DEPARTMENT OF PHYSICS

Programme Structure of M. Sc. (Physics)-2019

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 533	General Theory of Relativity	2-1-0	3	3	
PH 536	Basic Astronomy & Astrophysics	2-1-0	3	3	
PH 537	High Energy & Extragalactic Astrophysics	2-1-0	3	3	
PH 538	Introduction to Cosmology	2-1-0	3	3	
PH 541	Plasma and Astrophysics	2-1-0	3	3	
	Condensed Matter Physics				
PH 506	Physics of Thin Films	2-1-0	3	3	
PH 514	Superconductivity and Critical Phenomena	2-1-0	3	3	
PH 517	Physics of Solid State Devices	2-1-0	3	3	
PH 539	Advanced Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 543	Surface Science	2-1-0	3	3	
PH 542	Nanostructures	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	
PH 510	Fiber Optics and Optoelectronics	2-1-0	3	3	
	High Energy Physics				
PH 519	Quantum Field Theory	2-1-0	3	3	
PH 532	Quantum Electrodynamics	2-1-0	3	3	
PH 555	Particle Physics I	2-1-0	3	3	
PH 556	Particle Physics II	2-1-0	3	3	
PH 541	Plasma and Astrophysics	2-1-0	3	3	

Photonics					
PH 510	Fiber Optics and Optoelectronics	2-1-0	3	3	
PH 557	Photonics	2-1-0	3	3	
PH 523	Microwave systems and Antenna Propagation	2-1-0	3	3	
PH 603	Fourier Optics and Holography	2-1-0	3	3	
PH 558	Quantum Electronics	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 546	Plasma Generation and Application	2-1-0	3	3	
PH 547	Nonlinear Plasma Physics	2-1-0	3	3	
PH 539	Advanced Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 536	Basic Astronomy and Astrophysics	2-1-0	3	3	
PH 537	High Energy and Extragalactic Physics	2-1-0	3	3	
PH 541	Plasma and Astrophysics	2-1-0	3	3	

Nano-Science					
PH 542	Nanostructures	2-1-0	3	3	
PH 543	Surface Science	2-1-0	3	3	
PH 559	Nanophotonics	2-1-0	3	3	
PH 554	Soft Condensed Matter Physics	2-1-0	3	3	
PH 548	Nanobiophysics	2-1-0	3	3	
PH 549	Nanomagnetism	2-1-0	3	3	
PH 539	Advanced Condensed Matter Physics and Material Science	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)

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)

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)

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)

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)**

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)**

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).

PI 499/ PH 400 Computational Laboratory --

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)**

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)**

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)

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.

Random variables, expectation value, averages, mean, standard deviation, binomial distribution, normal distribution, variance, covariance and correlation, theory of errors, $\chi 2$ test.

Tensor analysis: Tensor in three and/or four dimensions, rank of tensors, covariant and intravariant tensors, symmetric and antisymmetric tensors, metric tensors, Christoffels symbols, equation of a geodesic, Riemann-Christoffel tensor, simple applications.

Group theory: Group representation, reducible and irreducible representation, unitary group, special unitary group, Lorentz group, rotation group, direct product, group theory in physics.
Linear Algebra: Vector space, linear transformations, determinants, inner product space.

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)**

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)**

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)**

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)

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 533	General Theory of Relativity	2-1-0	3	3	
PH 536	Basic Astronomy & Astrophysics	2-1-0	3	3	
PH 537	High Energy & Extragalactic Astrophysics	2-1-0	3	3	
PH 538	Introduction to Cosmology	2-1-0	3	3	
PH 541	Plasma and Astrophysics	2-1-0	3	3	

PH 533: General Theory of Relativity **(L2-T1-P0-CH3-CR3)**

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, Biranchi identity, Einstein tensor.

Elements of general theory of relativity: Brief review of special theory of real Mincowskhi dgn, equivalence ppl & ppl of general congruence, Einstein 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, bending of light, advance of perihelion of mercury and gravitational red shift, Shapiro delay, early Universe, the big bang theory vs. steady state theory, primordial Helium abundance, CMBR, decoupling of matter and radiation, formation of galaxies, gravitational lensing and microlens, elements of quantum gravity and quantum cosmology, Hawking radiation.

Text Books:

1. Chandrasekhar, S., *Introduction to the Study of Stellar Structure*, (Dover Publications, 1958).
2. Kippenhahn, R. A. and Weigert, A., *Stellar Structure and Evolution*, (Springer- Verlag, 1994).
3. Frank, S., *The Physical Universe*, (Universal Science Books, 1982).

Reference Books:

1. Stewart, J., *Advanced General Relativity*, (Cambridge University Press, 2008).
2. Landau, L. D. and Lifshitz, E. M., *The Classical Theory of Fields*, 4th edition, (Butterworth-Heinemann, 2000).
3. Erika, B., *Stellar Physics, Vol. I, II, III*, (Cambridge University Press, 1997).
4. Weinberg, S., *Gravitation and Cosmology*, (John Willey & Sons, 2005).
5. Shutz, B., *A First Course in General Relativity*, (Cambridge University Press, 2009).
6. Padmanabhan, T., *Theoretical Astrophysics, Vol. I, II, III*, (Cambridge University Press, 2003).

7. Giunti, C. and Kim C., *Fundamentals of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
8. Abhyankar, K. D., *Astrophysics: Stars and Galaxies*, (Tata McGraw Hill, 2002).
9. Bisnovatyi- Kogan, G. S., *Stellar Physics, Vol. I, II*, (Springer-Verlag, 2002).

PH 536: Basic Astronomy & Astrophysics **(L2-T1-P0-CH3-CR3)**

Basic Astronomy: Celestial co-ordinate systems, telescope and its operational principles and mounting, atmospheric extinctions, magnitude systems, constellations and zodiac.

Stellar structure and evolution: Mass, luminosity, chemical composition, temperature and equation of a star and their measurements; stellar spectra and classifications, main sequence stars, Colour-magnitude plot, Herzsprung-Russel (H-R) diagram, equation of hydrostatic equilibrium, polytropic stars and related integral theorems, stellar atmosphere, blackbody radiation, Saha equation, post-main sequence stars, red giants, nuclear reactions, reaction rates, p-p chain and carbon-nitrogen-oxygen (CNO) cycle.

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.

Text Books:

1. Chandrasekhar, S., *Introduction to the Study of Stellar Structure*, (Dover Publications, 1958)
2. Kippenhahn R. A., and Weigert, A., Stellar Structure and Evolution, (Springer- Verlag, 1994).
3. Abhyankar K. D., Astrophysics: Stars and Galaxies, (Universities Press, 2009).

Reference Books:

1. Stewart, J., *Advanced General Relativity*, (Cambridge University Press, 2008).
2. Landau, L. D. and Lifshitz, E. M., *The Classical Theory of Fields*, (Butterworth-Heinemann, Elsevier, 1987).
3. Vitense, E. B., *Stellar Physics, Vol. I, II, III*, (Cambridge University Press, 1992).
4. Weinberg, S., *Gravitation and Cosmology*, (Wiley, New York, 1972).
5. Shutz, B., *A First Course in General Relativity*, (Cambridge University Press, 2009).
6. Padmanabhan, T., *Theoretical Astrophysics, Vol. I, II, III*, (Cambridge University Press, 2003).
7. Giunti, C. and Kim, C., *Fundamentals of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
8. Bisnovatyi-Kogan, G. S., *Stellar Physics, Vol. I, II*, (Springer-Verlag, 2002).
9. Shu, F., *The Physical Universe*, (Universal Science Books, 1982).

PH 537: High Energy & Extragalactic Astrophysics (L2-T1-P0-CH3-CR3)

Advanced stages of evolution of stars, gravitational collapse, degeneracy pressure in stars, supernova.

Compact objects: White dwarfs (WD), onset of degeneracy, Chandrasekhar limit, masses, radii and cooling of WD, magnetic WD, neutron stars (NS), equation of state in nuclear domain, realistic theoretical models, Tolman-Oppenheimer-Volkoff (TOV) equation, observation of NS masses, maximum masses and effects of rotation, pulsars (PLSR): history and discovery, connections with fast rotating NS, magnetic dipole model for PLSR, braking index, PLSR emission mechanisms, PLSR glitches, X-ray PLSR, black holes (BH), Schwarzchild BH, Kruskal diagram, test particle motion, Kerr BH, area theorem, BH evaporation.

Galaxies: Hubble's classification of galaxies, rotation law, evolution of galaxies, cluster of galaxies – Virgo and Coma clusters, galaxy mergers, radio galaxies, quasars, active galactic nuclei (AGN).

Text Books:

1. Kippenhahn, R. A. and Weigert, A., *Stellar Structure and Evolution*, (Springer- Verlag, 1994).
2. Misner, C., Thorne, K. S. and Wheelar, J. A., *Gravitation*, (Freeman, 2003).
3. Kenyon, I.R., *General Relativity,* (Oxford University Press, 1990).

Reference Books:

1. Landau, L. D. and Lifshitz, E. M., The *Classical Theory of Fields*, (Butterworth-Heinemann, Elsevier, 1987).
2. Weingberg, S., *Gravitation and Cosmology*, (Wiley, New York, 1972).
3. Vitense, E. B., *Stellar Physics – Vol. I, II, III,* (Cambridge University Press, 1992).
4. Robert, J. and Mark, H., *An Introduction to Galaxies and Cosmology*, (Cambridge University Press, 2004).
5. Lindu, S. and John, S., *Galaxies in the Universe*, (Cambridge University Press, 2007).
6. Rosswog, S. and Bruggen, M., *Introduction to High Energy Astrophysics*, (Cambridge University Press, 2007).
7. Bradt, H., *Astrophysics Processes*, (Cambridge University Press, 2008).
8. Shu, F., *The Physical Universe*, (Universal Science Books, 1982).
9. Abhyankar, K. D., *Astrophysics Stars and Galaxies*, (Universities Press, 2009).
10. Shapiro, S. L. and Teukolsky, S. A., *Black Holes, White Dwarfs and Neutron Stars: The Physics of Compact Objects, (*Wiley-VCH, 1983).
11. Zel'dovich, Y. B. and Novikov, I. D., *Realistic Astrophysics Vol. I & II,* (University of Chicago Press, Chicago, 1983).

PH 538: Introduction to Cosmology (L2-T1-P0-CH3-CR3)

Introduction: Large-scale structure of universe, Olber's paradox, cosmological principle, elements of Newtonian cosmology.

Cosmological Models: Friedman-Robertson-Walker (FRW) metric, Commoving time, Hubble's law, Einstein universe, De-Sitter universe, big bang theory, steady state theory.

Early Universe: Inflationary universe, primordial helium abundance, cosmic microwave background radiation (CMBR), decoupling of matter and radiation, formation of galaxies, gravitational lensing and microlensing, elements of quantum gravity and quantum cosmology, Hawking radiation.

Text Books:
1. Narliker, J. V., *Introduction to Cosmology*, (Cambridge University Press, 2002).
2. Adler, R., Bazin, M. and Schriffer, M., *Introduction to General Relativity*, (McGraw-Hill, 1975).
3. Misner, C., Thorne, K. S. and Wheelar, J. A., *Gravitation*, (Freeman, 2003).

Reference Books:
1. Weinberg S., *Gravitation & Cosmology*, (Willey, New York, 1972).
2. Erika, Bohm, *Stellar Physics- Vol. I, II, III*, (Vitense, 1992).
3. Weinberg S., *Cosmology*, (Oxford University Press, 2008).
4. Liddle, A. and Loverday, J., *The Oxford Companion to Cosmology*, (Oxford University Press, 2008).
5. Kenyon, I. R., *General Relativity*, (Oxford University Press, 1990).
6. Shu, F., *The Physical Universe*, (Universal Science Books, 1982).
7. Abhyankar, K. D., *Astrophysics: Stars and Galaxies*, (Tata McGraw-Hill, 2002).
8. Shapiro S. L. and Teukolski S. A., *Black Hole, White Dwarf and Neutron Star*, (Addition-Wesley, 1983).
9. Zel'dovich Ya. B. and Novikov, I. D., *Relativistic Astrophysics, Vol. I & II*, (University Chicago Press, Chicago, 1983).

PH 541: Plasma and Astrophysics **(L2-T1-P0-CH3-CR3)**

Basic plasma concepts: Debye shielding, plasma frequency, plasma parameter, motion of charged particle in electromagnetic field, uniform E and B fields, gradient B drift, parallel acceleration and magnetic mirror effect.

Waves in plasma, electron and ion plasma waves, their dispersion relations and properties, fundamental equations of magneto-hydrodynamics (MHD), the MHD approximation, hydromagnetic waves, plasma confinement schemes, plasma in space.

Introduction to the interstellar medium: Neutral and ionized gas, gaseous nebulae, HII regions, supernova remnants, photo-dissociation regions, different phases of the interstellar medium: cold neutral medium, warm neutral and ionized medium, hot medium, diffuse clouds, dense clouds.

Radiative processes: Radiative transfer, emission and absorption coefficients, emission and absorption lines, the role of thermal and free electrons.

Text Books:
1. Bellan, P. M., *Fundamentals of Plasma Physics*, 1st edition (Cambridge University Press, 2008).
2. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd edition, Vol. 1, (Springer, 1984).

Reference Books:

1. Tielens, A. G. G. M., *Physics and chemistry of the interstellar medium*, (Cambridge University Press, 2010).
2. Dyson, J. E. and Williams, D. A., *The Physics of the interstellar medium*, 2nd edition (Taylor and Francis, 1997).
3. van der Hulst, J. M., *The interstellar medium in galaxies,* 1st edition (Astrophysics and Space Science Library, Springer; 2001).
4. Krishan, V., *Astrophysical Plasmas and Fluids*, 1st edition (Springer, 1999).
5. Spitzer, L., *Physical Processes in the interstellar medium*, (Wiley-VCH, 1998).
6. Draine, B. T., *Physics of the Interstellar and Intergalactic Medium*, (Princeton University Press, 2010).
7. Shu, F., *The Physical Universe*, (University Science Books, 1982).
8. Abhyankar, K. D., *Astrophysics: Stars and Galaxies*, (Sangam Books Ltd, 2002).

Course Code	**Course Name**	**L-T-P**	**CH**	**CR**	**Remarks**
	Condensed Matter Physics				
PH 506	Physics of Thin Films	2-1-0	3	3	
PH 514	Superconductivity and Critical Phenomena	2-1-0	3	3	
PH 517	Physics of Solid State Devices	2-1-0	3	3	
PH 539	Advanced Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 543	Surface Science	2-1-0	3	3	
PH 542	Nanostructures	2-1-0	3	3	
PH 554	Soft Condensed Matter Physics	2-1-0	3	3	

PH 506: Physics of Thin Films **(L2-T1-P0-CH3-CR3)**

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.

Analytical and characterization techniques, mechanical, electrical, electronic and dielectric properties of thin films, 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. Goswami, A., *Thin Film Fundamentals*, (New Age International (P) Ltd., New Delhi, 2008).

References Books:

1. George, J., *Preparation of Thin Films,* (Marcel Dekker Inc., New York, 1992).
2. Wagendristel, A. and Wang Y., *An Introduction to Physics and Technology of Thin Films*, (World Scientific Singapore, 1994).
3. Maissel, L. I. and Glang, R., *Handbook of Thin Film Technology*, (McGraw-Hill, 1970).

PH 514: Superconductivity and Critical Phenomena (L2-T1-P0-CH3-CR3)

Review of superconductivity, Type I and Type II superconductors, Thermodynamics of superconductivity, Rutger's formula, London equations, Frohlich model, e-p-e interaction, Cooper pairs, Concept of penetration depth & coherence length, Pippard's equation, G-L parameters, BCS theory, fictitious magnetic field and anti-ferromagnetic ordering, spin analogue treatment of Anderson.

Vortex state and flux pinning, Quantized vorticity, Energy between vortex states, Flux quantisation, A.C. and D.C. Josephson effects, SQUID, Cuprate and non-cuprate superconductors (YBCO, BSSCO etc. and MgB_2), In plane and out of plane structural ordering, role of CuO chains and planes in cuprate SC. *d*-wave structure of the superconducting energy gap, iron based SC.
Applications and limitations of HTSC in high voltage cables, magnetic levitation, ship propulsion and magneto-encephalography etc.

Critical Phenomena: First order and second order phase transitions, Phase diagrams, Examples of critical phenomena: liquid-gas, paramagnetic-ferromagnetic, normal to superconductor, and superfluid transitions. Mean field theory and Spin-1/2 and Spin-l Ising Models, X-Y and Heisenberg models. Universality class, scaling laws, critical exponents and inequalities.

Text Books:

1. Tinkham, M., *Introduction to Superconductivity*, *2^{nd} edition*, (Dover Publications, 2004).
2. Ketterson, J.B. and Song, S.N., *Superconductivity*, (Cambridge University Press, 1999).
3. Kittel, C., *Introduction to Solid State Physics, 8^{th} edition* (Wiley, 2004).

Reference Books:

1. Anderson, P. W., *Theory of Superconductivitty in high T_c Cuprates, 1^{st} edition*, (Princeton University Press, 1997).
2. Stanley, H. E. *Introduction to Phase transitions and Critical Phenomena*, (Oxford, 1971).
3. Huang, K. *Statistical Mechanics*, (John Wiley, 2000).
4. Pathria, R. K. *Statistical Mechanics*, (Oxford, 1999).
5. Chaikin, P. M. and Lubensky, T. C., *Principles of condensed matter Physics*, (Cambridge, 2000).

PH 517: Physics of Solid State Devices (L2-T1-P0-CH3-CR3)

Review of carrier transport phenomena in semiconductors, abrupt and graded junctions, homo and heterojunctions, Ohmic and Schottky contacts, high field transport, heterostructures, quantum wells, super-lattices, resonant tunneling, energy band scheme, field effect transistors using homo and hetero structures, JFET and HEMT. Tunnel diodes and amorphous semiconductor devices.

Magneto resistance (GMR) and colossal magneto resistance (CMR) effects, Magnetocaloric effect. Magnetic memory, shape memory, resistive switching, DRAM and FRAM, piezoelectric transducers and actuators. Spin injection, transport and spin valve devices.

Quantum confinement, energy states of spatially confined electrons, coulomb blockade, single electron transistors, ballistic scattering, quantum point contacts, Landauer formula, mesoscopic transport.

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.

Text Books:

1. Neamen, D. A., *Semiconductor Physics and Devices, 3rd edition*, (Tata McGraw-Hill, 2002).
2. Streetmann, B., *Semiconductor Devices, 6th edition*, (PHI, 2006).
3. Shur, M., *Physics of Semiconductor Devices*, (PHI, 1995).

Reference Books:

1. Davis, J., *Low dimensional structures, 1st edition* (Cambridge, 1998).
2. Colinge, J. P., and Colinge, C.A., *Physics of Semiconductor Devices*, Springer (2007).
3. Sze, S. M., *Semiconductor Devices, 3rd edition*, (Wiley, 2012).
4. Van der Vaart, N., *Single electron transport in semiconductor nanostructures*, (Ph.D. Thesis 1995).

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

Fermi surface, cyclotron resonance, de Hass-Van Alphen effect, electron motion in 2-dimension, Quantum Hall effect.

Dia, para and ferro magnetism; Langevin theory of dia and para magnetism, Curie-Weiss law, Pauli paramagnetism, exchange interaction, spin waves and magnons, dispersion relation, neutron scattering from magnetic materials-structure studies, elements of ferrimagnetism and antiferromagnetism. Neel temperature.

Dielectric constant, polarizability, ferroelectricity, displacive- nondisplacive and order-disorder types, Kronig-Kramer relations, Clausius-Mossoti relation, ferroelasticity.

Perfect conductors, superconductors, Meissner effect, critical magnetic field, transition temperature, energy gap parameter, isotopic effect, Type I & Type II superconductors, vortex state and flux pinning, thermodynamics of superconductivity, condensation energy, London equations and concept of penetration depth (λ).

Frohlich model, e-p-e interaction, formation of Cooper pairs, coherence length (ξ), Pippard's equation, G-L parameters, elements of BCS theory.

Flux quantization, single particle tunneling and Josephson effect, superconducting quantum interference device (SQUID).

Giant magneto resistance (GMR) and colossal magneto-resistance (CMR).

Text Books:

All books prescribed under *Condensed Matter Physics & Materials Science-I (PH-501).*

References Books:

All books prescribed under *Condensed Matter Physics & Materials Science-I (PH-501).*

PH 543: Surface Science **(L2-T1-P0-CH3-CR3)**

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, bulk electronic state, surface electronic state, Energy levels at metal interfaces, structural defects at surfaces - point defects, steps, faceting, adatoms, dislocations.

Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics.

Non-equilibrium growth, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, binding energies and activation barriers, adsorption isotherms, rate of desorption, lateral interaction.

Chemisorption, physisorption and dynamics, heterogenous catalysis process.

Atomistic mechanisms of surface diffusion – hopping mechanism, atomic exchange mechanism, tunneling mechanism.

Surface analysis: scanning probe microscopy, photoelectron spectroscopy, Auger electron spectroscopy, electron energy loss spectroscopy, low energy electron diffraction.

Text Books:

1. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
2. Oura, K. Lifshits, V. G. Saranin, A. A. Zotov, A. V. and Katayama M., *Surface Science: An Introduction*, 2nd edition, (Springer, 2010).
3. O'Connor, D. J. Sexton, B. A. and Smart R. S. C., *Surface Analysis Methods in Materials Science*, 2nd edition, (Springer, 2010).
4. Desjonqueres, M.-C. and Spanjaard, D., *Concepts in Surface Physics*, 2nd edition, (Springer, 2002).
5. Kolasinski, K. W., *Surface Science, Foundations of Catalysis and Nanoscience*, (Wiley, 2002).

Reference Book:

1. Richardson, N.V. and Holloway, S., *Handbook of Surface Science,* Vol. 4, (Elsevier, 2014).

PH 542: Nanostructures **(L2-T1-P0-CH3-CR3)**

Introduction to nanoscale materials: Quantum mechanical treatment, parabolic well, rectangular well, triangular well, cylindrical well and spherical well, quantum well, quantum wire and quantum dots, quantum size effect, size and dimensionality effects of density of states, Bohr excitons, strong and weak confinements, oscillator strength, blue-shift energy and effective mass approximation model, semiconductor nanoparticles, nanorods and nanotubes, metallic nanostructures, carbon nanotubes, graphene and layered systems.

Surface properties: Phonons in nanostructured systems, surface optic phonons, surface plasmons, interfacial charge transfer, grain growth, surface defects, Langmuir relation, Ostwald ripening, Hall-Petch relation, grain correlated properties.

Synthesis techniques: Top-down vs. bottom-up techniques, sol-gel method, solution growth and hydrothermal routes, mechanical milling and solid state reaction techniques, chemical and photochemical reduction routes, thermal evaporation and e-beam evaporation methods, molecular beam epitaxy.

Analytical tools: X-ray diffraction, optical absorption and emission spectroscopy, Raman spectroscopy, scanning and transmission electron microscopy.

Green nanotechnology, challenges in nanotechnology.

Text Books:

1. Cao, G. and Wang, Y., *Nanostructures and Nanomaterials: Synthesis, Properties and Applications, 2nd edition*, (World Scientific, 2011).
2. Rao, C. N. R., Thomas, P. J. and Kulkarni, G. U., *Nanocrystals: Synthesis, Properties and Applications*, (Springer-Verlag, 2007).
3. Poole, Jr. C. P. and Owens, F. J., *Introduction to Nanotechnology*, (Wiley, 2003).
4. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
5. Nouailhat, A., *An Introduction to Nanosciences and Nanotechnology*, (Wiley 2007).

Reference Book:

1. Ariga, K., *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics*, (Royal Society of Chemistry, 2012).

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

Phases of soft condensed matter: Colloidal fluids and crystals, Poisson-Boltzmann theory, DLVO theory, sheared colloids, polymer solutions, gels and melts; emulsions and foams, micelles, vesicles, surfactants, nature of amphiphilic molecules, lyophobic and lyophilic molecules, self-assembly, Langmuir-Blodgett technique, forces, energy and bonding, microgels, wetting-dewetting phenomena, super-hydropbobic surfaces, phospholipids and glycolipids, polyelectrolyte, polysachharides., biopolymers and biodegradable polymers.

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

Flow behaviour: Ferrofluids, shear thickening and shear thinning, diffusion and fluid flow, shear flow, linear and non-linear rheology, microfluidic devices, life at low Reynold number, electrostatics in soft matter, dynamics at equilibrium, glass formation 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.

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

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

Text Books:

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

Reference Books:

1. Kleman, M. and Lavrentovich, O. D., *Soft Matter Physics*, (Springer-Verlag, 2003).
2. Safran, S. A., *Statistical Mechanics of Surfaces, Interfaces and Membranes*, (Addison-Wesley, Reading, MA 1994).
3. Russel, W. B., Saville D. A. and Showalter, W. R., *Colloidal Dispersions*, (Cambridge University Press, New York, 1989).
4. Philip Nelson, *Biological Physics: Energy, Information and Life*, (Freeman, 2003).
5. Tabor, D., *Gases, Liquids and Solids*, (CUP, 1991).
6. Cotteril, R., *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 510	Fiber Optics and Optoelectronics	2-1-0	3	3	

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

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)

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)**

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)

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).

PH 510: Fiber Optics and Optoelectronics **(L2-T1-P0-CH3-CR3)**

Introduction to nature of light, optical fiber modes and configurations, mode theory for circular waveguides, single mode and graded-index fibers, fiber materials, fiber fabrication, mechanical properties of fibers.

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, LED coupling to multimode and single mode fiber, fiber splicing, optical fiber connector, non-linear effects in fibers, Raman scattering and Brillouin scattering in fibers, fiber Bragg gratings, communication network using fibers, WDM system.

Optical sources: Basic physics of semiconductor optoelectronic devices, light emitting diodes (LEDs), laser diode, light source linearity, modal partition and reflection noise, reliability consideration, fiber laser, fiber based optical amplifier.

Optical detectors: Physical principles of photodiodes, PIN and avalanche photodiode, photo detector noise, detector response time, photodiode materials.

Text Book:

1. Ghatak, A. K. and Thyagarajan, K., *Introduction to Fiber Optics,* (Cambridge Publisher, 2004).
2. Keiser, G., *Optical Fiber Communications*, (McGraw-Hill, 2010).

Reference Books:

1. Kasap, S. O., *Optoelectronics and Photonics Principle and applications*, (Pearson, 2009).
2. Sandbank, C. P., *Optical Fiber Communication Systems*, (John wiley &Sons, 1980).
3. Franz, J. H. and Jain, V. K., *Optical communications Components and systems*, (Narosa, 2009).

Course Code	Course Name	L-T-P	CH	CR	Remarks
	High Energy Physics				
PH 519	Quantum Field Theory	2-1-0	3	3	
PH 532	Quantum Electrodynamics	2-1-0	3	3	
PH 555	Particle Physics I	2-1-0	3	3	
PH 556	Particle Physics II	2-1-0	3	3	
PH 541	Plasma and Astrophysics	2-1-0	3	3	

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

Introduction to fields: Lagrangian and Hamiltonian formulation of continuous systems, introduction to relativistic field theories, Noether's theorem, Four-vector notations, Lorentz transformations, natural units.

Many particle systems: Non-relativistic quantum systems, free fields, Klein-Gordon equation, non-relativistic many particle systems, relativistic free scalar fields, Dirac equation, antiparticles, free Dirac fields.

Field quantization: Action principle, quantization of scalar fields, quantization of Dirac fields, quantization of vector fields, Lorentz transformation and invariance, parity, charge conjugation and time reversal, CPT theorem.

Interactions among fields: Interactive pictures, S-matrix, Wick's theorem, second-order processes, position space Feynman rules, momentum space Feynman rules, cross-sections.

Text Books:

1. Griffiths, D., *Introduction of Elementary Particles,* (Wiley-VCH Verlag, 2008).
2. Halzen, F. and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (Wiley India, 2008).
3. Ryder, L. H., *Quantum Field Theory,* (Cambridge University Press, 1996).

References Books:

1. Peskin, M. E. and Schroeder, D. V., *Introduction to Quantum Field Theory,* (Westview Press, 1995).
2. Weinberg, S., *The Quantum Theory of Field, Vol. I, II, III* (Cambridge University Press,2000).
3. Mandl, F. and Shaw, G., *Quantum Field Theory,* (John Wiley and Sons, 2010).
4. Perkins, D. H., *Introduction to High Energy Physics*, (Cambridge University Press, 2000).
5. Aitchison, I. J. R. and Hey Gauge, A. J. G., *Theories in Particle Physics*, (Taylor and Francis Group, 2002).
6. Chang, S. J., *Introduction to Quantum Field Theory,* (World Scientific Publishing, 1989).

PH 532: Quantum Electrodynamics (L2-T1-P0-CH3-CR3)

Classical electromagnetic fields, Quantization of electro-magnetic fields, Electron-electron scattering, Compton scattering, vacuum polarization, electron self-energy, zero temperature Fermi and Bose systems.

Path Integral Formalism*:* Hamiltonian path integrals, Scalar field theories, Dyson-Schwinger equation, Femion systems.
Gauge theories: Path integral formalism and Maxwell fields, Yang-Mills fields, path integral and Feynman rules, renormalization of QED, non-Abelian gauge theories, gauge field self-energy, spontaneous breaking of symmetry, Higgs mechanism; renormalization group.

Text Books:

1. Griffiths, D., *Introduction of Elementary Particles,* (John Wiley and Sons, 1987).
2. Halzen, F. and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008).
3. Ryder, L. H., *Quantum Field Theory,* (Cambridge University Press, 1996).

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).

PH 555: Particle Physics I (L2-T1-P0-CH3-CR3)

Conservation laws: strong, weak and electromagnetic interactions, invariance under charge (C), parity (P) and time (T) operators, non-conservation of parity in weak interactions.

Quark model: Quark model of mesons and baryons; quarks, gluons and colours, colour factors, symmetry groups - SU(2), SU(3), eightfold way of classification, discovery of J/Ψ and upsilon, quark masses.

Parton Model: Probing charge distribution with electrons, form factors, electron-proton scattering - proton form factor, elastic electron-proton scattering, Partons, Bjorken scaling Structure of hadrons: Quantum chromodynamics - dual role of gluons, gluon emission cross-section, scaling violation.

Text Books:

1. Griffiths, D., *Introduction of Elementary Particles*, (John Wiley and Sons, 1987)
2. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008)
3. Ryder, L. H., *Quantum Field Theory*, (Cambridge University Press, 1996).

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. Perkins, D. H., *Introduction to High Energy Physics*, (Cambridge University Press, 2000).
5. Huang, K., *Quarks, Leptons and Gauge Field*, (World Scientific, 1992).
6. Aitchison, I. J. R. and Hey, A. J. G., *Gauge Theories in Particle Physics*,(Adam Hillier,2004).
7. Chang, S. J., *Introduction to Quantum Field Theory*, (World Scientific, 1990).

PH 556: Particle Physics II **(L2-T1-P0-CH3-CR3)**

Weak Interactions: V-A theory, nuclear β -decay, neutrino-quark scattering, Cabibbo angle, weak mixing angle, CP violation.

Gauge theory: Local and global gauge theory, non-Abelian gauge theory, spontaneous symmetry breaking, Higg's mechanism, Goldstone theorem.

Unification of interactions: Electro-weak interaction, Weinberg-Salam model, grand unified theories, proton decay, neutrino oscillations and neutrino masses, elements of super-symmetry, elements of string theories, present experimental status.

Text Books:

1. Griffiths D., *Introduction of Elementary Particle*, (Wiley-VCH Verlag, 2008).
2. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics, (*Wiley India, 2008).
3. Ryder, L. H., *Quantum Field Theory*, (Cambridge University Press, 1996).

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, 2000).
3. Mandl, F., and Shaw, G., *Quantum Field Theory*, (John Wiley & Sons Inc, 1984).
4. Perkins, D. H., *Introduction to High Energy Physics,* 4th edition, (Cambridge University Press, 2000).
5. Huang, K., *Quarks, Leptons and Gauge Field*, 2nd edition, (World Scientific, 1991).
6. Aitchison, I. J. R. and Hey Gauge A. J. G., *Theories in Particle Physics*, (Taylor and Francis, 2002).
7. Chang, S. J., *Introduction to Quantum Field Theory*, (World Scientific, 1989).

PH 541: Plasma and Astrophysics **(L2-T1-P0-CH3-CR3)**

(Same as given under Astrophysics)

Course Code	Course Name	L-T-P	CH	CR	Remarks
Photonics					
PH 510	Fiber Optics and Optoelectronics	2-1-0	3	3	
PH 557	Photonics	2-1-0	3	3	
PH 523	Microwave systems and Antenna Propagation	2-1-0	3	3	
PH 603	Fourier Optics and Holography	2-1-0	3	3	
PH 558	Quantum Electronics	2-1-0	3	3	
PH 559	Nanophotonics	2-1-0	3	3	

PH 510: Fiber Optics and Optoelectronics **(L2-T1-P0-CH3-CR3)**

(Same as given under Electronics)

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

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.

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

Text and Reference Books:

1. Shen, Y. R., *Principle of Non-Linear Optics,* (Wiley India, 2013).
2. 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).
3. Boyd, R. W., *Non-Linear Optics*, (Elsevier, 2006) Second edition.
4. Fukuda, M., *Optical Semiconductor Devices*, (John Wiley & Sons, 2005).
5. Chuang, S. L., *Physics of Photonic Devices*, (Wiley Series, 2009).

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

(As under Electronics)

PH 603: Fourier Optics and Holography **(L2-T1-P0-CH3-CR3)**

Analysis of 2-dimensional signals: Fourier series, 2-dimensional signals, Fourier transform (FT) theorems, sampling theorem.

Diffraction Theory: Huygens' diffraction theory, Kirchhoff's diffraction theory, Fresnel diffraction, Fraunhofer diffraction, Talbot imaging.

Wave-optics analysis of coherent systems: Conditions for imaging and Fourier transformation by a lens, optical transfer function (OTF) of a lens.

Recording Materials: Photographic emulsions, thermoplastics, photopolymers, photo-refractives, spatial light modulators (SLM), charge coupled devices (CCD) and CMOS.

Applications: Filter types, Abbe-Porter experiment, 4-f optical processor, Zernike phase-contrast, Vander Lugt Filter, joint transform Correlator, matched filtering, inverse filter, processing of side looking radar (SAR) data.

Holography: Recording and reconstruction; hologram types: thin, thick, transmission, reflection, amplitude and phase, computer generated holograms, hologram interferometry (HI), applications of HI, digital holography.

Text Books:

1. Goodman, J., *Introduction to Fourier Optics*, 3rd edition, (Roberts and Company Publishers, 2004) (ISBN-10: 0974707724).
2. Steward, E. G., *Fourier Optics: An Introduction*, 2nd edition, (Dover Publications, 2011) (ISBN-10: 0486435040).
3. Hariharan, P., *Optical Holography: Principles, Techniques and Applications*, (Cambridge University Press, 1996) (ISBN-10:0521433487).
4. Sirohi, R. S., *Wave Optics and Applications*, (Orient Longman, 1993).

Reference Books:

1. Voelz, D. G., *Computational Fourier Optics: A MATLAB Tu*torial (SPIE Tutorial Texts Vol.TT89), (SPIE Press, 2011) (ISBN-10: 0819482048).
2. Gaskill, J. D., *Linear Systems, Fourier Transforms, and Optics*, (Wiley-Interscience, 1978) (ISBN-10: 0471292885).

PH 558: Quantum Electronics **(L2-T1-P0-CH3-CR3)**

Introduction to quantum electronics, review of electromagnetic theory, quantization of the electromagnetic field, coherent states.

Gaussian beams, optical resonators and rate equations, types of lasers.

Physical origin of nonlinear polarization, second harmonic generation, birefringence and quasi-phase matching, self-phase modulation, optical soliton.

Stimulated Raman scattering, higher-order nonlinearlities and phase conjugation, Q-switching and mode-locking.

Propagation in wave guides, photonic crystals, negative dispersion.

Text Books:

1. Yariv, A., *Quantum Electronics*, 3rd edition, (Wiley, 1989).
2. Saleh, B. E. A. and Teich, M. C., *Fundamentals of Photonics*, (John Wiley and Sons, 1991).

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 546	Plasma Generation and Application	2-1-0	3	3	
PH 547	Nonlinear Plasma Physics	2-1-0	3	3	
PH 539	Advanced Condensed Matter Physics and Material Science	2-1-0	3	3	
PH 536	Basic Astronomy & Astrophysics	2-1-0	3	3	
PH 537	High Energy and Extragalactic Physics	2-1-0	3	3	
PH 541	Plasma and Astrophysics	2-1-0	3	3	

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

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 546: Plasma Generation and Applications (L2-T1-P0-CH3-CR3)

Basic principles of gas discharge physics: Electrical breakdown, Generation of thermal and non-thermal plasma, DC and RF (radiofrequency) discharges, Microwave discharge, Dielectric barrier discharge.
Fundamentals of vacuum technology: Vacuum pumps- rotary, diffusion and turbo-molecular pumps, Low pressure measurement systems in laboratory plasma- pressure gauges.
Plasma diagnostic methods: Electric probes (Langmuir and emissive probe), Electric probe characteristics and measurement of plasma parameters (plasma potential, electron & ion density, electron temperature etc.), Magnetic probes, Mass and optical spectroscopy.
Application of Plasma Physics: Thermonuclear fusion- present status and problems, Requirements for fusion plasmas- confinement, beta, power and particle exhaust, Tokamak fusion reactors.
Dusty plasma in laboratory and space, Dust charging processes, Waves in dusty plasma, Dust crystal.
Laser plasma interaction, Inertial confinement, High-harmonic generation, Laser wakefield electron accelerator, X-ray laser.
Plasma engineering, Industrial applications of plasma.

Text Books:

1. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd edition, (Plenum, New York, 1984).
2. Hutchinson, I. H., *Principles of Plasma Diagnostics*, 2nd edition, (Cambridge University Press, 2002).
3. Shukla, P. K. and Mamun, A. A., *Introduction to Dusty Plasma Physics* (IoP, Philadelphia, 2001).
4. Vinod, K., *Astrophysical Plasmas and Fluids* (Springer, New Delhi, 1998).
5. Kruer, W. L., *The Physics of Laser Plasma Interactions* (Cambridge University Press, Cambridge 1988).
6. Lieberman, M. A. and Lichtenberg, A. J., *Principles of Plasma Discharges and Materials Processing* (John Wiley, New York, 1994).

Reference Books:

1. Nicholson, D. R., *Introduction to Plasma Theory* (John Wiley & Sons, New York, 1983).
2. Smirnov, B. M., *Physics of Ionized Gases* (John Wiley & Sons, New York, 2007).
3. Huddlestone R. H. and Leonard S. L., *Plasma Diagnostic Techniques* (Academic Press, Cambridge, 1965).

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

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).

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

(As under Condensed Matter Physics)

PH 536: Basic Astronomy & Astrophysics (L2-T1-P0-CH3-CR3)

(As under Astrophysics)

PH 537: High Energy & Extragalactic Astrophysics (L2-T1-P0-CH3-CR3)

(As under Astrophysics)

PH 541: Plasma and Astrophysics (L2-T1-P0-CH3-CR3)

(As under Astrophysics)

Course Code	Course Name	L-T-P	CH	CR	Remarks
Nano-Science					
PH 542	Nanostructures	2-1-0	3	3	
PH 543	Surface Science	2-1-0	3	3	
PH 559	Nanophotonics	2-1-0	3	3	
PH 554	Soft Condensed Matter Physics	2-1-0	3	3	
PH 548	Nanobiophysics	2-1-0	3	3	
PH 549	Nanomagnetism	2-1-0	3	3	

PH 542: Nanostructures (L2-T1-P0-CH3-CR3)

Introduction to nanoscale materials: Quantum mechanical treatment, parabolic well, rectangular well, triangular well, cylindrical well and spherical well, quantum well, quantum wire and quantum dots, quantum size effect, size and dimensionality effects of density of states, Bohr excitons, strong and weak confinements, oscillator strength, blue-shift energy and effective mass approximation model, semiconductor nanoparticles, nanorods and nanotubes, metallic nanostructures, carbon nanotubes, graphene and layered systems.

Surface properties: Phonons in nanostructured systems, surface optic phonons, surface plasmons, interfacial charge transfer, grain growth, surface defects, Langmuir relation, Ostwald ripening, Hall-Petch relation, grain correlated properties.

Synthesis techniques: Top-down vs. bottom-up techniques, sol-gel method, solution growth and hydrothermal routes, mechanical milling and solid state reaction techniques, chemical and photochemical reduction routes, thermal evaporation and e-beam evaporation methods, molecular beam epitaxy.

Analytical tools: X-ray diffraction, optical absorption and emission spectroscopy, Raman spectroscopy, scanning and transmission electron microscopy.

Green nanotechnology, challenges in nanotechnology.

Text Books:

1. Cao, G. and Wang, Y., *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, 2nd edition, (World Scientific, 2011).
2. Rao, C. N. R., Thomas, P. J. and Kulkarni, G. U., *Nanocrystals: Synthesis, Properties and Applications*, (Springer-Verlag, 2007).
3. Poole, Jr. C. P. and Owens, F. J., *Introduction to Nanotechnology*, (Wiley, 2003).
4. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
5. Nouailhat, A., *An Introduction to Nanosciences and Nanotechnology*, (Wiley 2007).

Reference Book:

1. Ariga, K., *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics,* (Royal Society of Chemistry, 2012).

PH 543: Surface Science **(L2-T1-P0-CH3-CR3)**

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, bulk electronic state, surface electronic state, Energy levels at metal interfaces, structural defects at surfaces - point defects, steps, faceting, adatoms, dislocations.

Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics.

Non-equilibrium growth, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, binding energies and activation barriers, adsorption isotherms, rate of desorption, lateral interaction.

Chemisorption, physisorption and dynamics, heterogenous catalysis process.

Atomistic mechanisms of surface diffusion – hopping mechanism, atomic exchange mechanism, tunneling mechanism.

Surface analysis: scanning probe microscopy, photoelectron spectroscopy, Auger electron spectroscopy, electron energy loss spectroscopy, low energy electron diffraction.

Text Books:

1. Deb, P., *Kinetics of Heterogeneous Solid State Processes*, (Springer, 2013).
2. Oura, K. Lifshits, V. G. Saranin, A. A. Zotov, A. V. and Katayama M., *Surface Science: An Introduction*, 2nd edition, (Springer, 2010).
3. O'Connor, D. J. Sexton, B. A. and Smart R. S. C., *Surface Analysis Methods in Materials Science*, 2nd edition, (Springer, 2010).
4. Desjonqueres, M.-C. and Spanjaard, D., *Concepts in Surface Physics*, 2nd edition, (Springer, 2002).
5. Kolasinski, K. W., *Surface Science, Foundations of Catalysis and Nanoscience*, (Wiley,2002).

Reference Book:

1. Richardson, N.V. and Holloway, S., *Handbook of Surface Science*, Vol. 4, (Elsevier, 2014)

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

(As under Photonics)

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

(As under Condensed Matter Physics)

PH 548: Nanobiophysics **(L2-T1-P0-CH3-CR3)**

Amphipathic molecules and packing parameters, prokaryotic and eukaryotic cells, properties of polysaccharides, proteins, lipids and nucleic acids. Structure and function of biological membranes. Electrokinetic phenomena, Electric double layer, Excitable membranes, Action potential, Hodgkin-Huxley model and ion channels. Free energy and entropy. Diffusion and sub-diffusion, Brownian and non-Brownian motion, life at low Reynold number.

Biosynthesis and characterization of nanoparticles, nano-bio conjugation, FRET, biopolymers, motor proteins, Staining of cells, organic and inorganic markers, cytotoxic and membrane stability tests, Artificial photo-synthesis. Elements of nanotoxicology and immunology.

Bio-imaging and analysis, fluorescence and confocal microscopy, FRAP, TIRF, STED and STORM. Linear and circular dichroism and related analytical tools. Monte Carlo and MD simulation techniques.

Gene structure and function, DNA sequencing, Gel-electrophoresis. Polymerase chain reaction (PCR), DNA chip and computing.

Applications in biosensors, diagnostics and therapeutics.

Text Books:

1. Niemeyer, C. M. and Mirkin, C. A., *Nanobiotechnology: Concepts, Applications and Perspectives*, (Wiley-VCH, 2004).
2. Cotteril, R., *Biophysics: An introduction*, 1st edition (Wiley, 2009).

Reference Books:

1. S. Dumitriu (Editor), *Polymeric biomaterial*, (Marcel Dekker, 1989).
2. Lodish, H., Berk, A., Matsudaira, P., Zipursky, S. L., Baltimore, D., Darnell, J., *Molecular Cell Biology*, 5th Edition, (Macmillan Higher Education, 2004).
3. Calladine and Drew, A. P., *Understanding DNA*, (Academic Press, 2004)
4. Yagle, P., *The membranes of cells*, (Academic press, 1993)
5. Glaser, R., *Biophysics*, 1st edition (Springer, 2001)
6. Brown, T. A., *Genomes*, 2nd edition, (Wiley-Liss, 2002).
7. Donbrow, M., (Editor), *Microcapsules and Nanoparticles in Medicine and Pharmacy*, (CRC Press, 1992).
8. Grigorenko, E. V., *DNA Arrays: Technologies and experimental strategies*, (CRC Press,2000).
9. Gregoriadis, G., *Liposomes in Biological systems*, (Wiley-Blackwell, 1980)
10. Nelson, P., *Biological Physics: Energy, Information and Life*, (Freeman, 2007).

PH 549: Nanomagnetism **(L2-T1-P0-CH3-CR3)**

Classical and Quantum Magnetism, Magnetism of Atoms, Magnetic Ordering, Micromagnetism, Domain and Hysteresis, Paramagnetism, Ferromagnetism, Anti-ferromagnetism, Ferrimagnetism, Magnons, Exchange Interactions.

Magnetic Anisotropy, Order and Broken Symmetry, Consequences of Broken Symmetry, Landau theory of Ferromagnetism, Heisenberg and Ising model, Domain and Domain Walls, Equation of Motion for Domain Walls.

Nanoscale Magnetism, Superparamagnetism, Stoner-Wohlfarth model, Interparticle Interaction.
Magnetoresistance - Magnetoresistance of Ferromagnets, Anisotropic Magnetoresistance.

Giant Magnetoresistance, Spintronics, Molecular magnetism.
Nuclear Magnetic Resonance, Magnetic Resonance Imaging.

Neutron Diffraction, SQUID.

Text Books:

1. Coey, J. M. D., *Magnetism and Magnetic Materials*, (Cambridge University Press, 2009).
2. Cullity, B. D. and Graham C. D., *Introduction to Magnetic Materials*, 2nd Edition, (Wiley IEEE Press, 2008).

Reference Books:

1. Peddie, W., *Molecular Magnetism*, (Nabu Press, 2011).
2. Spaldin, N. A., *Magnetic Materials: Fundamentals and Applications*, 2nd Edition, (Cambridge University Press, 2010).

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