DEPARTMENT OF PHYSICS

Programme Structure of M. Sc. (Physics)-2020

Minimum Credit Requirement: 80

Minimum Duration: 4 Semesters

Maximum Duration: 8 Semesters

SEM	Credit
I	23
II	21
III	21
IV	19

Semester I

Course Code	Course Name	L-T-P	CH	CR	Remarks
PH 405	Semiconductor Devices	2-1-0	3	3	
PH 408	Electromagnetic Theory I	2-1-0	3	3	
PH 416	Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 417	Advanced Classical Mechanics	2-1-0	3	3	
PH 418	Quantum Mechanics-I	2-1-0	4	3	
PH 400	Physics and Computational Lab	0-1-3	7	4	
PH 498	Physics Lab-I	0-0-4	8	4	
Total credits			**31**	**23**	

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remarks
PH 411	Statistical Physics	2-1-0	3	3	
PH 412	Analog and Digital Electronics	2-1-1	5	4	
PH 419	Advanced Mathematical Physics	2-0-1	4	3	
PH 551	Electromagnetic Theory II	2-1-0	3	3	
PH 552	Quantum Mechanics-II	2-1-0	3	3	
PH 455	Seminar	0-0-1	2	1	
PH 499	Physics Lab-II	0-0-4	8	4	
Total credits			**28**	**21**	

Semester III

Course Code	Course Name	L-T-P	CH	CR	Remarks
PH 500	Project I	0-0-6	12	6	To be carried out under the guidance of a faculty member
PH 415	Nuclear and Particle Physics	2-1-0	3	3	
PH 553	Atomic and Molecular Spectroscopy	2-1-0	3	3	
	Elective I	2-1-0	3	3	
	Elective II	2-1-0	3	3	
	Open Elective-I	2-1-0	3	3	
Total credits			**27**	**21**	

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remarks
PH 599	Project-II	0-0-10	20	10	To be carried out under the guidance of a faculty member
	Elective III	2-1-0	3	3	
	Elective IV	2-1-0	3	3	
	Open Elective II	2-1-0	3	3	
Total credits			**29**	**19**	

Elective Courses are offered by the department in Semester III and Semester IV. Minimum of four is to be chosen from any specialization.

Course Code	Course Name	L-T-P	CH	CR	Remarks
Astrophysics					
PH 564	Introductory Astrophysics	2-1-0	3	3	
PH 565	Elements of GTR and Cosmology	2-1-0	3	3	
Condensed Matter Physics					
PH 539	Advanced Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 554	Soft Condensed Matter Physics	2-1-0	3	3	
Electronics					
PH 522	Communication System	2-1-0	3	3	
PH 523	Microwave Systems and Antenna Propagation	2-1-0	3	3	
PH 524	Digital Signal Processing	2-1-0	3	3	
PH 525	Microprocessors and Digital Signal Processing Based Systems	2-1-0	3	3	
High Energy Physics					
PH 519	Quantum Field Theory	2-1-0	3	3	
PH 540	Particle Physics	2-1-0	3	3	
Photonics					
PH 557	Photonics	2-1-0	3	3	
PH 559	Nanophotonics	2-1-0	3	3	
Plasma Physics					
PH 545	Fundamental of Plasma Physics	2-1-0	3	3	
PH 547	Nonlinear Plasma Physics	2-1-0	3	3	

Nano-Science					
PH 562	Quantum Effects in Low Dimensional Systems	2-1-0	3	3	
PH 563	Physics of Nano devices	2-1-0	3	3	

L: Lectures; T: Tutorials; P: Practical; CH: Contact Hours: (All per week); CR: Credits

Total Credits =84

Total Credits in Open Elective (3+3) =06

Total Credits in Project and Seminar (10+6+1) =17

Total Credits in Phy Lab (4+4) =08

Total Credits in Theory Papers =53

Detailed Syllabi

Semester I

PH 405: Semiconductor Devices **(L2-T1-P0-CH3-CR3)**

Course Objective: It offers an introductory course with more focus on carrier transport property and band engineering concept in solid state devices. The students are exposed to popular theoretical aspects, techniques and experiments that would help gain insight wrt semiconductor based electronic devices.

Learning outcome: On completion of the course, the students should be able to understand operation of junction devices under biasing as well as their role in electronic circuits for different applications. Also, the students are expected to develop working knowledge on operational principles of electronic components.

Course Content:

Review: Schottky diodes, Hall effect and Four Probe measurements semiconductors, Transistors as amplifiers and oscillators.

Field Effect Transistors: JFET, MESFET, MOSFET, HEMT, HBT.
Optical Devices: Solar Cells, LED, Photovoltaic Cells, Semiconductor Laser, VCSEL, SET etc.
Power semiconductor devices: SCR, UJT, thyristors, diacs, and triacs.

Display devices: Active and passive, construction of display devices, applications of LCD, ECD, PDP, ELD, Flat panel types CRT.

Semiconductor Fabrication Technique: Diffusion, Epitaxy growth, Ion Implantation, Optical and Electron lithographical Technique, etching process, dielectric and polysilicon film depositions, metallization.

Text Books:

1. Neaman D.A. and Biswas,D., *Semiconductor Devices* (Tata McGraw Hill, 2012).
2. Kano, K., Semiconductor Devices, (Prentice Hall of India, 1998).

Reference Books:

1. Milliman J. & Halkias C.C., *Integrated Electronics* (Tata McGraw Hill, 2003).
2. Milliman J. & Halkias C.C, *Electronic Devices and Circuits* (Tata McGraw Hill, 2003).
3. Malvino, A.P., *Electronic Principles*, (McGraw-Hill Education (India) Pvt. Ltd, 2007).
4. Allison J., *Electronic Engineering Semiconductors and Devices*, Edition 2, (McGraw-Hill, 1990).

PH 408: Electromagnetic Theory-I **(L2-T1-P0-CH3-CR3)**

Course Objectives:

(a) It offers a precious scope of learning and enjoying the basics of electrostatics, electrodynamics and magnetism methodologically in both the non-relativistic and relativistic regimes.

(b) It opens inner stimulations to students to look creatively at the physical world from electromagnetic and wave communicative perspectives.

(c) It develops a broad mind setup to understand and solve all sorts of applied problems driven by electricity, magnetism, and so forth.

Learning outcomes:

(a) A full completion of the course is expected to build up strong creativity, analytical capability and innovativeness in the students.

(b) It enables potentiality improvement via diversified exercises of mathematical physics, vector operation, and electromagnetism.

(c) It shows the physical universe from a new perspective of electromagnetic origin eventually after judging the applicability of the various model theories competently.

Course Content:

Review of Electrostatics and magneto-statics: Electrostatic and magnetostatic fields in matter, Method of images, boundary value problems, Laplace equation in rectangular, cylindrical and spherical coordinates, multipole expansion.

Gauge transformation, Coulomb and Lorentz gauges, Maxwell's equations, conservation of energy and momentum in electrodynamics, Poynting Theorem, Maxwell's stress tensor.

Wave equation, reflection, refraction and propagation of electromagnetic waves in dispersive media, wave equation in a conducting medium.

Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

Text Books:

1. Griffiths, D. J., *Introduction to Electrodynamics.* (Prentice Hall India, 2009).
2. Jackson, J. D., *Classical Electrodynamics* (Wiley, Eastern Ltd, 3rd edition, 1998).

Reference Books:

1. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
2. Slater, J. C., and Frank, N. H., *Electromagnetism*, (Dover Publications, 2011).
3. Miah, W., *Fundamentals of Electromagnetism*, (Tata McGraw Hill, 1982).
4. Feynman, R. P., *Feynman Lecture Series Volume II*, (Addison Wesley Longman, 1970).

PH 416: Condensed Matter Physics and Materials Science (L2-T1-P0-CH3-CR3)

Course Objective: The course provides an introduction to the basic phenomena associated with condensed matter physics and materials science. The students are exposed to various theoretical aspects, techniques and experiments that would help understand condensed matter phenomena in real world systems.

Learning outcome: On completion of the course, the students should be able to connect material properties and solid state phenomena with the theoretical models. Also, the students are expected to familiarize with various experimental characterization techniques to ensure structure-property relationship.

Course content:

Review of elements of crystallography and typical crystal structures, Crystal diffraction, reciprocal lattice, atomic form factor, structure factor and Debye-Waller factor, x-ray, electron and neutron diffractions.

Lattice vibration in solids: Enumeration of modes, monoatomic linear chain, infinite and finite boundary conditions, dispersion relation, diatomic chain, acoustical and optical modes, quantization of lattice vibrations (phonons).

Einstein and Debye theory of specific heat of solids, free electron theory of metals, electronic specific heat, electrical conductivity, thermal conductivity, Wiedemann-Franz law.

Motion of electrons in periodic potential, Bloch theorem, Kronig Penney model, band theory of solids, Brillouin zones, insulators, semiconductors and metals, Fermi surface, holes, intrinsic and extrinsic semiconductors, concept of effective mass and law of mass action, Hall effect and magnetoresistance.
Inelastic neutron scattering, analysis of data by generalized Ewald construction, dispersion relations, frequency distribution function, thermal conductivity of insulators, Normal and umklapp processes, crystal imperfections, colour centres, linear and edge dislocations, Bergers' vector, thermo-luminescence.

Text Books:

1. Kittel, C., *Introduction to Solid State physics* 7th Edition (Wiley, Eastern Ltd., 1996).
2. Burns, G., *Solid State Physics* (Academic press, 1995).
3. Dekker, A. J., *Solid State Physics* (Macmillan India Ltd., 2003).
4. Ashcroft, N. W. & Mermin, N. D., *Solid State Physics* (Saunders, 1976).

Reference Books:

1. Ibach, H. & Luth, H., *Solid State Physics*, (Springer-Verlag).
2. Patterson, J. D., *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971).
3. Ghatak, A.K. and Kothari, L.S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. Hall, H.E. and Hook J.R., *Solid State Physics*, 2nd Edition, (Wiley, 1991).
5. Azaroff, L.V., *Introduction to Solids*, (Tata McGraw Hill, 1977).

PH 417: Advance Classical Mechanics **(L2-T1-P0-CH3-CR3)**

Course Objective:

The course aims to develop the ability of students to apply basic methods of classical mechanics towards solutions of various problems, including motion of oscillatory systems and that of rigid bodies. They will be familiarised with various methods of classical mechanics and will learn how to apply them to formulate equations of motion.

Learning Outcome:

After completion of the course, students will be able to use the calculus of variations to solve real physical problems. They will be able to describe and understand the motion of mechanical systems using Lagrange and Hamilton formalism. Students will understand Poisson brackets, canonical transformations and will be able to solve small oscillation problems.

Course Content:

Variational Principles: Derivation of Euler-Lagrange differential equation, Hamilton's principle and its deduction, derivation of Lagrange's equation from Hamilton's principle, modified Hamilton's equation (vibrational principle) and derivation of Hamilton's principle from it, principle of least action, method of Lagrange's undetermined multipliers.

Two-body Central Force Problems: Reduction of two-body problems to equivalent one body problem, equation of motion under central force, equation for an orbit, inverse square law of force, Kepler's laws of planetary motion and their deduction, Virial theorem, scattering in a central force field and Rutherford scattering.

Canonical Transformations and Brackets: Canonical and Legendre transformations, generating function, procedure for application of canonical transformation, condition for canonical transformation, bilinear invariant condition, integral invariant of Poincaré, Poisson brackets and Lagrange's brackets and their properties, relation between Poisson and Lagrange's brackets, application of Poisson bracket to mechanics, Liouville's theorem.

Hamilton-Jacobi Theory: Hamilton-Jacobi (HJ) equation, Hamilton's characteristic and principal function, HJ equation for Hamilton's characteristic function, solution of Kepler's problem by HJ method, action-angle variable and harmonic oscillator problem, separation of variables in HJ equation, transition from classical to quantum mechanics.

Mechanics of a Rigid Body: Generalised co-ordinates of a rigid body, body and space reference system, Eulerian angles, orthogonal transformations, infinitesimal rotations, kinematics of a rigid body, moving frame of reference, Euler equation, spinning top, gyroscope.

Small Oscillations: One dimensional oscillator; stable, unstable and neutral equilibriums, Normal co-ordinates and normal modes, Two coupled pendulum, double pendulum, vibration of a linear triatomic molecule, general case- system with 'n' degrees of freedom.

Text Books:

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Goldstein, H., *Classical Mechanics*, (Narosa Publishing House).

Reference Books:

1. Takawale, R. G., and Puranik, P. S., *Introduction to Classical Mechanics*,(Tata McGraw Hill).
2. Rana, N. C. and Joag, P. S., *Classical Mechanics*, (Tata McGraw Hill).
3. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).

4. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (Pragati Prakashan).

PH 418: Quantum Mechanics -I (L2-T1-P0-CH3-CR3)

Course Objective: This course is a post-graduate level course intended for the students of the first semester of M.Sc. and seventh semester of Integrated M.Sc. from the department of Physics. This is a core course and the requisites for it are the undergraduate level courses on Modern Physics, quantum Mechanics and Mathematical Physics. The prime objective of this course is to offer the students the application of linear algebra in quantum mechanics; quantum mechanical interpretation of simple systems using various mathematical tools and a detailed study of the hydrogen atom.

Learning outcome: The learners are expected to learn the mechanism of using linear algebra to express wave functions and associated operations. The learners are also expected to revise their undergraduate knowledge on solving simple quantum mechanical systems using various mathematical techniques. Understanding how to truncate a mathematical solution (mostly in power series format) to obtain realistic solutions is one of the important ideas that the learners are supposed to be able to apply. Last but not the least, the idea of the hydrogen atom, along with understanding the quantum numbers associated, is also a crucial outcome of this course. With these concepts, the learners should be ready for the next course on "Advanced Quantum Mechanics".

Course Content:

Review of wave-particle duality, uncertainty principle, Schrodinger equation, The basic postulates of quantum mechanics, superposition principle, expectation value, Heisenberg equation of motion.

Application of Schrodinger equation to one-dimensional problem- square well potential, Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method.

Quantum theory of hydrogen-like atoms, time independent Schrodinger equation in spherical polar coordinates, separation of variables for the second order partial differential equation, Orbital Angular momentum in spherical polar co-ordinates and quantum numbers, Radial wavefunctions, Eigen values and eigenfunctions of orbital angular momentum.
Spin Angular Momentum and Pauli's Spin matrices.

Hilbert space formalism for quantum mechanics, Dirac notation, linear operators, Hermitian operator, projection operators, unitary operators, eigenvalues and eigen vectors of an operator.

Matrix representation of Kets, Bras and Operators, harmonic oscillator and its solution by matrix method.

Text Books:
1. Schiff, L. S., *Quantum Mechanics*, (Tata McGraw-Hill Education).
2. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002).

Reference Books:
1. Waghmare, Y. R., *Fundamentals of Quantum Mechanics*, (Wheeler publishing).
2. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (Tata McGraw-Hill, 2007).
3. Pauling, L., *Introduction of Quantum Mechanics*, (McGraw-Hill).
4. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press).
5. Kemble, E. C., *The Fundamental principles of Quantum Mechanics*, (McGraw-Hill).

PH 400: Physics and Computational Laboratory (L0-T1-P3-CH7-CR4)

Cousre objective: To learn about computer hardware, operating systems and use C language program. To develop algorithms and programs of numerical techniques to solve problems in physics like Non-linear equations, linear equations, interpolation problems, differential equations, Eigen value problems, etc.

Learning outcome: Become skilled, both theoretically and practically, in computer programming, able to solve numerical problems that are frequently used in physics using computer programs.

Course content:

Numerical Analysis: Solution of non-linear equations - Newton's method, method of false position (regular falsi), solution of a system of linear equations - Gaussian elimination, iterative methods (Jacobi and Gauss-Seidel methods), Interpolation - Newton's interpolation formula, numerical differentiation and integration - Simpson's rule, trapezoidal rule, quadrature formula, numerical solution of ordinary differential equations - Euler's method, Runge-Kutta method, fitting of curves - principle of least squares.

Simulation: A system and its model, he basic nature of simulation, the simulation of continuous and discrete systems - suitable examples, stochastic simulation - generation of random numbers with different probability distributions, examples of simulation in physics.

Text Books:

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall, 1997).
2. Narsingh Deo, *System Simulation with Digital Computers*, (Prentice Hall, 1979).

Reference Books:

1. Yashwant Kanetkar, *Let us C*, (BPB Publications, 2012).
2. Gottfried, B .S., *Schaum's outline of theory and problems of programming with C*, (McGraw-Hill Professional, 1996).

PH 400 Computational Laboratory (L0-T1-P3-CH7-CR4)

a. To find mean, variance, standard deviation, moments etc. for a given set of data (about 50 entries).
b. To fit a linear curve for a given set of data.
c. To perform a polynomial fit for a given set of data.
d. To find the roots of a quadratic equation.
e. Fourier Analysis of a square.
f. To generate random numbers between 1 and 100.
g. To perform numerical integration of 1-D function using Simpson and Weddle rules.
h. To find determinant of a matrix, its eigenvalues and eigen vectors.
i. To simulate phenomenon of nuclear radioactivity using Monte Carlo technique.

PH 498: Physics Laboratory-I (L0-T0-P4-CH8-CR4)

1. To design and fabricate a phase shift oscillator for the given frequency and to study the output using Op-Amp. 741/ 324 / 325.
2. Determination of thermal conductivity of a substance by Lee's method.
3. Scintillation counter:

a. Find out the resolution and the FWHM of the given Scintillation counter.

b. Find out the gamma ray energy of the given radioactive sources.

4. Determination of the Young’s modulus of a beam by four-point bending.
5. To determine the velocity of sound in (a) dry air, and (b) rods by Kundt’s tube method.
6. Calculate the difference in wavelength between atomic transition lines and Zeeman lines using Zeeman effect set-up. (SES instruments Pvt. Ltd).
7. To study Talbot imaging and to obtain Talbot distances with moiré interferometry and to measure the focal length of a lens.
8. Determination of the boiling point of a liquid by platinum resistance thermometer and metrebridge.
9. To measure the diameter of a thin wire using (a) interference, and (b) diffraction and compare the results.
10. To measure the dielectric constant and loss using microwave bench.

Semester II

PH 411: Statistical Physics **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, statistical interpretation of thermodynamics, micro canonical, canonical and grand canonical ensembles and derive the phenomenological laws of thermodynamics from microscopic considerations. The methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and photon gases; learn concepts involved in phase transitions of various physical systems, in particular applicable to continuous phase transitions and phenomenological techniques to model phase transitions in few ideal physical systems.

Learning outcome: It is expected that after successfully completing the course, the students will to be able to explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics, apply the principles of statistical mechanics to selected problems, apply techniques and methodologies, language and conventions from statistical mechanics to a range of physical systems to test and communicate ideas and explanation, in particular condensed matter and low-dimensional systems in thermo dynamical limits. Students will also be able to explain equilibrium phase transitions in various physical systems.

Course content:

Review of Thermodynamics, Introduction to probability theory, Random walk, Central limit theorem and law of large numbers.

Dynamics in phase space, ergodicity and Liouville theorem, Macrostates, microstates and fundamental postulate of equilibrium statistical mechanics. Microcanonical ensemble, Boltzman definition of entropy, Canonical ensemble, partition function, calculation of thermodynamic quantities, Partition functions and few examples: Classical ideal gas, two level system, Harmonic oscillator, Paramagnetism, Curie's law, generalized expression for entropy, Gibbs entropy and mixing of entropy. Grand canonical ensemble, the grand partition function, grand potential and thermodynamic variables.

Introduction to Quantum Statistics, Density Matrix, Ideal Quantum Gases and their properties, Bose-Einstein Condensation, Black body radiation spectrum, non-interacting free Electron gas, Einstein and Debye model of specific heat, Pauli paramagnetism and negative temperature, diamagnetism, photons, phonons and White Dwarft.

Phase transitions, symmetry, order of phase transitions and order parameter, Landau's mean-field theory, Symmetry breaking. Elementary ideas on Ising, Heisenberg models of ferromagnetism, Critical point, critical exponents and their scaling.

Text Books:

1. Karder M. Statistical Physics of Particles, Cambridge University Press, 2007.
2. Pathria, R.K., Statistical Mechanics, Butterworth Heinemann, Second Edn, 1996.
3. Huang, K., *Statistical Mechanics,* 2nd Edition (Wiley,1987).
4. Reif, F., *Statistical Physics,* (Tata McGraw Hill, 2008).

Reference Books:

1. Landau and Lifshitz, *Statistical Physics,* 3rd edition (Butterworth-Heinemann;1980).
2. Statistical Mechanics of Phase Transitions: J. Yeomans (1992) Oxford University Press.
3. Introduction to Modern Statistical Mechanics: D. Chandler (1979) Oxford University Press.

PH 412 : Analog and Digital Electronics **(L2-T1-P1-CH5-CR4)**

Course Objectives: This course is designed so as to aquatint the realm of pure and applied part of digital and analog electronics. It has the objective to enable the students to understand and impart the basic idea and operating principle of digital as well as analog gadgets; thereby inculcating their pursuit for real field designing.

Learning Outcomes: After the completion of this course, a student should have acquired the knowledge with adequate facts and illustrations and thereby gathered the expertise in designing relevant application oriented schemes.

Course Content :

Op Amp non-linear applications: Voltage limiters, comparators, zero detector, Schmitt trigger, voltage to frequency and frequency to voltage converter, small-signal diodes, sample-and-hold circuits and signal generators: oscillators-square-wave, Wien bridge, phase shift.

Frequency response of an op-amp and active filter: Gain and phase shift vs. frequency, Bode plots, compensated frequency response, slew rate, active filter, first and second order low pass and high pass, Butterworth filter, band reject filter.

555 timer: monostable, astable.

Digital Electronics: Review of Boolean algebra, gates, transistor switching times, INHIBIT (ENABLE) operation, De Morgan's laws, gate assemblies, binary adders.

Combinatorial digital systems: arithmetic functions, decoder/demultiplexer, data selector/multiplexer, encoder, ROM and applications.

Sequential digital systems: flip-flops, shift registers and counters, random access memory (RAM), dynamic MOS circuits, MOS shift registers, MOS Read Only Memory, D/A and A/D systems, digital-to-analog converters, analog-to-digital converters, character generators.

Microprocessor: Architecture and Laboratory.

Text Books:

1. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003).
2. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits*, 3rd Edition, (PHI, 2001).
3. Gaonkar R.S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th Edition, (Prentice Hall, 2002).

Reference Books:

1. Malvino A.P.and Leach D.J., *Digital Principles and Applications,* (Tata McGraw Hill 1994).
2. Milliman, J. & Halkias, C.C., *Integrated Electronics,* (Tata McGraw Hill, 2003).
3. Tocci R.J., *Digital Systems,* (Pearson/Prentice Hall, 2004).
4. Bartee T.C., *Digital Computer Fundamentals,* (Tata McGraw Hill Publishing Company, 1985).

PH 417: Advanced Mathematical Physics **(L2-T0-P1-CH4-CR3)**

Course objective: The main objective of this course is to introduce some advance topics of mathematical physics related to linear algebra, group theory, complex variable and tensor calculus. This course will also motivate the students to apply the mathematical techniques in developing the physical theories.

Learning outcome: After completion of this course students will know how to use matrix mechanics in quantum mechanics, use of group theory in explaining symmetry in condensed matter physics and particle physics, uses of tensor calculus in electrodynamics and general relativity. This course will also help the students to evaluate the complicated integrals using complex variables theory arises in different physical problems.

Course content:

Linear equations of homogeneous and inhomogeneous types, linear vector spaces, scalar product, linear independence, change of basis, Schmidt orthogonalisation, special matrices, diagonalization, orthogonal and unitary transformations, functions of complex variables, limit, continuity, analytic function, Cauchy formula, Laurent series, isolated and essential singularities, Contour integrations, conformal transformations.

Complex variables: Complex algebra, graphical representation, analytical functions, Cauchy-Riemann conditions, complex integrations, Cauchy's theorem, Cauchy's integral formula, residue, Cauchy's residue theorem.

Tensor analysis: Tensor in three and/or four dimensions, rank of tensors, covariant and contravariant tensors, symmetric and antisymmetric tensors, metric tensors, mathematical operations involving tensors.

Group theory: Group representation, reducible and irreducible representation, unitary group, special unitary group, Lorentz group, rotation group, direct product, Young Tableau, Dynkin diagrams.

Text Books:

1. Harper, C., *Introduction to Mathematical Physics*, (Prentice Hall, 2009).
2. Joshi, A. W., *Group Theory for Physicists*, (Wiley Eastern, 1997).
3. Spiegel, M., Lipschutz, S., and Spellman, D., *Vector Analysis*, (Tata McGraw-Hill Education Private Limited, 2009).
4. Hoffman, K. and Kunze, R., *Linear Algebra*, (Prentice Hall India).

Reference Books:

1. Margenau, H., *The Mathematics of Physics and Chemistry*, (Young Press, 2009).
2. Rajput, B., and Gupta, B., *Mathematical Physics*, (Pragati Prakashan, 2011).
3. Ghatak, A., Goyal, I. C. and Chua, S. J., *Mathematical Physics: Differential Equations and Transform Theory*, (Macmillan India Ltd, New Delhi, 2000).
4. Dennery, P. and Krzywicki, A., *Mathematics for Physicists*, (Harper International Edition).

PH 551: Electromagnetic Theory II **(L2-T1-P0-CH3-CR3)**

Course objective: This course attempts to fill a special niche in the post-graduate curriculum, lying between E M Theory I and applied electromagnetism. In this course, the main concern will be with radiation phenomena associated with electromagnetic fields. Starting with a brief review of dynamic electromagnetism and electromagnetic waves, the course addresses retarded potentials and fields, antennas, interference and diffraction. The course will also treat electrodynamics by postulating special relativity and then deriving deductively many of the results that were originally obtained from experiment in the pre-relativity era.

Learning outcome: The course will provide the students sufficient preparation on macroscopic and microscopic descriptions of electromagnetic radiation with in depth understanding. Special attention will be given to the problem sets. Many problems lead the student to develop additional material, or to apply the theory to topics of contemporary interest.

Course Content:

Radiation: Retarded potentials, Hertzian dipole, antennas and arrays, half-wave dipole, Loop current element, Lenard-Wiechert potentials and electromagnetic fields of a moving point charge, electric and magnetic dipole radiations, power radiated by a moving point charge, motion of charged particles in electromagnetic fields, Cherenkov radiation, transmission lines, impedance of line, scattering and diffraction.

Four vectors, relativistic electrodynamics, field tensor, energy-momentum tensor, interdependence of electric and magnetic fields, transformation of electromagnetic fields under Lorentz transformation, invariance of Maxwell’s equations, Lagrangian for electromagnetic fields, Maxwell’s equations from least action principle.

Text Books:

1. Jordan, E. K. and Balmain, K. G., *Electromagnetic waves and Radiating systems*, (Prentice Hall, 1971).
2. Nasar, S. A., *2000 Solved Problems in Electromagnetics*, Schaum's series, (McGraw Hill,1992).
3. Puri, S. P., *Classical Electrodynamics*, 2nd edition, (Tata McGraw Hill Pub., 1997).
4. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
5. Jackson, J. D., *Classical Electrodynamics,* 3rd edition, (Wiley, Eastern Ltd, 1998).
6. Panofsky, W. K. H. and Phillips, M., *Classical Electricity and Magnetism*, 2nd edition, (Addison-Wesley, 1962).
7. Griffiths, D. J., *Introduction to Electrodynamics,* (Prentice Hall of India, 2009).

PH 552: Quantum Mechanics II **(L2-T1-P0-CH3-CR3)**

Course Objective:

I. To learn the approximation techniques for solving Schrodinger equation for various physical systems and apply these techniques to real physical system of microscopic particles.
II. To understand the concept of time dependent perturbation theory and its application in absorption and emission of light by matter.
III. To learn to calculate scattering cross-section for interaction processes and relate this to the understanding of structure of atoms and particles.
IV. To acquire the concept of spin formalism of elementary particles.
V. To learn the rules of addition of angular momenta, calculate Clebsch-Gordon co-efficients and to explain spin-orbit coupling.
VI. To learn formalism of relativistic quantum mechanics and explain physical properties of elementary particles.

Learning outcome:

It is expected that after completing this course, the students will be able to

I. acquire the mathematical skill such as use of complex variables, differential equations, Gaussian integrals, linear algebra, matrix formalism etc. to solve various quantum mechanical problems.

II. draw a correlation between mathematical techniques and underlying physical concepts behind angular momenta for elementary particles, approximation techniques and scattering theory and apply to solve for atomic and molecular physics problems.

III. calculate C.G. coefficients of addition of angular momenta of two electron system **and learn matrix formalism of spin angular moenta.**

IV. apply relativistic quantum mechanics to the world of elementary particles.

Course content:

Review of angular momentum, general formalism of angular momentum, addition of angular momenta, Clebsch-Gordon coefficients.

Time-independent perturbation theory, non-degenerate case, first-order and second-order perturbations, degenerate cases, first-order Stark effect in hydrogen atom.

Time-dependent perturbation theory, Fermi’s golden rule, transition probability.

WKB approximation, Ritz-variational method.

Scattering theory, partial wave analysis and phase shift.

Relativistic quantum mechanics: Relativistic wave equation (Klein-Gordon and Dirac equations), elementary idea about field quantization.

Text Books:

1. Schiff, L.S., *Quantum Mechanics,* (Tata McGraw-Hill, 2004).
2. Zettili, N., *Quantum Mechanics*, (John Wiley & Sons, 2001).

PH 455: Seminar **(L0-T0-P1-CH2-CR1)**

PH 499: Physics Laboratory II **(L0-T0-P4-CH8-CR4)**

1. Electron spin resonance spectrometer:

a. To find out the Lande' g – factor of 2,2-Diphenyl-1-picrylhydrazyl sample using ESR spectrometer.

b. To observe the E.S.R. signal of given sample (DPPH) and to measure its full width at half maximum (FWHM).

2. GM counter:

a. Determine the resolving time of the GM counting system.

b. Study and determine the statistical distribution low that governs nuclear decay.

c. Determine the characteristics of a GM tube to study the variations of count rate with applied voltage and thereby determine the plateau, the operating voltage and the slope of the plateau.

d. Determine the dead time of the GM tube using a single source.

3. To determine the coercivity, saturation magnetization and retentivity of different given samples using hysteresis loop tracer set-up.

4. To measure the impedance of a coaxial cable and a rectangular waveguide using microwave bench.

5. Determine the dielectric constant of the ferroelectric ceramic sample using the given experimental set-up.

6. Determine the electrical charge of an electron by Millikan oil drop experiment and determine the value of e/m.

7. To study response of a non-linear crystal as a function of intensity of Nd:YAG laser (532nm)

8. a. To plot intensity of Luminescence vs. Temperature glow curve using thermo-luminescence set-up.

b. To draw the glow curve and find out the activation energy (E) of different Alkali Halide Crystals using thermo-luminescence set-up (Demonstration only)

9. To study, take a measurement and prepare a report on

a. PL/UV-VIS Spectrophotometer

b. Scanning Electron Microscope (SEM).

c. X-Ray Difractometer (XRD).

Semester III

PH 500: Project I **(L0-T0-P6-CH12-CR6)**

PH 415: Nuclear and Particle Physics **(L2-T1-P0-CH3-CR3)**

Course Objective:

1. To impart the basic laws and concepts of nuclear and particle physics, and build a strong foundation in these fields.

2. Nuclear physics mainly deals with the low energy process(E<10MeV) ; and introduce students to:

(a) the general properties of nuclei and nuclear structure

(b) Central and non-central nuclear forces, and scattering problem

(c) Fermi theory of beta decay and it's offshoot like neutrino physics

(d) Predictions of spin and parity by shell model

(e) Different types of nuclear reactions and detectors

3. In (elementary) particle physics (E>10 MEV), students are introduced to the smallest building blocks of the matter/universe to understand the composition of the real physical world/universe at the very basic level.

Learning Outcomes:

Upon successful completion of the course, students will be able to

1. understand better of the basic properties of nuclei and nuclear structure

2. calculate the fermi theory of beta decay for zero and non-zero mass of neutrino

3.compute the ground state spin-parity of any nuclei using shell model

4. learn the variants of nuclear reactions n detectors

5. knowledge and understanding of the elementary particle interactions

6. capability of elementary problem solving of nuclear and particle physics

7. Overall professional competency in the subject

Course Content:

Basic nuclear properties: Nuclear size determination from electron scattering, nuclear form factors, nuclear radius and charge distribution, mass and binding energy, angular momentum, parity and symmetry, magnetic dipole moment and electric quadrupole moment.

Bound state problem: properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius and tensor forces, magnetic and quadrupole moments of deuteron.

Scattering problem: low energy n-p scattering and its spin dependence, effective range theory, scattering length, spin dependence (ortho & para-hydrogen), low energy p-p scattering, nature of nuclear forces, charge independence, charge symmetry and isospin formalism, evidence for saturation property, exchange character.

Fermi's theory of beta decay, Curie' Plot, electron capture, selection rules for Fermi and Gamow-Teller transitions, parity violation in -decay and Wu's experiment, twocomponent theory of neutrinos, neutrino helicity, concepts of neutrino mass and oscillation (solar and atmospheric neutrino puzzles), Reins and Cowen experiment, concept of double beta decay and Majorana neutrino, radioactive dating.

Evidence of shell structure, magic numbers, effective single particle potentials – square well, harmonic oscillator, Wood-Saxon with spin orbit interaction, extreme single particle model and its successes and failures in predicting ground state spin, parity, Nordheim rule.

Different types of nuclear reactions: fission, fusion, Breit-Wigner dispersion formula, Nuclear radiation detectors: GM counter, proportional, scintillation, solid state detectors, electrostatic accelerators, cyclotron, synchrotron, linear accelerators, colliding beam accelerators.

Particle Physics: Symmetries and conservation laws, quantum numbers, strange mesons and baryons, hadron classification by isospin and hypercharge, SU(2) and SU(3), CPT theorem, CP violation in K decay, Gell-Mann Nishijima relation, quark model, coloured quarks and gluons, quark dynamics.

Text Books:

1. Krane, K. S., *Introductory Nuclear Physics*, (Wiley India Pvt. Ltd, 1998).
2. Roy R. R. and Nigam, B. P., *Nuclear Physics: Theory and Experiment*, (New Age International, 1967).
3. Wong, S. S. M., *Introductory Nuclear Physics*, 2nd edition, (Wiley-VCH, 1999).

Reference Books:

1. Martin, B., *Nuclear and Particle Physics: An Introductory*, (Wiley, 2006).
2. Tayal, D. C., *Nuclear Physics*, (Pragati Prakashan, 2008).
3. Bernard L. Cohen, *Concept of Nuclear Physics*, (Tata McGraw-Hill Education Private Ltd, 2011).
4. Beiser, A. and Mahajan, S., *Concept of Modern Physics*, (Tata McGraw-Hill Pvt Ltd, 2009).
5. Mohapatra, R. N. and Pal, P. B., *Massive Neutrinos in Physics and Astrophysics*, (World Scientific).
6. Giunti, C. and Kim, C., *Fundamental of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
7. Halzen, F. and Martin, A. D., *Quarks and Leptons*, (John Wiley, 1984).
8. Griffiths, D., *Introductory to Elementary Particles*, 2nd edition, (Academic Press, 2008).
9. Leo, W. R., *Techniques for Nuclear & Particle Physics Experiments*, (Springer-Verlag, 1994).
10. Knoll, G. F., *Radiation Detection and Measurement*, (John Wiley & Sons, 2010).

PH 553: Atomic and Molecular Spectroscopy **(L2-T1-P0-CH3-CR3)**

Course Objective:

I. To learn to calculate spin-orbit interaction energy and explain the fine structure of atoms and to calculate energy due to ls and jj-coupling schemes of two electron system.

II. To explain the physical concept behind rotational, vibrational and electronic spectra of diatomic molecules.

III. To understand the principles of ESR, NMR and Mossbauer spectroscopy and apply these techniques for the study of material properties.

Learning outcome:

On completion of this course, the students will be able to

I. calculate energy levels, frequencies of spectral lines of alkali and alkaline earth spectra and learn to apply quantum mechanical processes in the field of spectroscopy.

II. apply the knowledge of molecular spectroscopy as a tool in understanding the material properties and for analysing the data received from astrophysical objects.

Course content:

Atomic emission and absorption spectra (AES and ASS), series spectra in alkali and alkaline earths, LS and jj coupling in central field approximation.

Spectra of diatomic molecules, pure rotation, pure vibration; vibration-rotation and electronic spectra, Born-Oppenheimer approximation and its application to molecular spectroscopy, formation of bands, structure of bands, dissociation and pre-dissociation, valence-bond theory, molecular orbital theory, bonding and anti-bonding of electrons for equal nuclear charges, energy level of symmetric top molecules, potential energy function.

Morse potential function, Raman spectroscopy, electron spin resonance (ESR) spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, Mossbauer spectroscopy.

Text Books:

1. White, H. E., *Introduction to Atomic Spectra*, (McGraw-Hill, New York, 1934).
2. Herzberg, G., *Atomic Spectra and Atomic Structure*, 2nd edition, (Dover Publications, 2010).
3. Banwell, C. N. and McCash E. M., *Fundamentals of Molecular Spectroscopy*, (McGraw-Hill, 1994).

Reference Books:

1. Kuhn, H. G., *Atomic Spectra*, (Longmans, 1969).
2. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta*, (McGraw-Hill, 1930).
3. Siegman A. E., *Lasers*, (University Science Books, 1986).

Elective I
Elective II
Open Elective I

Semester IV

PH 599: Project II **(L0-T0-P10-CH20-CR10)**

Electives:

Course Code	Course Name	L-T-P	CH	CR	Remarks
Astrophysics					
PH 564	Introductory Astrophysics	2-1-0	3	3	
PH 565	Elements of GTR and Cosmology	2-1-0	3	3	

PH-564: **Introductory Astrophysics** **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is based on the basics of Astronomy and Astrophysics. The course aims at giving the students introductory idea of the sky, celestial coordinates and celestial bodies.. This course intends to train students with those basic ideas which are essential for further research, teaching and public outreach activities.

Learning Outcome: This course offers an introduction to the basic astronomy and astrophysics. It is expected that the students would be able to get adequate idea on the Astronomy & Astrophysics specialization: about the astronomical observation, stellar structure, stellar evolution, the solar system, galaxies and also about the statistical tools to be used for astrophysical analysis. This course would be beneficial for students opting a career in teaching and research in astronomy and astrophysics. This will also be very useful for students pursuing a career in Astroparticle physics.

Course content:

Celestial coordinate systems: Horizontal and Equatorial coordinate system. Telescope: Operational principle, different types and mounting. Introduction to large telescopes.

Observational characteristics: Magnitude, mass, luminosity, astrometry, photometry, spectrometry and polarimetry. Various astronomical instruments and detectors.

Stellar structure and evolution:

Herzsprung-Russel (H-R) diagram and stellar classification. Stellar spectra

Hydrostatic equilibrium. Stellar structure equations. Polytropic stars and related integral theorems. Stellar atmosphere and Saha equation. Gravitational collapse, degeneracy pressure in stars – structure of white dwarf and neutron star.

Main sequence, pre- and post-main sequence stars. Red giants. Supernova, Black holes and types.

Preliminary idea of imaging of a black hole.

Energy production in stars: Nuclear reactions, reaction rates, p-p chain and carbon-nitrogen-oxygen (CNO) cycle, Triple alpha process.

Solar System: Sun and its properties, planets and satellites, asteroids, comets and Oort's cloud, dust in the solar system, origin of the solar system-different hypotheses.

Exoplanets, their experimental detection methods.

Galaxies: classification, structure and evolution. Orbits of stars in a galaxy; linear instability. galaxy mergers. Quasars, Active galactic nuclei (AGN), Blazars.

Statistical techniques for astrophysics: Basic principles of probability and statistics, Parameter estimation and hypothesis testing, Correlated errors and multi-variate Gaussians.

Text Books:

1. Kippenhahn R. A., and Weigert, A., Stellar Structure and Evolution (Springer, Berlin, 1994).
2. Abhyankar K. D., Astrophysics: Stars and Galaxies (Universities Press, 2009).
3. Vitense, E. B., Stellar Physics (Cambridge University Press, USA, 1992).
4. Glendenning N. K., Compact Stars (Springer, Berlin, 1996)

Reference Books:

1. Chandrasekhar, S., Introduction to the Study of Stellar Structure (Dover Publications, 1958).
2. Bertin G., Dynamics of Galaxies (Cambridge University Press, USA, 1992).
3. Basu B., Chattopadhyay T., Biswas S.N.; An Introduction to Astrophysics (Prentice Hall India, 2010)

PH-565: **Elements of GTR and Cosmology** **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is based on the basics of General Theory of Relativity and Cosmology. The course aims at giving the students an idea of the principles and mathematical formulation of those topics. This course intends to train students with those basic ideas which are essential for further research, teaching and public outreach activities.

Learning Outcome: This course offers an insight to the elements of the General Theory of Relativity and Cosmology. The idea of tensors, development of the Einstein Field Equation and its solution form an integral part of the developments in Physics in the 20^{th} century. Cosmology offers the collective study of the universe: from its birth to the modern age and into the future. This course would be beneficial for students in understanding the evolving field of relativity and cosmology. This course is also a pre-requisite for students opting for a career in theoretical astrophysics.

Course content:

Tensor Analysis: Covariant and contravariant tensors, quotient rule, metric tensor. Christoffel symbol, covariant derivative of contravariant and covariant tensors, equations of geodesics, Rhemmann-christeffel tensor, Ricci tensor, scalar curvature, Einstein tensor.

Elements of General Theory of Relativity: Principle of equivalence, Principle of General Congruence. Einstein Field Equation, low velocity and weak field approximation of Einstein field equation, Gravitational waves.

Solution of EFE: Static and Schwarzschild solution of Einstein equation, exterior and interior

solutions, Schwarzschild singularity & concept of black hole. Planetary orbits: advance of perihelion of mercury; bending of light: gravitational lensing and microlens, gravitational red shift.

Large-scale structure of universe: Cosmological principle, elements of Newtonian cosmology.

Cosmological Models: Friedman-Robertson-Walker (FRW) metric, Hubble’s law, Einstein universe, De-Sitter universe. Idea of dark matter and dark energy.

Early Universe: The big bang theory, steady state theory, Cosmic Microwave Background Radiation, decoupling of matter and radiation. Inflation.

Idea of quantum gravity and quantum cosmology. Idea of Hawking radiation. Gravitational Waves.

Text Books:

1. Misner, C., Thorne, K. S. and Wheelar, J. A., Gravitation (Freeman, 2003).
2. Kenyon, I.R., General Relativity (Oxford University Press, 1990).
3. Weinberg, S., Gravitation and Cosmology (Wiley, New York, 1972).
4. Ryden B., Introduction to Cosmology (Cambridge University Press, 2016)
5. Schneider P. , Extragalactic Astronomy and Cosmology: An Introduction (Springer, 2010)
6. Narliker, J. V., Introduction to Cosmology (Cambridge University Press, 2002).

Reference Books:

1. Schutz B., A First Course in General Relativity (Cambridge University Press, 2009)
2. Rindler W., Relativity: Special, General, and Cosmological 2nd Edition (Oxford University Press, 2006)
3. Wald R.M., General Relativity (University of Chicago Press, 1984)
4. Einstein A., Relativity - The Special and The General Theory (Fingerprint Classics, 2017)
5. Weinberg S., Cosmology (Oxford University Press, 2008).
6. Liddle, A. and Loverday, J., The Oxford Companion to Cosmology (Oxford University Press, 2008)
7. Bondi H. and Roxburg I., Cosmology (Dover Publications Inc. 2010)

Course Code	Course Name	L-T-P	CH	CR	Remarks
Condensed Matter Physics					

PH 539	Advanced Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 554	Soft Condensed Matter Physics	2-1-0	3	3	

PH-539: Advanced Condensed Matter Physics and Materials Science (L2-T1-P0-CH3-CR3)

Course Objective: The aim of the proposed course is to introduce the basic notion of the condensed matter physics and to familiarise the students with the various aspects of the interactions effects. This course will be bridging the gap between basic solid state physics and quantum theory of solids. It also introduces theoretical framework such as BCS theory of superconductivity.

Learning outcome: On completion of the course, the student should be able to connect between theory and experimental macroscopic scale observations to microsopic theory.

Course Contents:

Unit-1

Fermi surface, cyclotron resonance, de Hass-Van Alphen effect, electron motion in 2-dimension, Quantum Hall effect. Elements of ferrimagnetism and antiferromagnetism. Curie-Weiss law, exchange interaction, spin waves and magnons, dispersion relation, neutron scattering from magnetic materials-structure studies, Neel's temperature.

Unit-2

Born-Oppenheimer approximation, second quantization for Fermions and Bosons. Effects of electron-electron interactions - Hartree- Fock approximation, exchange and correlation effects, screening, dielectric function of electron systems, plasma oscillations, Fermi liquid theory, elementary excitations, quasiparticles. Dielectric function of electron systems, screening, plasma oscillation. Optical properties of metals and insulators, excitons. The Hubbard model, spin-and charge-density wave states, metal-insulator transition.

Unit-3

Superconductivity – phenomenology, Cooper instability, BCS theory, Bogoliubov transformation-notion of quasiparticles; Ginzburg-Landau theory. Type-I and Type II superconductors — characteristic length; Flux quantization, single particle tunneling and Josephson effects, superconducting quantum interference device (SQUID); “Novel High Temperature” superconductors, superconductivity of thin films

Unit-4

Critical Phenomena: liquid-gas, paramagnetic-ferromagnetic, normal to superconductor, and superfluid transitions. Landau theory; Mean field theory, Ising and Heigenberg model, Scaling hypothesis, universality class, scaling laws, critical exponents and inequalities, renormalisation group theory, real space renormalisation group with examples.

Unit-5

Thin films and thick films, their differences, deposition techniques of thin films and thick films, physical vapour deposition (PVD), chemical vapour deposition, electroless or solution growth deposition, electrochemical deposition (ECD), screen printing of thin films. Nucleation and growth processes, structure of thin films, epitaxial growth (VPE, MBE, MOCVD, etc.), thin film thickness measurement. transport phenomena in semiconducting and insulator films, superconductivity of thin films and HTSCs (high temperature superconductor films). Applications of thin films in electronics, thin films resistors, capacitors and active devices, thin film transducers, thin film, solar cells.

Text Books:

1. P. Marder, *Condensed Matter Physics*, 2nd Edition (John Wiley & Sons, Inc, 2010).
2. C. Kittel, *Introduction to Solid State physics* 7th Edition (Wiley, Eastern Ltd., 1996).
3. H. Ibach, & H. Luth, *Solid State Physics*, (Springer-Verlag, 2011).
4. A. J. Dekker, A. J., *Solid State Physics* (Macmillan India Ltd., 2003).
5. N. W. Ashcroft, & N. D. Mermin, *Solid State Physics* (Saunders, 1976).

Reference Books:

1. Philip Phillips, Advanced solid state physics , (Overseas Press, 2008)
2. J. D. Patterson, *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971).
3. A. K. Ghatak, and L. S. Kothari, *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. H. E. Hall, and J.R. Hook, *Solid State Physics*, 2nd Edition, (Wiley, 1991).
5. L. V. Azaroff, *Introduction to Solids*, (Tata McGraw Hill, 1977).
6. J. Solyom, Fundamentals of the Physics of Solids, Volumes 1, 2, and 3. (springer, 2007).

PH-554: Soft Condensed Matter Physics (L2-T1-P0-CH3-CR3)

Course Objective: The course provides an introduction to the basic phenomena that collectively define condensed matter physics, in particular, in living and non-living active matter. The students are exposed to various experiments as well as theoretical models that help in understanding physical behavior of vast pool of soft condensed matter in real world systems.

Learning outcome: On completion of the course, the student should be able to connect the theory solid state physics to micro organisms from the point of view of physical phenomena.

Course Contents:

Unit-1

Phases of soft condensed matter: Homogeneous solution and phase separation, Free energy, Osmotic pressure and Chemical potential. Colloids and Colloidal stability, sheared colloids, coagulation and flocculation, electric double layer (EDL), Poisson-Boltzmann theory, DLVO theory, polymer solutions and gels, lattice model, plastics and rubbers, Kuhn's theory, emulsions and foams, amphiphilic molecules: surfactant types and nature of packing, micelles and reverse micelles, planar bilayers, vesicles, lyophobic and lyophilic molecules, self-assembly and nanostructuring, principles and applications of Langmuir-Blodgett films, microgels, wetting-dewetting phenomena, super-hydropbobic surfaces, phospholipids and glycolipids, polyelectrolyte, polysachharides; biopolymers and biodegradable polymers.

Unit-2

Liquid crystals: types and properties, Frank free energy, Landau-de Gennes model of isotropic-nematic transition. Thermotropic and lyotropic LCs, orientational order, order parameters, Onsager equation, Landau description, optical retardation, Freedericksz transition.

Unit-3

Flow behaviour: Brownian motion and thermal fluctuation, shear thickening and shear thinning. Newtonian and Non-newtonian fluids, Ferrofluids. Diffusion and subdiffusion. Fluid flow and rheology, Implications of Marangoni effect, microfluidics, concept of glass forming and jamming, percolation model, random walks and dynamics, sandpile model, soft glassy rheology; Energy-elasticity, entropic spring, visco-elastic models, de Gennes-Taupin length, introduction to shape transitions.

Unit-4

Membrane physics: Membrane structure and membrane proteins, Bioenergetics, excitable membranes, resting potential, Hodgkin-Huxley model, ion channels, action potentials, patch clamp method. Life at low Reynold number.

Unit-5

Experimental techniques: Contact angle measurements, optical microscopy and optical profilometry, scanning probe microscopy, small angle scattering and diffraction, dynamic light scattering and diffusive wave spectroscopy, dynamics of soft matter using synchrotron x-ray and neutron scattering, rheometry, confocal microscopy.

Text Books:

1. I. W. Hamley, Introduction to Soft Matter, (Wiley, Chichester, 2000).
2. R. A. L. Jones, Soft Condensed Matter, (OUP, Oxford, 2002).
3. P. J. Collings, and M. Hird, Introduction to Liquid Crystals, (CRC Press, 1997).
4. R. Phillips, J. Kondev, and J. Theriot, Physical Biology of the Cell, (Garland Science, 2008).

Reference Books:

1. M. Kleman, and O. D. Lavrentovich, Soft Matter Physics, (Springer-Verlag, 2003).
2. S. A. Safran, Statistical Mechanics of Surfaces, Interfaces and Membranes, (AddisonWesley, Reading, MA 1994).
3. W. B. Russel, D. A. Saville, and W. R. Showalter, Colloidal Dispersions, (Cambridge University Press, New York, 1989).
4. Philip Nelson, Biological Physics: Energy, Information and Life, (Freeman, 2003).
5. D. Tabor, Gases, Liquids and Solids, (CUP, 1991).
6. R. Cotterill, Biophysics: An Introduction, (John Wiley, Singapore 2002

Course Code	Course Name	L-T-P	CH	CR	Remarks
		Electronics			
PH 522	Communication System	2-1-0	3	3	
PH 523	Microwave Systems and Antenna Propagation	2-1-0	3	3	
PH 524	Digital Signal Processing	2-1-0	3	3	
PH 525	Microprocessors and Digital Signal Processing Based Systems	2-1-0	3	3	

PH 522: Communication Systems **(L2-T1-P0-CH3-CR3)**

Course Objectives:

a. Understand how digital communication system works
b. Generation, transmission and receiving of digital signals in the communication system
c. An ability to design and conduct experiments

Learning outcomes:

Towards the end of the course, it is expected that the student would be able to get a basic knowledge of digital communication systems. Students will also have the idea of different modules applied in digital communication systems.

Course content:

Introduction to digital communications, sampling techniques, ESD, PSD, autocorrelation function, orthogonality.

Pulse modulation: PAM, PCM, DPCM, delta modulation, ADM.

Data transmission: FSK. PSK, DPSK, Mary modulation systems, error probability calculations.

Random process: PSD of random process, transmission of random process through linear systems, optimum filtering.

Behaviour of digital communication system in presence of noise: optimum threshold detection, OBR, carrier systems ASK, FSK, PSK and DPSK, spread spectrum systems, Optimum signal detection: Gaussian random process, optimum receiver, nonwhite channel noise.

Error control coding: block and convolution codes, combined modulation and coding, examples of typical communication systems: Modems, local area networks, computer communication, microwave, satellite, optical, cellular mobile etc.

Text Book:

1. Lathi, B. P., *Modern Analog and Digital Communication Systems*, (Oxford University Press, 2009).

Reference Books:

1. Haykins, S., *Communication systems*, 3rd edition, (Wiley India Pvt Ltd., 2006).
2. Gallager, R. G., *Principles of Digital Communication*, (Cambridge University Press, 2008).
3. Rao, P. R., *Digital Communication*, (Tata McGraw-Hill ***Publishing*** Co., 2007).
4. Sklar, B., *Digital Communications: Fundamentals & Applications*, 2nd edition, (Pearson Education, 2009).
5. Proakis, J. G. and Salehi, M., *Communication Systems Engineering*, (McGraw-Hill Higher Education, 2007).

PH 523: Microwave Systems and Antenna Propagation (L2-T1-P0-CH3-CR3)

Course Objective:

a. Develop understanding of the microwave systems and antennas.
b. Understanding how some practical microwave devices work.

Learning outcomes:

At the end of this course, students will have an understanding of fundamentals of microwave engineering as well as sufficient knowledge to apply it to problems of practical interests.

Course content:

Review of Maxwell's equations: Electromagnetic radiation, plane waves in dielectric and conducting media, reflection and refraction of waves.

Transmission lines, smith chart and its applications, rectangular wave guide, rectangular cavity, modes in waveguides and cavities, dielectric filled wave guides, dielectric slab guide, surface guided waves, non-resonant dielectric guide, modal expansion of fields and its applications.

Microwave semiconductor devices: Microwave transistor, microwave tunnel diode, varactor diode, Schottky diode.

MESFET: Principle of operation, MOS structure, MOSFET microwave applications transferred electron devices: Gunn diode, LSA diode, modes of operation.

Microwave generation and amplification, avalanche effect devices: Read diode, IMPATT diode, klystron: velocity modulation process, bunching process, output power and beam loading, reflex klystron: power output and efficiency, traveling wave tubes, magnetron.

Microwave waveguide components: attenuators, phase shifters, matched loads, detectors and mounts, slotted-sections, E-plane tee, H-plane tee, hybrid tees, directional couplers, tuners, circulators and isolators, quarter wavelength transformer, multi section transformer matching section.

Lumped planar components: capacitor, inductor and balun; power dividers, directional couplers, analysis of these components using the S-parameters, microwave planar filters, planar non reciprocal devices, signal generators: fixed frequency, sweep frequency and synthesized frequency oscillators, frequency meters, VSWR meters, measurements of frequency, attenuation, VSWR and impedance.

Antenna characteristics: radiation patterns, directive gain, side lobe, back lobe, polarization, co-polarization and cross polarization level, frequency reuse, beam width, input impedance, bandwidth, efficiency, antenna types: wire, loop and helix antennas, aperture antenna-slot, waveguide and horn antenna, parabolic reflector antenna.

Microwave integrated circuits: different planar transmission lines, characteristics of microwave integrated circuits, microstrip antenna: rectangular and circular patch, feed for microstrip antennas: probe feed, microstrip line feed, aperture feed, electromagnetically fed microstrip patch.

Text Book:

1. Rizzi, P. A., *Microwave Engineering*, (Prentice-Hall, 1999).

Reference Books:

1. Pozar, D. M., *Microwave Engineering*, 3rd edition, (Wiley India Pvt. Limited, 2009).
2. Liao, S. Y., *Microwave Devices and Circuits*, 3rd edition, (Prentice-Hall of India, 2000).
3. Collin, R. E, *Foundations for Microwave Engineering*, (McGraw-Hill, 1992).
4. Griffiths, D. J., *Introduction to Electrodynamics,* (Prentice-Hall, 2009).
5. Jackson, J. D., *Classical Electrodynamics*, 3rd edition, (John Wiley & Sons, 1998).

PH 524: Digital Signal Processing (L2-T1-P0-CH3-CR3)

Course Objectives:

a. Develop understanding of the DSP.

b. Practical implementation of DSP

Learning outcomes:

At the end of this course, students will know concept of digital signal processing and some typical applications along with its implementation with MATLAB.

Course content:

Introduction: digital signal processor, signals and systems, sampling and quantization,

Specialized transforms: z-transform, discrete cosine transform, Hilbert transform, Fourier transform, DFT, FFTs, convolution.

Digital filters:

FIR filters-Linear phase filter, windowing method, standard and multi band, constrained least square filtering, arbitrary response filter design IIR filter- design, Butterworth, Chebyshev type I and type II, elliptical, Bessel.

Spectral analysis: Welch’s method, multilayer method, Yule-Walker method, covariance methods, MUSIC and eigenvector analysis method.

Applications in real time problems like extraction of voice from noisy environment, filtering the signal using digital filters etc.

Text Books:

1. Proakis, J. G. and Manolakis, D. G., *Digital Signal Processing: Principles, Algorithms, and Applications*, 3rd edition, (Prentice Hall, 1996).
2. Mitra, S. K., *Digital Signal Processing: A Computer Based Approach*, (McGraw-Hill, 2001).
3. Lyons, R. G., *Understanding DSP*, 3rd edition, (Pearson Education, International, 2010).

Reference Books:

1. Hayes, M. H., *Digital Signal Processing*, Schaum's Outline Series, (McGraw-Hill, 1999).
2. Oppenheim, A. V. and Schafer, R. W., *Digital Signal Processing*, (Macmillan Publishing Company, New York, 1993).
3. Porat, B., *A course in Digital Signal Processing*, (John Wiley & Sons, 1996).
4. Soliman, S. S. and Srinath, M. D., *Continuous and Discrete Signals and Systems*, (Prentice Hall, 1998).
5. Sharma, S., *Signals and Systems*, (Katson Books, 2010).

PH 525: Microprocessor and Digital Signal Processing Based Systems (L1-T0-P2-CH5-CR3)

Course Objectives:

a. Develop understanding of industrial automation- software and hardware.

b. Practical interfacing

Learning outcomes:

At the end of this course, students will know how to interface hardware, acquire and process data.

Course Content:

Introduction to microprocessors programming and interfacing, Transducers and sensors: Load cells, strain gauges, weighing transducers, temperature sensors (e.g. RTDs, thermocouples, semiconductor sensors, etc.), displacement sensors (e.g. LVDTs, RVDTs, encoders, linear scale etc.), proximity sensors, magnetic sensors, opto-electronic sensors, fiber optic sensors, motion transducers (velocity, vibration and acceleration), fluid transducers, pressure transducers, level transducers, etc.

The signal conditioning circuits like current booster, current to voltage converter, instrumentation amplifier, level shifter, 4-20mA current loop, etc. with their design.

The open loop, feedback loop and feed forward loop and servo controllers with details of PI, PD, PID controllers, tuning methods of the same and also auto tuning methods.

Interfacing of sensors, stepper motor designing of the signal conditioning circuits along with microcontrollers.

Text Book:

1. Hall, D., *Microprocessors and Interfacing*, 2nd edition, (Tata McGraw-Hill, 1999).

Reference Book:

1. Gaonkar R. S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th edition, (Prentice Hall, 2002).

Course Code	Course Name	L-T-P	CH	CR	Remarks
High Energy Physics					
PH 519	Quantum Field Theory	2-1-0	3	3	
PH 540	Particle Physics	2-1-0	3	3	

PH 519:Quantum Field Theory (L2-T1-P0-CH3-CR3)

Course Objective: The course gives an understanding of the different classical fields and their quantisation, which describes the elementary particles and their interactions. The course also gives an understanding of Feynman's rules, a basis for calculating and understanding simple cross sections for collisions and particle production.

Course outcome: Quantum Field Theory (QFT) is the mathematical and conceptual framework for contemporary elementary particle physics. In a rather informal sense QFT is the extension of quantum mechanics (QM), dealing with particles, over to fields, i.e. systems with an infinite number of degrees of freedom. This course provides information of three of the four forces of nature and their interactions of force-carrying boson particles with matter-making fermions. It also contains quantisation of Scalar, Dirac and Vector field, interaction between the fields and renormalization theory. Towards the end of the course students would be able to deal with any kinds of elementary particle interaction specially QED, renormalization etc. The contents of this course are the prerequisite for doing research in modern particle and astro-particle physics.

Course Content:

Introduction to Fields: Lagrangian and Hamiltonian formulation of continuous systems, introduction to relativistic field theories, four-vector notations. Klein-Gordon equation, relativistic free scalar fields, Dirac equation, antiparticles, free Dirac fields, covariant formulation of Dirac equation and its gamma matrices and their algebra including trace calculations.

Quantization of Fields: Quantization of scalar fields (complex and real), Dirac fields and vector fields.

Conservation Laws and Associated Symmetries: Noether's theorem, discrete symmetries: C, P and T symmetries of free scalar, charged scalar, Maxwell and Dirac fields.

Interaction Among Fields: Interaction picture, S-matrix, wick's theorem, Feynman rules, Feynman diagrams for elementary processes, lowest order calculations for Compton scattering, Bremsstrahlung, Bhabha and Moller scatterings, renormalization.

Text Books:

1. Lahiri, A., and Pal, P. B., *Quantum Field Theory*, (Narosa Publishing House, 2017)
2. Ryder, L. H., *Quantum Field Theory*, (Cambridge University Press, 1996)
3. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008).

Reference Books:

1. Peskin, M. E., and Schroeder, D. V., *Introduction to Quantum Field Theory*, (Addison Wesley, 1995)

2. Weinberg, S., *The Quantum Theory of Fields* (Vol. I, II, III), (Cambridge University Press, 2005)
3. Mandl, F., and Shaw, G., *Quantum Field Theory* (John Wiley and Sons, 2010)
4. Huang, K., *Quarks, Leptons and Gauge Field,* (World Scientific, 1992)
5. Aitchison, I. J. R., and Hey, A. J. G., *Gauge Theories in Particle Physics*, (Adam Hillier, 2004)
6. Chang, S. J., *Introduction to Quantum Field Theory,* (World Scientific, 1990)

PH-540: Particle Physics **(L2-T1-P0-CH3-CR3)**

Course Objective: This course gives knowledge of fundamental particles, fundamental interaction and the range and strength of these interactions. This course is also for the understanding of fundamental particles like quarks, theory of weak different weak interactions and gauge theory of fundamental particles. It also includes a small portion of statistical data analysis.

Course outcome: This course provides some introductory and advanced knowledge of particle physics like classification of particles, fundamental interactions, quark model, parton model, weak interactions, gauge theories, statistical tools for particle physics etc. The course is developed in a way with increasing mathematical treatments and difficulties. The prerequisites of this course are mainly quantum mechanics, special theory of relativity, nuclear physics, some knowledge of elementary quantum field theory. Towards the end of the course, it is expected that the student would be able to get some introductory and some advance knowledge of elementary particles and their interactions, and gauge theories and some knowledge of statistical tools required for particle physics. All these are prerequisites for mainly research in more advanced topics of high energy physics.

Course Content

Introduction: Elementary particles, fundamental interactions (strengths and ranges), natural units. Conservation rules in fundamental interaction.

Quark Model: Quark model of mesons and baryons (quarks, gluons and colors), eightfold way of classification, symmetry groups: SU(2), SU(3), discovery of heavy quarks.

Parton Model: Probing charge distributions with electrons, form factors, e-p scattering, proton form factors, deep inelastic scattering, structure functions, partons, Bjorken scaling, QCD – dual role of gluons.

Weak Interactions: Introduction to neutrinos (postulation and discovery), V-A theory, nuclear beta decay, neutrino-quark scattering, Cabibbo angle, weak mixing angle, neutrino oscillations, CP violation.

Gauge theory: Local and global gauge theory, non-abelian gauge theory, spontaneous symmetry breaking, Higgs Mechanism, Goldstone theorem.

Statistical Tools and Data Analysis: Bayes' theorem, probability distribution functions, Monte-Carlo method, statistical tests: significance and power of a test, maximum likelihood method, examples of data analysis using the above tools in accelerator and neutrino experiments.

Text Books:

1. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008)

2. Griffiths, D., *Introduction of Elementary Particles*, (John Wiley and Sons, 1987)
3. Lyons, L., *Statistics for Nuclear and Particle Physicists*, (Cambridge University Press, 1989)

Reference Books:

1. Peskin, M. E., and Schroeder, D. V., *Introduction to Quantum Field Theory*, (Addison Wesley, 1995)
2. Mandl, F., and Shaw, G., *Quantum Field Theory* (John Wiley and Sons, 2010)
3. Huang, K., *Quarks, Leptons and Gauge Field*, (World Scientific, 1992)
4. Aitchison, I. J. R., and Hey, A. J. G., *Gauge Theories in Particle Physics*, (Adam Hillier, 2004)
5. Chang, S. J., *Introduction to Quantum Field Theory*, (World Scientific, 1990)
6. Perkins, D. H., *Introduction to High Energy Physics*, (Cambridge University Press, 2000)
7. Cowan, G., *Statistical Data Analysis*, (Oxford Science Publications, Clarendon Press, 1998)
8. Sakurai, J. J., Invariance principle and elementary particles, (Princeton Univ. press, 2016)

Course Code	**Course Name**	**L-T-P**	**CH**	**CR**	**Remarks**
	Photonics				
PH 557	Photonics	2-1-0	3	3	
PH 559	Nanophotonics	2-1-0	3	3	

PH 557: Photonics **(L2-T1-P0-CH3-CR3)**

Course objective: The **Photonics** course covers a wide spectrum of topics. The course has been designed in such a way that most of the important topics under photonics field can be taught within the stipulated period of time. A student pursuing this course is expected to learn different areas of the field that include optical modulation techniques, non-linear optical systems, photovoltaic cells, optical fiber and various form of communication devices. These are

Expected outcome: This special course is designed to provide fundamental knowledge in the field of photonics which primarily comprise of different forms of optical modulation techniques, non-linear optics, integrated optics and photovoltaic cells. Students taking this course is expected to gain knowledge on the following topics which have great interdisciplinary relevance spanning from material science to optical engineering in the future.

Non-linear photonics: Non-linear optical media, second-order and third-order non-linear optics, three-wave mixing, frequency and phase matching, self-phase modulation, self-focusing, spatial soliton, Raman amplification, Brillioun devices.

Electro-optic effects, intensity modulators, phase modulators, travelling wave modulators, Acousto-optic devices: Photoelastic effect, acousto-optic diffraction, acousto-optic modulators.

Magneto-optic devices: Magneto-optic effects, Faraday effect, magneto-optic Kerr effect, Integrated optical modulators: Phase and polarization modulation, Mach-Zehnder modulator, coupled waveguide modulator.

Photovoltaic devices: Photovoltaic device principles, equivalent circuit of solar cell, temperature effects, solar cell materials, devices and efficiencies.

Optical fiber modes and configurations, mode theory for circular waveguides, single mode and graded-index fibers, fiber materials, Attenuation in optical fibers, signal distortion in optical fibers, pulse broadening mechanism, mode coupling, design optimization of single mode fibers. Source to fiber launching, fiber to fiber joints, Non-linear effects in fibers, Raman scattering and Brillouin scattering in fibers, fiber Bragg gratings

Photonic switches, photodetectors, optical memory devices, optical communication devices.

Prerequisite qualification: Should have basic knowledge of optics, optoelectronics and electromagnetic theory,

Text Books:

1. Ghatak, A. K. and Thyagarajan, K., Introduction to Fiber Optics, (Cambridge Publisher, 2004).
2. Shen, Y. R., Principle of Non-Linear Optics, (Wiley India, 2013).
3. Chuang, S. L., Physics of Photonic Devices, (Wiley Series, 2009)

Reference Books:

1. Boyd, R. W., Non-Linear Optics, (Elsevier, 2006) Second edition.

2. Fukuda, M., Optical Semiconductor Devices, (John Wiley & Sons, 2005).

PH 559: Nanophotonics **(L2-T1-P0-CH3-CR3**)

Review of Maxwell’s equations, light-matter interaction, radiating dipole, radiation pressure, spontaneous and stimulated emissions.

Optical properties of noble metals and semiconductors, Drude Somerfield theory, surface plasmon and polariton, evanescent wave, localized surface plasmon, SERS, surface plasmon based sensors.

Diffraction limit, near-field optics, super resolution spectroscopy, nanoscale optical microscopy, two photon and multi photon absorption processes, optical tweezer and vortices, phase conjugation and frequency mixing, elements of quantum communication.

Electromagnetics in mixed dielectric media, symmetries and solid state electromagnetism, 1-D, 2-D and 3-D photonic crystals, dispersion relation, photonic crystal fiber, opals, OLED, quantum well and quantum dot lasers, photo-luminescence and bio-luminescence.

Application in nano-optics and bio-photonics.

Text Books:

1. Maier, S. A., *Plasmonics: Fundamentals and Applications, illustrated* edition (Springer, 2007).
2. Boyd, R. W., *Non-Linear Optics*, 2nd edition (Elsevier, 2006).
3. Haus, J. W., *Fundamentals and Applications of Nanophotonics*, (Elsevier, 2016).

Reference Books:

1. Di Bartolo, Baldassare, Collins, John (Editors), *Nano-optics for Enhancing Light-Matter Interactions on a Molecular Scale: Plasmonics, Photonic Materials and Sub-Wavelength Resolution*, (Springer, 2012).
2. Winn, J. N., Joannopoulos, J. D. and Johnson, S. G., *Photonic Crystal: Molding the flow of Light*, (Princeton Univ. Press, 2008).
3. Shen, Y. R., *Principle of Non-Linear Optics*, (Wiley India, 2013).
4. Fukuda, M., *Optical Semiconductor Devices*, (John Wiley & Sons, 2005).
5. Chuang, S. L., *Physics of Photonic Devices*, (Wiley Series, 2009).
6. Novotny, L. and Hecht, B., *Principles of Nano-optics*, (Cambridge Univ. Press, 2009).

Course Code	Course Name	L-T-P	CH	CR	Remarks
Plasma Physics					
PH 545	Fundamental of Plasma Physics	2-1-0	3	3	
PH 547	Nonlinear Plasma Physics	2-1-0	3	3	

PH 545: Fundamentals of Plasma Physics (L2-T1-P0-CH3-CR3)

Course Objective:

I. The course will help to understand the difference between ionized gas and plasma

II. To learn to use mathematical formalism such as single particle approach, fluid approach and kinetic approach to describe various plasma phenomena

III. To learn to derive dispersion relation of waves in plasma medium and understand the propagation of these waves in plasma and understand electrostatic and electromagnetic waves in plasma and their physical mechanism

IV. To understand the instabilities in plasma.

IV. To understand physical mechanism of Landau damping and its importance.

Learning outcome:

After completion of the course it is expected that the students will

I. have a strong foundation of plasma physics.

II. have understanding of charged particle motion in uniform and non-uniform electric and magnetic fields and learn about E×B drift, grad B drift, curvature drift, polarization drift, magnetic mirror etc.

III. be able to use mathematical techniques to describe normal modes in plasma and understand their behaviour.

IV. explain the concept of instabilities and analyse on the basis of dispersion relation.

Course content:

Plasma State: Ionized gas, Saha's ionization equation, Collective degrees of freedom, Definition of Plasma, Concept of Plasma temperature, Debye shielding, Quasi-neutrality, Plasma parameters, Plasma approximation, Natural existence of Plasma.

Single-particle motion: Dynamics of charged particles in electro-magnetic fields, Particle drifts, EXB drifts, Grad-B drift, Curvature drift, Polarization drift, Adiabatic invariants and their technological applications.

Kinetic theory of Plasma: Vlasov equations, Solution of linearized Vlasov equation, Langmuir waves, Ion-sound waves, Wave-particle interaction and Landau damping.

Fluid theory of Plasma: Plasma oscillations, Electron-acoustic waves, Ion-acoustic waves Electrostatic ion-waves perpendicular to magnetic field, Electromagnetic waves perpendicular to magnetic field.

Equilibrium and stability: Plasma instabilities and classification, Two-stream and gravitational instabilities.

Text Books:

1. Nicholson, D.R., *Introduction to Plasma Theory* (Wiley, USA, 1983).
2. Swanson, D. G., *Plasma Waves* (IoP, Bristol, 2003).
3. Bittencourt, J. A., *Fundamentals of Plasma Physics* (Springer, New York, 2004).
4. Bellan, P. M., *Fundamentals of Plasma Physics* (Cambridge, UK, 2006).
5. Cap, F. F, *Handbook on Plasma Instabilities* (Academic Press, New York, 1976).

Reference Books:

1. Piel, A., *Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas* (Springer, Heidelberg, 2010).
2. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd ed. (Plenum, New York, 1984).
3. Kono, M. and Skoric, M. M., *Nonlinear Physics of Plasmas* (Springer, Berlin, 2010).
4. Pecseli, H. L., *Waves and Oscillations in Plasmas* (CRC Press, New York, 2013).
5. Smirnov, B. M., *Theory of Gas Discharge Plasma* (Springer, Switzerland, 2015).
6. Spitzer, L., Physics of Fully Ionized Gases (John Wiley & Sons, New York).

PH 547: Nonlinear Plasma Physics **(L2-T1-P0-CH3-CR3)**

Course objectives:

(a) It offers a precious scope of learning and enjoying the basics of nonlinear shielding mechanisms in various conditions.
(b) It excites inner stimulations to students to look creatively at the physical world from the nonlinear wave communicative perspectives in astrospace circumstances.

(c) It develops a broad mind setup to understand and solve different sorts of applied problems driven by nonlinear wave kinetics.

Learning outcomes:

(a) A full completion of the course is expected to build up strong creativity, analytical capability and innovativeness in the students.
(b) It enables potentiality and skill development in diversified exercises of nonlinear wave physics including fluid dynamics.
(c) It parallelly offers a remarkable scope to explore the astrophysical dark universe from a new perspective of nonlinear eigenstructure stimulation and their evolution.

Course content:

Nonlinear Debye shielding, Evacuation of the Debye sphere, Basics of exotic plasma effects: Plasma as exotic medium, Shielding in three spatial dimensions.

Weakly nonlinear processes: Concept of nonlinearity and dispersion, Weakly nonlinear and weakly dispersive waves, Wave energy alteration with dispersion and dissipation mechanisms, Shock & soliton formation, Nonlinear wave equations and asymptotic integrations.

Strongly nonlinear processes: Excitation of strongly nonlinear and strongly dispersive waves, Energy integral methods, Nonlinear coherent structures in complex plasmas, Astrophysical-cosmic-space applications.

Text Books:

1. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd ed. (Plenum, New York, 1984).
2. Bittencourt, J. A., *Fundamentals of Plasma Physics*, 3rd ed. (Springer, New York, 2004).
3. Bellan, P. M., *Fundamentals of Plasma Physics* (Cambridge, UK, 2006).
4. Piel, A., *Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas* (Springer, Heidelberg, 2010).
5. Pecseli, H. L., *Waves and Oscillations in Plasmas* (CRC Press, New York, 2013).

Reference Books:

1. Swanson, D. G., *Plasma Waves* (IoP, Bristol, 2003).
2. Kono, M. and Skoric, M. M., *Nonlinear Physics of Plasmas* (Springer, Berlin, 2010).
3. Hasegawa, A., *Plasma Instabilities and Nonlinear Effects* (Springer, Berlin, 1975).
4. Davidson, R. C., *Methods in Nonlinear Plasma Theory* (Academic Press, New York, 1972).
5. Nicholson, D.R., *Introduction to Plasma Theory* (Wiley, USA, 1983).

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Nano-Science				
PH 562	Quantum Effects in Low Dimensional Systems	2-1-0	3	3	
PH 563	Physics of Nano devices	2-1-0	3	3	

PH-562: Quantum Effects in low dimensional systems (L2-T1-P0-CH3-CR3)

Course Objective: The course aims to survey various ground states of condensed matter many particle systems and explore their excitations and other properties in reduced dimension. The students will learn the appropriate theoretical framework for understanding and exploring existing physical systems and with the possibilities to predict new by using microscopic physical laws.

Expected outcome: On completion of the course, the student should be able to understand the governing laws required to understand physical behaviour in micro and nano dimensional condensed matter systems.

Course Contents:

Unit 1

Quantum mechanical treatment for quantum well; parabolic well, rectangular well, triangular well, cylindrical well and spherical well; quantum wire and quantum dots; quantum size effect, size and dimensionality effects on density of states, Bohr excitons, strong and weak confinements. [6 Lecture hours]

Unit 2

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, surface electronic state, structural defects at surfaces, Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics, Non-equilibrium growth, Ostwald ripening, Hall-Petch relation, grain correlated properties, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, lateral interaction, Chemisorption, physisorption. [8 Lecture hours]

Unit 3

Aperiodic solids and Quasicrystals, Fibonacci sequence, Penrose lattices and their extensions in 3 dimensions; Special carbon solids: Fullerene, Graphene and Carbon Nanotube - Structure, formation and characterizations; Synthesis; Density of states, Elementary electronic properties and band structure; Usual properties of Graphene – Dirac Fermion, single wall and multiwall carbon nanotube, Carbon Nanotubule based electronic devices, Transition Metal Dichalcogenide (TMDC). [5 Lecture hours]

Unit 4

Quantum mechanical modelling of materials: Hartree Fock and Density Functional Theory. Atomic pseudopotentials, Basis sets: Plane Waves and Augmented Basis sets. Plane Wave based DFT calculations. Simplified Approaches to the electronic problem: Tight binding methods;

Monte Carlo and Molecular dynamics simulations; [10 lecture hours].

Unit 5

Structure: X-ray Diffraction (XRD) patterns, Intensities of reflections, Thermal effects on diffraction patterns, Identification of phases. Effects of disorder, Strain and Crystallite size; Morphology: Scanning Electron Microscopy (SEM), Energy-dispersive and wavelength-dispersive spectrometry, Transmission Electron Microscopy (TEM), Selected Area Diffraction Patterns (SAED), Diffraction contrast to image defects;

Defect: Positron annihilation lifetime spectroscopy, defect analysis from PAS spectroscopy, defect property correlation. [10 Lecture hours].

Text Books:

1. G. Cao and Y. Wang, *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, 2nd edition, (World Scientific, 2011).
2. Jr. C. P. Poole, and F. J. Owens, *Introduction to Nanotechnology.* (Wiley, 2003).
3. C. Kittle, *Quantum Theory of Solids.* (Wiley, 2015).
4. N. W. Ashcroft and N. D. Mermin, *Solid State Physics.* (Cengage Learning Asia Pvt Ltd, Singapore, 2016).
5. J. Davis, *The Physics of Low-dimensional Semiconductors: An Introduction*, (Cambridge University Press, 1998).
6. J. P. Colinge and C. A. Colinge, P*hysics of Semiconductor Devices,* (Springer, 2007).
7. R. Zallen, *The Physics of Amorphous Solids* (Wiley VCH, 1998)

Reference Book:

1. K. Ariga, *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics (Royal Society of Chemistry, 2012)*
2. *W. Jones, and N. H. March, Theoretical Solid State Physics (Courier Corporation, 1985).*
3. G. Giuliani and G. Vignale, *Quantum Theory of the Electron Liquid (Cambridge Uni. Press, 2005)*
4. P. Fazekas, *Lecture Notes on Electron Correlation and Magnetism*. (World Scientific, 1999).
5. G. D. Mahan, *Many Particle Physics* (Springer Science & Business Media, 2000).
6. N. F. Mott and E. A. Davies, *Electronic Processes in Non-crystalline Materials* (Oxford *University Press, 2012)*
7. J. Solyom, *Fundamentals of the Physics of Solids, Volumes 1, 2, and 3. (springer, 2007).*

PH-563: Physics of Nano devices **(L2-T1-P0-CH3-CR3)**

Course Objective: The course aims to connect the quantum theory of solids to deal with interacting quantum systems to design devices for their practical use with various physical properties. Emphasis is on developing coherent directions for understanding and utilizing the concepts in nanodimensions for practical applications.

Expected outcome: On completion of the course, the student should be able to understand and design the macroscopic properties of nano dimensional devices in terms of microscopic scale phenomena.

Course Contents:

Unit I

Ballistic transport; Phase coherence, Aharonov – Bohm effect; quantized conductance, Landauer formula, conductance behavior of quantum point contact; Landauer – Buttiker formula for multileads, edge states – explanation of quantum hall effect; Single electron transport – Coulomb blockade, single electron transistor (SET), molecular electronics; Kondo effect in Nanostructures. [6 Lecture hours]

Unit II

Magnons, Exchange Interactions. Magnetic Anisotropy, Order and Broken symmetry, Consequences of Broken Symmetry, Heisenberg and Ising Model, Equation of motion for Domain walls, Superparamagnetism, Stoner-Wohlfarth model, Nuclear magnetic resonance, Magnetic Resonance Imaging. [8 Lecture hours]

Unit III

Ordinary and anisotropic magneto-resistance, mechanism; Giant Magneto-resistance (GMR): basic properties, mechanism, application – spin valves and spin switches; Colossal magnetoresistance (CMR): basic properties and phase diagram, comparison with GMR; structuretolerance factor, effect of doping, charge ordering; Theoretical understanding – Double exchange mechanism, crystal field splitting and Jahn-Teller distortion, electron-phonon coupling, Application-Magnetoresistive devices, Applications of superconductors in quantum computation. [9 Lecture hours]

Unit IV

Family tree of FET: General characteristics – field dependent mobility, two region model and saturated velocity model, related field effect devices, Surface charge in MOS-capacitors; Capacitance voltage characteristics of MIS structure.

Types of MOSFET, Basic devices characteristics, Non-equilibrium conditions, linear and saturation regions, subthreshold region, mobility behaviour, temperature dependence, threshold shift, short channel effects, subthreshold current, FAMOS, VMOS; Charge coupled devices (CCD); interface trapped charge, charge storage, basic CCD structure, Charge storage and frequency response, buried channel CCD. [10 Lecture hours]

Unit V

Applications of heterojunctions, white light LED, OLED, Quantum well, quantum dot and quantum cascade lasers, photodetectors and photovoltaics. Space charge limited current, Fowler Nordheim equations, field emission devices.

Magnetic Memory, Shape memory, resistive switching, DRAM and FRAM, piezoelectric transducers and actuators, spin injection, transport and spin valve devices. [6 Lecture hours]

Text Books:

1. N. W. Ashcroft, N. D. Mermin, *Solid State Physics*, (Cengage Learning Asia Pvt Ltd, Singapore, 2016).
2. M. P. Marder, *Condensed Matter Physics* (John Wiley & Sons, 2010).
3. H. Ibach and H. Luth, *Solid State Physics* (Springer, 2009).
4. D. A. Neamen, *Semiconductor Physics and Devices*, 3 rd edition, (Tata McGraw-Hill, 2002).
5. B. G. Streetmann, *Semiconductor Devices*, (PHI, 2006).
6. M. Shur, *Physics of Semiconductor Devices*, (PHI, 1995).
7. J. Davis, *The Physics of Low-dimensional Semiconductors: An Introduction*, (Cambridge University Press, 1998).
8. J. P. Colinge, and C. A. Colinge, *Physics of Semiconductor Devices*, (Springer, 2007).

Reference Books:

1. Philip Phylips, *Advanced Solid State Physics* (Cambridge University Press, 2012).
2. W. Jones, and N. H. March, *Theoretical Solid State Physics* (Courier Corporation, 1985).
3. G. Giuliani and G. Vignale, *Quantum Theory of the Electron Liquid* (Cambridge Uni. Press, 2005).
4. P. Fazekas, *Lecture Notes on Electron Correlation and Magnetism*. (World Scientific, 1999).
5. J. Solyom, *Fundamentals of the Physics of Solids, Volumes 1, 2, and 3. (springer, 2007).*

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