Course Structure of M. Sc. Programme

SEMESTER-l

Code	Name	L	T	P	C
PH401	Mathematical Physics-I	3	1	0	8
PH403	Classical Mechanics	3	1	0	8
PH405	Quantum Mechanics-I	3	1	0	8
PH407	Computer Programming	2	0	2	6
PH409	Electronics	3	1	0	8
PH411	Physics Laboratory-I	0	0	4	4
		14	4	6	42

SEMESTER-2

Code	Name	L	T	P	C
PH402	Mathematical Physics-II	3	1	0	8
PH404	Statistical Mechanics	3	1	0	8
PH406	Quantum Mechanics-II	3	1	0	8
PH408	Numerical Methods and Computational Physics	2	0	2	6
PH410	Electrodynamics- I	3	1	0	8
PH412	Physics Laboratory-II	0	0	6	6
		14	4	8	44

SEMESTER-3

Code	Name	L	T	P	C
PH501	Electrodynamics- II	3	1	0	8
PH503	Atomic and Molecular Physics	3	1	0	8
PH505	Solid State Physics	3	1	0	8
PH507	Nuclear and Particle Physics	3	1	0	8
PH511	Physics Laboratory-III	0	0	6	6
PH513	Project I	0	0	4	4
		12	4	10	42

SEMESTER-4

Code	Name	L	T	P	C
PH512	Measurement Techniques	2	0	3	7
PH514	Project II	0	0	12	12
PH5xx	Elective-I	3	1	0	8
PH5xx	Elective-II	3	1	0	8
PH5xx	Elective-III	3	1	0	8
		11	3	15	43

Note: Electives have to be taken from at least two different groups: Condensed Matter, Lasers and Photonics, and Theoretical Physics. One of the electives can be taken from Institute electives.

M. Sc. Courses:
PH401: Mathematical Physics – I 3 1 0 8

Vector Analysis: Gradient, divergence, and curl in curvilinear co-ordinate system. Tensors: Addition, subtraction, inner and outer products, contraction, symmetric and antisymmetric tensors, quotient law, metric tensor, covariant and contravariant derivatives, tensor differential operators.
Linear Algebra: Vector spaces, subspaces, linear independence, spans, basis, dimensions, linear transformation, image and kernel, rank and nullity, change of basis, similarity transformations, inner product spaces, orthonormal sets, Gram-Schmidt procedure, dual space, eigenvalues and eigenvectors, Hilbert space.
Complex Analysis: Functions, derivatives, Cauchy-Riemann conditions, analytic and harmonic functions, contour integrals, Cauchy-Goursat Theorem, Cauchy integral formula. series: convergence, Taylor series, Laurent series, singularities, residue theorem, applications of residue theorem, conformal mapping and applications.

Texts:

1. G. B. Arfken and H. J. Weber, *Mathematical Methods for Physicists*, Academic Press (1995).
2. T. Lawson, *Linear Algebra*, John Wiley & Sons (1996).
3. R. V. Churchill, *Complex Variables and Applications.* McGraw Hill (1990).

References:

1. M. L. Boas, *Mathematical Methods in Physical Sciences,* John Wiley & Sons (1983).
2. A. W. Joshi, *Matrices and Tensors in Physics*, New Age (1995).
3. S. Lang, *Introduction to Linear Algebra,* Springer (1986).

PH402: Mathematical Physics – II 3 1 0 8

Ordinary Differential Equations: First and second order equations with constant coefficients, series solution-Frobenius' method, Sturm-Liouville equations, Legendre, Bessel,
Hermite, and Laguerre functions, Hypergeometric and confluent hypergeometric equations.
Integral Transforms: Fourier and Laplace transforms, applications.
Partial Differential Equations: Laplace equation, method of separation of variables in Cartesian, Spherical, and Cylindrical coordinates, Green's function for Laplace equation, wave equations, Helmholtz equation.
Group Theory: Groups, subgroups, conjugacy classes, cosets, invariant subgroups, factor groups, homomorphism, kernels, continuous groups, Lie groups, generators, SO(2) and SO(3), SU(2). Group representations.

Texts:

1. G. B. Arfken and H. J. Weber, *Mathematical Methods for Physicists,* Academic Press (1994).
2. A. W. Joshi, *Elements of Group Theory,* New Age (1997).

References:

1.M. L. Boas, *Mathematical Methods in Physical Sciences,* John Wiley & Sons (1983). 2. E. A. Coddington, *Introduction to Ordinary Differential Equations,* Prentice Hall of India (1995).
3. I. Sneddon, *Elements of Partial Differential Equations,* McGraw Hill (1986).
4. M. Hamermesh, Group Theory and Its Applications to Physical Problems, Dover (1989).

PH403: Classical Mechanics 3 1 0 8

Review: Application of Newton's Laws and Conservation Laws
Lagrangian Dynamics: Mechanics of a system of particles, constraints and generalized coordinates, Lagrange's equations, applications. Variational calculus and Least Action principle.
Central force problem: Equations of motion, orbits, Virial theorem, Kepler problem, scattering in a central force field.
Rigid body motion: Orthogonal transformations, Euler angles, coriolis effect, angular momentum and kinetic energy, tensors and dyadic, inertia tensor, Euler equations, applications, heavy symmetrical top.
Hamiltonian formulation: Legendre transformations, Hamilton equations, cyclic coordinates and conservation theorems, principle of least action, canonical transformations, Poisson brackets, Hamilton-Jacobi theory, Action-angle variables.
Small oscillations: Eigenvalue problem, frequencies of free vibrations and normal modes, forced vibrations, dissipation.
Classical field theory: Lagrangian and Hamiltonian formulation of continuous system.

Texts

1. H. Goldstein, *Classical Mechanics,* 2nd Edition, Narosa, (1985).

References

1. L. Landau and E. Lifshitz, *Mechanics,* Oxford (1981).
2. F. Scheck, *Mechanics,* Springer (1994).

PH404: Statistical Mechanics 3 1 0 8

Review of Thermodynamics: Laws of thermodynamics, entropy, potentials.
Statistical Thermodynamics: Macroscopic and microscopic states, connection between statistics and thermodynamics, classical ideal gas, entropy of mixing and Gibb's paradox.
Ensemble Theory: Phase space, Liouville's theorem, microcanonical ensemble, examples, quantum states and phase space.
Canonical Ensemble: Equilibrium, partition function, energy fluctuation, equipartition and Virial theorem, harmonic oscillators, statistics of paramagnetism

Grand Canonical Ensemble: Equilibrium, partition function, density and energy fluctuation, correspondence with other ensembles, examples.
Formulation of Quantum Statistics: Quantum mechanical ensemble theory, density Matrix, statistics of various ensembles, examples.
Theory of Simple Gasses: Ideal gas in different quantum mechanical ensembles. Systems of: monatomic, diatomic and polyatomic molecules.
Ideal Bose Gas: Thermodynamics, Bose-Einstein condensation, blackbody radiation, phonons, Helium II.
Ideal Fermi Gas: Thermodynamics, Pauli paramagnetism, Landau diamagnetism, DeHassVan Alphen Effect, thermionic and photoelectric emissions, white dwarfs.
Interacting Systems: Cluster expansion, Virial Expansion, evaluation of Virial coefficients.

Texts:

1. R. K. Pathria, *Statistical Mechanics,* Butterworth-Heinemann (1996).

References:

1. F. Reif, *Statistical and Thermal Physics,* McGraw-Hill (1985).
2. W. Greiner, L Neise, and H. Stocker, *Thermodynamics and Statistical Mechanics,* Springer (1994).
3. K. Huang, *Statistical Mechanics,* John Wiley Asia (2000).
4. L. D. Landau and E. M. Lifshitz, *Statistical Physic~I,* Pergamon (1980).

PH405: Quantum Mechanics-I 3 1 0 8

Introduction to Quantum Theory: Wave-Particle duality, matter waves, group velocity, phase

velocity, uncertainty principle, wave packets.
Basic postulates of quantum mechanics, concept of probability and probability current density, Schrodinger equation. Operators, eigenvalues and eigenfunctions.
Simple potential problems: Particle in a box, steps, barriers, wells, bound states, deltafunction potential, linear harmonic oscillator, Hermite polynomials.
Matrix formulation of Quantum Mechanics: Linear and matrix algebra, Dirac's bra and ket notation, matrix representations of vectors and operators, expectation values, different representations in quantum mechanics, parity operation. Matrix theory of harmonic oscillator.
Theory of Angular Momentum: Spherical harmonics, eigenvalues for L^2, *Lz,* commutation relations, quantum numbers, degeneracies.
Schrodinger Equation for Central Potential: Hydrogen atom, power series solution for the radial part, energy quantization, quantum numbers, Laguerre polynomials, 3-dimensional harmonic oscillator.

Texts

1. S. Gasiorowicz, *Quantum Physics*, John Wiley (Asia) (2000).

References

1. P. W. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics,* Tata McGraw Hill (1995).
2. F. Schwabl, *Quantum Mechanics,* Narosa (1998).
3. L. 1. Schiff, *Quantum Mechanics*, Mcgraw-Hill (1968).
4. E. Merzbacher, *Quantum Mechanics,* John Wiley (Asia) (1999).
5. B. H. Bransden and C. J. Joachain, *Introduction to Quantum Mechanics*, Longman (1993)

PH406: Quantum Mechanics-II 3 1 0 8

Perturbation Theory: Non-degenerate and Degenerate Cases. applications: Zeeman and Stark effects. Induced electric dipole moment of Hydrogen
Real Hydrogen Atom: Relativistic correction, spin-orbit coupling, hyperfine interaction, Helium atom, exclusion principle, exchange interaction.
Schr6dinger equation for a slowly varying potential, WKB approximation, turning points, connection formulae, derivation of Bohr-Sommerfeld quantization condition, applications ofWKB.
Time Dependent Perturbation Theory: Sinusoidal perturbation, Fermi's Golden Rule, special topics in radiation theory, semi-classical treatment of interaction of radiation with matter, Einstein's coefficients, spontaneous and stimulated emission and absorption, application to lasers.
Scattering Theory: Born Approximation, scattering cross section, Greens functions. scattering for different kinds of potentials, applications.
Relativistic Invariance, Dirac equation, solution offree field Dirac equation, Klein-Gordon equation.

Texts:

1. S. Gasiorowicz, *Quantum Physics,* John Wiley (Asia) (2000).
2. E. Merzbacher, *Quantum Mechanics,* John Wiley (Asia) (1999).

References:

1. P. W. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics,* Tata McGraw Hill (1995).
2. F. Schwabl, *Quantum Mechanics,* Narosa (1998).
3. L. I. Schiff, *Quantum Mechanics*, Mcgraw-Hill(1968).
4. B. H. Bransden and C. J. Joachain, *Introduction to Quantum Mechanics*, Longman (1993)

PH407: Computer Programming 2 0 2 6

Introduction to personal computers and operating systems (DOS/Windows and Linux), graphics packages.
C Programming Language: Algorithms, flow charts, constants, variables, expressions,

conditional statements, loops, arrays, logical expressions, control statements, functions, structures, pointers, bit operation, files in C.
Solving simple problems using C programming Language.

Texts:

1. V. Rajaraman, *Computer programming in C*, Prentice-Hall (2000).

References:

1. M. M. Mano, *Computer System Architecture*, Prentice Hall (1993).
2.P. Norton, *Complete Guide to Windows*, Prentice Hall (1995). 3. K.
Srirengan, *Understanding Unix*, Prentice Hall (1999).
4. B. W. Kernighan and D. M. Ritchie, *The C Programming Language*, Prentice-Hall (2001).

PH408: Numerical.Methods qnd Computatlonal-Physics 2 0 2 6

Errors: Its sources, propagation and analysis, computer representation of numbers. Roots of Nonlinear Equations: Bisection, Newton-Raphson, secant method. System of Nonlinear equations, Newton's method for Nonlinear systems. Applications in Physics problems.
Solution of linear systems: Gauss, Gauss-Jordan elimination, matrix inversion and LU decomposition. Eigenvalues and Eigenvectors. Applications.
Interpolation and Curve fitting: Introduction to interpolation, Lagrange approximation, Newton and Chebyshev polynomials. Least square fitting, linear and nonlinear. Application in Physics problems.
Numerical Differentiation and Integration: Approximating the derivative, numerical differentiation formulas, introduction to quadrature, trapezoidal and Simpson's rule, Gauss-Legendre integration. Applications.

Solution of ODE: Initial value and boundary value problems, Euler's and Runge-,Kutta methods, Finite difference method. Applications in Chaotic dynamics, Schrodinger equations.
Solution of PDE: Hyperbolic, Parabolic, and Elliptic Equations by finite difference. Application to 2-dimensional Electrostatic Field problems.

Texts:

1. K. E. Atkinson, *Numerical Analysis*, John Wiley (Asia) (2004).
2. S. C. Chapra and R. P. Canale, *Numerical Methods for Engineers*, Tata McGraw Hill (2002).

References:

1. J. H. Mathews, *Numerical Methods for Mathematics, Science, and Engineering*, Prentice Hall of India (1998).
2. S. S. M. Wong, *Computational Methods in Physics*, World Scientific (1992).
3. W. H. Press, S. A. Teukolsky, W. T. Verlling and B. P. Flannery, *Numerical Recipes in C*, Cab ridge (1998).

PH409: Electronics 3 1 0 8

Analog electronics: Network theorems; application to simple circuits.
p-n junction devices, diode, transistors; biasing schemes; small signal amplifiers; feed-back theory; oscillators; power supply; wave shaping circuits.
JFET and MOSFET characteristics and small signal amplifier.
OP-AMP: Differential amplifiers; Op-Amp (741) circuits (amplifiers; scalar; summer; subtractor; comparator; logarithmic amplifiers; multiplier; divider; differentiator, integrator; analog computer; wave shapers; oscillators).

Multivibrators: Astable, monostable and bistable MV using BJT and IC555.
Digital electronics: number systems; decimal, binary, octal and hexadecimal system arithmetics; logic families; logic gates; Boolean algebra; De Morgan's laws; simplifying Boolean expressions; arithmetic circuits (adders, subtractor); flip-flops; registers; counters; memOrIes.
AID and D *I* A conversion: resolution and speed; various circuits.
INTEL 8085 microprocessor: Architecture and function; addressing modes; instruction codes and their execution; programmable peripheral interface; simple programming.

Texts:

1. A. Mottershead, *Electronic Devices and Circuits,* Prentice Hall of India (1993).
2. J. Millman and C. C. Halkias, *Integrated Electronics,* Tata McGraw Hill (1995).

3.R. Gaekwad, *Op-Amps and Linear Integrated Circuits*, Prentice Hall of India (1995). 4. A. P. Malvino and D. P. Leach, *Digital Principles and Applications,* Tata McGraw Hill (1991).
4.R. S. Gaonkar, *Microprocessor Architecture: Programming and Applications with the 8085,* Penram India (1999).

PH410: Electrodynamics - I 3 1 0 8

Electrostatics: Continuous Charge Distribution, Delta Function, Field and Potential, Poisson and Laplace's equations, Boundary Conditions and Uniqueness theorems, Electrostatic potential energy, Capacitance, Conductors.
Boundary Value Problems: Solution of Laplace and Poisson equations in 2 & 3 dimensions. Method of images, separation of variables in Cartesian, Cylindrical and Spherical coordinate systems, Multipole expansion, Green's function approach.
Dielectrics: Polarization, bound charges, susceptibility, energy and force, boundary conditions, boundary value problems.
Magnetostatics: Biot-Savert's Law, Ampere's law, vector potential, magnetic field, moments, force, torque and energy of localized current distributions. Boundary conditions, boundary value problems.
Electrodynamics: Electromotive force, Ohm's law, Faraday's law, self and mutual inductance, energy in magnetic fields, Maxwell's equations, Gauge transformations, potential formulation, energy and momentum conservation, Poynting theorem.
Electromagnetic Waves: Wave equation, Propagation of electromagnetic waves in non conducting medium, reflection, transmission, Snell's law, Brewster's angle, critical angle, Dispersion in non conducting medium.

Texts:

1. J. D. Jackson, *Classical Electrodynamics,* John Wiley (Asia) (1999).

References:

1. J. R. Reitz and F. J. Millford, *Foundation of Electromagnetic Theory,* Narosa (1986).
2. W. Greiner, *Classical Electrodynamics,* Springer (1998).
3. L. D. Landau and E. M. Lifshitz, *Electrodynamics of Continuous Media,* Butterworth Heimemann (1995)

PH411: Physics Laboratory-I 0 0 4 4

Typical experiments: I-V characteristics of a Zener and voltage regulation; diode clipping, clamping and voltage doubler circuits; half-wave, full-wave and bridge rectifier circuits; I/O. characteristics of BJT in CB and CE configuration; Single stage amplifier using a FET; OP-Amp. Circuits: Inverting and non-inverting amplifier, addition, subtraction, differentiation and integration; ColI pitt and Wien bridge oscillators; monostable and astable multivibrator using NE555; Ttut4 table of logic gates; universality of NOR/NAND gates; Verification of De Morgan's theorem, half-adder, JK flip-flop, binary counter; assembly language programming exercises with the INTEL 8085 microprocessor kit.

References:

1. P. B. Zbar and A. P. Malvino, *Basic Electronics: a text-lab manual,* Tata McGraw Hill (1983).
2. D. P. Leach, *Experiments in Digital Principles,* McGraw Hill (1986).
3. R. S. Gaonkar, *Microprocessor Architecture: Programming and Applications with the 8085,* Penram India (1999).

PH412: Physics Laboratory-II 0 0 6 6

A set of experiments in:
General Physics: Phase and group velocities of sound waves, Dielectric constant of a liquid, Ultrasonic velocity in liquid, Young's modulus, Magnetic susceptibility of a liquid, etc.
Optics: Diffraction of light, Speed of light in glass/liquid, Polarization of light, etc. Electronics: Study of p-n junction, Interfacing experiments with microprocessor kit, etc. Solid State

Physics: Electrical resistivity of semiconductors, Hall effect in semiconductors, Study of magnetic hysteresis, etc.

References:

1. R. A. Dunlop, *Experimental Physics,* Oxford University Press (1988).
2. A. C. Melissinos, *Experiments in Modern Physics,* Academic Press (1996).

PH501: Electrodynamics - II 3 1 0 8

Electromagntic Waves in Conducting medium: Reflection and transmission, frequency dependence of permittivity, permeability and conductivity, electrons in conductors and plasma.
Wave Guides: Waves between parallel conductors, TE and TM waves, Rectangular and Cylindrical wave guides.
Radiations: Moving Charges, Lienard- Wiechert potential, accelerated charges, angular distribution of radiations, distribution of frequency and energy, Thomson's scattering, Bremsstrahlung in Coulomb collisions.
Radiating Systems and Multipole fields: Electric dipole fields and radiations, quadrupole fields, multipole expansion, Energy, angular momentum, multipole radiations.
Scattering and Diffraction: Scattering at long wavelengths, perturbation theory, Rayleigh scattering, diffraction theory-Kirchhoff's integral and applications.
Special Theory of Relativity: Lorentz Transformations and it's consequences, conservation laws, mass energy relation, relativistic momentum and energy, relativistic force. Relativistic Electrodynamics: Covariant formalism of Maxwell's equations, Transformation laws and their physical significance, relativistic generalization of Larmor's formula, Relativistic formulation of radiation by single moving charge.

Texts:

1. J. D. Jackson, *Classical Electrodynamics,* John Wiley (Asia) (1999).
2. R. Resnick, *Introduction to Special Relativity* John Wiley (Asia) (1999)

References:

1. E. C. Jordan and K. G. Balmain, *Electromagnetic Waves and Radiating Systems*, Prentice Hall (1995).
2. J. Schwinger et aI, *Classical Electrodynamics*, Persesus Books (1998).
3. G. S. Smith, *Clasical Electromagnetic Radiation*, Cambridge (1997).

PH503: Atomic and Molecular Physics 3 1 0 8

Review of one-electron and two-electron atoms: Schrodinger equation, para and ortho states, Pauli exclusion principle, Excited states, doubly exciteq states, Auger effect, resonance.
Many electron atoms: Central field approximation, Thomas-Fermi model, Hartee-Fock method and self-consistent field, Hund's rule, L-S and j-j cuopling.
Interaction with Electromagnetic fields: Selection rules, spectra of alkalis, Helium and alkaline earths, multiplet structure, Zeeman and Stark effect.
Molecular structure: General nature, Born-Oppenheimer separation, rotation and vibration of diatomic molecules, electronic structure of diatomic molecules, structure of polyatomic molecules.
Molecular spectra: Rotational, vibrational, electronic spectra of diatomic molecules, electronic spin and Hund's cases and nuclear spin, Raman and Infra-Red spectrums.
Atomic collisions: Types of collisions, channels, thresholds, cross-sections, potential scattering, general features, Born approximation.
Resonance Spectroscopy: NMR, NQR, ESR and Mossbauer spectroscopies.

Texts:

1. B. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules,* Longman (1996).

References:

1. G. K. Woodgate, *Elementary Atomic Structure*, Clarendon Press (1989).
2. F. L. Pilar, *Elemntary Quantum Chemistry*, McGraw Hill (1990).
3. H. E. White, *Introduction to Atomic Spectra*, Tata McGraw Hill (1934).
4. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy,* Tata McGraw Hill (1994) ....

PH505: Solid State Physics 3 1 0 8

Crystal physics: Symmetry operations; Bravais lattices; Point and space groups; Miller indices and reciprocal lattice; Structure determination; diffraction; X-ray, electron and neutron; Crystal binding; Defects in crystals; Point and line defects.
Lattice vibration and thermal properties: Einstein and Debye models; continuous solid; linear lattice; acoustic and optical modes; dispersion relation; attenuation; density of states; phonons and quantization; Brillouin zones; thermal conductivity of metals and insulators.
Electronic properties: Free electron theory of metals; electrons in a periodic potential; Bloch equation; Kronig-Penny model; band theory; metal, semiconductor and insulators; bandgap; intrinsic and extrinsic semiconductors, Hall Effect, p-n junction.
Dielectrics: Polarizability; Clausius-Mossotti formula; Dielectric constant; ferroelectrics.
Magnetism: Diamagnetism, paramagnetis'm, ferromagnetism, antiferro magnetism and ferrimagnaetism.
Superconductivity: Meissner effect; London equations; coherence length; type-I and typeII superconductors.

Texts:

1.H. P. Myers, *Introduction to Solid State Physics,* Viva books (1998). 2. M. A. Omar, *Elementary Solid State Physics,* Addison-Wesley (1975).

References:

1. C. Kittel, *Introduction to Solid State Physics,* John Wiley (1996).
2. A. J. Dekker, *Solid State Physics,* Macmillan (1986).
3. N. W. Ashcroft and N. D. Mermin, *Solid State Physics,* HBC Publ., (1976).

PH507: Nuclear and Particle Physics 3 1 0 8

Nuclear properties: radius, size, mass, spin, moments, abundance of nuclei, binding energy, excited states.
Nuclear forces: deuteron, n-n and p-p interaction, nature of nuclear force.
Nuclear Models: liquid drop, shell and collective models.
Nuclear decay and radioactivity: radioactive decay, detection of nuclear radiation, alpha, beta and gamma decays, radioactive dating.
Nuclear reactions: conservation laws, energetics, isospin, reaction cross section, Coulomb scattering, nuclear scattering, scattering cross section, optical model, compound nucleus, direct reactions, resonance reactions, neutron physics, fission, fusion.
Particle accelerators and detectors: electrostatic accelerators, cyclotron, synchrotron, linear accelerators, colliding bean accelerators, gas-filled counters, scintillation detectors, semiconductor detectors.
Elementary particles: forces, quantum numbers, mesons and Yukawa's hypothesis, pions, CPT theorem, strange mesons and baryons, production and decay of resonances, CP violation in K decay.
Particle physics: Symmetries and conservation laws, Feynman diagrams, Gell-MannNishijima relation, Quark model, coloured quarks and gluons, quark dynamics, standard model.

Texts:

1. K. S. Krane, *Introductory Nuclear Physics,* John Wiley (1988).

Reference:

1. R. R. Roy and B. P. Nigam, *Nuclear Physics: Theory and Experiment,* New Age (1967).
2. A. Das and T. Ferbel, *Introduction to nuclear and particle physics,* John Wiley (1994).
3. I. S. Hughes, *Elementary Particles,* Cambridge (1991).
4. F. Halzen and A. D. Martin, *Quarks and Leptons,* John Wiley (1984).

PH511: Physics Laboratory III 0 0 6 6

A set of experiments in:
Optics: Michelson interferometer, wave guides, etc.
Solid State Physics: Monatomic and diatomic lattice characterisation, Photo-voltaic effect, Magneto-resistance of semiconductors, X-ray diffraction, etc.
Atomic and Molecular Physics: Zeeman effect, emission spectra of gases, Absorption spectrophotometry, etc
Nuclear Physics: Study of alpha and Gamma-rays, etc.

References:

1. R. A. Dunlop, *Experimental Physics*, Oxford University Press (1988).
2. A. C. Melissinos, *Experiments in Modern Physics*, Academic Press (1996).

PH512: Measurement Techniques 2 0 3 7

Sensors: Resistive, capacitative, inductive, electromagnetic, thermoelectric, elastic, piezoelectric, piezoresistive, photosensitive and electrochemical sensors; interfacing sensors and data acquisition using serial and parallel ports.
Low pressure: Rotary, sorption, oil diffusion, turbo molecular, getter and cryo pumps; Mcleod, thermoelectric (thermocouple, thermister and pirani), penning, hot cathode and Bayard Alpert gauges; partial pressure measurement; leak detection; gas flow through pipes and apertures; effective pump speed; vacuum components.
Low temperature: Gas liquifiers; Cryo-fluid baths; liquid He cryostat design; closed cycle He refrigerator; low temperature measurement.
Analytical Instruments: X-ray diffractometer; Spectrophotometers; FT-IR; DSC; lock-in amplifier; spectrum analyzer, fluorescence and Raman spectrometer, scanning electron microscope, atomic force microscope, interferometers.
Laboratory component: physical parameter measurement using different sensors; low pressure generation and measurement; calibration of secondary gauges; cryostat design; CCR operation; data collection from analytical instruments in the department.

References:

1. A. D. Helfrick and W. D. Cooper, *Modern electronic instrumentation and measurement techniques*, Prentice Hall of India (1996).
2. J. P. Bentley, *Principles of measurement systems*, Longman (2000).
3.G. K. White, *Experimental techniques in low temperature physics*, Calrendon (1993). 4. A. Roth, *Vacuum technology*, Elsevier (1990).
5. D. A. Skoog, F. J. Holler and T. A. Nieman, *Principles of Instrumental analysis*, Saunders CoIl. Publ. (1998).

PH514: Project 0 0 12 12

PH5xx: Electives 3 1 0 8

Electives have to be taken from at least two different groups. One of the electives can be taken from Institute electives available.

Group-I: Condensed Matter

PH521: Topics in Condensed Matter Physics

Second Quantization, Diagrammatic Perturbation Theory, Bose and Fermi Liquid Examples; Electron Gas, Hartree Fock Approximation, Dielectric Response, Hubbard Model; Electron-Phonon Interaction, Superconductivity, BCS Theory; Low Dimensional Magnetic Systems, Spin Representations, Linear and Nonlinear Spin Wave Theory, Heisenberg Antiferromagnet, XY Model.

References:
1. W. Fetter and J. D. Walecka, *Quantum Theory of Many-Particle Systems*, McGraw Hill (1971).
2. G. D. Mahan, *Many-Particle Physics*, Plenum Press (1990).
3. C. Kittel, *Quantum Theory of Solids*, John Wiley (1987).
4. M. Tsvelik, *Quantum Field Theory in Condensed Matter Physics*, CUP (1995).
5. N. Nagaosa, *Quantum Field Theory in Condensed Matter Physics*, Springer-Verlag (1999).
6. J. W. Negele and H. Orland, *Quantum Many-Particle Systems*, Addison-Wesley (1988).
7. A. Auerbach, *Interacting Electrons and Quantum Magnetism*, Springer Verlag (1998).
8. E. Fradkin, *Field Theories of Condensed Matter Systems*, Addison Wesley (1991).
9. P. W. Anderson, *Basic Notions of Condensed Matter Physics*, Addison Wesley (1997).

PH522: Physics of Semiconductors

Energy Band Structure, occupation probabilities, Impurities and Imperfection in Semiconductors, carrier concentration in thermal equilibrium, Electron Transport Phenomenon, Thermal Effects in Semiconductors, Excess Carriers in semiconductors, recombination, contact phenomenon, Photoconductivity, Photovoltaic Effect, Scattering Process in Semiconductors: Optical and high frequency effects in semiconductors, Semiconducting Materials, Amorphous semiconductors, structural and electronic properties, applications of amorphous semiconductors.

References:
1. R. A. Smith, *Semiconductors*, Academic Press (1978).
2. K. Seeger, *Semiconductor Physics: An introduction*, Springer Verlag (1991).
3. C. Hamaguchi, *Basic semiconductor physics*, Springer verlag (2001).
4. J. Singh, *Physics of semiconductors*, Tata Mcgraw Hill (1993).
5. K. Morigaki, *Physics of Amorphhous Semiconductor*, Imperial college Press (1999).

PH523: Magnetism and Superconductivity ,

Magnetism: Review of diamagnetism, paramagentism, ferromagnetism, antiferromagnetism, ferri magnetism. Circular and helical order. Direct, exhange, double exchange, indirect and RKKY interactions. enviroment effects: crystal field, tetrahedral and octahedral sites; Jahn-Teller effect; Hund's rule and rare earth ions in solids. Consequences of broken symmetry, phase transition, Landau's theory, rigidity, excitation, magnons, domains and domain walls, magnetic hysteresis, pinning effects. Magneto resistance, giant magneto resistance, nuclear magnetic resonance, technological aspects of magnetic materials.
Superconductivity: Properties of conventional (low temperature) superconductors, London and Pippard equation, Type II superconductors, intermediate state, vortex lines; flux pinning; Non-ideal behaviour of Type II superconductors; Thermodynamics of Type I and II superconductors; Ginzburg Landau (G-L) theory; G-L equations; current density; Josephson equations; superconducting quantum interference device. Cooper pairs and BCS theory; Energy gap; magic number; experimental determination of energy gap from 1- V characteristics; McMillan's upper limit of Tc. Properties of high Tc superconductors, flux pinning, current density, granular nature. Technological aspects of superconductors.

References:
1. S. Blundell, *Magnetism in Condensed Matter*, Oxford (2001).
2. D. Craik, *Magnetism: Principles and Applications*, John Wiley (1995).
3. J. B. Ketterson and S. N. Song, *Superconductivity*, Cambridge (1999).
4. T. P. Sheahen, *Introduction to high-temperature Superconductivity*, Plenum (1994).
5. M. Tinkham, *Introduction to Superconductivity*, McGraw Hill (1996).
6. A. C. Rose-Innes and E. H. Rhoderick, *Introduction to Superconductivity*, Pergamon (1978).

PH524: Thin Film Phenomena

Theory: Basic definitions; thin film deposition methods: PVD, CVD, Epitaxy, theory of nucleation & growth in thin films, defects, diffusion, methods of control and measurement of film thickness, Structural, optical, electrical and mechanical characterization of films, metallic, semiconducting and insulation films, non-crystalline films, applications of thin films.
Laboratory work: Vacuum evaporation of thin films, Physical characterization of evaporated films.

References:

1.M. Ohring, *The Material Science of Thin Films*, Academic (1992). 2. A. Goswami, *Thin Film Fundamentals*, New Age (1996).
3. A. Wagendristel and Y.Wang, *An introduction to Physics and Technology of Thin Films*, World Scientific (1994)
4. J. George, *Preparation of Thin Films*, Marcel Dekker Inc (1992).

PH525: Semiconductor Optoelectronics

Elemental and compound semiconductors, Crystal growth and device processing, electronic properties of semiconductors: band structure, doping and carrier transport, Optical properties of semiconductors: Interband and intraband transitions, charge injection and radiativejnonradiative recombination, Exitonic effects and modulation of optical properties, Semiconductor junction theory, Optoelectronic detectors, Solar cell, Light emitting diode, Laser diode: static and dynamic properties, Optical modulators and Amplifiers, Optical fibers.

References:

1. J. Singh, *Semiconductor Optoelectronics: Physics and Technology*, McGraw Hill (1995).
2.P. Bhattacharya, *Semiconductor Optoelectronic Devices*, Pearson Education, (2003). 3. J. Singh, *Optoelectronics: An Introduction to Materials and Devices*, Tata McGraw Hill (1996).

PH526: Soft Condensed Matter

Forces, Energies, and time scales: Intermolecular forces in Gases, liquids, and solids. Viscous, elastic and viscoelastic behaviour. Liquids and Glasses.
Phase transitions: Review of critical phenomena through percolation. Phase transition in soft matter. Equilibrium phase diagrams, Kinetics of phase separation, Growth processes, Liquid-Solid transition, freezing and melting.
Polymers: Synthesis, Polymer Chain Conformation, Flory theory, Characterization, Polymer solutions, Bioploymers.
Colloids: Types of Colloids, Characterization of Colloids, Charge and steric Stabilization, Kinetic properties, Forms of colloids: Sols, Gels, Clays, Foams, Emulsions, Electrorheological and Magneto-rheological fluids.
Amphiphilies: Types of Amphiphilies, Surface activity, Surfactant Monolayers and Langmuir-Blodgett Films, detergency, solubilzation in Micelles, Interfacial curvature and Molecular structure, liquid Crystal phase, membranes, templated structure.
Liquid Crystals: Types of liquid crystals, Characterization and identification of liquid crystal phases, Orientational order, elastic properties, Phase transition in liquid crystals, Applications.
Granular Materials through sandpile model and self-organized criticality.

References:

1. Ian W. Hamley, *Introduction to Soft Matter*, John Wiley (2000).
2. R. A. L. Jones, *Soft Condensed Matter*, Oxford (2002).
3. D. Stauffer and A. Aharony, *Introduction to Percolation Theory*, Taylor and Frnacis (1994).
4. M. V. Gandhi and B. S. Thompson, *Smart Materials and Structures*, Chapman and Hall (1992).
5. H. J. Jensen, *Self-Organized Criticality*, Cambridge (1998).

Group-II: Lasers and Photonics

PH 531: Laser Physics

Interaction of radiation with matter, semi classical theory, stimulated emission, life times and line widths, Laser rate equations, gain coefficient, threshold conditions, gain saturation, optimum output coupling, cw and pulsed operation, pumping mechanism theory of optical resonator, longitudinal and transverse modes, Q-switching, mode locking, pulse compression, different types of lasers, laser amplifier, applications of laser

References:

1. O. Svelto, *Principles of Laser*, Plenum (1998).
2. W. T. Silfvast, *Laser and Fundamentals*, Cambridge (1996).
3. A. E. Seigman, *Lasers,* Oxford (1986).
4. A. Yariv, *Quantum Electronics,* John Wiley (1988).

PH 532: Laser Spectroscopy

Interaction of radiation with matter, strong field approximation, Rabi oscillations, line widths, Doppler limited spectroscopy, laser induced absorption and fluorescence spectroscopy, optogalvanic spectroscopy, high resolution spectroscopy, double resonance techniques, Laser Raman spectroscopy, time resolved laser spectroscopy, homo dyne and hetrodyne spectroscopy, measurement of ultrashort pulses, pump and probe techniques, quantum beat spectroscopy, photon echo, correlation spectroscopy, single ion spectroscopy, atom interferometry, polarization spectroscopy, Laser cooling, multiphoton transistions.

References:

1. W. Demtroder, *Laser Spectroscopy Basic Concepts and Instruments,* Springer (1996).
2. M. S. Feld and V. S. Lethokov, *Non linear laser Spectroscopy,* Springer (1980).
3. S. Stenholm, *Foundations of laser spectroscopy,* Wiley (1999).
4. V. I. Balykin and V. S. Lethokov, *Atom Optics with Laser Light,* Harwood Academic Publishers (1995).

PH 533: Non Linear Optics

Electromagnetic waves in non linear media, symmetry properties, density matrix and perturbative approach to non linearities, Feynman diagralll, three waves and four waves mixing, harmonic generation, parametric processes, optical phase conjugation, optical bistability, stimulated Raman and brillouin processes, self focussing, quantum size effects, optical non linearities in low dimensional semiconductors, photorefractive crystals, linear and non linear interference filters, electrooptics, magneto optics and acoustoptics effects and devices, optical rectification, optical modulators, Multiphoton processes, transient coherent non linear optical effects, solitons.

References:

1. W. Bloembergen, *Non Linear optics,* World Scientific (1992).
2. Y. R. Shen, *The principles of Non linear Optics,* John Wiley (1984).
3. A. Yariv, *Quantum Electronics*, John Wiley (1985).
4. M. Schburt and B. Wilnel, *Non linear optics and Quantum Electronics,* John Wiley (1986).

PH 534: Fibre Optics

Basic Characteristics of optical fiber, Ray and modal analysis of single and multimode fibers (step index and graded index), material dispersion, losses, coupling polarization, leaky modes, pulse chirping, solitons, fiber optic communication system, WDM, fiber amplifiers, switches. Fiber optics sensors and application, optical components, sources and detectors for fibre, optical integrated devices, experiments based on characterization of optical fibre and basic principle of communication through fibre.

References:

1. K. Okamoto, *Fundamentals of Optical Waveguides*, Academic Press (2000).
2. A. K. Ghatak and K. Thyagarajan, *Introduction to Fiber Optics*, Cambrid~e (1999).
3. N. S. Kapany, *Fiber Optics: Principles and Applications*, Academic Press l1998).
4. G. Keiser, *Optical Fibre communication*, McGraw **Hill** (1991).

PH536: Quantum Optics

Pictures of Quantum mechanics. Density matrix formalism.

Two-level model of atom, Interaction with an electromagnetic field, Bloch equation, Density matrix treatment. Quantization of electromagnetic field, Commutation relations, Momentum and spin of a photon, Fock states, Lamb Shift, Quantum beats. Models: Dicke Hamiltonian, Jaynes-Cummings model.

Stochasticity: Langevin equation, Fokker-Planck equation, Master equation for a harmonic oscillator and a two-level atom, Characteristic function, Quasi-probability distribution. Coherence: Correlation functions, Hanbury-Brown Twiss effect, Quantum correlation functions, Bunching and anti-bunching effects. Coherent and Squeezed states: Squeezed coherent states, Fock state representation, Coherent state representation, Q-representation, Wigner-Weyl distribution, Squeezed states of a two-mode electromagnetic field, Squeezing in the Jaynes-Cummings model.

Resonance fluorescence, Dressed canonical transformation, Transition among dressed states, Line width, Intensity distribution, Density matrix theory. Optical Bistability: Construction of quantum mechanical Hamiltonian, Master equation. Virtual photon effects: Time evolution of phase operator, Phase fluctuation, Effect of virtual photons on squeezed states.

References:

1. C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg, *Atom-Photon Interaction: Basic Processes and Applications*, John Wiley, 1992.
2. S. M. Barnett and P. M. Padmore, *Methods of Theoretical Quantum Optics*, Clarendon Press, Oxford, 2002.
3. D. F. Walls and G. J. Milburn, *Quantum Optics*, Springer Verlag, 1995.
4. M. O. Scully and M. S. Zubairy, *Quantum Optics*, Cambridge University Press, 1997.
5. J. S. Peng and G. X. Li, *Introduction to Modern Quantum Optics*, World Scientific, 1998.
6. C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg, *Photons and Atoms: Introduction to Quantum Electrodynamics*, John Wiley, 1989.
7. L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics*, Cambridge University Press, 1995.
8. R. Loudon, *The Quantum Theory of Light*, Clarendon Press, Oxford, 1997.

Group-III: Theoretical Physics

PH541: Quantum Information Theory

Brief review of basic concepts, Density operator representation, Pure and mixed states, Reduction postulate, Theory of measurement, The von Neumann theory, Einstein-Podolsky-Rosen arguments and incompleteness, Hidden variables, Bell's inequalities, Gleason's Theorem, Dense coding, Teleportation, Bell-state analyzer, Entanglement swapping, Quantum networks, Transmission of quantum states, Multiparticle entanglement, GHz states, Entanglement quantification, The von Neumann entropy, Kochen-Specker construction, Lattice propositions.

References:

1. D. Bouwmeester, A. Ekert and A. Zeilinger, *The Physics of Quantum Information*, Springer (2000).
2. MacChiavello, Palma, and Zeilinger, *Quantum Computation and Quantum Information Theory*, World Scientific (2000).

PH542: Phase Transitions and Critical Phenomena

Critical Phenomena: Phase transitions in different systems, First order and second order, Thermodynamics and statistical mechanics of phase transition, Critical point exponents and exponent inequalities.
Models: Spin-l/2 and Spin-l Ising Models, q-state Potts model, X-Y and Heisenberg models. Universality.
Mean Field Theory: Mean Field Theory for Ising model, Landau theory, Correlation functions, Classical mean field theories, Scaling hypothesis.
Transfer matrix: Setting up the transfer matrix, Calculation of free energy and correlation functions, Results of Ising model.
Series Expansion: High and low temperature series, application in 1-d Ising model, Analysis of series.
Monte Carlo: Importance sampling, Metropolis algorithm, Data analysis, statistical error, finite-size effect. Examples
Renormalization Group: Definition of a RG transformation, Flow in parameter space, Universality, Scaling and critical exponents, scaled variables. Application in 1-d Ising model.

References:
1. H. E. Stanley, *Introduction to Phase transitions and Critical Phenomena*, Oxford (1971).
2. J. M. Yeomans, *Statistical Mechanics of Phase transitions*, Oxford (1992).
3. K. Huang, *Statistical Mechanics,* John Wiley (2000).
4. R. K. Pathria, *Statistical Mechanics,* Oxford (1999).
5. M. Plischke and B. Bergersen, *Equilibrium Statistical Physics,* Prentice Hall (1989).

PH543: Quantum Field Theory

Action principle, Cannonical Transformations, Poisson Brackets, Symmetries and conservation laws, Green's functions, Klein Gordon equation, Dirac equation, Free propogators Quantization of fields, Real and charged scalars, Massless and massive vector and spinor fields Perturbation Theory, Feynman Rules, Regularization schemes, Renormalizability, Renormalization group equations, QED and Electro-weak Interactions.

References:
1. C. Itzykson and J. B. Zuber, *Quantum Field Theory,* McGraw Hill (1985).
2. P. Ramond, *Field Theory: A Modern Primer,* Addison-Wesley (1990).
3. T. P. Cheng and L. F. Li, *Gauge Theory of Elementary Particle Physics,* Clarendon Press, Oxford, 1984.
4. K. Huang, *Quantum Field Theory From Operators to Path Integrals,* John Wiley (1998).

PH545: General Theory of Relativity

Review of Riemannian geometry: Metric tensor, covariant differentiation, curvature tensor, Bianchi Identities, Ricci tensor.

Motion of a particle in a gravitational field, geodesic. Equations of electrodynamics in the presence of a gravitational field. Gravitational field equations: Action for gravitational field, Energy-momentum tensor, Extremum principle, Einstein field equations, Energy-momentum pseudotensor.

Field of gravitating bodies: Schwarzschild solution, Birkhoff’s theorem, Motion in a centrally symmetric gravitational field, Precession of perihelion of Mercury, Deflection of light, Gravitational lens. Black holes: Schwarzschild black holes, Kruskal space, Black hole thermodynamics. Gravitational waves: Plane waves, Weak field approximation, Gravitational radiation, Transverse-traceless gauge, Electromagnetic analogy.

Cosmological constant: Einstein space, de Sitter space, Anti-de Sitter space. Relativistic Cosmology: Thermal background, Hubble expansion, Big bang, Age and density of the universe. Introduction to Friedmann-Robertson-Walker universe.

References:

1. W. Rindler, *Relativity---Special, General, and Cosmological*, Oxford University Press, New York, 2001.
2. C. W. Misner, K. S. Thorne, and J. A. Wheeler, *Gravitation*, Freeman, NewYork, 2000.
3. L. D. Landau and E. M. Lifshitz, *The Classical Theory of Fields*, Butterworth Heinmann, 1996.
4. J. V. Narlikar, *Introduction to Cosmology*, Cambridge University Press, New Delhi, 1993.
5. A. Einstein, *The Meaning of Relativity*, Oxford & IBH, 1990.
6. P. A. M. Dirac, *General Theory of Relativity*, Prentice Hall of India, 2001.
7. W. Pauli, *Theory of Relativity*, Dover, 1981.
8. R. P. Feynman, F. B. Moronigo, and W. G. Wagner, *Feynman Lectures on Gravitation*, Addison-Wesley, 1995.
9. S. Wienberg, *Gravitation and Cosmology*, John Wiley, 2004 (Indian Reprinting).

PH-546 String Theory (3-1-0-8)

Prerequisites: PH-403, PH-406, PH-501 (Classical Mechanics, Quantum Mechanics II, Electrodynamics II), or equivalent courses.

Short review of basics. Classical mechanics of non-relativistic string. Relativistic string: World sheet, reparametrization invariance, Nambu-Goto action, Polyakov action, boundary conditions and D-branes, static gauge, transverse velocity, motion of open string and points, string wave equation. World sheet currents: conserved currents, momentum current, Lorentz symmetry. Choices for tau and sigma parametrization, mode expansions, light-cone solution. Quantization of relativistic open and closed strings: Light-cone Hamiltonian, string as harmonic oscillator, Virasoro operators, Lorentz generators, state space, photon states, Tachyons and D-brane decay, dilaton and string coupling. D-branes and gauge fields: Open strings on Dp branes, and between parallel branes. T-duality of closed and open strings: winding closed strings, left and right movers, state space of compactified closed strings, T-duality and D-branes, U(1) gauge transformation, Wilson lines. Electromagnetic fields on D-branes. String interactions, Riemann surfaces, Schwarz-Christoffel map, moduli spaces.

Text Book:

1. B. Zwiebach, A First Course in String Theory, Cambridge (2004).

References:

2. K. Becker, M. Becker, and J. H. Schwarz, String Theory and M-Theory, Cambridge (2007).
3. J. Polchinski, String Theory, vols. I and II, Cambridge (1998).
4. M. B. Green, J. H. Schwarz, and E. Witten, Superstring Theory, vols. I and II, Cambridge (1987).