**3**	**2**	**3**	**3**	**3**	**3**
CO5	**3**	**1**	**3**	**3**	**3**	**3**
CO6	**3**	**2**	**3**	**3**	**3**	**3**
CO7	**3**	**2**	**3**	**3**	**3**	**3**
CO8	**3**	**2**	**3**	**3**	**3**	**3**
CO9	**3**	**2**	**3**	**3**	**3**	**3**
CO10	**3**	**2**	**3**	**3**	**3**	**3**

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.

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, Hartree and Hartree-Fock method, Periodic table and atomic properties: ionization potential, electron affinity.

Atomic spectra

Spectroscopic terms: L-S and J-J couplings, Many electron atoms, 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, selection rules, Raman spectra, Electronic spectra- Franck Condon principle.

Many-electron Atoms

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, Hund's rule.

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.

Prerequisites: Students must have done the course of Quantum Mechanics

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, by B.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: Written & Assignment

Any need for revision of existing rules: No

PHY 502: NUCLEAR AND PARTICLE PHYSICS [Credits 4, 3-1-0]

Course Outcome:

- Students will be enriched with the fundamental knowledge of the nucleus and its properties
- The principles behind the modern medical instruments such as nuclear magnetic resonances will be clear to the students
- Students will be enshrined in detail about the radiation hazards, peaceful use of nuclear energy and carbon dating for fossil’s age determination
- The students will be able to do higher studies in this field. They may get employment opportunities in radiology and medical field

Program Outcomes (PO): PO-1 to PO-6.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**1**
CO2	**2**	**3**	**3**	**3**	**2**	**3**
CO3	**2**	**2**	**3**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**3**	**3**	**3**

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.

Course Objectives

The objectives of the course are as under:

- To familiarize about the essential properties of the nucleus such as its shape, size, radius, density, magnetic moment, electric quadrupole moment etc.
- In order to probe these properties several models have been proposed such as liquid drop model, shell models, collective models
- The most useful part of this knowledge is nuclear energy which has immense applications. The concept behind this energy was first given by Hans Bethe in the form of a semi-empirical mass formula which is in the course content.
- Carbon dating, modern medical applications, radio-physics all require the knowledge of radio-activity. One complete unit is dedicated for this purposes
- It is a well-known fact that all kinds of interactions which we perceive in our life are essentially four in number viz. gravitational, electromagnetic, weak and strong. The ultimate aim of particle physics is to unify these interactions.

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.

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

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: Written & Assignment

Any need for revision of existing rules: No

PHY 503: STATISTICAL MECHANICS [Credits 4, 3-1-0]

Course Outcome:

At the end of the course a student would be able to competently employ a whole host of formalisms of statistical mechanics to a variety of problems in physics, chemistry, biology, computer science, economics and several other disciplines.

Program Outcome: PO1-PO5

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**2**	**1**

Course Level: Reinforce

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.

Course Objectives

The methods of statistical ensembles and partition sums are very specific to the subject of Statistical Mechanics. An aim is to introduce the methodologies to the students so that they can apply it to the problems not only in statistical mechanics but in other fields also. A case in point is the method of ensemble which has been carried over to Quantum Mechanics to provide an *Ad hoc* description of Quantum measurements

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.

Prerequisite to take the course: B.Sc. with Physics as one of the subjects

Text Book and Reference Book:

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: Written, assignments and final exam

Any need for revision of existing rules: No

PHY 504 ELECTRONICS [Credit 3 (L T P: 3-0-0)]

Course Outcome:

- At the end of this course, the students will be able to understand the fundamentals behind analog and digital devices.

Program Outcomes (PO): PO1-PO6

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	3	3	3

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 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.

Course Objectives:

- To make the students familiar about the concepts of components used in various electronic devices
- To make the students learn the basics of digital electronics which will be useful to them in understanding the concept behind digital world

Syllabus:

Semiconductor devices: p-n junction diodes and its I-V characteristics, p-n-p-n devices, clipper and clamper circuits, Optoelectronic devices: light-emitting diodes, solar cells, photodetectors, Field effect devices: JFET and MOSFET transistors, Bipolar Junction transistor: transistor as an amplifier, stability factor, different gain stabilizing circuits, emitter follower, switching action of a transistor, multivibrators using transistors: astable, monostable and bistable multivibrators, oscillators devices using transistors: Colpitt, Hartley phase shift, Wein bridge oscillators.

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. Basic D to A conversion: weighted resistor, DAC binary R-2R ladder, basic A to D conversion, 555 timer IC and its applications

Number systems-binary, octal, decimal, hexadecimal and their conversion from one to another, Boolean algebra, de-Morgan's theorem, Karnaugh mapping, multiplexers, combinational and sequential circuits, flip-flops, Counters, Registers, introduction to microprocessors and microcontrollers

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.

Any need for revision of existing rules: No

PHY 505 ELECTRONICS LAB [Credit 2 (L T P: 0-0-2)]

Course Outcome:

- The students are trained enough in handling various electronic equipments

Program Outcomes (PO): PO1-PO6

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**3**	**2**	**3**	**3**	**3**

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 provide hands-on practice of various components and parts used in electronic devices. This is an ability enhancement (AE) or skill development (SD) course to cater the needs of skill India, a flagship program of the Government of India.

Course Objective:

- To train the students to perform hand-on experiments in the laboratory

Syllabus:

1. Transistor as a feedback amplifier
2. Learning of various OP-amp applications
3. Learning of various Flip flops
4. Learning of counters
5. Learning of registers
6. Multiplexers and demultiplexers
7. Multivibrators using transistor and 555 timer IC
8. Learning operation of multimeter, digital oscilloscope etc.

Prerequisite of the Course: Graduation level knowledge of electronics

Text Book and Reference Book:

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 performing 8 experiments by the students. Each student will have to give a viva examination to the instructor at the completion of each practical along with the complete lab record of the practical. The instructor will judge the performance of the student and will give marks out of 5. Thus eight practicals will carry 40 marks. The EoSE of the practicals will consist of performing one practical and giving viva to the examiner. This will consist of 60 marks.

Any need for revision of existing rules: No

PHY 507: D-Internship/Summer P/PBL [2 credits]

Course Outcome:

Internship will provide the insights of the research field, uses of research methodologies and interpretation of research data to a learner. The successful completion of the internship work will lead the students in future research work.

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3

Level: Introductory

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.

Course Objective

- The aim of the internship is to develop analytical skill and critical thinking in the fields of Physical sciences.
- Study the basic concepts of programming
- To conduct a literature survey on a preferred field of study.
- To get familiar with software and hardware used for research

Prerequisites: Students must have completed the first two semesters.

Assessment Method: As per university Ordinance

Annexure-II

DISCIPLINE SPECIFIC ELECTIVES (DSE)

M.Sc. and Pre-PhD

1.	Materials Science	PHY 601	3
2	Advanced Computational Physics	PHY 602	4
3	Fundamentals of Semiconductor	PHY 603	3
4	Fiber Optics: Fundamentals And Applications	PHY 604	3
5	Introduction to Dynamical Systems	PHY 605	3
6	Science & Technology Of Thin Films	PHY 606	3
7	Ferroelectric Materials and Devices	PHY 607	3
8	Magnetic and Superconducting Properties of Solids	PHY 608	3
9	Introduction to Fourier Optics	PHY 609	3
10	Monte Carlo-Theory And Practice	PHY 610	3
11	Semiconductor Devices and Technology	PHY 611	3
12	Nonlinear Dynamics And Chaos	PHY 612	3
13	Concepts of Laser Physics and Fiber Optics	PHY 613	3
14	Introduction to Plasma Physics	PHY 614	3
15	Introduction to Nanomaterials and Nanotechnology	PHY 615	3
16	Quantum Many-Body Physics	PHY 616	4
17	Theory Of Complex Networks And Applications	PHY 617	3
18	Computational Condensed Matter Physics	PHY 618	3
19.	Phase Transitions and Critical Phenomena	PHY 619	3
20	Special Topics in Mathematical Physics	PHY 620	3
21	Advanced Plasma Physics	PHY 621	3
22	Concepts of Laser Physics and Fourier Optics	PHY 622	3
23	Solid State Magnetism	PHY 623	3
24	Functional Nanomaterials	PHY 624	3

PHY 601: MATERIALS SCIENCE [3 Credits (L T P: 3-0-0)]

Course Outcomes:

At the end of this course, the students will

- appreciate fascinating electrical properties of materials
- be equipped with the knowledge of synthesis and characterization of materials
- comprehend the applications of various applications

Program Outcome: The course covers the program outcomes from PO-2 to PO-6

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**1**	**1**	**3**	**3**	**3**	**3**
CO2	**1**	**1**	**3**	**3**	**2**	**3**
CO3	**1**	**1**	**3**	**3**	**3**	**3**

Course Level: Mastery

Course Description:

This course has been designed keeping in mind the importance of new materials synthesis and their applications. The course will impart knowledge of the different synthesis and characterization methods.

Course Objectives:

- To disseminate knowledge various electrical properties viz. dielectric, ferroelectric, piezoelectric and piezoelectric
- To impart knowledge of the synthesis and characterization of materials and their applications

Syllabus

Electrical Materials: Static dielectric constant, electronic, ionic and orientation polarizations, Internal or local fields in solid and liquids. Lorentz field in cubic materials, Clausius-Mosotti equation, complex dielectric constant, determination of dipole moment for polar substances, dielectric losses, frequency dependence of electronic, ionic, orientation polarizabilities, Ferroelectric and piezoelectric materials, classification of ferroelectric materials, dipole theory of ferroelectricity, ferroelectric domains, phase transitions, piezoelectric, pyroelectric materials and applications, responsivity, figures of merit. Temperature/infrared light sensors. Infrared image sensors.

Synthesis Methods: Physical Methods: Thermal evaporation deposition, pulsed laser deposition, sputtering, Chemical methods: sol-gel technique, hydrothermal and solvothermal technique, microwave synthesis.

Materials characterization techniques: scanning electron microscopy, transmission electron microscopy, atomic force microscopy, scanning tunneling microscopy, atomic absorption spectroscopy, differential scanning calorimetry, X-ray diffractometry

Prerequisite of the Course: Graduation level Physics and basic knowledge of Chemistry

Text books and Reference books:

1. Principles and Applications of Ferroelectrics and Related Materials: M. E. Lines and A. M. Glass, Clarendon Press
2. Principles of Electronic materials and devices: S. O. Kasap, McGraw Hill publication
3. Ferroelectric Devices: K. Uchino, CRC Press
4. Electroceramics – Materials properties and Applications: A. L. Moulson and J. M. Herberh, Chapman & Hall
5. Materials Science and Engineering : An Introduction: W. D. Callister, Wiley publication
6. Introduction to Solid State Physics: C. Kittel, Wiley publication
7. Solid State Physics: A. J. Dekker, S. Chand publication
8. Electronic Processes in Materials: Azaroff and Brophy , McGraw Hill publication
9. Nanomaterials: Synthesis, Properties and Applications: A.S. Edelstein and R.C. Cammarata, Institute of Physics Publishing, London

Assessment Method:

This course will consist 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.

Any need for revision of existing rules: No

PHY 602: ADVANCED COMPUTATIONAL PHYSICS [Credits 4, 3-0-1]

Course Outcomes:

At the end of this course, the students will be capable to apply these computational algorithms to solve different complex problems in various fields

Program Outcomes: The course covers the program outcomes from PO-1 to PO-6.

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3

Course Objectives:

Students will learn different computational algorithm to analyze the different computational problems

Syllabus

Monte Carlo Techniques

Basic theory, random number generation, Markov chain, Metropolis Algorithm, Applications to Statistical Mechanics, 1D and 2D Ising Model, Phase transitions.

Exact diagonalization

Large scale diagonalization techniques (Lanczosand Davidson) to calculate the lowest few eigenvalues and eigenvectors for large matrices, Introduction to strongly correlated systems, Hubbard model, t-J model, finite systems.

Optimization techniques

Local optimization techniques: conjugate gradient method, steepest descent method, global optimization techniques, simulated annealing, genetic algorithms, minima hopping method, applications to small systems with model potentials.

Molecular Dynamics

Introduction to classical molecular dynamics, Verlet algorithm, Microcanonical ensemble (NVE), Canonical ensemble (NVT), Isothermal-isobaric ensemble (NPT), calculation of standard averages, errors in measurement.

Parallel Computing

Theory and working principles, simplest coding techniques, algorithms and architectures.

Prerequisites: Knowledge of any computer languages

Text Books and Reference Books:

1. Harvey Gould, Jan Tobochnik, and Wolfgang Christian, Introduction to Computer Simulations Methods, Addison Wesley.
2. Mark E. J. Newman and G. T. Barkema, Monte Carlo Methods in Statistical Physics, Oxford University Press.
3. Daan Frenkel and Berend Smit, Understanding Molecular Simulations: From Algorithms to Applications, Academic 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. R. H. Landau et al., Computational Physics: Problem Solving with Computers, Wiley- VCH.
8. D. P. Landau and K. Binder, A Guide to Monte Carlo Simulations in Statistical Physics (4th edition), Cambridge University Press.
9. Avella, Adolfo, Mancini, Ferdinando (Eds.), Strongly Correlated Systems: Numerical Methods, Springer.
10. KálmánVarga and Joseph A. Driscoll,Computational Nanoscience: Applications for Molecules, Clusters, and Solids,Cambridge University Press.

Assessment Method: Written examination and assignments

Any need for revision of existing rules: No

PHY 603 FUNDAMENTALS OF SEMICONDUCTOR [Credit 3 (L T P: 3-0-0)]

Course Outcomes:

At the end of this course, the students will

- have sufficient knowledge of the structures and properties of various semiconductors
- appreciate the applications of semiconductors in real-life devices
-

Program Outcome: This course covers PO1 and PO4

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**1**	**1**
CO2	**2**	**1**	**3**	**3**	**1**	**1**

Course Description: This course is designed to impart knowledge of the semiconductor basics and their applications in devices

Course Level: Mastery

Course Objectives:

- To disseminate the conceptual knowledge of the structure and various properties of semiconductors
- To make the students familiar about the differences between semiconductors, insulators and conductors
- To impart the knowledge of applications of semiconductors in various electronic devices

Syllabus

Crystal structure, density of states, basic concepts of energy bands in materials, electron-hole concepts, Intrinsic and extrinsic semiconductors, binary, quaternary and ternary semiconductors, donors and acceptors impurities, compensate doping, concept of forbidden gap, Fermi level and its dependency on doping concentration and temperature, Quasi Fermi levels, direct and indirect band gap semiconductors, wide bandgap semiconductors, degenerate and non-degenerate semiconductors, amorphous semiconductors, magnetic semiconductors, Hall effect in semiconductors

Equilibrium and non-equilibrium conditions, diffusion and drift of carriers, temperature dependence of conductivity of semiconductors, carrier concentration temperature dependence, drift mobility: temperature and impurity dependence, generation and recombination of carriers, minority carrier injection, minority carrier lifetime, optical properties of semiconductors, Einstein’s relations, continuity equations and its solution, diffusion lengths, Ohmic and non- Ohmic contacts, different semiconductor contacts, metal-semiconductor contacts.

Growth techniques for semiconductors, p-n junction diode, depletion layer, I-V characteristics, reverse bias breakdown: Avalanche and Zener Breakdown; diode resistance, capacitance, Zener diode, tunnel diode, Schottky diode, bipolar junction transistors,; Optoelectronic devices: photodiodes, solar cells, light emitting diodes (LEDs), semiconductor laser diodes, pin diodes, impact avalanche and transit time (IMPATT) diodes; Bipolar Junction transistor (BJT): low frequency and high frequency transistor behaviour

Prerequisite of the Course: Graduation level Physics

Text Books and Reference Books:

1. Principles of Electronic materials and devices: S. O. Kasap, McGraw Hill publication
2. Principles of Semiconductor devices, B. Van Zeghbroeck, Internet Resources
3. Semiconductor Devices (Basic Principles): Jasprit Singh, Wiley Publisher
4. Semiconductor Devices (Physics and Technology): S. M. Sze and M. K Lee, Wiley Publisher
5. Semiconductor Physics and Devices: D. A. Neamen and D. Biswas, McGraw Hill Publication
6. Semiconductor Physics and Devices: S. S. Islam, Oxford Higher Education Publisher
7. Solid State Electronic Devices: B. G. Streetman and S. K. Banerjee, Pearson Education Publisher
8. Solid State Electronic Devices: D. K. Bhattacharya and R. Sharma, Oxford Higher Education Publisher

Assessment Method:
This course will consist 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 surprise test, quiz or classroom presentation as decided by the course instructor.

Any need for revision of existing rules: No

PHY604: FIBER OPTICS: FUNDAMENTALS AND APPLICATIONS

[Credit 3 (LTP: 3-0-0)]

Course Outcomes:

- Students will have adequate knowledge of different characteristics of the optical fiber
- Beam guidance, numerical aperture, spot size will be conceptualized
- Students will learn the application of Maxwell’s equations in the communication

Program Outcomes: PO 1- PO 5

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**3**	**1**
CO2	**2**	**1**	**3**	**3**	**3**	**1**
CO3	**2**	**1**	**3**	**3**	**3**	**1**

Course description: This course is designed keeping in mind the important application of light in communication. It is believed that the course will infuse the basic knowledge of optical fiber and also develop the understanding of practical applications.

Course Objectives:

- To impart the knowledge of the fundamental concepts of fiber optics
- To familiarize about the application of optical fibers in optical communication techniques
- Generation and propagation of different fiber optic laser modes

Syllabus:
Fiber numerical aperture, Sources of signal attenuation and dispersion Step and graded index multimode fibers, including plastic fibers
LP modes in optical fibers: Single-mode fibers, mode cutoff and mode field modes in optical fibers: Single-mode fibers, mode cutoff and mode field diameter,
Pulse dispersion in single-mode fibers: dispersion-tailored and dispersion-compensating fibers Birefringent fibers and polarization mode dispersion.
Fiber bandwidth and dispersion management, Erbium-doped fiber amplifiers and lasers

Prerequisite: It is expected from the students that they should have done a basic course on Optics at undergraduate level

Text Books and Reference Books:
1. Introduction to fiber optics: A. K. Ghatak and Thyagarajan, Cambridge University Press
2. Essentials in fiber optics: K Thyagarajan and A.K. Ghatak, Wiley Publication
3. Fiber Optics: J. C. Palice, 4th Edition, Pearson
4. Fiber Optics and optoelectronics: Gerd Keiser, McGraw Hill, 4th Edition

5. Fundamentals of Photonics: Saleh and Teech, Wiley
6. Fiber Optics Edited: B.P. Pal, Jonh Wiley, Newyork
7. Lasers: Theory and Applications K. Thyagarajan and A.K. Ghatak, Springer
8. Optical Electronics: A.K. Ghatak and K. Thyagarajan, Cambridge University Press

Assessment Method:
This course will consist 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 surprise test, quiz or classroom presentation as decided by the course instructor.

Any need for revision of existing rules: No

PHY 605 INTRODUCTION TO DYNAMICAL SYSTEMS [Credit 3 (LTP: 3-0-0)]

Course Outcomes:

At the end of the course, students will be

- Able to grasp the fundamentals concepts of nonlinear dynamics
- Capable to implement such phenomenon in society, science and engineering

Program Outcomes (PO): The course covers the program outcomes from PO-1 to PO-4.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**1**	**1**
CO2	**2**	**1**	**3**	**3**	**1**	**1**

Course Level: Mastery

Course description:
This interdisciplinary course provides an introduction to nonlinear dissipative and Hamiltonian systems. The course concentrates on simple models of dynamical systems, and their relevance to natural phenomena. The content is structured to be of general interest to graduates in science and engineering.

Course Objectives:

- The main goal of the course is to introduce and describe the non-linear and chaotic phenomena in natural and engineering systems using a minimum background in physics and mathematics
- Understanding the applications of nonlinear phenomenon in society, science and engineering

Syllabus

Introduction: Physics of nonlinear systems, dynamical equation and constants of motion, phase space, fixed points, stability analysis, bifurcations and their classifications, Poincare section and iterative maps

Dissipative Systems: One-dimensional noninvertible maps, iterative maps, period-doubling and universality, intermittency. Simple and strange attractors. Invariant measure, Lyapunov exponents, fractal geometry, generalized dimension and examples of fractals. Higher- dimensional systems: Henon map, Lorenz equations.

Hamiltonian Systems: Integrability, Liouville's theorem, action-angle variables, introduction to perturbation techniques, KAM theorem, Smale Horseshoes, area-preserving maps, concepts of chaos, and stochasticity

Prerequisite: students must have completed a course of classical mechanics.

Text and Reference Books:

1. Chaos in Dynamical Systems by E. Ott, Cambridge University Press, 2nd edition, 2002.
2. Nonlinear Dynamics and Chaos by S. H. Strogatz, CRC press; 2018.
3. Regular and Stochastic Motion by A. J. Lichtenberg and M. A. Lieberman, Springer; 2nd edition, 1992.
4. Chaos and Integrability in Nonlinear Dynamics by M. Tabor, Wiley-Blackwell, 1989.
5. Nonlinear Dynamics by M. Lakshmanan and S. Rajasekar, Springer, 2003.

Assessment Method: As per University Ordinance

Any need for revision of existing rules: No

PHY 606: SCIENCE & TECHNOLOGY OF THIN FILMS [Credit 3 (LTP: 3-0-0)]

Course Outcome:

At the end of this course, students will understand essential aspects of science and technology of thin film growth, advanced characterization techniques and their applications.

Program Outcomes: PO1-PO6

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3

Course Description:

Thin film technology is pervasive in applications like microelectronics, optics, magnetic, hard resistant coatings, micromechanics, etc. These applications need selective and controlled deposition thin films with desired physical properties. There are a vast number of deposition methods with their specific merits and demerits in terms of involved processes, film quality, substrate material limitations, expected film properties, scalability and cost.

This course will introduce a variety of thin film deposition methods and their limitations from applications points of view. Fundamentals related to nucleation and growth of thin films as well as characterization and applications are outlined.

Course Objectives:

- To impart the knowledge of thin films in modern technology
- To understand different physical and chemical fabrication approach of thin film
- To give the flavor of use of thin films in various potential applications

Syllabus

Physical Vapor Deposition - Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys, Raoult's law;

Electron-beam, pulsed laser and ion beam evaporation, Glow Discharge and Plasma, Sputtering - mechanisms and yield, dc and rf sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Hybrid and Modified PVD- Ion plating, reactive evaporation, ion beam assisted deposition, Chemical Vapor Deposition - reaction chemistry and thermodynamics of CVD; Thermal CVD, laser & plasma enhanced CVD, Chemical Techniques - Spray Pyrolysis, Electrodeposition, Sol-Gel and LB Techniques,

Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & mechanisms, amorphous thin films, Epitaxy - homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors, Scope of devices and applications.

Prerequisites: BSc with Physics as one of the subjects or a course on Materials Science or Nanotechnology

Text Book and Reference Book:

1. Milton Ohring, The Materials Science of Thin Films, academic Press Sanden, 1992
2. Kasturi L. Chopra, Thin Film Phenomena, McGraw Hill (NewYork), 1969
3. Donald L. Smith, Thin – Film Deposition: Principles and practice, Mc. Grow Hill, Inc. 1995
4. Kigotakawasa, MokotaKitabatke and HineakiAdadi,Thin Film Materials Technology, Shurtting of Compound Materials, Elsevier Science and Technology Book, (2004)
5. Renald M. Matten, Handbook of Physical Vapor Deposition (PVP) Processions,Norses Publication, 1998
6. John E. Mahan, Physical Vapor Deposition of Thin Film, John Wiley & Sons, 2000
7. D. M. Dolokin, M.K. Zwrow, Principles of Chemical Vapor Deposition, Kluwer Academic Publisher, Natterlande, 2003
8. Pradeep George, Chemical Vapor Deposition, VDM Verles Dr. Mueller E.K., 2007

Assessment Method: Written, assignments, seminar/term paper and final exam

Any need for revision of existing rules: No

PHY 607: FERROELECTRIC MATERIALS AND DEVICES [Credit 3 (L T P: 3-0-0)]

Course Outcomes: At the end of this course, the students will have sufficient knowledge of the fundamentals of various electric materials and their usage in devices

Program Outcomes: This course covers PO1 and PO4

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	1	1

Course Description: The course is intended to impart knowledge about various electric materials like dielectrics, ferroelectrics, piezoelectric and pyroelectrics, which are integral part of many modern devices.

Course Level: Mastery

Course Objectives:

- To impart the basics of electric polarization and related phenomena
- To disseminate the knowledge of electric devices

Syllabus

Polarization, Macroscopic electric field, Local electric field at an atom, Dielectric constant and polarizability, Structural phase transitions, Classification of ferroelectric crystals, Displacive transitions, Soft optical phonons, Landau theory of the phase transition, Antiferroelectricity, Ferroelectric domains, Ferroelectric memory devices, Piezoelectricity, High permittivity dielectrics: Ceramic capacitors, Relaxor ferroelectrics, High permittivity, Diffuse phase transition, Dielectric relaxation.

Piezoelectric materials and properties, Figures of Merit, Pressure sensors, accelerometers, gyroscopes, Piezoelectric vibrators, piezoelectric resonance, equivalent circuits, ultrasonic transducers, Resonators/filters, Surface acoustic wave devices, Piezoelectric transformers, Piezoelectric actuators

Pyroelectric materials, pyroelectric effect, responsivity, figures of merit. Temperature/infrared light sensors, Infrared image sensors.

Prerequisite of the Course: Graduation level Physics

Text Books and Reference Books:

1. Ferroelectric Devices: Kenji Uchino, CRC Press publication
2. Electrets: R. Gerhard, Springer
3. Electroceramics – Materials properties and Applications: A. L. Moulson and J. M. Herberh, Wiley publication
4. Principles and Applications of Ferroelectrics and Related Materials: M. E. Lines and A. M. Glass, Clarendon Press publication

Assessment Method:

This course will consist 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 surprise test, quiz or classroom presentation as decided by the course instructor.

Any need for revision of existing rules: No

PHY 608: MAGNETIC AND SUPERCONDUCTING PROPERTIES OF SOLIDS
[Credit 3 (LTP: 3-0-0)]

Course Outcome:

At the end of this course, the students will

- learn the basic properties of various magnetic materials and their applications
- understand the basic theoretical models to explain the magnetic behaviours
- gain basic knowledge of superconducting materials.

Program Outcomes (PO): PO1 to PO5

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	1
CO2	3	1	3	3	2	1
CO3	3	1	3	3	3	1

Course Description: Magnetic materials are a fertile playground for understanding fundamental physics phenomena as well as tremendous practical applications from data storage to high-tech magnetic levitations. This course introduces the basic types of magnetic behaviours and the microscopic theories to explain these magnetic properties.This course also covers the basic properties of superconducting materials along with its theories (phenomenological and microscopic-BCS) to explain the conventional superconductivity. Finally, it touches upon the phenomena of high-Tc superconductors.

Course Objectives:

- To make familiar various types of magnetic materials and their interesting properties.
- To discuss the basic theoretical models to explain the magnetic properties
- To impart the basic knowledge of the exotic properties of superconducting materials along with the microscopic theory (BCS) to explain the conventional superconductors.

Level: Reinforce

Syllabus:

Magnetism: Free electron in external field: Landau levels, Pauli paramagnetism, Electrons in atoms: Diamagnetism, Larmour precession, atomic magnetic moments, paramagnetism, ideal magnetic gas, classical and quantum mechanical treatment. Magnetism in condensed phase: Ferromagnetic ordering, mean field theory, Electrostatic origin of magnetic interaction, magnetic properties of a two-electron system, Heitler-London theory, Heisenberg Hamiltonian, Ground state, excited states, Weiss Molecular field theory, Antiferromagnetism, Ferrimagnetism.

Magnons and dispersion relation for magnons, origin of domains and domain walls, coercive force, hysteresis, motion of domain walls, experimental methods to determine the magnetic susceptibility. Magnetism in small and nanoparticles, superparamagnetism, Magnetic resonance.

Superconductivity: The Meissner effect, D.C. resistivity, the heat capacity, flux quantization, Superconducting energy gap, coherence length, London penetration depth, (Landau Ginzburg formulation along with) BCs theory, Interacting Cooper pairs, the condensate, Type I and II superconductors. Tunneling, phase and momentum, Dc and Ac Josephson effects, SQUID, Introduction to high TC superconductors.

Prerequisite: Basic Condensed Matter Physics

Text Books and Reference Books:

1. Introduction to Solid State Physics, Charles Kittel, (John Wiley and Sons), 8th Edition, 2012
2. Solid State Physics, N. W. Ashcroft and N. D. Mermin, (CBS Publishing Asia Ltd.).
3. Magnetism in Condensed Matter, S. Blundell (Oxford) 1st Edition, 2001
4. Introduction to Magnetic Materials, B. D. Culity and C D Grahim (Wiley), 2nd Edition, 2008

Assessment Methods: Written, Seminar/Assignment/Viva

Any need for revision of existing rules: No

PHY 609: INTRODUCTION TO FOURIER OPTICS [Credit 3 (LTP: 3-0-0)]

Course Outcomes:

On completion of this course the students will

- be capable to understand the fundamentals of Fourier optics and to analyze the rigorous theory of different kinds of optical wave propagation theory
- gain the advanced knowledge of the beam propagation theory and diffraction pattern
- understand the principles involved in the different components of optical filters and lenses used in communication systems.
- be trained enough to design different optical holographic masks

Program Outcomes: The course covers the program outcomes from PO-1 to PO-6

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**3**
CO2	**3**	**1**	**3**	**3**	**3**	**3**
CO3	**3**	**1**	**3**	**3**	**3**	**3**
CO4	**3**	**1**	**3**	**3**	**3**	**3**

Course Level: Mastery

Course Description:
This is an advanced level course that covers mathematical explanation of wave propagation through different optical elements and their underlying theory. Importance of Fourier theorem for basic understanding of light waves propagation. Designing of different optical apertures and analysis of their diffraction pattern.

Objectives:

- Rigorous understanding of recent intricate theories of Fourier transform, Hankel Transform, Fourier-Bessel Transform
- Physical interpretation of scalar diffraction theory and angular spectrum propagation method
- Fresnel and Fraunhofer diffraction theory and propagation of light beams through different optical systems

Syllabus:

Analysis of Two-Dimensional Signals and Systems
Fourier Analysis in Two Dimensions, Fourier Transform Theorems, Separable Functions, Hankel transforms, Functions with Circular Symmetry: Fourier-Bessel Transforms, Local Spatial Frequency and Space-Frequency Localization, Linear Systems, Transfer Functions, Two-Dimensional Sampling Theory, The Whittaker-Shannon Sampling Theorem.

Foundations of Scalar Diffraction Theory
The Rayleigh-Somrnerfeld Formulation of Scalar Diffraction Theory, The Angular Spectrum of Plane Waves: The Angular Spectrum and Its Physical Interpretation, Propagation of the Angular Spectrum, Effects of a Diffracting Aperture on the Angular Spectrum, The Propagation Phenomenon as a Linear Spatial Filter.

Fresnel and Fraunhofer Diffraction
The Fresnel Diffraction Approximation: Positive vs. Negative Phases, Accuracy of the Fresnel Approximation, The Fresnel Approximation and the Angular Spectrum; The Fraunhofer Diffraction Approximation, Examples of Fraunhofer Diffraction Patterns: Rectangular Aperture, Circular Aperture, Thin Sinusoidal Amplitude Grating, Thin Sinusoidal Phase Grating; Examples of Fresnel Diffraction Calculations: Fresnel Diffraction by a Square Aperture/Sinusoidal amplitude grating-Talbot Images

Wave-Optics Analysis of Coherent Optical Systems
A Thin Lens as a Phase Transformation, Fourier Transforming Properties of Lenses, Image Formation: Monochromatic Illumination, Analysis of Complex Coherent Optical Systems

Prerequisite: Student must have completed Optics Course

Text Books and References Books:

1. Introduction to Fourier Optics: Joseph W. Goodman, The McGraw-Hill Companies Inc.
2. The Fourier transform and its applications: R. N. Bracewell, McGraw-Hill, NY
3. Fourier Optics and Computational Imaging: Kedar Khare, , Wiley Publications
4. Linear systems, Fourier transforms, and optics: Jack D. Gaskill, Wiley Publications
5. The Fourier transform and its applications to optics: P. M. Duffleux, John Wiley and Sons
6. Diffraction, Fourier Optics, and Imaging: Okan K. Ersoy, John Wiley and Sons

Assessment Method: Written and Assignments

Any need for revision of existing rules: No

PHY 610: MONTE CARLO-THEORY AND PRACTICE [Credit 3 (LTP: 3-0-0)]

Course Outcomes:
Students will acquire skills to simulate complex phenomenon on a computer and make useful inferences. These skills will be useful to them whatever be the career they embark on, after completing their studies in the university.

Program Outcomes: The course covers the program outcomes from PO-1 to PO-6.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**3**

Course Level: Mastery

Course Description:
Computational science has emerged as an important discipline along with the traditional ones: theoretical and experimental science. Amongst numerous computational methods, the technique of Monte Carlo simulation has gained importance, thanks to the phenomenal developments in computers. This course will teach the students not only of the theory behind Monte Carlo simulation methods but also of how to implement it on a variety of problems.

Course objectives
With the advent of modern computing machines which are fast and which have large memory, Monte Carlo methods have emerged as useful techniques to solve a variety of problems in physics, chemistry, biology, economics and a host of other disciplines. The students will acquire a deeper understanding of a phenomenon when they simulate the phenomenon on a computer.

Syllabus

Elements of Probability Theory

Sample Space; events, mutually exclusive events; independent events; probability of events; axioms of probability; conditional probability; Bayes' theorem.

Random variable; probability density function; discrete probabilities: Binomial distribution; Poisson distribution; geometric distribution; moments; moment generating function and its applications; Master equation for Poisson process.

Continuous random variables; probability density functions; uniform, exponential, Gaussian and Caucchy probbility density functions; characteristic functions; moments and cumulants.

Function of many random variables; sum of independent random variables; formal expression for the probability density function of sum of independent random variables; characteristic function of sum of identically distributed independent random variables; Chebyshev inequality; law of large numbers; cumulant generating function; central limit theorem.

Random number generation and testing:

pseudo random numbers; mid-square method; linear congruential method; Testing of random numbers; uniformity test; run down and run up tests; tests based on correlation;

Random Sampling Techniques:

Techniques of random sampling from distributions; inversion - analytical and numerical; rejection algorithms; Metropolis Rejection;

Boltzmann Monte Carlo Methods:

Metropolis algorithm; Markov chains; time homogeneous Markov Chains; balance and detailed balance; reversible Markov chains; Markov matrices; invariant probability vectors; convergence to equilibrium ensemble; canonical ensembles; Boltzmann Monte Carlo methods; simulation of Ising spins systems; second order phase transition; critical slowing down; cluster algorithm; super critical slowing down; first order phase transition

Non-Boltzmann Monte Carlo Method:

Umbrella sampling; flat histogram methods; multi canonical sampling; entropic sampling; Wang-Landau algorithm, Work fluctuations; Jarzynski identity; combining Jarzynski identity and Wang Landau Monte Carlo to calculate equilibrium free energies.

Prerequisite of the Course: Graduation level Physics

Text Books and Reference Books:

1. J. M. Hammersley and D. C. Handscomb, Monte Carlo Methods, Chapman and Hall, London (1964)
2. M. H. Kalos and P. A. Whitlock, Monte Carlo Methods, Vol. 1: Basics, John Wiley, New York (1986).
3. D P Landau and K Binder, A Guide to Monte Carlo Simulations in Statistical Physics, Cambridge University Press (2009.).
4. K P N Murthy, Monte Carlo: Basics, ISRP/TD-3, Indian Society for Radiation Physics, February, 2000. cond-Mat:arXiv:0104215 vi [cond-mat-stat.phy) 12 April 2001

5. K. P. N. Murthy, Monte Carlo Methods in Statistical Physics, Universities Press (India) Private Limited, distributed by Orient Longmann Private Limited (2004)

Assessment Method: Written and Assignments

Any need for revision of existing rules: No

PHY611 SEMICONDUCTOR DEVICES AND TECHNOLOGY [Credit 3 (L T P: 3-0-0)]

Course Outcomes:

At the end of the course, the students will

- Be familiar with the peculiar behaviour of semiconductors
- be equipped the knowledge of different semiconductor devices
- have the knowledge about various fabrication techniques of semiconductors

Program Outcomes: This course covers PO1 and PO4

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**1**	**1**
CO2	**3**	**1**	**3**	**3**	**1**	**1**
CO3	**3**	**1**	**3**	**3**	**1**	**1**

Course Description: The course is intended to disseminate the basic and applied knowledge of various semiconductors, the difference between homo- and hetero-junction based semiconductor devices, provide the knowledge about various fabrication techniques of semiconductors and various applications of semiconductors in devices

Course Level: Mastery

Course Objectives:

- To disseminate the basic and applied knowledge of various semiconductors
- To impart the knowledge about the difference between homo- and hetero-junction based semiconductor devices
- To provide the knowledge about various fabrication techniques of semiconductors
- Applications of semiconductors in devices

Syllabus

Crystal and crystal structures, Common semiconductor crystal structures, Energy bands, Density of states, Carrier distribution functions, Carrier densities, Carrier transport, Carrier recombination and generation Continuity equation the drift-diffusion model, Semiconductor thermodynamics, Growth of semiconductor crystals: silicon crystal growth from the melt, silicon float-zone process, GaAs growth techniques, epitaxial growth technique, structure and defects in epitaxial layers
Structure, principle of operation and electrostatic analysis of p-n diode, Current-Voltage characteristics, Reverse bias breakdown, Depletion capacitance, Charge storage and transient behaviour, Uniformly doped and linearly graded junctions, Hyper-abrupt junctions, Heterojunctions, Optoelectronic devices, Photodiodes, Solar Cells, Light Emitting Diodes (LEDs), Laser diodes; Microwave diodes: Tunnel diode, IMPATT diode, Transferred electron devices
Structure and principle of operation of metal semiconductor contacts: Schottky barriers, Rectifying contacts, Ohmic contacts, Electrostatic analysis, Schottky diode current, Metal- Semiconductor Field Effect Transistors (MESFET), Schottky diode with an interfacial layer, MOS capacitor and MOSFET fundamentals, Heterojunction bipolar transistors, BJT technology, Frequency response and switching of bipolar transistors, High Electron Mobility Transistors (HEMTs)

Prerequisite of the Course: Graduation level Physics

Text Books and Reference Books:

1. Principles of Electronic materials and devices: S. O. Kasap, McGraw Hill publication
2. Principles of Semiconductor devices, B. Van Zeghbroeck, Internet Resources
3. Semiconductor Devices (Basic Principles): Jasprit Singh, Wiley publication
4. Semiconductor Devices (Physics and Technology): S. M. Sze and M. K Lee, Wiley publication
5. Semiconductor Physics and Devices: D. A. Neamen and D. Biswas, McGraw Hill publication
6. Semiconductor Physics and Devices: S. S. Islam, Oxford Higher Education publication
7. Solid State Electronic Devices: B. G. Streetman and S. K. Banerjee, Pearson Education publication
8. Solid State Electronic Devices: D. K. Bhattacharya and R. Sharma, Oxford Higher Education publication

Assessment Method:

This course will consist 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.

Any need for revision of existing rules: No

PHY 612: NONLINEAR DYNAMICS AND CHAOS [Credit 3 (LTP: 3-0-0)]

Course Outcomes:

At the end of the course, students will be

- Able to grasp the fundamentals concepts of nonlinear dynamics
- Capable to implement such phenomenon in society, science and engineering

Program Outcomes (PO): The course covers the program outcomes from PO-1 to PO-6.

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	3	3	3	3

Course Level: Mastery

Course description:

This interdisciplinary course provides an introduction to nonlinear dynamics, chaos and fractals. We will investigate how to determine the qualitative behaviour of the solutions of nonlinear differential and difference equations, without having to determine the actual solutions explicitly. The course concentrates on simple models of dynamical systems, and their relevance to natural phenomena. The content is structured to be of general interest to graduates in science and engineering.

Course Objectives:

- The main goal of the course is to introduce and describe the non-linear and chaotic phenomenon in natural and engineering systems using a minimum background in physics and mathematics
- Understanding the applications of nonlinear phenomenon in society, science and engineering
- Learn an extensive use of computational tools and laboratory experiments to explore chaotic behaviour

Syllabus:

The qualitative analysis of nonlinear dynamical flows: Stability of fixed points, existence of limit cycles, Bifurcations theory

Nonlinear Oscillators: Lorenz and Rossler equations; Iterated maps: Logistic and Henon maps;

Period doubling, Intermittency and other routes to Chaos
Fractal geometry; Strange Chaotic and Nonchaotic Attractors; Characterization of Regular and Chaotic motions: Lyapunov exponent, Power spectrum, Autocorrelation, and Dimension

Prerequisite of the Course: Graduation level Physics

Text and Reference Books:

1. S. H. Strogatz, Nonlinear Dynamics and Chaos, Perseus, 2000 (Indian Edition, 2009)
2. K. T. Alligood and *et al*, *Chaos – An Introduction to Dynamical Systems*, Springer, 1996
3. E. Ott, *Chaos in Dynamical Systems*, Cambridge, 2002
4. M. Lakshmanan and S. Rajasekar, *Nonlinear Dynamics*, Springer, 2003
5. S. Lynch, *Dynamical Systems with Applications using MATLAB*, Birkhauser, 2004

Assessment Method: As per University Ordinance

Any need for revision of existing rules: No

PHY 613: CONCEPTS OF LASER PHYSICS AND FIBER OPTICS [Credit 3 (LTP: 3-0-0)]

Course Outcomes:
At the end of the course, the students will

- appreciates the working principles of laser and their utilities
- get the exposure of techniques underlying optical communication using single and multimode fibers
- be able to apprehend the phenomenon of dispersion, communications wavelengths and transmission losses

Program Objective: The course covers the program outcomes from PO-1 to PO-6

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	3	3	3	3
CO3	3	1	3	3	3	3

Course Level: Mastery

Course Description:

This course is divided in two parts: First part covers the physics of light-matter interaction, stimulated and spontaneous emission, Einstein Coefficients, two level, three level, four level LASER system, Ultrafast Laser and their underlying characteristic properties. Second part covers different types of Optical fibers and their underlying principles and further propagation of LASER through these optical fibers.

Objectives:

- To conceptualize the basics of lasers and light matter interaction
- To ingrain the knowledge of optical communications on utilitarian ground
- To infuse the knowledge of various characteristics of optical fiber and their peculiar properties

Syllabus:

Introduction, Physics of interaction between Radiation and Atomic systems including: Stimulated emission, emission line shapes and dispersion effects Einstein coefficients; Line shape function, Line-broadening mechanisms, Condition for amplification by stimulated emission, the meta-stable state and laser action. 3-level and 4-level pumping schemes. Laser Rate Equations: Two-, three- and four level laser systems, condition for population inversion, gain saturation;
Carrier wave communication and necessity of communication at optical frequencies Introduction to optical fibers, concepts of core and cladding, necessity of cladding structure, Total internal reflections, evanescent wave, penetration depth and propagation concept of evanescent waves, type of optical fibers, glass fibers, plastic cladded silica fibers, single mode and multi-mode optical fibers, index Profiles of the optical fibers step index and graded index core optical fibers, Numerical aperture, Experimental technique to measure numerical aperture of the optical fiber Ray paths and pulse dispersion in optical waveguides, Ray paths in homogeneous and square law profiles, calculation of dispersion in terms of relative core cladding refractive index parameter, Transit time calculation in step index and parabolic index waveguide, Material dispersion, material dispersion in pure and doped silica, Zero material dispersion wavelength (ZMDW)

Prerequisite: Atomic Physics and spectra

Reference Books:

1. Principles of lasers by O. Svelto, Springer, Fifth Edition, (2010)
2. Lasers by Anthony ESiegman,University Science Books; Revised Ed. (1986)
3. Lasers and Non-linear optics: B. B. Laud, Wiley
4. Lasers: Theory and Applications: K. Thyagarajan and A.K. Ghatak, Springer, First Edition (1981)
5. Introduction to fiber optics: A. K. Ghatak and Thyagarajan
6. Essentials in fiber optics: K Thyagarajan and A.K. Ghatak
7. Introduction to Fiber Optics by John Crisp, Newnes, Third Edition (2007)
8. Fiber Optics: J. C. Palice
9. Fiber Optics and optoelectronics: G. Keiser

10. Fundamental of Photonics: B.E.A.Saleh and Teich, John Wiley & Sons; 1st edition
11. Fiber Optics Edited: B.P. Pal

Assessment Method: Written examinations and assignments

Any need for revision of existing rules: No

PHY 614: INTRODUCTION TO PLASMA PHYSICS [Credit 3 (LTP: 3-0-0)]

Course Outcomes:

On completion of the course, the students will be able

- To understand the basic properties of plasma state and the motion of charged particles in the electromagnetic fields
- To understand the nonlinear effects in plasma and their inswing applications
- To realize the application of ionospheric plasma used for telecommunications

Course Outcomes (PO): The course covers the program outcomes from PO-1 and PO-5 to PO-6.

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	1	1	3	3
CO2	3	1	1	1	3	3
CO3	3	1	1	1	3	3

Level: Mastery

Description: The course is planned to introduce the basic knowledge and various applications of plasma . Plasma, the most common state of ordinary matter in the universe, is fascinating and has importance in lightning, microelectronics, nano science, polymer, textile processing and medicine.This course is recommended for students who have strong interests in electrodynamics.

Course Prerequisites: Students must have some basic understanding of mathematical tools and have studied electrodynamics.

Objectives:

- To impart the theoretical and analytical knowledge in the field of plasma physics
- To introduce plasma phenomena relevant to energy generation by controlled thermonuclear fusion
- To grasp the concept of Debye length, Debye shielding, plasma sheath and plasma oscillation

Syllabus:

Introduction to Plasmas and Particle Dynamics: Definition and general properties of plasma, plasma oscillations, Debye shielding and criteria for plasma, motion of charged particles in electromagnetic field and non-uniform magnetostatic field, electric field drift, gradient B drift, parallel acceleration and magnetic mirror effect, curvature drift, adiabatic invariants.

Waves and Transport Processes in Plasmas: Fluid description of plasmas, continuity and momentum balance equations of fluid mechanics, electron plasma waves, ion acoustic waves, electromagnetic waves in plasma , magnetosonic and Alfven waves and their dispersion relations and properties, stability of plasmas, ambipolar diffusion, hydromagnetic equilibrium, diffusion of magnetic lines and frozen-in fields, concept of magnetic pressure, plasma confinement schemes.

Nonlinear Effects and Controlled Fusion: Vlasov equation, landau damping, plasma sheath, pondermotive force, wave-wave interaction, nuclear fusion, plasma pinching, toroidal devices.

Text Books:

- Introduction to plasma physics and controlled fusion Chen, Francis F, Springer, 3rd edition, 2016.
- The physics of fluids and plasmas: an introduction for astrophysicists. Choudhuri, ArnabRai. Cambridge University Press, 2015.
- Principles of Plasma Discharges and Materials Processing.Lieberman and Lichtenberg,Wiley-Interscience; 2nd edition, 2008.
- Introduction to dusty plasma physics. Shukla P. K. and Mamun A. A., CRC Press; 2001.

Assessment Method: First CIA (20 %), second CIA/assignments (20 %) and EOSE (60 %)

Any need for revision of existing rules: No

PHY 615: INTRODUCTION TO NANOMATERIALS AND NANOTECHNOLOGY
[Credit 3 (LTP: 3-0-0)]

Course Outcomes:

At the end of the course the students will

- Appreciate the unusual properties of materials at nanoscale
- Gain deep insights about modern synthesis and characterization techniques
- Have knowledge of nanomaterials applications in day-to-day life

List of PO that the course covers: PO1, PO3-PO6

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**3**	**3**
CO2	**3**	**1**	**3**	**3**	**3**	**3**
CO3	**3**	**1**	**3**	**3**	**3**	**3**

Level: Mastery

Course Description:

The physical properties change drastically as the material size shrinks towards the atomic scale. Nanomaterials have a much greater surface area to volume ratio than their conventional forms and quantum effects become important. They can be engineered to possess unique composition and functionalities. In this course, many key concepts related to nanomaterials and nanotechnology will be discussed. Fundamental aspects and applications of nanotechnology in the areas of Physics, Chemistry, materials science, biology, energy and electronics will be outlined.

Course Objectives:

Introduction of various physical properties at nanoscale

- To impart the knowledge of synthesis and characterization techniques of nanomaterials
- To familiarize the fascinating application of nanomaterials

Syllabus:

Classification of nanomaterials, effect of nanometer length scale on system total energy, structure and properties. Hydrothermal Synthesis, Solvothermal Method, Chemical Vapor Deposition (CVD), Thermal Decomposition and Pulsed Laser Ablation, Templating, Microwave Synthesis, Conventional Sol-Gel Method. Scanning electron microscope (SEM), transmission electron microscope (TEM), atomic force microscope (AFM), X-ray photoelectron spectroscopy (XPS), X-ray diffraction, UV-Vis and FTIR, Raman spectroscopy and Network analyzer.

Fabrication of metallic, magnetic, carbon-based nanomaterials (Carbon nanotube, graphene, fullerene and nano-diamond), other inorganic nanomaterials. Electrical, Magnetic, Thermal, Mechanical and Optical properties of thin films, foam, layered materials, nanofiber, nanowire, nanocrystals and composite nanomaterials. Viscoelastic and liquid crystalline properties.
Examples of potential applications in biomedical; drug delivery, tissue engineering, opto-electronic, thermal management, electromagnetic interference shielding, solar cells, fuel-cells, batteries, supercapacitors, hydrogen storage, catalysis, aerospace, military, High-Sensitivity

Sensors, water desalination and composites.

Prerequisite of the course: Graduation level Physics and Chemistry

Text Books and Reference Books:

1. Massimiliano Ventra, Stephane Evoy and James R. Heflin (Editors), Introduction to Nanoscale Science and Technology, Springer, Boston, 2004.
2. Guozhong Cao and Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2nd edition, World Scientific Publishing Company, 2010.
3. A.S. Edelstein and R.C. Cammarata (Editors), Nanomaterials: Synthesis, Properties and Applications, Institute of Physics Publishing, London, 1996.
4. E. L. Wolf, Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, 2nd edition, Wiley VCH, 2006.

Course Assessment: Assignments: 20 %, Presentation: 20 %, End of semester examination: 60 %

Any need for revision of existing rules: No

PHY 616: QUANTUM MANY-BODY PHYSICS [Credits 4, 3-1-0]

Course Outcomes:
This course will help the learners in modeling and understanding the real world problems contained in transport phenomenon, magnetic properties, superconductivity, quantum hall effect, etc. which have numerous relevance in industrial applications and research.

Program Outcomes (PO): The course covers the program outcomes from PO-1 to PO-5.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO	3	1	3	3	3	1

Level: Mastery

Course Description:
Most of the condensed matter systems are interacting ones. In such systems, the experimental outcomes cannot be understood at the level of a single body. Nobel Laureate Philip Warren Anderson is famously quoted as saying “More is different." In other words, condensed matter systems are challenging to deal with due to many-body interactions. This course offers several quantum many-body techniques which are essentially devised for such complex systems.

Objectives:

- To give the exposure of second quantized world
- To learn the Feynman diagrams and their importance in interacting quantum many-body systems where either exact solutions do not exist or hard to find

Syllabus

Second Quantization

Fock space, creation and annihilation operators, one-body operators, two-body operators, field operators, electron gas.

Green's Functions at Zero Temperature

Interaction representation, Green's functions, Wick's theorem, Feynman diagrams, Dyson's equations, linear response theory, examples.

Green's Functions at Finite Temperatures

Imaginary-time representation, Matsubara Green's functions, Wick's theorem, Feynman diagrams, Dyson's equations, linear response theory, examples.

Green's Functions and Phonons

Green's function for free phonons, electron-phonon interaction and Feynman diagrams, combining Coulomb and electron-phonon interactions, phonon renormalization by electron screening in random phase approximation, Cooper instability and Feynman diagrams.

Superconductivity

Cooper instability, Bardeen–Cooper–Schrieffer (BCS) ground state, microscopic BCS theory, BCS theory with Matsubara Green's functions, Nambu formalism of the BCS theory, gauge symmetry breaking and zero resistivity, Josephson effect.

Prerequisite of the course:A course on Quantum mechanics

Text Books and Reference Books:

1. A. A. Abrikosov et al., Methods of Quantum Field Theory in Statistical Physics, Dover.
2. L. D. Lifshits et al., Statistical Physics (Part 2: Volume 9; 3rd Edition), Pergamon Press.
3. A. L. Fetter and J. D. Walecka, Quantum Theory of Many-Particle Systems, Dover.
4. G. D. Mahan, Many-Particle Physics (3rd Edition), Springer.
5. R. D. Mattuck, A Guide to Feynman Diagrams in the Many-Body Problem (2nd Edition), Dover.
6. A. Zagoskin, Quantum Theory of Many-Body Systems (2nd Edition), Springer.
7. Xiao-Gang Wen, Quantum Field Theory of Many-body Systems, Oxford University Press.
8. H. Bruus and K. Flensberg, Many-body Quantum Theory in Condensed Matter Physics, Oxford University Press.
9. P. Coleman, Introduction to Many-Body Physics, Cambridge University Press(CUP).
10. J. W. Negele, Quantum Many-particle Systems, Perseus Books.
11. R. A. Jishi, Feynman Diagram Techniques in Condensed Matter Physics, CUP.
12. D.J. Thouless, The Quantum Mechanics of Many-Body Systems (2nd Edition), Dover.

Assessment Method: Written examinations and assignments

Any need for revision of existing rules: No

PHY 617: Theory of Complex Networks and Applications [Credit 3 (LTP: 3-0-0)]

Course Outcome:

Students who successfully complete this course will gain a broad conceptual and technical introduction to the modern theory and applications of complex networks. Specifically the students will learn fundamentals of graph and network theory well as a dynamical system based approach to large scale networks and they will be able to analyze real world networks empirically and generate network models to study their collective behaviour on a computer.

Program Outcomes (PO): The course covers the program outcomes from PO-1 to PO-6.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**3**

Course Level: Mastery

Course description:

This interdisciplinary course provides an introduction to complex network theory and its applications in physics, biology, technology and social sciences. Basic graph theory and the statistical physics foundations as well as applications to real world networks will be covered. A hands-on approach to analytical and computational techniques for real world networks will be provided.

Course Objectives

A complex network is a graph (network) with non-trivial topological features - features that do not occur in simple networks such as lattices or random graphs but often occur in real graphs. In this course, we investigate the topology and dynamics of such complex networks, aiming to better understand the behavior and properties of the underlying systems. The applications of complex networks cover physical, informational, biological, cognitive, and social systems.

Prerequisite: students must have completed a course of classical mechanics.

Syllabus

Introduction to Networks, basic concepts of graph theory: Properties of real networks: small- world and scale-free networks, community structure, hierarchies, Centrality measures, Clustering, assortativity, Motifs, Characteristics of weighted networks.

Network Models: Erdős Rényi, Watts-Strogatz, and Barabási-Albert. Analysis and stability of networks.

Random Graphs, Community Structures, Modular networks, Processes on networks, Growth models, Random walks on networks.

Network Examples: Social network, The Internet as a complex network, Complex networks in economy and finance, Cellular networks, Networks of neurons and ecosystems, Epidemics.

Text and Reference Books

1. Networks: An Introduction, Oxford University Press, Oxford, 2010.
2. Networks, Crowds and Markets by D Easley and J Klienberg, Cambridge Univ Press, 2010.
3. Dynamical Processes on Complex Networks, A. Barrat *et al*, Cambridge Univ Press, 2008.

Assessment Method: As per University Ordinance

Any need for revision of existing rules: No

PHY 618: Computational Condensed Matter Physics [Credit 3 (L-T-P: 2-1-0)]

Course Outcomes:

At the end of the course, the students should:

- Learn the basics of the formulation of various theoretical models in condensed matter physics
- Learn the basics of at least one programming language (Fortran90, C++, Python)
- Be able to write the basic simulation codes for Condensed Matter Physics Models
- Gain general understanding of how computational physics works.

Program Outcomes: PO1, PO3 to PO6

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**3**
CO2	**3**	**1**	**3**	**3**	**3**	**3**
CO3	**3**	**1**	**3**	**3**	**3**	**3**
CO4	**3**	**1**	**3**	**3**	**3**	**3**

Level: Mastery

Course Description: Condensed Matter Physics (CMP) is the fundamental science of solids and liquids. It is undoubtedly one of the fast moving and very active research fields which often uncovers phenomena (superconductivity, magnetism, topological insulators etc) that are technologically important. Nowadays, computational methods are well established in studying various phenomena in all branches of science. Indeed, very often the computer simulation is the only route for systematic studies and improved understanding.

This course introduces some of the numerical techniques applied to the models in CMP covering phenomena of metal-insulating transitions, magnetism, topological insulators etc. The pedagogical approach of the lecture will be to start from a model description of a phenomena and then develop a numerical approach starting from there. The practical implementation of the basic code writing (e.g. with Fortran 90/95) would be monitored.

Course Objectives:

Students will learn the basics of various condensed matter physics models and how to solve these models by computer simulation.

Syllabus:

Matrix formulation of Quantum Mechanics, Exact diagonalization, Illustrations by Heisenberg spin models, Hubbard models, Lanczos diagonalization for large systems, tight binding bands and density of states calculations for various lattice systems: square, triangular, honeycomb etc, band structure of Su-Schrieffer-Heeger (SSH) model as the simplest case for topological insulator

Monte Carlo methods, Basic theory, random number generations, Markov Process, Metropolis algorithm, Applications to Ising model, Heisenberg models in various lattices, Frustrated magnetic systems, magnetic phase transitions, itinerant magnetic systems (localized spin and electron systems), hybrid Monte Carlo method

Willson’s numerical Renormalization Group (RG) method, Particle in a box problem, Basics of Density Matrix and Density matrix RG method, Matrix product states, Basis Truncation in DMRG method, Infinite system algorithm, finite system algorithm, Application to Heisenberg, Hubbard and t-J models

Pre-requisites of the Course: Basic solid-state physics, basic quantum mechanics

Text Books and Reference books:

1. Computational Physics, Nicholas J. Giordano, Hisao Nakanishi, Pearson Addison-Wesley; 2 edition (July 2005)
2. Monte Carlo Simulation in Statistical Physics: An Introduction, Kurt Binder, Dieter Heermann (Springer, 6th Edition)
3. The density-matrix renormalization group, U. Schollwöck, Reviews of Modern Physics, 77, 259 (2005)
4. Fortran 90/95 2nd Edition: For Scientists And Engineers by Chapman S J, Tata

Mcgraw Hill

Assessment Method: written, tutorials, viva, seminar, assignment

Any need for revision of existing rules: No

PHY 619: Phase Transitions and Critical Phenomena [Credit 3 (LTP: 3-0-0)]

Course Outcomes:

The student is expected to gain a good understanding of various types of phase transitions and their description. Obtain a considerable insight of the modern theory of critical phenomena and of the behavior of canonical theories and models, and the skills required to solve problems useful for future professional activity

Program Outcomes: PO1, PO3-PO6

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**3**

Level: Mastery

Course Description: Thermodynamic systems exist in various stable homogeneous states (phases) which differ in their structure, symmetry, order or dynamics. At certain (critical) values of the thermodynamic variables the system undergoes an abrupt change from one phase to another phase which is called a phase transition. Critical phenomena investigates the relevant observable physical properties exhibiting singularity or discontinuity in the vicinity of a critical point. It is often the existence of phase transitions that give materials the properties that are exploited in technological applications and therefore, forms an important subject of interest to physicists, chemists, and material scientists.

This is an advanced course on Statistical Physics, with a particular emphasis on Phase Transitions and Critical Phenomena, exploring a wide range of phase transitions like magnetic transitions, liquid-gas transition, ferroelectric, atomic ordering transitions and other displacive phase transitions.

Course Objectives:

(1) to provide insights into the Physics of phase transitions and critical phenomena through a systematic presentation of the formalism and the models

(2) to train students in the analytical and numerical methods of modern statistical mechanics to solve the exercises proposed during the course.

(3) to enable the student to recognize the nature and type of the phase transitions that occur in nature and to study the main implications of critical phenomena in various branches of Physics independently.

Syllabus:

Phase equilibrium and phase transition. Examples. Critical point exponents, inequalities and universality classes. Overview of simple models. Mean field Approximation, Landau theory, Beyond mean field, correlations and fluctuations, Scaling hypothesis, Renormalization Group and Crossover Phenomena, Dynamics of phase transitions (nucleation, spinodal decomposition, critical slowing down, mode-coupling)

Prerequisites of the Course: Statistical Mechanics

Text Books and Reference Books:

1. H E Stanley, Introduction to Phase transitions and Critical Phenomena, Oxford Science Publications (1987).
2. S. K. Ma, Modern Theory of Critical Phenomena, Westview Press, Oxford (2000).
3. N. Goldenfeld, Lectures on Phase Transitions and the Renormalization Group, Addison & Wesley (1992)
4. J. M. Yeomans, Statistical Mechanics of Phase Transitions, Oxford University Press, New York, NY (1992).
5. J. J. Binney, N. J. Dowrick, A. J. Fisher and M. E. J. Newman, The Theory of Critical Phenomena: An Introduction to the Renormalization Group, Oxford University Press, Oxford (1992).
6. J. Zinn-Justin, Quantum Field Theory and Critical Phenomena, Oxford University Press (2002)
7. I. Herbut, A Modern Approach to Critical Phenomena, Cambridge, University Press (2006)
8. H. Nishimori, G. Ortiz, Elements of Phase Transitions and Critical Phenomena, Oxford University Press (2011).

Course Assessment: Presentation: 20 % (on a subject chosen by the student and validated by the teacher), Assignments: 20 % and End of Semester examination: 60 %

Any need for revision of existing rules: No

PHY 620: Special Topics in Mathematical Physics [Credit 3 (LTP: 300)]

Course Outcomes:

Successful students will be able

- To work with integral transforms
- To work with vectors, tensors, coordinate transformations
- To define the a group, order of a finite group, permutation groups, different types of subgroups such as normal subgroups, cyclic subgroups
- To describe the symmetries in figures
- To construct Green's functions and use to solve boundary value problems.

Program Outcomes (PO): The course covers PO-1 and PO-5 to PO-6.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**1**	**1**	**3**	**3**
CO2	**3**	**1**	**1**	**1**	**3**	**3**
CO3	**3**	**1**	**1**	**1**	**3**	**3**
CO4	**3**	**1**	**1**	**1**	**3**	**3**
CO5	**3**	**1**	**1**	**1**	**3**	**3**

Course Level: Mastery

Course description: The purpose of the course is to introduce mathematical skills required to solve problems in quantum mechanics, electrodynamics, condensed matter physics and other fields of theoretical sciences.

Course Objectives:

- To expose the students to the fascinating world of symmetry in physics and chemistry
- To make the students learn about tensor calculus special functions essential in solving physics problems
- To model and solve physical phenomena using Green's functions

Syllabus:

Integral Transforms

Definition and properties of Dirac delta function. Fourier and inverse Fourier transform, Fourier Series, development of the Fourier integral from the Fourier Series, simple applications of Fourier and inverse Fourier Transform, Finite wave train, Wave train with Gaussian amplitude, Fourier transform of derivatives, solution of wave equations and application. Convolution theorem. Laplace transforms and their properties, Laplace transform of derivatives integrals, derivatives and integrals of Laplace transform. Impulsive function, Application of Laplace transform in solving linear, differential equations with constant coefficient with variable coefficient and linear partial differential equation.

Introduction to elements of Group theory

Introduction to group theory, representation of groups, symmetry in physics, Discrete groups, Continuous groups, Lorentz groups, space groups

Green's functions

Dirac-delta function, three-dimensional delta function, definition of Green's functions, Green's function for one dimensional equations, Green's functions for two and three dimensional equations, Symmetry property of Green's function, eigenfunction expansion of Green's functions, Green's function for Poisson's equation.

Tensors in Physics

Scalar, vector and tensor quantities, Coordinate transformations, simple applications of tensors in non-relativistic physics, moment of inertia tensor, electrical conductivity, electrical polarizability and magnetic susceptibility tensors, stress and strain tensors, generalized Hook's law, Maxwell's equations in tensor form, Lorentz covariance of Maxwell's equations.

Prerequisites:

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

Text Books and Reference 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 , Robert L. Walker. Mathematical Methods of Physics, Pearson Education.

Assessment Method: First CIA (20 %), second CIA/assignments (20 %) and EOSE (60 %)

Any need for revision of existing rules: No

PHY 621: Advanced Plasma Physics [Credit 3 (LTP: 300)]

Course Outcomes:
After completing the course the students will be able

- To analyze the motion of charged particles in electric and magnetic fields
- To discuss plasma resistivity and diffusion in plasma
- To linearize equations describing plasma and derive differential equations for various types of waves in plasma and their dispersion relation
- To explain the concept of plasma instability and analyze the instabilities based on the dispersion relation
- To explain the use of plasma in thermonuclear fusion for energy production and future directions of research.

Course Outcomes (PO): The course covers PO-1 and PO-5 to PO-6.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**1**	**1**	**3**	**3**
CO2	**3**	**1**	**1**	**1**	**3**	**3**
CO3	**3**	**1**	**1**	**1**	**3**	**3**
CO4	**3**	**1**	**1**	**1**	**3**	**3**
CO5	**3**	**1**	**1**	**1**	**3**	**3**

Course Level: Mastery

Course Description: The course is designed to provide the advance understanding of physical processes that govern by ordinary plasmas, space plasmas, laboratory plasmas and dusty plasmas. This course is recommended for students those have research interests in plasma physics and electrodynamics.

Course Objectives:

The objectives of course are

- To study the interactions of charged particles with electromagnetic fields.
- To study the various instabilities in plasma medium
- To study the different applications of plasma physics
- To study the nonlinear effects in plasma physics

Syllabus:

Plasma Generations a**nd Transport Processes**: Plasma oscillations, Debye shielding and criteria for plasma, ionization of atoms and molecules, AC and DC discharges, conduction in ionized gases, Low temperature plasma generation, motion of charged particles in electromagnetic field and non-uniform magnetostatic field, fluid description of plasmas, continuity and momentum balance equation of fluid mechanics, ambipolar diffusion, hydromagnetic equilibrium, diffusion of magnetic lines and frozen-in fields, concept of magnetic pressure.

Nonlinear Effects in Plasmas: Vlasov equation, landau damping, Plasma Sheath, pondermotive force, solitary waves and solitons, Kortewegde Vries (kdv) equation, wave-wave interaction.

Plasma Waves and Instabilities: Electron plasma waves, ion acoustic waves, electromagnetic waves in plasma, magnetosonic and Alfven waves, Rayleigh-Taylor instability, Resistive instability, Two stream instability, Waveguide modes in the presence of plasma, Dusty plasma, Current flow in dust grains, Waves in dusty plasma. Absorption of EM waves in plasmas, Radiation by coulomb collisions.

Dusty Plasmas: definitions of the dusty plasma, dusty plasmas in the solar system and earth, The charge on a dust grain in a plasma, The forces on a dust grain in a plasma, Weakly vs. strongly coupled dusty plasmas, Formation and growth of dust particles in a plasma, Dusty plasmas in the solar system and on earth, Spokes in Saturn's B ring, Dust streams from Jupiter, Dusty plasmas in industry, Dust contamination in plasma processing devices, Applications of dusty plasmas, Dedicated dusty plasma experiments, Dusty plasma devices, Coulomb crystals, Dust in fusion devices.

Applications of Plasma technology: Plasma based terahertz radiation generation, Hall thrusters, Plasma production & characterization, Laser driven fusion, plasma furnace in steel making, plasma cutting, plasma pinching, toroidal devices, sputtering, plasma enhanced chemical vapor deposition, plasma nitriding and surface cleaning.

Course Prerequisites: Students must have some basic understanding of mathematical tools, basic plasmas physics and electrodynamics.

Text Books:

1. Introduction to plasma physics and controlled fusion Chen, Francis F, Springer, 2016.
2. The physics of fluids and plasmas: an introduction for astrophysicists. Choudhuri, ArnabRai. Cambridge University Press, 2015.
3. Principles of Plasma Discharges and Materials Processing.Lieberman and Lichtenberg,Wiley-Interscience; 2nd edition, 2008.
4. Introduction to dusty plasma physics.Shukla P. K. and Mamun A. A, CRC Press, 2001.

Assessment Method: First CIA (20 %), second CIA/assignments (20 %) and EOSE (60 %)

Any need for revision of existing rules: No

PHY 622 Concepts of Laser Physics and Fourier Optics [Credit 3 (LTP: 3-0-0)]

Course Outcomes:

On completion of this course the students will

- be capable to understand the fundamentals of Laser Physics and Fourier optics
- be able to analyse the rigorous theory behind the Laser and their applications,
- be capable to understand the fundamentals of Fourier optics and to analyze the rigorous theory of different kinds of optical wave propagation theory
- gain the advanced knowledge of the beam propagation theory and diffraction pattern
- understand the principles involved in the different components of optical filters and lenses used in communication systems.
- be trained enough to design different optical holographic masks

Program Objective: The course covers the program outcomes from PO-1 to PO-6.

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

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	3	3	3
CO2	3	1	3	3	3	3
CO3	3	1	3	3	3	3
CO4	3	1	3	3	3	3
CO5	3	1	3	3	3	3
CO6	3	1	3	3	3	3

Course Level: Mastery

Course Description:

The first part covers the basic concepts of Laser physics that includes the different phenomena involved for the generation of laser radiation, their components, and types of LASER. Second part of the course covers mathematical explanation of wave propagation through different optical elements and their underlying theory. Importance of Fourier theorem for basic understanding of light waves propagation. Designing of different optical apertures and analysis of their diffraction pattern.

Course Objective:

A detailed exposition of the course for the student, opting for physics is so vitally important for a clear understanding of recent intricate theories of Laser Physics and Fourier optics.

- Understand the different phenomenon involved for the generation of Laser
- Different types of Lasers and their applications
- Rigorous understanding of recent intricate theories of Fourier transform, Hankel Transform, Fourier-Bessel Transform
- Physical interpretation of scalar diffraction theory and angular spectrum propagation method
- Fresnel and Fraunhofer diffraction theory and propagation of light beams through different optical systems

Syllabus:

Introduction, Physics of interaction between Radiation and Atomic systems including: Stimulated emission, emission line shapes and dispersion effects Einstein coefficients; Line shape function, Line-broadening mechanisms, Condition for amplification by stimulated emission, the meta-stable state and laser action. 3-level and 4-level pumping schemes. Laser Rate Equations: Two-, three- and four level laser systems, condition for population inversion, gain saturation; Some Laser Systems: Ruby, Nd: YAG, He-Ne, CO 2 and excimer lasers,

Fourier Analysis in Two Dimensions, Fourier Transform Theorems, Separable Functions, Hankel transforms, Functions with Circular Symmetry: Fourier-Bessel Transforms, Local Spatial Frequency and Space-Frequency Localization, Linear Systems, Transfer Functions, Two-Dimensional Sampling Theory, The Whittaker-Shannon Sampling Theorem, The Rayleigh - Somrnerfeld Formulation of Scalar Diffraction Theory, The Angular Spectrum of Plane Waves: The Angular Spectrum and Its Physical Interpretation, Propagation of the Angular Spectrum. The Fresnel Approximation and the Angular Spectrum; The Fraunhofer Diffraction Approximation, Examples of Fraunhofer Diffraction Patterns: Rectangular Aperture, Circular Aperture, Thin Sinusoidal Amplitude Grating, Thin Sinusoidal Phase Grating; A thin Lens as a Phase Transformation, Fourier Transforming Properties of Lenses.

Prerequisite: Student must have completed Optics Course

Reference Books:

1. Lasers: Theory and Applications, K. Thyagarajan and A.K. Ghatak.
2. Optical Electronics, A.K. Ghatak and K. Thyagarajan, Cambridge University Press
3. Laser Fundamentals, W. T. Silfvast, Cambridge Publications
4. Laser and Non-linear Optics, B.B. Laud, New Age International Publishers
5. Introduction to Fourier Optics, Joseph W. Goodman, The McGraw-Hill Companies Inc.
6. The Fourier transform and its applications, R. N. Bracewell, McGraw-Hill, NY
7. Fourier Optics and Computational Imaging, Kedar Khare, Wiley Publications
8. Linear systems, Fourier transforms, and optics, Jack D. Gaskill, Wiley Publications
9. The Fourier transform and its applications to optics, P. M. Duffleux, John Wiley and Sons

Assessment methods: Written examinations and Assignments

Any need for revision of existing rules: No

PHY 623: Solid State Magnetism (Credit: 3, L-T-P: 3-0-0)

Course outcomes: After the successful completion of this course, students are expected to:

- explain the atomic origins of magnetism and describe various kinds of magnetic materials and interactions
- understand major experimental techniques that are employed in the investigation of magnetism

Program Outcomes: This course covers PO1 and PO4

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**1**	**1**
CO2	**3**	**1**	**3**	**3**	**1**	**1**

Course Description: This course is about magnetism in condensed form of matter. It connects the phenomenon of magnetism and its various manifestations to atomic and electronic systems and their interactions. The electronic systems could be localized or itinerant. During the course discussion, we shall find the origins of magnetism within angular momentum and start exploring the magnetism of isolated systems. We shall then assemble these angular moments into crystal structures and shall begin exploring the impact of crystal environments and interactions. We shall spend considerable time on various exchange interactions and how the interplay of exchange effects and crystal structure leads to long range magnetic order of multiple kinds. We shall also discuss various measurement techniques to investigate magnetism.

Course Level: Mastery

Course objectives:

- connecting macroscopic magnetism with its microscopic origin
- understand various magnetic phenomena and experimental methods to measure them

Syllabus

Concept of electron spin: Stern Gerlach experiment; Pauli's exclusion principal, Hund's rules, Spin-orbit interaction and LS coupling; Crystal electric field: Orbital degeneracy, octahedral and tetrahedral environment, weak- and strong-field ligands, high spin and low spin states, static, dynamic and cooperative Jahn Teller effect; Quenching of orbital angular momentum; Magnetic interactions: Dipole versus exchange magnetic interaction, Direct and indirect exchange interactions, Anisotropic exchange like Dzyaloshinskii-Moriya (DM) interaction, Itinerant exchange interaction, Orbital versus magnetic ordering: GoodenoughKanamori-Anderson rules, Rudermann-Kittel-Kasuya-Yosida (RKKY) interaction; hyperfine interaction

Quantum treatment of diamagnetic and paramagnetic susceptibilities; Orbital Contribution: Landau levels and Landau diamagnetism, Van Vleck susceptibility, Susceptibility of conduction electrons, relation between Pauli and Landau susceptibilities, Ferromagnetism in insulators and metals, Magnetocrystalline anisotropy and domain theory, Barkhausen effect, Stoner model of magnetism, Half metals; Landau theory of ferromagnetism, Critical exponents, Antiferromagnetism and ferrimagnetism, Excitations in magnetic materials; Kondo effect; Magnetoresistance (MR): anisotropic, ballistic, extraordinary, giant, colossal and tunneling MR; Frustrated magnetism; Brief introduction to magnetism at nanoscale.

Measurement techniques: Magnetic Force Microscopy; Vibrating sample magnetometry & SQUID; measurement of susceptibility in A.C. field; Nuclear magnetic resonance; electron spin resonance; Neutron scattering.

Prerequisite of the Course: Graduation level Physics and XII standard Chemistry

Reference books:

1. S. J. Blundell, Magnetism in Condensed Matter (Oxford University Press)
2. A.H. Morrish, Physical principles of Magnetism (John Wiley & Sons)
3. J. M. D. Coey, Magnetism and magnetic materials (Cambridge University Press)
4. J. Stöhr and H.C. Siegmann, Magnetism from Fundamentals to Nanoscale Dynamics (Springer)

Assessment Method:

This 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.

Any need for revision of existing rules: No

PHY 624: Functional Nanomaterials [Credit 3 (LTP: 300)]

Course Outcomes:

After completing this course, the students will

- be able to describe the principles of important methods for the characterization of materials
- be able to describe the preparation and properties of metal alloys, ceramics and polymers of technical importance
- be able to explain how the micro-and nanostructure at different levels affects the properties of materials

Program Outcomes: This course covers PO1, PO3, PO4 and PO5.

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

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**1**	**3**	**3**	**3**	**1**
CO2	**3**	**1**	**3**	**3**	**3**	**1**
CO3	**3**	**1**	**3**	**3**	**3**	**1**

Course Description:

The course intends to give fundamental understanding of the properties of different materials, with special reference to the connection to atomic structure, preparation and function.

Course Objectives:

- to provide the student with an overview of inorganic and polymer materials of technical importance, as well as their applications, from an atomic and molecular perspective
- to give examples of applications of materials science in the field of nanotechnology
- to give the student insight into how to manufacture functional materials, i.e. materials, or combination of materials which are designed on the atomic or nanolevel scale for a specific property.

Syllabus

Zero-, One-, Two- and Three- dimensional structure, Size control of metal Nanoparticles, Optical, Electronic, Magnetic properties; Surface plasmon Resonance, Concept of phonon, Thermal conductivity, Specific heat, Exothermic & Endothermic processes. Nano ceramics, Dielectrics, ferroelectrics and magneto ceramics, Magnetic properties; Nanopolymers, Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers, Metal-Metal nanocomposites, Polymer-Metal nanocomposites, Ceramic nanocomposites, Nano Semiconductors, Nanoscale electronic devices (CMOS, sensors) Thermo Electric Materials (TEM),

Prerequisite of the Course: Graduation level knowledge of Physics and Chemistry.

Text Books and Reference Books:

1. D.R. Askeland, D.K. Wright, The Science and Engineering of Materials, (Cengage) 2015,
2. J.R. Fried, Polymer Science & Technology, (Prentice Hall) 2014,
3. Brian Cantor, Novel Nanocrystalline Alloys and Magnetic Nanomaterials (CRC Press) 2004,
4. Guozhong Cao and Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2nd edition, (World Scientific Publishing Company,) 2010.
5. A.S. Edelstein and R.C. Cammarata (Editors), Nanomaterials: Synthesis, Properties and Applications, (Institute of Physics Publishing, London,) 1996.