DEPARTMENT OF PHYSICS

SUMMARY OF COURSES

Sub Discipline: Condensed Matter Physics

Theories of Condensed Matter Physics

PH 311	Fundamentals of Thermal & Statistical Physics	3-0-0	3
PH 312	The Physics of Quantum World	3-0-0	3
PH 405	Statistical Mechanics	3-1-0	4
PH 406	Condensed Matter Physics	3-1-0	4
PH 407	Quantum Mechanics - I	3-1-0	4
PH 408	Quantum Mechanics - II	3-1-0	4
PH 511	Advanced Quantum Mechanics	3-1-0	4
PH 512	Advanced Statistical Mechanics	3-1-0	4
PH 513	Density Functional Theory and its Recent Applications	3-1-0	4
PH 514	Advanced Condensed Matter Physics	3-1-0	4

Semiconductor Physics

PH 321	Physics of Semiconducting Materials	3-0-0	3
PH 522	Physics of Semiconductors : from Bulk to quantum dots	3-1-0	4
PH 523	Semiconductor Spintronics & Quantum Computation	3-1-0	4

Computational Condensed matter Physics

PH 402	Numerical Techniques in Physics	3-1-0	4
PH 422	Theory & Simulation of Nanostructures	3-0-0	3
PH 524	Computational Condensed Matter Physics	3-1-0	4
PH 525	Electronic Structure of Disordered Alloys	3-1-0	4
PH 573	Computational Physics Laboratory	0-0-3	2

Soft Condensed Matter

PH 532	Physics of Macromolecules	3-1-0	4

Linear & Non-Linear Dynamics

PH 101	Physics - I	3-1-0	4
PH 332	Physics of the Universe	3-0-0	3
PH 401	Mathematical Methods in Physics	3-1-0	4
PH 403	Classical Mechanics	3-1-0	4
PH 431	Non-linear systems & Chaos	3-0-0	3
PH 531	Non-Linear dynamics, Chaos & its recent applications	3-1-0	4

PH 533	Synchronizations & its recent applications in Chaotic Systems	3-1-0	4

Sub Discipline: Functional Materials

Properties of Materials

PH 102	Physics - II	3-1-0	4
PH 404	Electrodynamics	3-1-0	4
PH 508	Atomic & Molecular Physics	3-1-0	4
PH 541	Dielectric & Magnetic Properties of Materials	3-1-0	4
PH 542	Physics & Applications of Dielectric Materials	3-1-0	4

Synthesis & Characterization techniques

PH 351	Science of Nano materials	3-0-0	3
PH 352	X-Ray techniques for Structure Evaluation	3-1-0	4
PH 507	Nuclear & Particle Physics	3-1-0	4
PH 553	Advanced X-rays structure analysis	3-1-0	4
PH 554	Physics of Thin Film Technology	3-1-0	4
PH 555	Physics of material synthesis & Charaterization	3-1-0	4
PH 556	X-rays and Nano-Science	3-1-0	4

Sub Discipline: Low Temperature Physics

Superconductivity

PH 562	Superfluidity and Superconductivity	3-1-0	4

Instrumentation & Experimental Physics

PH 462	Vacuum Science and Applications	3-1-0	4
PH 561	Physics of Microelectronic and Photonic Devises	3-1-0	4

Sub Discipline: Laboratory Courses

PH 170	Physics Laboratory	0-0-3	2
PH 471	General Physics Laboratory	0-0-3	2
PH 472	Solid State Physics Laboratory	0-0-3	2
PH 473	Spectroscopy Laboratory	0-0-3	2
PH 571	Instrumentation Laboratory	0-0-3	2
PH 572	Advanced Material Synthesis Laboratory	0-0-3	2
PH 573	Computational Physics Laboratory	0-0-3	2
PH 574	Advanced Characteristics Techniques Laboratory	0-0-3	2

Sub Discipline: Project Seminar & Special Courses

PH 538	Special Topics in Condensed Matter Physics - I	3-1-0	4
PH 539	Special Topics in Condensed Matter Physics - II	3-1-0	4
PH 558	Special Topics in Functional Materials – I	3-1-0	4
PH 559	Special Topics in Functional Materials – II	3-1-0	4
PH 568	Special Topics in Low Temperature Physics – I	3-1-0	4
PH 569	Special Topics in Low Temperature Physics – II	3-1-0	4
PH 591	Research Project – I	0-0-6	4
PH 592	Research Project – II	0-0-9	6
PH 593	Seminar & Technical Writing – I	0-0-3	2
PH 594	Seminar & Technical Writing – II	0-0-3	2
PH 595	Short Term Industrial / Research Experience	0-0-0	2
PH 596	Comprehensive Viva-Voice	0-0-0	2

COURSES OFFERED AS OPEN ELECTIVES

Sl. No	Sub. Code	Subject	L-T-P	Credit
1	PH 311	Fundamentals of Thermal & Statistical Physics	3-0-0	3
2	PH 312	Physics of Quantum World	3-0-0	3
3	PH 321	Physics of Semiconducting Materials	3-0-0	3
4	PH 332	Physics of the Universe	3-0-0	3
5	PH 351	Science of Nano-materials	3-0-0	3
6	PH 352	X-Ray techniques for Structure Evaluation	3-0-0	3
7	PH 422	Theory & Simulation of Nanostructures	3-0-0	3
8	PH 431	Non-linear systems & Chaos	3-0-0	3
9	PH 462	Vacuum Science and Applications	3-0-0	3

DETAILED CONTENT OF SYLLABI OF COURSES

Sub. Code	Subject	L-T-P	Credits
PH 101	Physics - I	3-1-0	4
PH 102	Physics - II	3-1-0	4
PH 170	Physics Laboratory	0-0-3	2
PH 311	Fundamentals of Thermal & Statistical Physics	3-0-0	3
PH 312	The Physics of Quantum World	3-0-0	3
PH 321	Physics of Semiconducting Materials	3-0-0	3
PH 332	Physics of the Universe	3-0-0	3
PH 351	Science of Nano materials	3-0-0	3
PH 352	X - Ray techniques for Structure Evaluation	3-1-0	4
PH 401	Mathematical Methods in Physics	3-1-0	4
PH 402	Numerical Techniques in Physics	3-1-0	4
PH 403	Classical Mechanics	3-1-0	4
PH 404	Electrodynamics	3-1-0	4
PH 405	Statistical Mechanics	3-1-0	4
PH 406	Condensed Matter Physics	3-1-0	4
PH 407	Quantum Mechanics - I	3-1-0	4
PH 408	Quantum Mechanics - II	3-1-0	4
PH 422	Theory & Simulation of Nanostructures	3-0-0	3
PH 431	Non - Linear systems & Chaos	3-0-0	3
PH 462	Vacuum Science and Applications	3-1-0	4
PH 471	General Physics Laboratory	0-0-3	2
PH 472	Solid State Physics Laboratory	0-0-3	2
PH 473	Spectroscopy Laboratory	0-0-3	2
PH 507	Nuclear & Particle Physics	3-1-0	4
PH 508	Atomic & Molecular Physics	3-1-0	4
PH 511	Advanced Quantum Mechanics	3-1-0	4
PH 512	Advanced Statistical Mechanics	3-1-0	4
PH 513	Density Functional Theory and its Recent Applications	3-1-0	4
PH 514	Advanced Condensed Matter Physics	3-1-0	4
PH 522	Physics of Semiconductors : from Bulk to quantum dots	3-1-0	4
PH 523	Semiconductor Spintronics & Quantum Computation	3-1-0	4
PH 524	Computational Condensed Matter Physics	3-1-0	4
PH 525	Electronic Structure of Disordered Alloys	3-1-0	4
PH 531	Non - Linear dynamics, Chaos & its recent applications	3-1-0	4
PH 532	Physics of Macromolecules	3-1-0	4
PH 533	Synchronizations & its recent applications in Chaotic Systems	3-1-0	4
PH 538	Special Topics in Condensed Matter Physics - I	3-1-0	4
PH 539	Special Topics in Condensed Matter Physics - II	3-1-0	4
PH 541	Dielectric & Magnetic Properties of Materials	3-1-0	4
PH 542	Physics & Applications of Dielectric Materials	3-1-0	4
PH 553	Advanced X-rays structure analysis	3-1-0	4

PH 554	Physics of Thin Film Technology	3-1-0	4
PH 555	Physics of material synthesis & Charaterization	3-1-0	4
PH 556	X-rays and Nano-Science	3-1-0	4
PH 558	Special Topics in Functional Materials - I	3-1-0	4
PH 559	Special Topics in Functional Materials - II	3-1-0	4
PH 561	Physics of Microelectronic and Photonic Devises	3-1-0	4
PH 562	Superfluidity and Superconductivity	3-1-0	4
PH 568	Special Topics in Low Temperature Physics - I	3-1-0	4
PH 569	Special Topics in Low Temperature Physics - II	3-1-0	4
PH 571	Instrumentation Laboratory	0-0-3	2
PH 572	Advanced Material Synthesis Laboratory	0-0-3	2
PH 573	Computational Physics Laboratory	0-0-3	2
PH 574	Advanced Characteristics Techniques Laboratory	0-0-3	2
PH 591	Research Project - I	0-0-6	4
PH 592	Research Project - II	0-0-9	6
PH 593	Seminar & Technical Writing - I	0-0-3	2
PH 594	Seminar & Technical Writing - II	0-0-3	2
PH 595	Short Term Industrial/ Research Experience	0-0-0	2
PH 596	Comprehensive Viva - Voice	0-0-0	2

PH 101 PHYSICS - I 4 Credits [3-1-0]

Wave optics: Superposition of waves: stationary waves in a string and of light waves, superposition of two / more sinusoidal waves of equal frequency and different frequencies , Fourier analysis of complex waves, Fourier series and Integral, group wave, group velocity and pulse dispersion; Interference: Division of wave front (two beam interference): conditions for interference pattern, Young's double slit experiment using monochromatic light, fringe pattern on transverse and longitudinal planes, intensity distribution, Fresnel's biprism, interference with white light, displacement of fringes; Division of amplitude (two beam interference) : phase change on reflection, Michelson Interferometer, fringes of equal inclination (cosine law) and equal thickness, determination of refractive index , Newton's rings experiment (fringes of equal thickness), (multiple beam interference) : plane parallel thin film (fringes of equal inclination) illuminated with point source , extended monochromatic and white light source, interference with reflected and transmitted light, colour of thin film, Febry-Perot etalon & interferometry, modes of Febry-Perot cavity, flatness of coated surfaces; Diffraction: Fraunhofer, Fresnel's diffraction and Ray optics, single slit (infinite beam interference), two and N slits(Grating) (multiple beam interference) Fraunhofer diffraction pattern and intensity distribution, Oblique incidence. Fresnel's half period zones and zone plates, application of zone plates; Electromagnetic Waves: Divergence and curl of static Electric & magnetic fields, Farady law and Maxwell's correction for time dependent fields, Maxwell's equatuions in vaccum & media, em waves & transverse nature of waves, boundary conditions on electric & magnetic fields, propagation of em waves in wave guide; Polarization: polarized and unpolarized light, linearly polarized light, polarizer & Law of Malus, superposition of two mutually perpendicular linearly polarized light, circularly and elliptically polarized light, polarization due to reflection (Brewster's law) & scattering, polarization by double refraction and phenomena of double refraction in uniaxial crystals, quarter and half wave plates and production of circular and elliptical polarized light, Nicole prism, Faraday rotation; Fiber Optics**:** Propagation of light in fibers, numerical aperture, single mode and multi mode fibers, attenuation in optical fibers, spot size in fundamental mode, pulse dispersion in optical fibers, ray dispersion in step index fibers, parabolic- index fibers & material dispersion, applications of fiber optics; **Special Relativity**: Reference frames, inertial frames, Michelson-Morley experiment (constancy of speed of light), Gallelian relativity and transformation (concept of absolute time and length interval), simultaneous events and simultaniety, postulates of relativity, Lorentz transformation, length contraction and time dialation, meson decay, dopler effect, the expanding universe, twin paradox, spacetime, velocity addition, relativity in electricity and magnetism, relativistic momentum, relativistic mass and mass-energy relation, general relativity (introduction); **Particle properties of waves :** Black body radiation, photoelectric effect, x-ray diffraction and Compton effect, pair production, photon and gravity; **Wave properties of Particles :** De Broglie wave as matter waves, waves of probability & wave function, matter waves as group waves, phase velocity & group velocity, particle diffraction & Davison-Germer experiment, particle in a box, uncertainty principle and its application; **Quantum Mechanics :** Wave equation, time dependent Schrodinger equation , linearity & superposition, expectation values, observables as operators,, stationary states and time evolution of stationary states, eigenvalues & eigenfunctions, boundary conditions on wave function, application of SE to one dimensional problems (particle in a box, potential barrier & step, one dimensional harmonic oscillator).

Essential Reading:

1. A. Ghatak, *Optics*, Tata-McGraw Hill, 2004.
2. A. Beiser, *Concept of Modern Physics (or Perspective of Modern Physics),* Tata-McGraw Hill, 2005.

Supplementary Reading:

1. R. Resnick, *Relativity*, Wiley Eastern Pvt. Ltd., 2007.
2. Jenkin & White, *Fundamentals of Optics*, McGraw-Hill, 4th Edition.
3. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson, 2007.
4. D. J. Griffith, *Introduction to Electrodynamics*, Pearson, 2007.

Prerequisite:

PH 102 PHYSICS - II 4 Credits [3-1-0]

Statistical Mechanics: Statistical distributions, M-B statistics, molecular energies in ideal gas, quantum statistics: B-E & F-D statistics, Rayleigh-Jeans formula, Planck's radiation law, specific heats of solids, free electrons in metals, electron-energy distribution, dying stars; **Spectroscopy :** quantum theory of hydrogen atom, quantum number for three dimensions : principal, orbital & magnetic quantum numbers (space quantization), electron probability density, radiative transitions, selection rules, Zeeman effect. Electron spin, exclusion principle, symmetric & anti-symmetric wave functions, atomic structures, spin-orbit coupling, total angular momentum, X-ray spectra. LASER: Coherent time & length (temporal coherence), Line width, spatial coherence(Michelson stellar Interferometer), optical beats, Fourier analysis of Coherence time and line width, visibility in Young's double slits experiment, Fourier transform spectroscopy (introduction). Spontaneous & stimulated emission, metastable states, optical pumping, population inversion, Einstein approach of stimulated emission, Einstein coefficient, components of laser: optical cavity & resonator, optical amplification, Fiber laser, Ruby & He-Ne lasers; **The Solid State :** Crystalline & amorphous solids, Crystal structure, Bravais lattice, packing fraction, atomic radius, point defect, dislocations, reciprocal lattice & Brilloin zones, wide & small angles X-ray- crystellography: crystal planes, Bragg's diffraction & diffraction condition in reciprocal lattice, Ionic, metallic, covalent and Van der Waals bonds, nano-tubes. Band theory of solids : formation of allowed & forbidden bands due to periodicity, Kronig-Peny model for periodic potential. Origin of resistivity, effective mass of electron, classification of solids on the basis of band theory, impurity in semiconductors. Dielectric (including ferroelectric & piezoelectyric) & Magnetic properties of solids (dia-, para and ferromagnetism), Langevin theory, Weiss theory of ferromagnetism, hysteresis, superconductivity: zero resistence, type-I & type-II superconductors, magnetic properties of superconductors (Meissner effect), flux quantization & Josephson junction, vacuum science and its application; **Nuclear Physics :** Nuclear structure, atomic masses, mass spectrograph, nuclear properties, stable nuclei, binding energy, nuclear models: liquid drop and shell models, meson theory of nuclear forces, cross section, nuclear reactions, nuclear fissions, nuclear reactors, fusion in stars, fusion reactors: energy source for future, constituents of nuclear particles: quarks, hadrons, Glons.

Essential Reading:

1. A. Ghatak, *Optics*, Tata-McGraw Hill, 2004.
2. A. Beiser, *Concept of Modern Physics (or Perspective of Modern Physics),* Tata-McGraw Hill, 2005.

Supplementary Reading:

1. C. Kittel, *Introduction to Solid State Physics*, Wiley & Sons, 2004.
2. D. J.Griffith, *Introduction to Quantum Mechanics*, Pearson, 2007.

Prerequisite: PH 101- Physics-I

PH 170 PHYSICS LABORATORY 2 Credits [0-0-3]

Error & error analaysis, graph drawing, least square fitting

List of Expts:

1. Bar pendulum
2. Lee's Disc
3. Young's modulus
4. Newton's rings
5. Diffraction grating(spectrometer)
6. Optical rotation
7. Carry Foster's bridge
8. Hall effect
9. Temperature dependent of band gap of semiconductor-Four probe method
10. Helmohltz coil
11. High Resistance by Ballistic Galvanometer
12. Photo-electric effect
13. AC frequency by horse-shoe method.

Reference: 1. Laboratory Manual,

Prerequisite:

PH 311 FUNDAMENTALS OF THERMAL & STATISTICAL PHYSICS 3 Credits [3-0-0]

Concept of thermodynamic state, extensive and intensive variables; heat and work, internal energy function and the first law of thermodynamics; ideal engine and Carnot cycle, concepts of entropy and temperature as conjugate pair of variables; second law of thermodynamics, entropy maximum and energy minimum principles. Entropy: multiplicity and disorder, Maxwell's demon ; Thermodynamic potentials; conditions of equilibrium, concepts of stability, Maxwell's equations, metastable and unstable equilibrium; components and phases, Gibbs-Duhem relations; first order phase transitions and Clausius-Clapeyron equation; critical phenomena, some chosen applications from magnetic, dielectric and superconducting; heat engines and black body radiation. Thermodynamics of irreversible processes: entropy production; Elementary kinetic theory of gases; transport phenomena; Introduction to statistical mechanics and distribution functions. occupation probability in M-B, B-E, F-D statistics, distribution functions, criteria for applicability of classical statistics, specific heat of classical gas, Fermi gas, Fermi energy, electronic contribution to specific heat of metals, energy bands in conductors, insulators and semiconductors, modifications at metal-metal contact, p-n junction, details of tunnel diode.

Essential Reading:

1. M. W. Zemansky, *Heat and Thermodynamics*, McGraw-Hill Ltd., 6th Edition, 1999.
2. R. Bowley and M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.

Supplementary Reading:

1. H. B. Callen, *Thermodynamics and Thermostatistics*, John Wiley & Sons 2nd Ed.
2. L. A. Girifalco, *Statistical Mechanics of Solids*, Oxford University press, 2000.
3. A. Bieser, *Perspective of Modern Physics / Concept of Modern Physics*, Tata McGraw-Hill, 2005.

Prerequisite:

PH 312 PHYSICS OF QUANTUM WORLD 3 Credits [3-0-0]

Historical background of quantum theory, wave function and its Born interpretation, relation with measurement of dynamical variables, double slits experiments with em wave and matter wave; Delta-function as definite position and plane wave as definite momentum wave function, wave-packet as superposition of delta-functions and of plane waves, uncertainty principle, Gaussian wave packets, applicability of classical physics on the basis of uncertainty product, observables and operator formulation, eigenvalue and eigenstates, Schrodinger equation for time evolution, stationary states, spread of free particle wave packets, time energy uncertainty, natural line width of spectral lines, probability currents and their relation with the flux in beams of particles; Square well potentials (finite & infinite) and their applications, double, well potentials and examples like ammonia inversion, delta function potentials and examples like electron sharing in covalent bonds; Kronig-Penney model of 1-d crystals. Linear harmonic oscillator, outline of getting stationary states, molecular vibrations and spectroscopy. barrier tunneling, examples of alpha-decay, scanning tunneling microscope, principle of tunnel diode etc; Angular momentum operators, eigenvalues and eigenfunctions, spin angular momentum, hydrogen atom using coulomb interaction, structure of H-line due to L-S interaction (derivation not needed), J-J coupling, fine structure and hyperfine structure, space quantization; Quatum statistics and its applications to metals, semiconductors etc.

Essential Reading:

1. A. Bieser, *Concept of Modern Physics*, Tata-McGraw Hill, 2005.
2. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson Education, 2007.

Supplementary Reading:

1. R. P. Feynman, *Lectures on Physics, V*ol.III, Narosa Publishing, 2008.
2. C. Cohen-Tannoudji, *Quantum Mechanics*, John Wiley & Sons, 2005.
3. C. Kittel, *Introduction to Solid State Physics*, John Wiley & Sons 7th Ed., 2004.
4. R. Bowley & M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.

Prerequisite: First level Physics course

PH 321 PHYSICS OF SEMICONDUCTING MATERIALS 3 Credits [3-0-0]

Crystal structure, periodic lattice and reciprocal lattice, application of quantum mechanics to periodic potentials, Bloch's theorem, band energies and band gap. Properties of metals, Fermi surface and transport properties, density of states, metal surface states and work function, bulk semiconductors and semiconducting devices, effective mass theory of band energy, tight binding model; Novel materials: super lattices, quantum well, quantum DOT and quantum wires, superconductivity, high Tc superconductors and their applications, polymers and optical materials; Density functional theory and properties of bulk and small clusters of atoms, Carr-Perinello method of molecular dynamics.

Essential Reading:

1. C. Kittel, *Introduction to solid state physics*, John Wiley & Sons, 2004.
2. S. Dimitrijev, *Principles of Semiconductor Devices*, Oxford University, 2006.

Supplementary Reading:

1. J. Singh, *Semiconductor Devices: Basic principles*, Wiley India, 2008.
2. P.Y. Yu and M.Cardona, *Fundamentals of Semiconductors Physics & Material Properties*, Springer Verlag, 1999.
3. Y. D. Jiles, *Introduction to Magnetism and Magnetic Materials*, Chapmean and Hall. (2^{nd} edition)
4. J.M. Haile, *Molecular Dynamics*, John Wiley & sons, 1997.

Prerequisite: First level Physics course

PH 332 PHYSICS OF THE UNIVERSE 3 Credits [3-0-0]

Astronomy and physics, photometry, observational instruments, stellar spectra, stellar evolution, classification of stars, star clusters and binary stars, nucleo-synthesis and formation of elements, galaxies and observed universe. Evolution of galaxies and their origin, quasars and active galaxies; Theories of the universe: from Newtonian cosmology to modern cosmology: Big-Bang theory and early universe, the universe and the arrow of time, confrontation between theories and observations.

Essential Reading:

1. E. Harrison, *Cosmology*, Cambridge University Press. 2^{nd} Ed., 2000.
2. J. Narliker, *Introduction to Cosmology*, Cambridge University Press. 3^{rd} Ed., 2002.

Supplementary Reading:

1. J. Narlikar, *Structure of the Universe*, Prentice Hall (Indian Edition)
2. Bormer and Gerhard, *The early Universe*, Springer Verlag, Berlin, 2003.
3. *The early Universe and Observational Cosmology*, Lecture Notes in Physics (vol.646), Springer Verlag, 2007.

Prerequisite:

PH 351 SCIENCE OF NANO MATERIALS 3 Credits [3-0-0]

Introduction to nano science and nano technology, nano structure and it's manipulation, nano particles and nano materials, Applications of nano functional material in different fields of science and technology, Different experimental techniques for evaluation of nano ordered structures in materials(XRD,SAXS,TEM etc); Introduction to biological macromolecules and their characterization with special emphasis to Small Angle X-ray Scattering (SAXS) ; Introduction to synthesis of nano particles and their characterization, physics of nano particles and their composites.

Essential Reading:

1. G. L. Hornyak, H. F. Tibbals, J. Dutta, H. F. Tibbals, *Introduction to nanoscience*, Taylor and Francis Inc, 2008.
2. Z. L. Wang, Y. Liu, Z. Zhang, *Handbook of Nanophase and nano structured materials Vol-I Synthesis*, Klwer Academic Publications, 2002.

Supplementary Reading:

1. T. Pradeep, *Nano: The essentials: Understanding Nanoscience &Nanotechnology*, McGraw-Hill professional publishing (1st Edn).
2. T. Chakraborty, F. Peeters, U. Sivan, *Nano-physics & Bio-electronics: A new Odyssey*, Elsevier Publications, 2002.

PH 352 X-RAY TECHNIQUES FOR STRUCTURE EVALUATION 3 Credits [3-0-0]

Production, properties and applications of x-rays, x-ray absorption and its roll in stricture evaluation, x-ray detectors, real and reciprocal space, structure factor, form factor, X-ray diffraction (XRD) and its applications, x-ray scattering and its applications, introduction to small Angle X-ray Scattering (SAXS) and its advantage in structure evaluation; Introduction to X-ray spectroscopy, Moseley's law and its applications, x-ray fluorescence (XRF), energy dispersive x-ray (EDX), particle induced x-ray emission (PIXE) and their applications; Introduction to medical x-ray and x-ray techniques (radiography, radiotherapy, CT scanning etc.)

Essential Reading:

1. J. A. Nielson and D. McMorrow, *Elements of Modern X-ray physics*, John Wiley&sons, 2001.
2. G. V. Pavlinsky, *Fundamentals of x-ray physics*, Cambridge International sci Pub, 2008.

Supplementary Reading:

1. A. K. Singh, *Advanced X-ray Techniques in Research and Industry*, Capital Publishing Company, 2006.
2. N. Kasai, M. Kakudo, *X-ray diffraction by macromolecules*, Springer, 2005.

PREREQUISITES: FUNDAMENTALS OF MODERN PHYSICS

PH 401 MATHEMATICS METHODS IN PHYSICS 4 Credits [3-1-0]

Curvilinear coordinates systems, Vector algebra and vector analysis, Vector & function spaces, Hilbert spaces, expansion of state vector, operators in infinite vector space. Determinants & matrices, eigenvalues and eigenfunctions, Vector calculus, gradient, divergent and curl, Tensors and linear algebra; Polynomials, generalized functions, Dirac delta function, gamma function, Fourier series & transform, Legendre functions and Transformation; Function of complex variable and complex analysis; Elementary group theory

Essential Reading:

1. G. B. Arfken and H. J. Weber, *Mathematical methods for Physicists*, Elsevier Academic Press, 6th Ed., 2005.
2. M. L. Boas, *Mathematical Method in Physical Science*, John Willy & Sons, 3rd Ed., 2006.

Supplementary Reading:

1. J. Mathews and R. L. Walker, *Mathematical Methods of Physics*, Pearson Education, 2005.
2. S. D. Joglekar, *Mathematical Physics*, Universities Press, 2005.
3. R. V. Churchil and J. W. Brown, *Complex Variables &Applications*, 7th Ed., 2003.

Prerequisite: First level Mathematics course

PH 402 NUMERICAL TECHNIQUES IN PHYSICS 4 Credits [3-1-0]

Ordinary differential equations & partial differential equations, Green's functions, Calculus of variations. Solutions of differential equatuions by various numerical techniques: Numerical techniques: finite difference calculus, interpolation & extrapolation, solution of simultaneous linear equations & roots of equations, least square curve fitting, numerical integration, matrix eigenvalue problems; Probability: random variables, binomial distribution, Poisson distribution & Gauss/normal distribution. Monte Carlo simulation: random walk problem, random number generators, magnetization at a finite temperature, diffusion & percolation problems.

Essential Reading:

1. G. B. Arfken and H. J. Weber, *Mathematical methods for Physicists*, Elsevier Academic Press, 6^{th} Ed., 2005.
2. J. Mathews and R. L. Walker, *Mathematical Methods of Physics*, Pearson Education, 2005.

Supplementary Reading:

1. S. D. Joglekar, *Mathematical Physics*, Universities Press, 2005.
2. R. V. Churchil and J. W. Brown, *Complex Variables &Applications*, 7^{th} Ed., 2003.
3. M. L. Boas, *Mathematical Method in Physical Science*, John Willy & Sons, 3^{rd} Ed., 2006.
4. S. C. Chapra, *Numerical Methods for Engineers*, Tata-McGraw-Hill. 5^{th} Ed, 2007.

Prerequisite: PH 501: Mathematical Methods in Physics - I

PH 403 CLASSICAL MECHANICS 4 Credits [3-1-0]

Review of Newton's and conservation laws, system of particles, constraint, de-Alembert principle, generalized coordinates & Lagrangian equations, variational & Principle of least action and Hamilton principles and Lagrangian formalism, Hamilton equation of motions, Canonical transformations and Hamilton-Jacobi theory; The two-body central force problem, collisions and scattering by central force. The kinematics of rigid body motion and non-inertial frames, rigid body equation of motion; Liouvile's theorem, small oscillations, general wave motion, phase and group velocities, dispersion; Lagrangian and Hamiltonian formalisms for continuous systems and fields; Special theory of Relativity

Essential Reading:

1. H. Goldstein, *Classical Mechanics*, Addison Wesley, Pearson Education, 2007.
2. R. D. Gregory, *Classical Mechanics*, Cambridge University Press, 2006.

Supplementary Reading:

1. L. D. Landau and E. M. Lifshitz, *Course of Theoretical Physics- Mechanics*, (vol.-1), 3^{rd} Ed., Pergamon Press.
2. R. P. Fynman, *Lectures on Physics (vol-1)*, Narosa Publishing, 2008.
3. D. Morin, *Introduction to Classical mechanics (with problems & solutions)*, Cambridge University Press, 2008.
4. T. W. B. Kibble and F. H. Berkshire, *Classical Mechanics*, 5^{th} Ed., Imperial College Press, 2004.
5. N. C. Rana and P. S. Joag, *Classical Mechanics*, Tata-McGraw-Hill, 1991.

Prerequisite: Knowledge of Newtonian Mechanics & first level of mathematics course

PH 404 ELECTRODYNAMICS 4 Credits [3-1-0]

Potential formulation, Laplace & Poisson equations, Boundary value problems, method of images, multipole expansion, dielectrics and magnetic properties of materials; Time-varying fields, continuity equation, Maxwell's correction and equations, Poynting theorem, conservation of energy and momentum in of em fields, electromagnetic potentials, gauge invarience and transformations; Electromagnetic waves & its propagation in conducting and non-conducting media. Wave guides. Interference, diffraction and polarizations, coherence; Relativistic formulation of electrodynamics, co-variant form of Maxwell's equations, Gauge invariance and four potential, electromagnetic energy momentum tensor; Electrodynamics of a charged particle, radiation from a accelerated charge particle, retarded & Lienard-Weichert potentials, bremsstrahlung & synchrotron radiation, scattering by charged particles, applications to wave guides, fibres and plasmas.

Essential Reading:
1. D. J. Griffth, *Introduction to Electrodynamics*, Pearson Education. 3rd Ed., 2007.
2. D. Jackson, *Classical Electrodynamics*, Wiley and sons Ltd. 3rd Ed., 1998.

Supplementary Reading:
1. J. R. Reitz, F. J. Milford and R. W. Christy, *Foundation of Electromagnetic theory*, Addison Wesley Company / Narosa Publishing. 4th Ed., 2008.
2. A. Ghatak, *Optics,* Tata McGraw-Hill, 2004.
3. R. P. Feynman *Lectures on Physics (vol.II),* Addison Wesley, Narosa, 2008.

Prerequisite: 2nd level of electricity & magnetism course and 1st level of mathematics course

PH 405 STATISTICAL MECHANICS 4 Credits [3-1-0]

Review of thermodynamics - Laws of thermodynamics, entropy, thermodynamic potentials & Maxwell's relations, chemical potential & phase equilibria; Equilibrium statistical mechanics- phase space, micro-states, macrostates, micro-canonical, canonical & grand-canonical ensembles & and partition functions; Maxwell-Boltzmann, Fermi-Dirac & Bose-Einstein distributions, applications of statistical mechanics to ideal quantum gas, interacting systems, theories of phase transitions etc; Elementary concepts of non-equlibrium statistical mechanics.

Essential Reading:
1. H. B. Callen, *Thermodynamics & Thermostatistics*, John Wiley & Sons. 2nd Ed.
2. R. Bowley and M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.

Supplementary Readings:
1. M. W. Zemansky, *Heat & Thermodynamics*, McGraw-Hill, 1999.
2. L. Landau and E.M. Lifshitz: course in theoretical physics vol.5 (part-I) & vol.9 (part-II) - Statistical Mechanics, 3rd ed., Pergamon Press.
3. B. B.Laud, *Fundamentals of Statistical mechanics*, New Age Publication, 2007.
4. J. K. Bhattacharya, *Statistical Mechanics*, Allied Publishers Ltd., 1996.
5. L. E. Reichl, *A modern course in Statistical Physics*, Wiley & Sons, 2nd Ed., 1997.

Prerequisite: 1st level of thermodynamics course & elementary knowledge of Probability theory.

PH 406 CONDENSED MATTER PHYSICS 4 Credits [3-1-0]

Crystal systems & reciprocal lattice, Bragg's Law in reciprocal Lattice. Free & nearly free electron models & Fermi surface for metals, electron in periodic potential, Bloch's theorem and energy bands, tight binding model for band structure, density of states. Bondings in crystals, van-der walls, ionic, & covalent solids, electron in DC electric field; Transport properties - electrical & optical, effective mass, holes in semiconductors, laws of mass action, intrinsic & extrinsic semiconductors, electron & holes mobilities, impurity level & p-n junctions; Lattice vibrations, phonons, adiabatic & harmonic approximations, lattice heat capacity, Einstein and Deby models, dielectric-polarization mechanism, Piezo, Pyro & ferro electricity; Magnetism: exchange interaction, dia-magnetism, para-magnetism, ferro-magnetism & anti-ferromagnetism, Hund's rule, Pauli magnetism, Heisenberg model, giant & colossal magneto-resistance, Hall effect; Superconductivity-basic phenomology, Meissner effect, Type-I & II super- conductors, BCS pairing mechanism.

Essential Reading:

1. C. Kittel, *Introduction to solid state physics*, John Wiley & sons, 8^{th} Ed., 2004.
2. Ashcroft and Mermin, *Solid State Physics*, Thomson Learning, 2007.

Supplementary Reading:

1. J. Callaway, *Quantum Theory of Solid*, Academic Press, 2^{nd} Ed.
2. D. Craik, *Magnetism Principles and Applications*, John Wiley, 2003.
3. F. Duan and J. Guojun, *Introduction to Condensed Matter Physics*, World Scientific, 2005.
4. L. Mihali and M. C. Martin, *Solid State Physics*, John Wiley & Sons, 1996.

Prerequisite: Basic quantum mechanics & electrodynamics

PH 407 QUANTUM MECHANICS - I 4 Credits [3-1-0]

Historical perspective and origin of quantum theory, wave mechanics, group waves and wave packets, uncertainty principle, motion and spread of wave packets. Schrodinger equation, application to one-dimensional problems, central potentials-hydrogen atom; Hilbert space formalism, state space and Dirac,s notation, mathematical formulation. Commutation relations and commutating observables. Creation and anhilation operators. Schrodinger, Heisenberg and interaction pictures, symmetries in quantum mechanics; General treatment of angular momentum, various commutations relations of angular mementum. Spin- Stern - Garlach experiment. Application of general theory to orbital and spin angular momentum. Identical particles, Pauli exclusion principle.

Essential Reading:

1. C. Cohen-Tannoudji, *Quantum Mechanics (vol.1),* John Willey & sons, 2005.
2. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson Education, 2007.

Supplementary Reading:

1. A. Bieser, *Perspective of Modern Physics / Concept of Modern Physics*, McGraw-Hill, 2005.
2. R. P. Feynman, *Lectures on Physics (vol.III),* Narosa Publishing, 2008.
3. L. Landau and E. M. Lifshitz, *Course in theoretical physics vol.3-Quantum Mechanics (non-relativistic),* 3^{rd} Ed.

1. J. J. Sakurai, *Modern Quantum Mechanics*, Pearson Education, 2005.

Prerequisite: 2^{nd} level mathematics and wave mechanics courses

PH 408 QUANTUM MECHANICS - II 4 Credits [3-1-0]

Addition of angular momenta. Clebs-Gordan coefficients; Approximate methods: WKB approximation, variational method. Bound state perturbation theory, application to fine structure, anharmonic oscillators and Zeeman Effect, time-dependent perturbation theory. Interaction with classical radiation fields; Scattering theory- Scattaring cross section, unbound states; EPR paradox & Bell's inequality, quantum teleportation, idea of quantum computation & informations.

Essential Reading:

1. C. Cohen-Tannoudji, *Quantum Mechanics (vol.2),* John Willey & sons, 2005.
2. D. J. Griffith, *Introduction to Quantum Mechanics*, Pearson Education, 2007.

Supplementary Readings:

1. R. P. Feynman *Lectures on Physics (vol.III)*, Narosa Publishing, 2008.
2. L. Landau & E. M. Lifshitz, *Course in theoretical physics vol.3-Quantum Mechanics (non-relativistic),* 3^{rd} Ed.
3. J. J. Sakurai, *Modern Quantum Mechanics*, Pearson Education, 2005.
4. M. A. Nielsen and I. L. Chuang, *Quantum Computation & Quantum Information,* Cambridge University Press, 2002.

Prerequisite: PH 51: Quantum mechanics-I

PH 422 THEORY & SIMULATION OF NANOSTRUCTURES 3 Credits [3-0-0]

Inter atomic Potentials: Potential energy surface, pair potential approximation, phenomenological potentials, Buckingham, Morse, Lenard-Jones and Berker potentials, Pseudo potentials, Many-body potentials; Molecular Dynamics: Models for MD calculations, initial value, isothermal equilibrium, boundaries, nano-design and nano-construction, solution of the equation of motion, Verlet, Gear-Predictor, and other methods, efficient force field computation, force derivation, list method, cell algorithm, scalable parallel method, Tight-binding MD, Carr-Perrinello MD; Characterization: Thermal stability, material properties, wear at nanometer level, mean values and correlation functions; Nano-engineering: Functional nanostructures, nano-machines, nano-clusters, influence of initial conditions, temperature, crystalline structure, etc. Simulated nano structure transformations.

Essential Reading:

1. M. A. Ratner and D. Ratner, *Nanotechnology: A Gentle Introduction to the next Big Idea,* Pearson, 2002.
2. J. M. Haile, *Molecular Dynamics*, John Wiley & sons, 1997.

Supplementary Reading:

1. M. Rieth, *Nano Engineering in Science and Technology: An Introduction to the world of Nano-Design,* World-Scientific, 2003.
2. C. Delerve and M. Lannoo, *Nanostructures-Theory & Modeling*, Springer Verlag, 2004.

Prerequisite: First level physics course

PH 431 NONLINEAR SYSTEM & CHAOS 3 Credits [3-0-0]

Dynamical systems with nonlinearity, phase portraits and flow in one, two and three dimensions, fixed point, limit cycle motions, bifurcation. Stability of fixed point, limit cycles; Deterministic chaos and strange attractors: Population growth, logistic maps etc., routes to chaos-period doubling, intermittancy, quasi periodicity. Concept of universality and renormalization, measure of Chaos-Poincare section, Lyapunov exponent; Idea of Fractal geometry and dimension: Euclidean and topological dimensions, Cantor set and Koch curves, Fractal boundaries, determination of fractal geometry, Hausdor exponent, Self affinity, Hurst exponent. Examples from physics, Engineering, biology and chemistry.

Essential Reading:

1. P. S. Addison, *Fractals and Chaos*, Overseas Press, 2005.
2. S. H. Strogatz, *Nonlinear dynamics & Chaos*, Levent Books (Kolkata) Indian Ed., 2007.

Supplementary Reading:

1. G. L. Baker and J. P. Gollub, *Chaotic dynamics-An Introduction*, Cambridge University Press, 1996.
2. F. Verhulst, *Nonlinear differential equations and dynamical systems,* Springer, 2^{nd} Ed, 1999.
3. T. Kapitaniak, *Chaos for Engineers*, Springer, 1998.
4. D. W.Jordan and P. Smith, *Nonlinear Ordinary Differential Equations*, Oxford Univ. Press, 4^{th} Ed., 2007.

Prerequisite: First level mathematics course

PH 462 VACUUM SCIENCE AND APPLICATION 3 Credits [3-0-0]

Vacuum and its necessity. Gas flow in vacuum systems, Pumping speed and through put; *Creation of Vacuum:* Rotary vane pump, Roots blower pump, Diffusion pump, Ionization pump, Diaphragm pump, Adsorption pump, Turbo molecular pump; *Measurement of Vacuum:* Pirani/Thermocouple gauge, Penning/Ionization Gauge (hot cathode and cold cathode), Capacitance gauge, Bourdon gauge, McLeod gauge; *Quality of vacuum:* Residual gas analyzer, Leak detection. Material selection and vacuum chamber; *Application of Vacuum in thin film deposition:* Thermal evaporation, DC and RF sputtering, Molecular beam epitaxy (MBE), Pulsed LASER deposition (PLD).

Essential Reading:

1. V. V. Rao, T. B. Ghosh and K. L. Chopra, *Vacuum Science and Technology*, Allied Publishers – 1998.
2. *N. Harris,* Modern Vacuum Practice *[Freely available on net] (*www.modernvacuumpractice.com/editor/user_DocView.asp?DocumentID=18*)*

Supplementary Reading:

1. D. M. Hoffman, B. Singh & J. H. Thomas, *Handbook of Vacuum Science and technology,* Academic press: 2005.
2. J. M. Lafferty, *Foundations of Vacuum science and Technology*, John Wiley and Sons, New York, 1998.
3. A. Chambers, R. K. Fitch & B. S. Halliday, *Basic Vacuum technology*, 2^{nd} Ed, Overseas press, New Delhi -2005 or CRC press – 1998.

Prerequisite:

PH 471 GENERAL PHYSICS LABORATORY 2 Credits [0-0-3]

Error & Error analysis, least square fitting, Graphical analysis of data.

List of Experiments:

1. To determine fundamental charge by Milliken's oil drop expt.,
2. To determine Plank's constant by Black body radiation,
3. Measurement of e/m,
4. Measurement of Hall coefficient,
5. To obtain B-H loop,
6. Measurement of different noise level using sound level meter,
7. Franck-Hertz Experiment,
8. Refractive Index of medium by Michelson interferometer,
9. Current balance,
10. Variation of magnetic field by Helmholtz coil

Reference: Laboratory Manual

Prerequisite: 1^{st} level physics courses

PH 472 SOLID STATE PHYSICS LABORATORY 2 Credits [0-0-3]

List of Experiments:

1. Band gap of semiconductor crystal by four-probe arrangement,
2. Magneto resistance of a given sample,
3. Measurement of Dielectric constant & Curie temperature,
4. Dispersion relation of mono & diatomic lattice,
5. Tc & Jc of superconducting sample,
6. Young's modulus by Piezoelectric oscillator,
7. Mass susceptibility by Guoy balance,
8. Lande's g factor by ESR spectrometer in MHz range,
9. V vs I of semiconductor by varying temperature(low),
10. Refractive Index of transparent solid media at different temperature,
11. Study of Hysteresis loop of Ferroelectric/Ferromagnetic materials & estimate the energy.

Reference: Laboratory Manual

Prerequisite: 1^{st} level physics courses

PH 473 SPECTROSCOPIC LABORATORY 2 Credits [0-0-3]

List of Experiments:

1. Determination of wavelength of x-ray radiation from diffraction pattern of the given cubic crystal system,
2. Study of absorption lines of Na vapour,
3. Determination of wavelength of the given LASER source with the aid of grating,
4. Obtain and analyze the U-V spectra of an unknown system for different types of bonds,

5. Investigation of hyperfine structure of organic/inorganic/ionic radicals using EPR(ESR) spectrometer,
6. Optical microscopic studies of treated and untreated systems,
7. To obtain holographic image of a given object using LASER source
8. Diffraction of LASER by a narrow wire,
9. Wavelength of LASER source by Michelson interferometer,
10. To determine the resolution of gamma-ray spectrometer.

Reference: Laboratory Manual

Prerequisite: 1st level physics courses

PH 507 NUCLEAR & PARTICLE PHYSICS 4 Credits [3-1-0]

Properties of Nuclei, nuclear two-body problem, nuclear force, binding energy and stability of nuclei. Nuclear models : Liquid drop and Shell models; Nuclear decay, nuclear kinematics & classification of nuclear reactions, fusion & fission reactions; Brief overview of ion-beam applications for materials (various types of detectors); Elementary particles and their properties, fundamental forces.

Essential Reading:

1. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles,* Wiley India Pvt. Ltd., 2006.
2. Pehodgson, E. Gadioi , E. Gadioli-Erba, *Introductory Nuclear Physics*, Clarendon Press, 1997.

Supplementary Reading:

1. D. J. Griffith, *Introduction to Elementary particles*, John Wiley & sons. 2nd Ed., 2008.
2. D. H. Perkins, *Introduction to High Energy Physics*, 4th edition, Cambridge University Press, 2000.

Prerequisite: Quantum Mechanics courses

PH 508 ATOMIC & MOLECULAR PHYSICS 4 Credits [3-1-0]

Review of atomic structure of H, two electron systems, alkali system, Hartree-Fock method, density functional theory based Khon Sham equation, models for exchange co-relation functional, L-S coupling, JJ-coupling, fine structure & hyperfine structure. Zeeman, Stark & Paschen-Back effects. Auger & X-rays transitions; Molecular binding, LCAO, LCMO, molecular spectra (electronic, vibrational, rotational etc.); Principles of NMR, ESR, Raman spectra, LASERS.

Essential Reading:

1. R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles,* Wiley India Pvt. Ltd., 2006.
2. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill Publishing Company limited, New Delhi, 2007.

Supplementary Reading:

1. B. H. Bransden, C. J. Joachain, *Physics of Atoms and Molecule*, Prentice Hall, 2003.

2. P. W. Atkin and R. S. Friedman, *Molecular Quantum Mechanics*, Oxford University Press, Indian Edition, 2004.
3. D. A. McQuarrier, *Quantum Chemistry*, Viva Books Private Limited, Indian Edition, 2007.
4. P. Atkins, J. D. Paula, *Atkins' Physical Chemistry*, Oxford University Press, (Indian Edition), 8th Edition, 2008.
5. H. E.White, *Introduction to Atomic Spectra*, McGraw-Hill.

Prerequisite: Quantum Mechanics courses

PH 511 ADVANCED QUANTUM MECHANICS 4 Credits [3-1-0]

Integral formulation of Quantum mechanics, Path Integral Integral, Relativistic wave equations, field quantization & particle processes, second quantization, interaction picture, S-matrix, many particle Green's functions and diagrametric methods, Feynman diagrams, many body physics, relativistic quantum mechanics of spin-1/2 particles, quantum theory of radiation, co-variant of perturbation theory, elements of quantum electrodynamics. Applications in condensed matter physics.

Essential Reading:

1. J. J. Sakurai, *Advanced Quantum Mechanics*, Pearson Education, 2007.
2. P. Strange, *Relativistic Quantum Mechanics: with Applications in Condensed Matter & Atomic Physics,* Cambridge University press, 1st Ed., 1998.

Supplementary Reading:

1. L. D. Landau and E. M. Lifshitz, *Quantum Electrodynamics (vol.4),* 3rd Ed. Pergamon Press.
2. S. Doniach and E. H. Sondheimer , *Green's Functions for Solid State Physicists*, Imperial College Press, 1998.
3. E. N. Economou, *Green's Functions in Quantum Physics*, Springer, 3rd Ed., 2006.

Prerequisite: Quantum mechanics courses.

PH 512 ADVANCED STATISTICAL MECHANICS 4 Credits [3-1-0]

Review of equilibrium statistical mechanics and its applications, theory of phase transition, critical phenomena, critical points and order parameter, thermodynamic properties and exponents, fluctuation of the order parameter, mean field theory .The renormalization group: the definition, fixed points and exponents, RG in selected models, perturbation expansion and dynamics. Ising Model and magnetism, correlation functions, superconductivity, superfluidity, Bose-Einstein condensation, fluctuation problems. Percolation problems; Kadona transformations, Ginzberg-Landau form. The correlation length and scaling hypothesis, scale transformation and dimensional analysis; Non-equilibrium statistical mechanics, ergodic hypothesis and basic postulates, Langevin equations, Focker-Planck equations, diffusion equation, entropy from trajectory of motion, instability of a trajectory

Essential Reading:

1. L. E. Reichl, *A modern course in Statistical Physics*, Wiley & Sons, 2nd Ed., 1997.
2. R. Zwanzig, *Nonequilibrium Statistical Mechanics*, Oxford University Press, 2001.

Supplementary Reading:

1. L. Landau and E. M. Lifshitz, *Course in theoretical physics vol.5 (part-I) & vol.9 (part-II) - Statistical Mechanics,* 3rd Ed., Pergamon Press.
2. R. Bowley and M. Sanchez, *Introductory Statistical Mechanics*, Oxford Press, 2007.
3. V. Balakrishnan, *Elements of Nonequilibrium Statistical Mechanics*, CRC Press, 2008.
4. D. S. Lemons, *An Introduction to Stochastic process in Physics*, John Hopkins Univ. Press, 2002.

Prerequisite: Statistical mechanics course

PH 513 DENSITY FUNCTIONAL THEORY & ITS RECENT APPLICATIONS 4 Credits [3-1-0]

Origin : Thomas-Fermi Theory, Electron Density, Potential Relation, Minimum Energy Principle and Chemical Potential, Exchange energy from Fermi hole, Hartree-Fock Method, Exchange energy in atoms, Correlations in Thomas Fermi Framework; Hohenberg-Kohn Theorem, v-Representability, derivative discontinuity, Spin Polarised systems, Density Matrix Functional, Basic Kohn-Sham equations, Variational principle and self consistent equations, Extension to magnetic and multi-component systems, approximations for exchange correlation energies, applications to atoms, molecules and solids; Relativistic and time dependent density functional theory and its application to excited states problems.

Essential Reading:

1. R. E. Nalewajski, *Density Functional Theory (Relativistic & Time Dependent),* Springer Verlag, 1996.
2. R. M. Dreizder and E. K. U. Gross, *Density Functional Theory*, Plenum Press, 1995.

Supplementary Reading:

1. M. Marques, C. A. Ullrich, C. A. F. Nogueira, A. Rubio, K. Burke, K. E. K. U. Gross, (Eds.) ,Springer, 2006.
2. R. M. Martin, *Electronic Structure: Basic Theory and Practical Methods*, Cambridge University Press, 2004.
3. J. Kohanoff, *Electronic Structure Calculations for Solids and Molecules: Theory and Computational Methods,* Cambridge University Press, 2006.
4. C. Fiolhais, F. Nogueira, M. Marques (eds.), *A Primer in Density Functional Theory*, Springer-Verlag, 2003.

Prerequisite: quantum mechanics and condensed matter physics courses.

PH 514 ADVANCED CONDENSED MATTER PHYSICS 4 Credits [3-1-0]

Second quantization, Fermi liquid, electron-electron interaction, electron-hole interaction in semiconductors, elementary excitation, electron-phonon interaction, polarons; Density functional theory and advanced band structure calculations, approximation in exchange potentials, molecular dynamics; Cooperative phenomena, paramgnetism, ferromagnetism, Ising model, superconductivity, BCS and Ginzberg-Landau theories, Bose-Einstein condensation, Dynamical mean field theory.

Essential Reading:

1. W. G. Aulbur, L. Jonsson, and J. W. Wilkins, *Quasiparticle Calculations in Solids, Solid State Physics Vol.54*, Academic Press, 2000
2. G. D. Mahan, *Many Particle Physics (Physics of Solids and Liquids)*, Springer, 3rd Ed., 2007.

Supplementary Reading:

1. F. Duan and J. Guojun, *Introduction to Condensed Matter Physics*, World Scientific, 2005.
2. R. M. Dreizder and E. K. U. Gros, *Density Functional Theory*, Plenum Press, 1995.
3. Avella, Adolfo; Mancini, Ferdinando (Eds.), *Lectures on the Physics of Strongly Correlated Systems X*I, (Eleventh Training Course in the Physics of Strongly Correlated Systems) Springer, 2006.
4. S. Doniach and E. H. Sondheimer , *Green's Functions for Solid State Physicists*, Imperial College Press, 1998.
5. H.Bruus and K. Flensberg, *Many-Body Quantum Theory in Condensed Matter Physics: An Introduction,* Oxford University Press, 2004.

Prerequisite: Condensed matter physics course

PH 522 PHYSICS OF SEMICONDUCTORS: FROM BULK QUANTUM DOTS 4 Credits [3-1-0]

Crystal structure of Bulk semiconductors, theories of band structure, effective mass theory, k-p method etc. Band gap tailoring, doping with tri- and penta-valent elements, electron and holes, Fermi- Dirac statistics and electron & holes charge concentrations. Computational Method of band structure calculation, preparation of bulk and low dimensional semiconductors; Transport properties: Transport phenomena in bulk semiconductors : quantum mechanical theories of the interaction of photon with matter and first principle techniques for the calculation of transport properties, applied electric field and drift velocity, carrier mobility and ohm’s law, Diffusion and diffusion current equations , diffusion coefficient, Einstein relation, continuity equation, generation and recombination mechanism, minority carrier life time and diffusion length; Semiconductor heterostructures and their novel properties. Low dimensional semiconductors: two, one and zero dimensional semiconductors. Effect of quantum confinement. Semiconductor nono-structures and nano-tubes: the band structure and ground state properties. Dilute magnetic semiconductors: magnetic properties of doped semiconductors with magnetic impurities.

Essential Reading:

1. P. Y. Yu, and M. Cardona, *Fundamentals of Semiconductors Physics & Material Properties,* Springer Verlag, 1999.
2. J. Singh, *Semiconductor Devices: Basic principles*, Wiley India, 2008.

Supplementary Reading:

1. S. Dimitrijev, *Principles of Semiconductor Devices,* Oxford University, 2006.
2. C. Kittel, *Introduction to solid state physics*, John Wiley & Sons, 2004.
3. S. M. Sze, *Semiconductor Devices: Physics and Technology*, John Willey and Sons-2004.
4. Y. Fu and M. Wilander, *Physical Models of Semiconductor Quantum Devices*, Kluwar Academics, 1999.

Prerequisite: Quantum mechanics courses and basic knowledge of solid state physics

PH 523 SEMICONDUCTOR SPINTRONICS & QUANTUM COMPUTATION 4 Credits [3-1-0]

Properties of ferromagnetic semiconductor heterostructures, spin dependent scattering and tunneling, magneto-resistance, spin injection in ferromagnetic semiconductor heterostructures, spin injection and transport properties of micro- and nanoscale devices; Towards a semiconducting spin transistor, spin dynamics in semiconductors; coherent ensembles of spins, spin coherence in bulk and nanostructure semiconductors; Optical manipulation, transport and storage of spin coherence in semiconductors. Spin in quantum information processing. Electron spins in quantum; dots as Qubits for quantum information processing.

Essential Reading:

1. D. D. Awschaldm, *Semiconductor Spintronics & Quantum Computation*, Springer Verlag, 2002.
2. M. A. Nielsen and I. L. Chuang, *Quantum Computation & Quantum Information*, Cambridge University Press, 2002.

Supplementary Reading:

1. E. L. Nagaev, *Colossal Magneto-Resistance and phase separation in magnetic semiconductors,* World Scientific, 2002.
2. P. Kaye, R. Laflamme, M. Mosca, *An Introduction to Quantum Computing,* Oxford University press, 2007.
3. S. Bandyopadhyay and M. Cahay, *Introduction to Spintronics*, CRC Press, 2008.
4. S. Maekawa, *Concepts in Spin Electronics*, Oxford University Press, 2006.

Prerequisite: quantum mechanics & condensed matter physics courses

PH 524 COMPUTATIONAL CONDENSED MATTER PHYSICS 4 Credits [3-1-0]

Review of linear methods of band structure calculation. Density functional theory, Time dependent density functional theory, Pseudopotential, tight binding, KKR, augmented plane wave methods for band structurecalculations; Greens' function method-GW approximation coupled with density functional theory for first principle calculations. Calculation of transport properties. Application to bulk materials; Molecular Dynamics: Simulation of nano materials and their properties, tight binding and Carr-Perrinello molecular dynamics(Emphasis would be given to numerical calculations and development of computer codes.)

Essential Reading:

1. R. M. Martin, *Electronic Structure: Basic Theory and Practical Methods*, Cambridge University Press, 2004.
2. J. Kohanoff, *Electronic Structure Calculations for Solids and Molecules: Theory and Computational Methods,* Cambridge University Press, 2006.

Supplementary Reading:

1. R. M. Dreizder and E. K. U. Gros, *Density Functional Theory*, Plenum Press, 1995.
2. R. E. Nalewajski, *Density Functional Theory (Relativistic & Time Dependent),* Springer Verlag, 1996.
3. I. Turek, V. Drchal, J. Kudrnovsky, M. Sob, P. Weinberger, *Electronic Structure of disordered alloys, structure & interfaces,* Kluwar Academic Publishers, 1997.

4. V. V. Nemoshkalenko and V. N. Antonov, *Computational Methods in Solid State Physics,* CRC Press, 1998.
5. D. Hugues(ed), *Electronic Structure & Physical Properties of Solids (lecture notes*), Springer, 1998.

Prerequisite: Quantum mechanics & condensed matter physics courses.

PH 531 NON-LINEAR DYNAMICS, CHAOS & RECENT APPLICATIONS 4 Credits [3-1-0]

Introduction to non-linear dynamics, Chaos & Fractals. One Dimensional Flow: Fixed points and Stability, Bifurcations, flow on the circle. Two Dimensional Flow: Linear systems, Phase plane, Limit cycles, bifurcation in two dimensional systems. Chaos: Chaos on a strange attractor, Lorenz map, Periodic windows, Liapunov exponents, universality, Renormalization. Strange attractors: Henon map, Rossler system. Spatio-Temporal Chaos in extended system; Synchronization in nonlinear and chaotic systems. Fractals. (With examples from physics, chemistry, biology, fluid dynamics and electronic circuits.)

Essential Reading:

1. D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equations,* Oxford Univ. Press, 4th Ed., 2007.
2. S. H. Strogatz, *Nonlinear dynamics & Chaos*, Levent Books (Kolkata) Indian Ed., 2007.

Supplementary Reading:

1. G. L. Baker and J. P. Gollub, *Chaotic dynamics-An Introduction*, Cambridge University Press, 1996.
2. F. Verhulst, *Nonlinear differential equations and dynamical systems,* Springer, 2nd Ed, 1999.
3. T. Kapitaniak, *Chaos for Engineers*, Springer, 1998.
4. P. S. Addison, *Fractals & Chaos,* Overseas Press, 2005.
5. D. Kaplan and L..Glass, *Understanding Nonlinear Dynamics,* Springer, 1998.

Prerequisite: Good knowledge of Partial differential equations and algebra

PH 532 PHYSICS OF MACROMOLECULES 4 Credits [3-1-0]

Variety of macromolecules, synthetic, natural and biopolymers, synthesis of macromolecules, molecular weight, concept of mono dispersity and poly dispersity, review of mathematical statistics, distribution of molecular weight, Review of thermodynamics for small molecules, thermodynamics of macromolecules, entropy of mixing, the Flory-Huggins lattice theory, enthalpy and free enthalpy of mixing, partial molar quantities, partial specific volume, chemical potential, static's and dynamics of dilute of polymer solution, Rouse model, Zimm model, Chain conformations and configurations, single ideal chain, mean square end to end distance, radius of gyration, freely joined chain, worm like chain, the random flight model, excluded volume, solvent quality, theta temperature, semi-dilute and concentrated polymer solutions, chain cross-over and chain entanglement; Experimental techniques: Macromolecular structure, principles of x-ray diffraction, x-ray diffraction by macromolecules. Viscosity, intrinsic viscosity, viscoelasticity. Osmotic pressure, determination of molecular weight by osmometer, second virial coefficient. Diffusion, Fick's first and second law, Einstein equation of diffusion. Light scattering, Rayleigh scattering, Fluctuation theory, determination of molecular weight, radius of gyration, second virial coefficient, diffusion coefficient and hydrodynamic radius of macromolecules; Some concepts of electrolytes and polyelectrolytes, Debye-Huckle theory, Donnan equilibrium, flexible plyelectrolytes, polypeptides, proteins, nucleic acid, self-assembly, colloids, surfactants, micelles. Scaling and universality.

Essential Reading:

1. S. F. Sun, *Physical Chemistry of Macromolecules,* John Wiley & Sons, 2004.
2. P. Munk and T. M. Aminabhavi, *Introduction to Macromolecular Science*, Wiley-Interscience, 2002.

Supplementary Reading:

1. G. Pattersom, *Physical Chemistry of Macromolecules*, CRC Press, 2007.
2. M. Doi and H. See, *Introduction to Polymer Physics*, Oxford University Press, 1996.
3. M. Doi, S. F. Edwards, *The Theory of Polymer Dynamics*, Clarendon Press, 1999.
4. A. E. Tonelli, *Polymers from Inside Out:In introduction to Macromolecules*, John Wiley-Interscience, 2001

Prerequisite: Basic Mathematics and statistics, basic thermodynamics.

PH 533 SYNCHRONIZATIONS AND ITS RECENT APPLICATION IN CHAOTIC SYSTEMS 4 Credits [3-1-0]

Synchronization in historical perspective. The basic notions: the self sustained oscillators and its phase, self sustained oscillators in nature, synchronization of a driven periodic oscillators, phase and frequency locking; Synchronization of higher order and Arnold tongues, synchronization of relaxor oscillators. Synchronization of two and many periodic oscillators, frequency locking, chains, lattices and oscillatory media; Synchronization in chaotic oscillators: Lorentz, Rossler, Marhieu oscillators; phase synchronization of chaotic oscillators, synchronization in the presence of noise, populations of globally coupled oscillators.

Essential Reading:

1. A. Pikovsky, M. Rosenblum and J. Kurths, *Synchronization: A Universal Concept in Nonlinear Science,* Cambridge University Press, 2002.
2. S. H. Strobatz, *SYNC: How Order Emerges From Chaos In the Universe, Nature, and Daily Life,* Hyperion, 2004.

Supplementary Reading:

1. G. V. Osipov, J. Kurths and C. Zhou, *Synchronization in Oscillatory Networks* (Springer Series in Synergetics), Springer, 2007.
2. S. H. Strogatz, *Nonlinear dynamics & Chaos*, Levent Books (Kolkata) Indian Ed., 2007.
3. Y. Kuramoto, *Chemical Oscillations, Waves, and Turbulence,* Dover Publications, 2003.
4. A. T. Winfree, *The Geometry of Biological Time*, Springer, 2001.

Prerequisite: Good knowledge of differential equations and linear algebra.

PH 541 DIELECTRIC & MAGNETIC PROPERTIES OF MATERIALS 4 Credits [3-1-0]

Review of crystallography: - Symmetry, point groups, Miller indices, Laue's condition, Reciprocal lattice, Brillouin zones; **Magnetic Properties and magnetic materials**: - Van Vleck paramagneism Quantum theory of paramagnetism and Ferromagnetism. Temperature dependence spontaneous magnetization, magnetic domain, hystersis, Exchange interaction. Molecular field theory(Weiss law). Technological application of magnetic materials & multilayers in memory device, sensors, magnetic bubbles; **Phenomenological theories of magnetic order**- Interaction of atomic spins at large distance, molecular field theory, Spin waves, Ising model, Magnetic phase transition; **Di electric material :-** Classical & Quantum, theory of electronic polarisability and ionic polarisability spontaneous polarization , Hystersis, Frequency dependent polarization, Piezoelectricity; **An introduction to relaxor ferroelectricity**. Pervoskite crystal structure, Ferroelectric phases and domains , Curie Weiss behavior, Diffuse phase transition, Physics of Relaxor ferroelctricity , ABO3 relaxors, Application of ferroelectricity.

Essential Reading:

1. S. Blundell*, Magnetism in condensed matter*, Oxford university press, 2001.
2. A. Aharoni, *Introduction to the theory of ferromagnetism,* Oxford university press, 2001.

Supplementary Reading:

1. C. Kittel, *Introduction to solid state physics*, John Wiley & Sons, 2004.
2. Y. D. Jiles*, Introduction to magnetism and magnetic materials*, Chapmean and Hall. (2^{nd} edition).
3. Ashcroft/ Mermin, *Solid state physics*, India edition IE, Thomsom books, Reprint, 2007.
4. L. L. Hench, J. K. West, *Principles of electronic ceramics*, John Wiley and sons,1995.

Prerequisite: 5^{th} level condensed matter physics and quantum mechanics courses

PH 542 PHYSICAL & APPLICATION OF DIELECTRIC MATERIALS 3 Credits [3-0-0]

Maxwell Equations & Polarization, Macroscopic Electric Field, Local Electric Field at an Atom, Chemical Bond in Dielectrics, Structure of Dielectrics, Electrical Conduction in Dielectrics, Polarization Mechanisms in Dielectrics, Dielectric Relaxation, Ferro-electricity: Theory of Ferroelectrics, Domain, Imperfections & Polarization Reversals, Experimental Study of Thermodynamic Properties, Oxygen Octahedron, Order Disorder Ferroelectric, Critical Phenomena, Size Limit on Ferro-electricity, Applications of Ferroelectric Materials: Ferroelectric Ceramics Applications, Applications of Piezoelectric Ceramics, Ferroelectric Thin Films Applications, Electro-optic Applications.

Essential Reading:

1. A. J. Moulson and J. M. Herbert, *Electroceramics: Materials, Properties and Applications,* Wiley; 2^{nd} Edition, 2003.
2. K. Uchino, *Ferroelectric Devices*, New York: Marcel Dekker, 2000.

Supplementary Reading:

1. M. E. Lines and A. M. Glass, *Principles and Applications of Ferroelectric and Related Materials,* Clarendon Press, Oxford, 2007.
2. Y. H. Xu, *Ferroelectric Materials and Their Applications*, Noth-Holland, 1991.
3. C. Kittel, *Introduction to Solid State Physics*, 8^{th} Ed. John Wiley & Sons Pvt. Ltd, 2004.

Prerequisite: Basic knowledge of Electrostatics, Magnetostatics & Dielectric Materials

PH 553 ADVANCED X- RAYS SRUCTURE ANALYSIS 4 Credits [3-1-0]

Introduction to x-rays, Introduction to X-ray diffraction_techniques, Qualitative and quantitative analysis of XRD data, prerequirements of Sample preparation for XRD data, Measurement of line intensities, Various factors effecting XRD intensities, Quantitative methods based on intensity ratios, The absorption diffraction method, Internal standard method, General RIR method, Normalized RIR method, Constrained XRD phase analysis, Detection limit issues Preliminary idea about XRF, PIXE, SAXS, GISAXS, EDX and their applications to characterize the materials with limitations of the techniques. X-ray spectroscopy and its application in characterization of materials. Advantages and disadvantages of the above mentioned techniques; Introduction to Medical application of X-rays and different equipments used for diagnosis purposes.

Essential Reading:

1. B. D. Culiety and S. R. Stock, *Elements of x-ray diffraction*,Pearson, 3rd Edn, 2001.
2. A. R. Verma, O. N. Srivastava, *Crystallography Applied to Solid State Physics*, New New Age International Publication, 2001.

Supplementary Reading:

1. A. K. Singh*, Advanced X-ray Techniques in Research and Industry*, Capital Publishing Company, 2006.

Prerequisites: Elementary knowledge on modern physics.

PH 554 PHYSICS OF THIN FILM TECHNOLOGY 4 Credits [3-1-0]

Physical vapor deposition (PVD):- Physical fundamentals and technical aspects Theories of film growth and applications, Sputtering(RF &DC), Pulse laser deposition and Molecular beam epitaxy; **Chemical vapor deposition (CVD):-** Physical fundamentals and technical aspects Theories of film growth and applications; Ferro Magnetic, dielectric and superconducting thin film and multilayers; **Langumuir Blodgett thin film:-** Technical details, Isotherm, Applications to organic electronics sensors etc Self assembly; **Sol-gel Spin coating:-** Technical details-hydrodynamics of spin coating (Newtonian and non-Newtonian behavior), dip coating; **Thin film characterizing technique:-** Surface Plasmon resonance spectroscopy , Ellipsometry, Atomic force Microscopy, and Tunneling electron microscopy, Transmission electronmicroscopy

Essential Reading:

1. Milton Ohring, material science of thin film deposition and structure, academic press, John Wiley New york, 2006.
2. Maissel L I, Glang R Hand book thin film technology Mc Graw Hill 2 nd edition.

Supplementary Readi:

1. R. Sahu, *Physics of solid, nuclei and particle*, Narosa publishing house, 2006.
2. K. L. Chopra,*Thin film phenomena* , Mcgraw- Hill book company latest Edition.
3. C. C Julian, *Introduction of electron Scanning Tunneling Microscopy*, Coulombia university press, 2006

Prerequisite: condensed matter physics and quantum mechanics courses

PH 555 PHYSICS OF MATERIAL SYNTHESIS AND CHARACTERIZATION 4 Credits [3-0-0]

Bulk Materials Synthesis Techniques: Powders synthesis method; mechanical methods, hydrothermal synthesis of ceramic oxide powders, chemical methods, synthesis of nano-scale ceramic powders, powder characterization, particle size, shape, surface area, chemical composition, crystal structure and phase composition. **Thin Film Synthesis Techniques:** Physical vapor deposition, Chemical vapor deposition, Pulsed LASER Deposition, Sol-Gel, Molecular Beam Epitaxy, **Characterization Techniques:** X-Ray Diffraction Methods, X-Ray Fluorescence, Electron Dispersion Spectroscopy, Thermo gravimetric Analysis, Differential Thermal Analysis, Differential Scanning Calorimetery, Electron Microscopy-Transmission and Scanning Electron Microscopy, STM and AFM, Compositional analysis employing AES, ESCA and Electron Probe Microanalysis. Fourier Transform Infrared Spectroscopy.

Essential Reading:

1. M. Ohring,*The materials Science of Thin films*, Amazon, 2001.
2. M. N. Rahaman, *Ceramic Processing*, CRC Press, Taylor & Francis Group, FL, 2007.

Supplementary Reading:

1. D. A. Skoog, F. J. Holler and T. A. Nieman, *Principles of Instrumental Analysis*, 5th Ed., Hartcourt College Publishers, 1998.
2. *Lecture notes of AICTE Short term Winter School on Advanced Techniques for Characterization of Materials*, Feb. 12-23, 1996, IIT Delhi.
3. B. D. Culiety and S. R. Stock, *Elements of x-ray diffraction* ,Pearson, 3rd Edn, 2001.

Prerequisite: Basic knowledge of Quantum Mechanics

PH 556 X- RAY AND NANO- SCIENCE 4 Credits [3-1-0]

Production and properties of X-rays. Introduction to Nanoscience, Roll of X-ray in Nanoscience. Real and reciprocal space, application of reciprocal space to diffraction, Ewald’s sphere, X-ray crystallography including space group and symmetries, scattering of X-ray by free and bound electrons, scattering by liquids; Introduction to Small Angle X-ray Scattering (SAXS), postulates of SAXS theory, Idea of different systems (ideal, non-ideal, monodisperse, polydisperse, dilute and dense systems). Overview of experimental SAXS system, Calculation of scattered intensity from a single particle & many particle systems, Refinement of SAXS data. Characterization of nano materials using SAXS data. General application of SAXS technique.

Essential Reading:

1. B. D. Culiety and S. R. Stock, *Elements of x-ray diffraction*, Pearson, 3rd Edn, 2001.
2. P. Linder, Z. Th. Neutron, *X-ray and Light: scattering methods applied to soft condensed matter,* Elsevier Science, 2002.

Supplementary Reading:

1. G. V. Paulinsky, *Fundamentals of x-rays*, Cambridge international science, 2008.
2. N. Kasai, M. Kakudo, *X-ray diffraction by Macromolecules*, Springer, 2005.
3. E. J. Mittemeijer, P. Scardi, Diffraction Analysis of microstructure of materials, Springer, 2003.

Prerequisites: Elementary knowledge on physics.

PH 561 PHYSICS OF MICROELECTRONIC AND PHOTONIC DEVICES 4 Credits [3-1-0]

The course introduces carrier transport in materials, physics of phenomena in semiconductors and optical fiber communications. This course provides basic idea to carry research in the area of semiconductors and photonics; Carrier Drift, Drift velocity, Carrier mobility, Carrier Diffusion, Generation and Recombination Process, Diffusion and diffusion current equations, Diffusion coefficient, Einstein relation, Continuity equation, Thermionic Process, Tunneling Process, High Field Effects; Thermal equilibrium condition, Depletion region, Depletion capacitance, Current voltage characteristics, Junction breakdown, Heterojunction, junction potential; Behaviour of charged particles in conducting, insulating and semiconductor materials - thin film phenomena - Transport properties of thin films - Epitaxial growth - Microelectronics - Lithography and etch techniques - Microelectronic devices for Magnetic, dielectric, conductive and optical memory applications; Radiative Transition and optical absorption, Light emitting Diode, Semiconductor Laser, Laser Diodes, Optical Modulators, optical fibers, couplers, electro-optic devices, magneto-optic devices, Photo detector, Solar cell.

Essential Reading:

1. B. G. Streetman and S**.** Banerjee , *Solid State electronic devices*,, 5th edition**,** Prentice Hall of India Private Limited, New Delhi, 2000.
2. S. M. Sze, *Semiconductor Devises (Physics and Technology),* John Wiley & Sons Inc. 2nd Edition 2002

Supplementary Reading:

1. C. Kittel, *Introduction to solid state physics*, 7th Edition, Wiley Student Edition Reprint 2006.
2. Jean-pierre Colionge, C. A. Colinge, *Physics of SemiconductorDevices,* Klumer Acamedic Publication, 2002.
3. N. D. Gupta, *Amitav Das Gupta,Semiconductor Devices Modelling and Technology*, Prentice Hall of India,2004.
4. S. Dimitrijeo, *Principle of Semiconductor Devices,* Oxford University 2006.
5. jia- Ming Liu, *Photonic Devices*, Published by Cambridge University Press, 2005.

Prerequisites: knowledge in elementary solid state Physics and semiconductor properties**.**

PH 562 SUPERFLUIDITY AND SUPERCONDUCTIVITY 4 Credits [3-1-0]

Superdiamagnetism, Bose-Einstein Condensate, Quantum vortex, Supersolid, Superfluid film, gauge symmetry breaking, Claussius-Clapeyron relation Phenomenology of superconductivity, review of basic properties, thermodynamics of superconductors, Meissner effect, London equations, Cooper pairs, coherence length, Ginzburg-Landau theory, BCS theory, Josephson effect, SQUID, excitations and energy gap, magnetic properties of type-I and type-II superconductors, flux lattice; Introduction to high-temperature superconductors, Inhomogeneities, Superconducting order parameter fluctuation. Experimental Techniques for Low-Temperature Measurements, Material Properties and Superconductor Critical-Current Testing.

Essential Reading:

1. C. Kittel, *Introduction to Solid State Physics,* John Wiley & Sons 7th Edition, 2004, Reprint 2006.
2. D. R. Tilley and J. Tilley , *Superfluidity and superconductivity*, 3rd Ed., New Delhi: Overseas Press, 2005.

Supplementary Reading:

1. N. W. Ashcroft and N. D. Mermin, *Solid State Physics,* Thomson India, Edition, 4th Indian Reprint 2007.
2. M. Tinkham, *Introduction to Superconductivity*. 2nd Edition Dover, 2004, 2nd edition of the work first published by McGraw-Hill Book Co., New York, in 1975.
3. H. Kleinert, *Gauge Fields in Condensed Matter, Vol-I SUPERFLOW AND VORTEX LINES,*
4. *G. Deutscher, New Superconductors: From Granular to High Tc*, World Scientific, 2006.
5. J. Ekin, *Experimental Techniques*, Oxford Uni.Press,2006

Prerequisites: Knowledge in elementary solid state Physics and Statistical Mechanics.

PH 571 INSTRUMENTATION LABORATORY 2 Credits [0-0-3]

List of Experiments:

1. Microprocessor based Physics experiments
2. AD/DA converter circuits for interfacing
3. Creation of low temperature and its measurement
4. Measurement of Resistance of material at low temperature
5. Design of temperature sensor using commertial circuit resister and diods.
6. Design of power supply using IC
7. Design of power supply having + and –ve voltage supply to be used in OPAMP
8. Design and fabrication of a constant current source.
9. Demonstration of group wave using sound waves.

Reference: Laboratory Manual

Prerequisite: 1st level electronics laboratory course

PH 572 ADVANCED MATERIALS SYNTHESIS LABORATORY 2 Credits [0-0-3]

Synthesis of Nanomaterials, thin films, hydrogel, colloids, electroceramics etc. in research laboratories.

PH 573 COMMUNICATIONAL PHYSICS LABORATORY 2 Credits [0-0-3]

Programming for numerical calculations using various numerical techniques- roots of a equation, matrix eigenvalue problems, solving differential equations, use of Monte-Carlo simulation for statistical problems, etc., with Fortran & C languages application of MATLAB & OCTAVE.

Essential Reading:

1. S. C. Chapra, *Numerical Methods for Engineers*, Tata-McGraw-Hill. 5th Ed., 2007.
2. V. Rajaraman, *Programming in Fortran 77*, PHI, 4th Ed., 2003.

Supplementary Reading:

1. S. Chandra, *Computer Applications in Physics*, Narosa Publications, 2003.
2. S. J. Chapman, *MATLAB Programming for Engineers*, Thomson Learning.
3.

Prerequisite: Knowledge of C-programming

PH 574 ADVANCED CHARACTERISTICS TECHNIQUES LABORATORY 2 Credits [0-0-3]

Use of Characteristics techniques like XRD, SEM, Particle Analyzer, etc.