UNIVERSITY OF PUNE

DEPARTMENT OF PHYSICS (ACADEMIC FLEXIBILITY)

M. Sc. (Physics) Course Pattern under Credit System

NOTE: **The Department of Physics, University of Pune has wielded the academic flexibility endowed to it is a gainful way by having the syllabi for Master's Degree in Science (M. Sc.) [Physics] in consonance with those at various peer institutes internationally. During the second year, a host of elective courses are offered. The following in a nutshell gives the scope and extent of each course offered. Each core theory course has two levels of teaching: Lectures and Tutorials (which are intensive problem solving sessions). There are common laboratories as well as special laboratories associated with electives. A Project Course, equivalent to two full theory courses enables the student to work on specific problems of her/his interest under a faculty member's guidance.**

These syllabi have been approved by the Pune University Board of Studies (BOS) in Physics on July 10, 2010. Further, a formal approval by the Academic Council will be sought shortly.

Course Titles

Semester I

PHY-P101 Basic Physics Laboratory-I *

PHY-P102 Computer Laboratory*

PHY-T103 Quantum Mechanics-I

PHY-T104 Electronics

PHY-T105 Classical Mechanics

PHY-T106 Mathematical Methods in Physics

Semester II

PHY-P201 Basic Physics Laboratory-I*

PHY-P202 Computer Laboratory*

PHY-T203 Quantum Mechanics-II

PHY-T204 Electrodynamics-I

PHY-T205 Statistical Mechanics

PHY-T206 Atoms, Molecules & Solids

* Basic Physics Laboratory OR Computer Laboratory in a given semester, depending on the student-batches. Thus half the class performs BPL, the remaining half Computer Lab in Semester I. In Semester II, these laboratories are interchanged; so that by the end of the first year, a student will have carried ***both*** these laboratories.

Semester III

Mandatory Courses:

PHY-P301 Basic Physics Laboratory-II (A)

PHY-T302 Solid State Physics

PHY-T303 Electrodynamics-II

One of the following two courses is mandatory:

PHY-T304 Methods of Experimental Physics

PHY-T305 Methods of Computational Physics

Electives that could be offered at Semester III (ONE ELECTIVE to be chosen):

PHY-T306 Physics of Thin Films & Device Technology

PHY-T307 Condensed Matter-I

PHY-T308 Microwaves : Theory and Applications

PHY-T309 Quantum Mechanics-III

PHY-T310 Materials Science-I

PHY-T311 Astronomy and Astrophysics-I

PHY-T312 Nuclear Techniques-I

PHY-T313 Biophysics-I

PHY-T314 Bioelectronics-I

PHY-T315 Laser-I

PHY-T321 Accelerator Physics-I

PHY-T323 Nonlinear Dynamics-I

PHY-T324 Chemical Physics-I

PHY-T325 Nanotechnology-I

PHY-T-327 Energy Studies-I

Semester III : Special Laboratory Courses

PHY-P306 Experiments based on PHY-T306

PHY-P307 Experiments based on PHY-T307

PHY-P308 Experiments based on PHY-T308

PHY-P309 Experiments based on PHY-T309

PHY-P310 Experiments based on PHY-T310

PHY-P311 Experiments based on PHY-T311

PHY-P312 Experiments based on PHY-T312

PHY-P313 Experiments based on PHY-T313

PHY-P314 Experiments based on PHY-T314

PHY-P315 Experiments based on PHY-T315

PHY-P321 Experiments based on PHY-T321

PHY-P323 Experiments based on PHY-T323

PHY-P324 Experiments based on PHY-T324

PHY-P325 Experiments based on PHY-T325

PHY-P327 Experiments based on PHY-T327

Semester IV

Mandatory Courses:

PHY-P400-A Project

PHY-P400-B Project

PHY-P401 Basic Physics Laboratory-II (B)

PHY-T402 Nuclear Physics

Electives: Parts “II” of the PHY-T3## quoted above:

PHY-T406 Thin Films and Device Technology

PHY-T407 Condensed Matter-II

PHY-T408 Radiowave Applications

PHY-T409 Quantum Mechanics-IV

PHY-T410 Materials Science-II

PHY-T411 Astronomy and Astrophysics-II

PHY-T412 Nuclear Techniques-II

PHY-T413 Biophysics-II

PHY-T414 Bioelectronics-II

PHY-T415 Laser-II

PHY-T421 Accelerator Physics-II

PHY-T423 Nonlinear Dynamics-II

PHY-T424 Chemical Physics-II

PHY-T425 Nanotechnology-II

PHY-T-427 Energy Studies-II

Sem. IV Special Laboratory Courses

PHY-P406 Experiments based on PHY-T406

PHY-P407 Experiments based on PHY-T407

PHY-P408 Experiments based on PHY-T408

PHY-P409 Experiments based on PHY-T409

PHY-P410 Experiments based on PHY-T410

PHY-P411 Experiments based on PHY-T411

PHY-P412 Experiments based on PHY-T412

PHY-P413 Experiments based on PHY-T413

PHY-P414 Experiments based on PHY-T414

PHY-P415 Experiments based on PHY-T415

PHY-P421 Experiments based on PHY-T421

PHY-P423 Experiments based on PHY-T423

PHY-P424 Experiments based on PHY-T424

PHY-P425 Experiments based on PHY-T425

PHY-P426 Experiments based on PHY-T426

PHY-P427 Experiments based on PHY-T427

M.Sc. (Physics) Course Pattern under Credit System Syllabus

PHY-P101/P201 : BASIC PHYSICS LABORATORY-I (25 Credits, 120 Lab. Hours)

Group A (Electronics)

1. Temperature to frequency conversion using a thermister and astable multivibrator circuit.
2. Transfer characteristics of UJT & FET.
3. Operational Amplifier characteristics using IC 741.
4. Capacitance measurement using IC 555.
5. Characteristics of a solar cell.

Group B (Basic Processes)

1. Study of thermionic emission & measurement of work function.
2. Critical potential measurement using Franck-Hertz tube.
3. Measurement of de Broglie wavelength (λ) and interplanar distance (d) using electron-diffraction method.
4. Counting statistics for radioactive decay
5. Determination of mass absorption coefficient for beta rays.

Group C (Measurement of Physical Constants)

1. e/m ratio of electron using Thomson method.
2. Magnetic susceptibility measurement using Gouy's Method.
3. Milikan's oil drop experiment.

Group D (Optics)

1. Wavelength measurement of Na-source using Michelson interferometer.
2. Study of Fabry Perot interferometer & measurement of d.
3. Rydberg's constant using constant deviation prism.
4. Zeeman effect-study and use of L G Plate.
5. Coherence & width of spectral lines using Michelson interferometer.

Recommended Reference Books :

1. *Practical Physics*: Worsnop and Flint.
2. *Measurement, Instrumentation and Experiment.*
3. *Design in Physics,* Michael Sayer, Abhai Mansingh.
4. *Fundamentals of Optics,* Jenkins and White, McGraw-Hill, International Edition.
5. *Solid State Physics,* A. J. Dekker, Macmillan India Ltd., (1998).
6. *Electronics Principles,* Malvino.
7. *Physics Lab. Experiments,* Jerry D. Wilson, D. C. Heath and Company.

PHY-P102/202 : COMPUTER LABORATORY 5 Credits (120 Lab. Hours)

A. Exercises for acquaintance: (Using FORTRAN 90)

1. To find the largest or smallest of a given set of numbers.
2. Bubble sort.
3. Division of two complex numbers (treating a complex number as an ordered pair of reals).
4. To generate and print first hundred prime numbers.
5. To generate and print an odd ordered magic square.
6. Transpose of a square matrix using only one array.
7. Matrix multiplication.
8. Raising a real number to a large integer power.
9. Fibonacci search.
10. Merging of files.

B. Numerical Analysis :

1. Lagrange Interpolation.
2. Divided difference interpolation.
3. Binary search.
4. Regula falsi.
5. To locate the extrema of a function.
6. Evaluation of Bessel Functions.
7. Newton-Raphson Method.
8. Method of successive approximations.
9. Secant method.

Simultaneous equations :

1. Gaussian Elimination.
2. Gauss-Seidel method.

Least Squares Approximation :

1. Linear fit.
2. Fitting an exponential.
3. Fitting a trigonometric function.

Numerical Integration :

1. Simpson's rule.
2. Gaussian Quadrature.
3. And experiments similar to the above. (*Note* :— The course is expected to comprise 20 exercises).

Books :

1. *Computer Programming in FORTRAN 77,* V. Rajaram, Prentice Hall of India, 3rd Edition.
2. *Computer Oriented Numerical Methods,* V. Rajaraman, Prentice Hall of India.
3. *Numerical Methods for Scientist and Engineers,*
4. H. M. Antia, Tata McGraw Hill.
5. N*umerical Methods with Fortran IV case studies,* Dorn & McCracken, John Wiley and Sons.
6. *Numerical Recipes in FORTRAN (2nd Edn.),* W. H. Press, S. A. Teakalsky, W. T. Vellerling, B. P. Flannery, Cambridge University Press.
7. Programming in Fortran 90/95 – Rajaram, Prentice-Hall of India

PHY-T103 : QUANTUM MECHANICS-I

Module-1 : 1 Credit (10L, 5T/S/D)

Revision, Inadequacy of classical concepts, wave-particle duality, thought experiments, uncertainty relations.

Schrödinger equation, continuity equation, Ehrenfest's theorem; solutions of Schrödinger equation, admissible wave functions, stationary states.

Simple one-dimensional problems; harmonic oscillator and its stationary states using Schrödinger equation one dimensional wells and barriers.

Module-2 : 1 Credit (10L, 5T/S/D)

Obtaining of uncertainty relation of x and p from commutation relation, states with minimum uncertainty product.

General formalism of wave mechanics; representation of states and dynamical variables; observables, self-adjoint operators; completeness of Eigenfunctions; Dirac delta functions; commutability and compatibility, Bra and Ket notation; matrix representation of an operator, change of basis; unitary transformations.

Module-3 : 1 Credit (10L, 5T/S/D)

Simple harmonic oscillator by operator method.

Angular momentum in quantum mechanics; Pauli theory of spins; addition of angular momenta; computation of Clebsch-Gordan coefficients in simple cases.

Central forces, hydrogen atom.

Module-4 : 1 Credit (10L, 5T/S/D)

Evolution of system with time; constants of motion, Heisenberg, Schrödinger and Interaction pictures.

Time-independent perturbation theory; non-degenerate and degenerate cases; Applications such as the Stark effect.

Module-5 : 1 Credit (10L, 5T/S/D)

Variational method, helium atom, van der Waals' interaction.

Prescribed Text Books :

1. *Quantum Mechanics,* L. I. Schiff, (McGraw-Hill).
2. *Quantum Physics,* S. Gasiorowicz, (Wiley International).
3. *Introduction to Quantum Mechanics,* L. Pauling and E. B. Wilson, (McGraw Hill).
4. *Quantum Mechanics,* B. Crasemann and J.D. Powel, (Addison-Wesley).
5. *Quantum Mechanics,* Cohen-Tannaudji, Din, Laloe Vols. I & II (John Wiley).
6. *Quantum Mechanics, Messiah,* A.P., Q.M.-Vol. I & II.

7. *Quantum Mechanics,* L. D. Landau and E. M. Lifshitz. (Addison Wesley).
8. *The Principles of Quantum Mechanics,* P. A. M. Dirac, (Clarendon Press, Oxford).
9. *Modern Quantum Mechanics,* J. J. Sakurai, (Addison Wesley).
10. *Quantum Mechanics,* I. Levine, (Allyn and Bacon).
11. *Quantum Mechanics,* D. J. Griffths (Pearson Education).
12. *Quantum Mechanics, Non- relativistic Theory,* L.D. Landau and E.M. Lifshitzm (Addison-Wesley)
13. *A Modern Approach to Quantum Mechanics* - Townsend (University Science Books)
14. *Essential Quantum Mechanics* - Bowman (Oxford University Press)
15. *Quantum Physics* - Le Bellac (Cambridge University Press)

PHY-T104 : ELECTRONICS

Module-1 : 1 (Credit (10L, 5T/S/D)

Four-terminal networks, input, output, hybrid parameters and equivalent circuits.

Amplifiers and their biasing (CE, CB, CC).

Differential Amplifier, its parameters, CMRR.

Module-2 : 1 (Credit (10L, 5T/S/D)

OPAMP : Operational feedback, parameters, applications (Adder, subtractor, active filters, AC voltmeter).

Power Amplifiers, push pull for PA system, Class-C tuned amplifiers-frequency multipliers.

Module-3 : 1 (Credit (10L, 5T/S/D)

Positive and negative feedback and their effects on the performance of amplifier, Barkhausen criteria.

Oscillators-LC and RC : Wien bridge, phase shift Hartley and Colpitt.

Module-4 : 1 (Credit (10L, 5T/S/D)

Power supplies-series, shunt and line filters.

Wave shaping circuits, clipping differentiation, integration using passive and active components.

Module-5 : 1 (Credit (10L, 5T/S/D)

Digital Electronics-Logic gates, Arithmetic circuits, Flip Flops, Clocks counters, Shift registers, ADC, DAC, Introduction to Microprocessors.

Elements of Microprocessors.

Books :

1. *Electronics Principles,* A. P. Malvino, Tata McGraw Hill, New Delhi.
2. *Electronics Fundamentals and Applications,* J. D. Ryder, John Wiley-Eastern Publications.
3. *Integrated Circuits, Milman and Halkias,* Prentice-Hall Publications.
4. *Digital Principles and Applications,* A. P. Malvino, D.P. Leach, McGraw Hill Book Co., 4th Edition (1986).

PHY-T105 : CLASSICAL MECHANICS

Module-1 : 1 (Credit (10L, 5T/S/D)

Mathematical Preliminaries, Newtonian mechanics of single and many particle systems. Conservation laws, work energy theorem, open systems (with variable mass).

Constraints, their classification, D'Alembert's principle, generalized coordinates.

Module-2 : 1 (Credit (10L, 5T/S/D)

Lagrange's equations, gyroscopic forces, dissipative systems, Jacobi integral, gauge invariance, generalized coordinates and momenta, integrals of motion, symmetries of space and time with conservation laws, invariance under Galilean transformation, (impulsive forces).

Rotating frames, inertial forces, terrestrial and astronomical applications of Coriolis force. Rotating and translating frames.

Module-3 : 1 (Credit (10L, 5T/S/D)

Central force, Definition and characteristics. Two-body problem. Closure and stability of circular orbits, general analysis of orbits. Kepler's laws and equation. Artificial satellites, scattering. Relationship between CM and Lab frames (Rutherford scattering).

Module-4 : 1 (Credit (10L, 5T/S/D)

Legendre transformation, Hamilton's equations. Phase portraits of some simple systems.

Principle of least action, Derivation of equations of motion. Variation of end points and Hamilton's principle and characteristic functions, Hamilton-Jacobi equation.

Module-5 : 1 (Credit (10L, 5T/S/D)

Canonical Transformations, Generating Functions, Properties, Group property, Examples, Infinitesimal generators. Poisson bracket, Poisson's theorems. Angular momentum PBs. Small oscillations. Normal modes and coordinates. Case study of a coupled system of oscillators Rigid bodies. Euler and Chasel's theorems, Moment of Inertia, M.I. tensor and ellipsoid Euler equation for rotating rigid body and its solutions. Eulerian angles. Symmetric top. Introduction to classical scalar fields (optional).

Books :

1. *Classical Mechanics,* N. C. Rana and P. S. Joag (Tata McGraw Hill, 1991).
2. *Classical Mechanics, Herbert Goldstein,* Second Edn. (Addison Wesley, 1980).
3. *Mechanics, A Sommerfield,* (Academic Press, 1952).
4. *Introduction to Dynamics,* I Percival and S. Richards, (Cambridge Univ. Press, 1982).
5. *Classical Dynamics of particles and systems Marrion and Thornton.*
6. *Mechanics* - Landau & Lifshitz (Buuterworth-Heinmann)

7. *Classical Mechanics* – Taylor (University Science Books)

Additional Books for Reference :

8. *Calculus of Variations,* IM Gel'fand and S.V. Formin.
9. *Mathematical Methods of Classical Mechanics,* V.I. Arnold (Springer Verlag).
10. *New Foundation of Classical Mechanics,* David Hestenes (Kluwer Scientific).
11. *Classical Mechanics,* Jose' and Saletan Cambridge Univ. Press (1999).
12. *Mechanics,* F. Scheck, Springer, Verlag, Third Edition.
13. *Mechanics of Atom, Max Born,* Fedrik Under Publishing Co.
14. *Problems of Atomic Dynamics,* Max Born, Fredrik Unger Publishing Co.

PHY-T106 : MATHEMATICAL METHODS IN PHYSICS

Module-1 : 2 Credit (20L, 10T/S/D)

Complex Analysis : Complex numbers, Complex functions (polynomials, Exponential, Trigonometric complex functions, Logarithm). Limits and continuity, differentiation, Analytical functions, Cauchy-Riemann conditions, Rectifiable arcs, Line integrals, Cauchy's theorem, Cauchy integral formula, Derivatives of analytical functions, Liouville's theorem. Power series Taylor's theorem, Laurent's theorem. Calculus of residues, evaluation of real definite integrals, summation of series, elementary discussion of branch cuts, Applications : Principal value integrals and dispersion relations.

Module-2 : 1 Credit (10L, 5T/S/D)

Fourier series, Fourier integrals, Fourier transform, Parseval Relations, Convolution, Applications, Laplace transform, Bromwich integral (without proof) simple applications. Power series and contour integral solutions of second order diff. equations (Legendre, Bessel, Hermite, Laguerre as special examples properties of these functions). Legendre polynomials, Spherical harmonics and associated Legendre polynomials. Hermite polynomials. Sturm-Liouville systems and orthogonal polynomials.

Module-3 : 2 Credit (20L, 10T/S/D)

Linear spaces and operators : Vector spaces, Linear independence, Bases, dimensionality isomorphisms. Linear transformations, inverses, matrices, similarity transformations, Eigenvalues and Eigenvectors. Inner product, orthogonality and completeness, complete orthogonal set, Gramm Schmidt orthogonalization procedure, Self-adjoint and unitary transformations. Eigenvalues and Eigenvectors of Hermitian and Unitary transformations, diagonalization. Function space and Hilbert space. Complete orthonormal sets of functions. Weierstrass's theorem (without proof) approximation by polynomial.

Books :

1. *Mathematics of Classical and Quantum Physics,* Byron and Fuller, (Dover 1990).
2. *Mathematical Methods in Physics,* Arfken.
3. *R. V. Churchill*, Complex variables and Applications, 7th Edition McGraw Hill.
4. *Ablowitz and Fohas,* Complex variables, Cambridge Univ. Press.
5. *R. V. Churchill,* Fourier Series and Boundary value problems, McGraw Hill.
6. *Tulsi Dass and Sharma,* Mathematical Methods of Physics, Univ. Press.
7. *P. R. Halmos, inite dimensional vector spaces*, Springer Verlag.
8. *I. Stackgold,* Boundary value problems.
9. *Kreyszig, Advanced Engineering Mathematics,* John Wilely & Sons.

PHY-T203 : QUANTUM MECHANICS-II

Module-1 : 1 Credit (10L, 5T/S/D)

WKB approximation connection formulas for linear potential, Bohr's quantization condition, application to tunneling. Revision of time-independent perturbation theory (nondegenerate as well as degenerate). Variational method and applications (revision) Time-dependent perturbation theory, Harmonic perturbation, Fermi's golden rule, ionization of hydrogen atom, adiabatic and sudden approximations.

Module-2 : 1 Credit (10L, 5T/S/D)

Collisions in 3-D and scattering : Laboratory and CM reference frames; scattering amplitude, differential scattering cross section and total scattering cross section : scattering by spherically symmetric potentials; Method of partial waves; Phase shift; Ramsauer-Townsend effect; scattering by a perfectly rigid sphere and by square well potential.

Module-3 : 1 Credit (10L, 5T/S/D)

Complex potential and absorption. The Born approximation, Lippman-Schwinger equation, applications and validity of the Born approximation.

Module-4 : 1 Credit (10L, 5T/S/D)

Semiclassical theory of radiation, Coulomb gauge. Transition probability for absorption and induced emission, Electric dipole transitions and "forbidden" transitions. Transition probability for spontaneous emission; detailed balance, selection rules, decays, lifetime, natural linewidth.

Module-5 : 1 Credit (10L, 5T/S/D)

Symmetry in Quantum Mechanics, space and time translations, discrete lattice translations, parity, time reversal, discrete symmetries. Elementary theory of angular momentum, coupling of angular momenta, Clebsch-Gordan coefficients, the Wigner-Eckart theorem. Identical particles, symmetric and antisymmetric wave functions, Slater determinants, collision of identical particles, spin angular momentum, spin functions for systems with more than one electron.

Books :

1. *Modern Quantum Mechanics,* J. J. Sakurai, (Addison-Wesley).
2. *Quantum Mechanics,* L. I. Schiff, (McGraw Hill).
3. *Quantum Mechanics,* L. D. Landau and E. M. Lifshitz, (Addison-Wesley).
4. *Intermediate Quantum Mechanics,* H. A. Bethe and R. W. Jackiw, (W. A. Benjamin).
5. *Quantum Mechanics,* K. Gottfried, Vol. I, (W. A. Benjamin).
6. *Quantum Mechanics,* Cohen-Tannoudji, Din, Laloe, Vols. I & II (John Wiley).
7. *Lectures on Quantum Mechanics,* G. Baym,
8. *Quantum Mechanics,* A. S. Davydov, (Pergamon).

PHY-T204 : ELECTRODYNAMICS-I

Module-1 : 1 Credit (10L, 5T/S/D)

Electrostatics : Coloumb's law, Gauss's law, Poisson and Laplace's equations. Surface distribution of charges. Electrostatic potential energy.

Module-2 : 1 Credit (10L, 5T/S/D)

Simple boundary value problems illustrating various techniques, using Green's functions, the method of images, separation of variables etc.

Module-3 : 1 Credit (10L, 5T/S/D)

Magnetostatics : The laws of Biot-Savart and Ampere. Vector potentials. Magnetic field of a localized charge distribution, magnetic moment. Magnetic shielding.

Module-4 : 1 Credit (10L, 5T/S/D)

Multipole expansions and material media : Multipole expansions for a localized charge distribution. Static electric and magnetic fields in material media. Boundary conditions.

Module-5 : 1 Credit (10L, 5T/S/D)

Time varying fields : Faraday's law, Maxwell's displacement current, Maxwell's equations, Scalar and vector potentials, Gauge invariance. Wave equations. Poynting's theorem. Conservation laws.

Books :

1. *Classical Electrodynamics,* J. D. Jackson, (John Wiley).
2. *Introduction to electrodynamics,* D. J. Griffiths,
3. *Classical theory of fields,* L. D. Landau and E. M. Lifshitz, (Addison-Wesley).
4. *Electrodynamics of continuous media,* L. D. Landau and E. M. Lifshitz, (Addison-Wesley).
5. *Electrodynamics,* A. Sommerfeld, (Academic Press, Freeman and Co.).
6. *Classical Electricity and Magnetism,* W.K.H. Panofsky and M. Phillips : (Addison-Wesley).
7. *Feynman Lectures* Vol. II.
8. *Berkeley Series* Volume II.
9. *Electricity and Magnetism,* Reitz, Milford, Christy
10. *Introduction to Electrodynamics,* A. Z. Capri and P. V. Panat (Narosa).

PHY-T205 : STATISTICAL MECHANICS

Module-1 : 1 Credit (10L, 5T/S/D)

Elementary probability theory : Preliminary concepts, Random walk problem, Binomial distribution, mean values, standard deviation, various moments, Gaussian distribution, Poisson distribution, mean values. Probability density, probability for continuous variables. (Brief).

The laws of thermodynamics and their consequences (Brief).

The problem of kinetic theory : phase space, Gibbsian ensemble, Liouville's theorem and its consequences.

Module-2 : 1 Credit (10L, 5T/S/D)

Statistical description of system of particles : State of a system, microstates, ensemble, basic postulates, behavior of density of states, density of state for ideal gas in classical limit, thermal and mechanical interactions, quasi-static process.

Statistical thermodynamics : Irreversibility and attainment of equilibrium, Reversible and irreversible processes. Thermal interaction between macroscopic systems, approach to thermal equilibrium, dependence of density of states on external parameters, Statistical calculation of thermodynamic variables.

Module-3 : 1 Credit (10L, 5T/S/D)

Classical statistical mechanics : Microcanonical ensembles and their equivalence, Canonical and grand canonical ensembles, partition function, thermodynamic variables in terms of partition function and grand partition function, ideal gas, Gibbs paradox, validity of classical approximation, equipartition theorem. Maxwell-Boltzmann gas velocity and speed distribution. Chemical potential, Free energy and connection with thermodynamic variables, First and Second order phase transition; phase equilibria.

Module-4 : 1 Credit (10L, 5T/S/D)

Formulation of quantum statistics, Density Matrix, ensembles in quantum statistical mechanics, simple applications of density matrix.

The theory of simple gases : Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac gases. Statistics of occupation numbers, Evaluation of partition functions, Ideal gases in the classical limit.

Module-5 : 1 Credit (10L, 5T/S/D)

Ideal Bose system : Thermodynamic behavior of an Ideal Bose gas, Bose-Einstein condensation.

Thermodynamics of Black body radiation, Stefan-Boltzmann law, Wien's displacement law. Specific heat of solids (Einstein and Debye models).

Ideal Fermi System : Thermodynamic behavior of an ideal Fermi gas, degenerate Fermi gas, Fermi energy and mean energy, Fermi temperature, Fermi velocity of a particle of a degenerate gas, White dwarfs as an example with order of magnitude.

Text Books :

1. *Fundamentals of Statistical and Thermal Physics,* F. Reif (International Student Ed.) McGraw Hill.
2. *Statistical Mechanics*, K. Huang, John Wiley & Sons, 2nd Ed.
3. *Statistical Mechanics,* R. K. Pathria, (Pergamon Press).
4. *Fundamentals of Statistical Mechanics,* B. B. Laud, (New Age International Edition).
5. *Heat and Thermodynamics*, by Mark W. Zemansky and Richard H. Dittman (McGraw Hill)
6. *Statistical Physics*. (Vol. V) by Frederick Reif and R. A. Sevenich (Berkeley Physics Course)
7. *Statistical Mechanics* (Parts I and II) by. L. D. Landau and E. M. Lifshitz .
8. *Statistical Mechanics* (Frontiers in Physics) by Richard P. Feynman
9. *Thermodynamics and Statistical Physics* by P. V. Panat (Narosa)

PHY-T206 : ATOMS, MOLECULES AND SOLIDS

Module 1 : 1 Credit (10L+5T)

Atomic Structure and Atomic Spectra : Revision of quantum numbers, exclusion principle, electron configuration, Hund's rule etc. origin of spectral lines, selection rules, some features of one-electron, two-electron spectra and X-ray spectra, fine spectra, hyperfine structure, Zeeman effect.

Text Book :

1. *Quantum Physics,* Robert Eisberg and Robert Resnick, (John Wiley and Sons).

Reference Books :

1. *Introduction to Atomic Spectra,* H. E. White, (McGraw Hill International Ed.)
2. *Perspectives of Modern Physics,* Arthur Beiser, (McGraw Hill International Ed.)

Module 2 : 1 Credit (10L+5T)

Molecular Structure and Molecular Spectra : Valence bond approach and molecular orbital approach for molecular bonding and electron structures in homo nuclear di-atomic molecules, electro-negativity, bonding in polyatomic molecules, hybrid orbitals, bonding in hydrocarbons. Rotational levels in di-atomic and polyatomic molecules, vibrational levels in di-atomic and polyatomic molecules.

Text Book :

1. *Molecular Spectra and Molecular Structure,* Gerhard
2. Herzberg, (D. Van Nostrand Company, Inc.)

Reference Books :

1. *Molecular Spectra and Molecular Spectroscopy* (Vol. 1), G. Herzberg
2. *Fundamentals of Molecular Spectroscopy,* C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited)

Module 3 : 1 Credit (10L+5T)

Crystal structures : Basic structures, symmetry properties, packing fractions, directions and position orientation of planes in crystal, concept of reciprocal lattice, concept of Brillouin zones, closed packed structures and structures of some binary/tenary compounds.

Text Book :

1. *Introduction to Solid State Physics,* Charles Kittel

(Wiley Eastern Limited).

Reference Books :

1. *Solid State Physics,* N. W. Ashcroft and N. D. Mermin, (Harcourt Asia Limited).
2. *Elementary Solid State Physics,* M. Ali Omar, (Addision-Wesely).

3. *Solid State Physics,* Harald Ibach and Hans Luth, (Springer.)

Module 4 : 1 Credit (10L+5T)

Elementary concepts of polycrystalline, nanocrystalline and amorphous materials. Elementary concept of defects in solids. Bragg's law in direct and reciprocal lattice, Ewald sphere, Geometrical structure factor and atomic form factor, concept of neutron and electron scattering.

Text Book :

1. *Introduction to Solid State Physics,* Charles Kittel, (Wilely Eastern Limited).

Reference Books :

1. *Solid State Physics,* N. W. Ashcroft and N. D. Mermin (Harcourt Asia Limited).
2. *Elementary Solid State Physics,* M. Ali Omar, (Adision-Wesely).
3. *Solid State Physics,* Harald Ibach and Hans Luth, (Springer).

Module 5 : 1 Credit (10L+5T)

Lattice vibrations : Revision of specific heat of solids, Einstein and Debye models, density of modes, Thermal conductivity, Umklapp processes, phonons : vibrations of mono and diatomic lattices, disperson relations, phonon scattering.

1. *Text Book : Introduction to Solid State Physics, Charles Kittel,*

(Wiley Eastern Limited).

Reference Books :

1. *Solid State Physics,* N. W. Ashcroft and N. D. Mermin, (Harcourt Asia Limited).
2. *Elementary Solid State Physics,* M. Ali Omar, (Addision-Wesely).
3. *Solid State Physics,* Harald Ibach and Hans Luth, (Springer).

PHY-P301, PHY-P401: BASIC PHYSICS LABORATORY-II

PHY-P301 : Basic Physics Laboratory-II (A) : 2 Credits (4 Experiments, 48 Lab Hours)

PHY-P401 : Basic Physics Laboratory-II (B) : 3 Credits (6 Experiments, 72 Lab Hours)

Experiments from the following List will be offered :

1. Study of field electron emission.
2. To investigate the characteristics of radiation emitted by bodies at elevated temperatures (Black Body Radiation) and determine the various constants.
3. Determination of lattice constant of given powder sample using X-ray diffraction method.
4. Laue/X-ray absorption.
5. Gamma Ray Spectrometry : Understanding the three interactions of γ-rays with matter and determination of resolution of γ-ray spectrometer.
6. Investigation of the conductivity behavior of NaCl and determination of the activation energy for ionic conduction.
7. Determination of skin depth of aluminum and iron through the measurement of amplitude and phase changes of transmitted low frequency electromagnetic waves.
8. Investigation of propagation of electromagnetic wave through a transmission line and determination of propagation constant under boundary conditions.
9. Investigation of Electron Spin Resonance spectrum for the given DPPH sample and determination of Lande's "*g*" factor.
10. Investigation of thermoluminescence of X-ray irradiated KCl/KBr single crystal sample and determination of activation energy of thermoluminescence.
11. Determination of band gap of semiconductor from temperature dependence of resistivity using Four Probe Method.
12. Study of Hall Voltage as a function of probe current and magnetic field and determination of Hall Coefficient and carrier concentration in given sample.
13. Study of Magnetoresistance in semiconductors and magnites.
14. Study of Optical fiber.

Books :

1. *The Art of Experimental Physics,* D. W. Freston, E. R. Dietz, 1991 (John Wiley and Sons, Ins.).
2. *Advanced Practical Physics for Students,* Worsnop and Flint. (Asia Publishing House).

PHY-T302 : SOLID STATE PHYSICS

Pre-Requisites :

Concepts/Credits covered in following courses. Quantum Mechanics-I and II Atoms, Molecules and Solids : Concepts of Real

Lattices, Reciprocal Lattices, Free Electron Theory

Module-1 : 2 Credit (20L, 10T/S/D)

Introduction (4 Lectures; compulsory with no credit) Review of free electron theory and Reciprocal lattice, Brillouin zones revised.

(1) Band Structure (electron levels in periodic potential) : Bloch theorem, statement, proofs, crystal momentum, number of orbitals in a band, band index and the concept of effective mass. Motion of electrons in bands. Reduced, periodic and extended zone schemes. Construction of Fermi surfaces. Nearly free electron model : qualitative proof for the origin of gap in periodic potential and perturbation theory. Tight binding model : assumptions and applications to SC, FCC and BCC structures. Band structure calculation methods-basic principles.

(2) Semiconductors : Direct and indirect band gap, optical methods to determine the forbidden gap. Electrical parameters, resistivity, carrier concentration, mobility, temperature dependence, experimental methods to study the electrical parameters, thermoelectric effect and Hall effect. Intrinsic carrier concentration, doping in semiconductors, extrinsic semiconductors, law of mass action (Fermi level position as a function of charge carrier concentration). Effect of quantum confinement on electrons and phonons in semiconductors.

Module-2 : 1 Credit (10L, 5T/S/D)

Dielectric and optical properties of solids : Electronic, ionic and orientational polarizabilities for free atoms and molecules, Lorentz cavity, Clausius-Mossotti relation, static and frequency dependence of dielectric constant. Macroscopic theory of dielectric polarization and oscillating fields, electromagnetic waves in solid, reflectivity at an interface, Kramers-Kroning relations, damped harmonic oscillator (Lorentz oscillator), oscillator strength.

Module-3 : 1 Credit (10L, 5T/S/D)

Magnetism : Free electrons in external magnetic field : Landau levels, Pauli paramagnetism. Electrons in atoms : Diamagnetism, Larmor precession, atomic magnetic moments, paramagnetism, ideal magnetic gas, classical and quantum mechanical treatment. Magnestism in condensed phase : Ferromagnetic ordering, mean field theory, Heisenberg exchange interaction. Magnons and dispersion relation for magnons, antiferromagnetic ordering. Origin of domains, domain walls, coercive force, hysteresis, motion of domain walls. Experimental methods to determine the magnetic susceptibility.

Module-4 : 1 Credit (10L, 5T/S/D)

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

Text Books :

1. *Solid State Physics,* N. W. Ashcroft and N. D. Mermin, (CBS Publishing Asia Ltd.)
2. *Introduction to Solid State Physics,* Charles Kittel, (John Wiley and Sons.)
3. *Introductory Solid State Physics,* H. P. Myers, (Viva Books Pvt. Ltd.)
4. *Solid State Physics,* H. Ibach and H. Luth, (springer-Verlag).
5. *Fundamentals of Solid State Physics,* J. R. Christman, (John Wiley and Sons.)
6. *Solid State Physics,* A. J. Dekkar, (Prentice Hall).
7. *Physics of Semiconductor Devices,* S. M. Sze (John Wiley and Sons.)

PHY-T303 : ELECTRODYNAMICS-II

Module-I : 1 Credit (10 L, 5 T/S/D)

(i) Scalar waves : Plane waves, spherical waves, phase and group velocities and wave packets (ii) Vector waves : Electromagnetic plane waves, harmonic plane waves, elliptic linear and circular polarization, Stokes parameters

(iii) Reflection and refraction of plane waves, Fresnel polarization on reflection and refraction, (iv) Propagation in dielectric films.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Symmetries of Maxwell equations : Lorentz transformations, Covariance of electrodynamics, 4-vectors and tensors covariant formulation of Electrodynamics, Lorentz gauge condition, equation of continuity and Maxwell equations, electrodynamics field tensor and its transformation. Relativistic field theory, Lagranigan for EM field conservation laws, conformal invariance.

Module-3 : 1 Credit (10 L. 5 T/S/D)

Motion of a charge in EM fields : Lorentz force, motion in uniform, static, electric and magnetic fields and combined static EM fields.

Module-4 : 1 Credit (10 L, 5 T/S/D)

The wave equation : Electric dipole, electric quadrupole and magnetic dipole radiation, half wave and full wave antenna.

Radiation by a moving charge : Lienard-Wiechert potentials of a point charge, Larmor's formula, Angular distribution of radiation.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Wave guides : Cylindrical cavities, fields on the surface and within a conductor, modes in a rectangular wave guide, fields and radiation of a localized oscillating source, electric dipole, magnetic dipole and electric quadrupole fields. Bremsstarhlung : virtual quanta, synchrotron radiation.

Books :

1. *Electrodynamics*, J. D. Jackson
2. *Classical theory of fields,* Landau & Lifshitz
3. *Principles of Optics,* M. Born & E. Wolf Pergamon Press
4. *Electromagnetism and Classified Thoery*, A. D. Barut, Dover
5. *Electrodynamics,* W. Panofsky and M. Phillips
6. *Mathematics of Classical and Quantum Mechanics Byron and Fuller (Dover)*
7. *Introduction to Electrodynamics,* A. Z. Capri and P. V. Panat (Narosa)

PHY-T304 : METHODS OF EXPERIMENTAL PHYSICS

Module-1 : 1 Credit (10 L, 5T/S/D)

Signal Processing : Analog to digital and digital to analog convertors, amplifiers, multiplexers, sample and hold circuits, data filtering, concepts of digital filters, interfacing with microporcessors. Time and frequency domain analysis, spectral analysis, random signals, auto and cross correlation, transfer functions of system etc.

Module-2 : 1 Credit (10 L, 5T/S/D)

Vacuum Physics : Important and fields applications of vacuum, gas properties, gas flow regimes, gas transport properties, gas conductance of apertures, elbows, tubes etc. for viscous and molecular flow regimes, principles of pumping concepts (vacuum pumps), vacuum measurement, leak detection, source of gases in vacuum system, evaluation of gas load, vacuum system design.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Low temperatures techniques : Refrigeration principle (including thermodynamical aspects) and low temperature production techniques, production of solid CO_2 and its applications, Liquifaction of hydrogen, helium and nitrogen, principles of magnetic cooling, measurement techniques of low temperatures.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Sources and detectors : Techniques of production of UV/Visible, microwave, IR radiations, classification of sensors/detectors, sensor characteristics, operation principles of sensors based on electric, dielectric, acoustic, thermal, optical and mechanical phenomena and important types of sensing position, temperature, humidity, pressure and different types of radiations, basics of image processing

Module-5 : 1 Credit (10 L, 5 T/S/D)

Structural characterization : Microscopy: optical, electron, FEM-FIM, STM, AFM, ANOM, Diffraction techniques, XRD, Electron and Neutron diffraction, LEED.

Module-6 : 1 Credit (10 L, 5 T/S/D)

Spectroscopic characterization : Spectroscopy : IR, UV-VIS, PL, X-ray Abs, AES, XPS, SIMS, NMR, ESR, Mössbauer Spectroscopy.

Books :

1. *Introduction to analysis and processing of signals,* Paul Lynn, Howard W. (Sams and Company, 1983).
2. *Probability, Random Variables and Stochastic Process,* A. Papoulis, international student Edition (McGraw-Hill International Book Company, 1984)

3. *Vacuum Physics and Techniques,* T. A. Delchar, Chapman and Hall.
4. *Vacuum technology,* A. Roth, (North Holland, Elsevier Science B.V. 1990)
5. *High vacuum techniques,* J. Yarwood, (Chapman and Hall, Londong, 1967)
6. *Nuclear Radiation Detectors,* S.S. Kapoor, V. S. Ramamurthy, (Wiley-Eastern Limited, Bombay)
7. *Experimental Principles and Methods below 1K,* O. U. Lounasmaa, (Academic Press, London and New York, 1974)
8. *Thermometry at ultra low temperatures,* W. Weyhmann in Methods of Experimental Physics, Vol. II (R. V. Coleman, Academic Press, New York and London, 1974).
9. *Cryophysics,* K. Mendelssohn, Interscience (London, 1960)
10. *Characterization of Materials,* John B. Wachtman & Zwi. H. Kalman, Pub. Butterworth-Heinemann (1992)

PHY-305 : METHODS OF COMPUTATIONAL PHYSICS

(*Note :* Module No. 1 is compulsory; Any two modules out of 2 to 8 will be offered depending on the instructor)

Module-1 : 1 Credit (10 L, 5T/S/D)

Numerical Methods : Solution of differencial equations, Applications to potential well problem. Understanding of special functions, Generation and graphs, Random number generators, various tests.

Module-2 : 2 Credits (20 L, 10 T/S/D)

Stochastic processes, Markov chain, Metropolis sampling, Simple idea of Monte-Carlo integration, Application to 2d Ising model.

Module-3 : 2 Credit (20 L, 10 T/S/D)

Hubbard model : Motivation, representation of S_z basis, Generation of basis states, construction of Hamiltonian. Exact diagonalization, Calculation of correlation function.

Module-4 : 2 Credit (20 L, 10 T/S/D)

Lanczos method and applications to tight binding Hamiltonians, Calculation of spectral properties.

Module-5 : 2 Credits (20 l, 10 T/S/D)

Numerical solution of Schrödinger equation for spherically symmetric potentials - scattering states, Calculation of phase shifts, Resonance.

Module-6 : 2 Credits (20 L, 10 T/S/D)

Quantum Monte Carlo, Variational Monte Carlo, Diffusion Monte Carlo.

Module-7 : 2 Credits (20 L, 10 T/S/D)

Electrons in Periodic potential, Calculation of band structure by using plane wave methods.

Module-8 : 2 Credits (20 L, 10 T/S/D)

Molecular dynamics, Interacting particles with Lennard-Jones potentials.

Books :

1. *A first course in computational Physics,* Paul, L. Pavries, Pub. John Wiley and Sons, 1994.
2. *Monte Carlo Methods,* M. H. Kalos and P. A. Whitelock, John Wiley & Sons, NY 1986.
3. *Understanding Molecular Simulation,* Daan Frenkel and B. Smit, Academic Press, 1996.
4. *Computational Physics,* J. M. Thijssen, Cambridge Univ. Press, 1999.
5. *A Guide to Monte Carlo Simulations in Statistical Physics* - Landau & Binder (Cambridge University Press)
6. *Statistical Mechanics* - *Algorithms and Computations* - Krauth (Oxford University Press)
7. *Molecular Dynamics Simulation*- Haile (Wiley Professional)

PHY-T306 : PHYSICS OF THIN FILMS AND DEVICE TECHNOLOGY

Module-1 : 1 Credit (10, 5 T/S/D)

Vacuum Science and Technology : Vacuum pumps, gauges, vacuum seals and motion and electrical feedthroughs UHV materials and technology

Module-2 : 1 Credit (10 L, 5 T/S/D)

Thin film growth and nucleation theories growth modes.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Thin film deposition techniques : Physical vacuum deposition, e-beam, MBE, sputtering, laser ablation, chemical - CVD MOCVD, electrochemical deposition, plasma assisted techniques.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Thick film deposition techniques : screen printing. Thickness measurements of films Talystep, quartz crystal microbalance, optical methods.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Mechanical properties and adhesion characterization techniques to determine hardness, adhesion and stress. Lithorgraphy for pattern generation.

Books :

1. *Handbook of Thin Film Technology,* L. L. Maissel and
2. R. Glang (McGraw - Hill, 1970).
3. *Thin Film Phenomena,* K. L. Chopra; (McGraw - Hill, 1969),
4. *Thin Film processes,* J. L. Vossen and W. Kern (Academic Press, 1978)
5. *Active and Passive Thin Film Devices,* T. J. Coutts (Academic Press, 1978).
6. *Analysis of Microelectronic Materials and devices,*
7. M. Grasserbauer and H. W. Werner, (John Wiley and Sons, 1991),
8. *The Materials Science of Thin Films,* M. Ohring. (Academic Press, 1992)
9. *An introduction to Physics and Technology of Thin Films,* A Wagendristel and Y. Wang, (World Scientific, 1994)

PHY-P306 : Experiments based on PHY-T306 (3 Credits, 72 lab. hours)

1. Thin film deposition by vacuum evaporation to measure its thickness.
2. Thin film deposition by spray pyrolysis and to study its UV-VIS response.
3. Thin film deposition by CVD and to determine refractive index.
4. Thickness measurements by optical methods.
5. Pattern generation by Photolithography.
6. Structural Analysis by XRD.
7. Study of vacuum system to measure speed of rotary pump.

PHY-T307 : CONDENSED MATTER-I

Module-1 : 2 Credits (20 L, 10 T/S/D)

Magnetism : Paramagnetism and diamagnetism, Larmor diamagnetism, Hund's rules, Pauli paramagnetism. Electrostatic origin of magnetic interaction, magnetic properties of a two-electron system, Heitler-London theory, connection with spin Hamiltonian - Antiferromagnetism.

Ferromagnetism : Heisenberg Hamiltonian, Ground state, excited states, Weiss Molecular field theory (mean field), Magnetic resonance.

Module-2 : 2 Credits (20 L, 10 T/S/D)

Phase transitions and critical phenomena : phenomenology, critical exponents, Landau mean field theory, scaling hypothesis, relations between exponents, real space renormalization group in one dimension using model and transfer matrix method of solution.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Physics of disordered systms : spin-glasses, models of free energy, concept of frustration.

Books :

1. *Solid State Physics,* N. W. Ashcroft and N. D. Mernin (Holt, Richard & Wilson)
2. *Solid State Physics,* C. Kittel (Wiley Eastern)
3. *Theory of Magnetism,* V. 1 and V. 2, D. C. Mattis (Springer).
4. *Phase Transition and Critical Phenomena,* E. P. Stanley (Oxford University Press, 1971).
5. *Principles of the Theory of Solids,* J. M. Ziman (Cambridge Publishing).

PHY-P307 : EXPERIMENTS BASED ON PHY-T307 (3 Credits, 72 lab hours)

Computational Experiments/Exercises/Mini Projects.

PHY-R308 : MICROWAVES : THEORY AND APPLICATIONS

Module-1 : 1 Credit (10, 5 T/S/D)

Transmission lines : (i) Parallel wire transmission lines: Lumped components representation, basic equation, voltage and current distributions on transmission lines with different receiving and terminations, characteristic impedance, SWR, transmission line as curcuit elements, resonant lines, impedence matching (ii) Microstrip lines : Analysis of microstriplines : Conformal mapping hybrid mode analysis, components-reciprocal and non-reciprocal, technology of hybrid MIC's lumped elements for MIC's microstrip circuit design.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Waveguides : Rectangular and circular waveguide, modes, concepts of voltage, current and impedance at microwave frequency, characteristic impedance, standing wave ratio, effect of terminating impedance matching, power handling capacity, design dimensions (at various bands) and fabrication process (with specifications), Faraday rotation, Waveguide components : attenuators, directional couplers, T junctions, hybrid T. filters, slots, bends, shorts, isolators, circulators, phase shifters, cavity resonators, modes in cavity, frequency meter, gyrator.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Active Elements : Klystron, magnetron, BWO, TWT, basic principles of operation, specifications, limitations, Solid State Devices : Varactors, p-ipn diodes, tunnel diodes, gunn diodes.

TRAPATT, IMPATT, microwave transistors, schottky devices, basic operation, characteristics (no derivation of formulas) specifications, where and how used other devices

-Thermistors, Bolometers.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Mesurements : Smith Chart : Derivation, use of chart for solving various problems in waveguide/transmission lines, Rieke diagram : Theory and use of rieke diagram.

Microwave Measurements : Measurements of impedance, power, frequency, attenuation, SWR, dielectric constant, quality factor.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Applications :

1. Radar : Types of Radar pulsed, CW, MT, Tracking FM, pulse doppler (Basic principle of operation, advantages and disadvantages, applications areas). Block diagram of pulsed Radar only and its working.
2. Microwave ovens : Design requirements, size available, application areas,
3. Medical application.

4. Satellite : active passive, design requirements, payload, launching sequence.
5. Microwave link.
6. Masers and Lasers.

Books :

1. *Collins, Foundations of Microwave Engineering,* McGraw Hill, 1969.
2. *Atwater* - *Introduction to Microwaves,* McGraw Hill 1962-63.
3. *Termann* - *Electronics and Radio Engineering,* McGraw Hill, 1954
4. *Kleen* - *Electronics on Microwave Tubes,* Academic Press, 1958.
5. *Watson* - *Microwave Devices and their Circuit Applications,* McGraw Hill, 1969.
6. *Sze* - *Physics of Semiconductor Devices,* John Willey and Sons, 1981.
7. *Solnik* - *Introduction to Radar,* McGraw Hill, 1962.
8. Lance - Introduction to Microwave Theory.

PHY-P308 : Experiment based on PHY-T308 (3 Credits, 72 lab hours)

1. Study of passive components.
2. Study of various loads.
3. Determination of constants of transmission line, striplines.
4. Study of cavity resonator.
5. Study of ring resonator and rejection filter.
6. To design fabricate and test a stripline resonater.

PHY-T309 : QUANTUM MECHANICS-III

Module-1 : 1 Credit (10L, 5 T/S/D)

The Dirac Equation : The Klein-Gordon and the Dirac equations, Reduction of the Dirac equation to the Pauli equation in the non-relativistic limit. Charge and current densities from the Dirac equation, continuity equation.

Lorentz Covariance of the Dirac equation : Generators of the Lorentz group, constructive proof of the Lorentz covariance of the Dirac equation, Gamma Matrices. The Pauli fundamental theorem on Gamma matrices, Covariance of the continuity equation, spinors. Dirac-bilinear covariants. Clifford Algebra.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Solutions of the Dirac equation: Free particle Dirac equation solutions, Covariant normalization and completeness, Energy and spin projection operators. Construction of wave packets in the Dirac theory of both positive and negative energy free particle solutions. Conserved quantities in the Dirac theory. Spin and Helicity (chirality). Zitterbewegung, conservation of total angular momentum. Dirac particle in a one dimensional rigid box and a non-rigid box. Dirac particle encountering a potential step. Klein's paradox. A Dirac particle in a uniform magnetic field, Landau levels. Gordon decomposition of the vector current.

Module-3 : 1 Credit (10 L, 5 T/S/D)

The Foldy-Wouthuysen transformation : Free-particle FW Transformation. FW Transformation in the presence of an electromagnetic field. Interpretation of different terms, such as the spin orbit-coupling, Darwin term. Introduction to the Lamb Shift.

The Dirac-Hydrogen Atom : The Dirac particle in a spherically symmetric potential, spin-angular functions. Reduction of the Dirac problem for an attractive Coulomb potential, solutions of the problem. Fine structure (exact formula). Reduction to the non-relativistic case.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Positron Theory : Dirac's concept of positron, Dirac vacuum, Free positron. Charge conjugation, Parity and time reversal as discrete symmetries of the Dirac theory with an electromagnetic coupling. CPT invariance of the Dirac theory.

Modern derivation of the Dirac equation : SU(2) TO O(3) double connectivity, Cayley-Klein parameters; SL(2,C) and the Lorentz group.

Module-5 : 1 Credit (10L, 5 T/S/D)

Classical radiation field, reduction of radiation in a box to an assembly of decoupled simple harmonic oscillators, second quantization, quantization of the electromagnetic field in Coulomb gauge, fluctuations in the quantum fields, time dependent perturbation theory, emission (spontaneous and stimulated) and absorption of radiation (dipole approximation) selection rules, Thomson Scattering, Rayleigh scattering and the Raman effect, Plank's Radiation law.

Books :

1. *Relativistic Quantum Mechanics*, J. Bjorken and S. Drell (McGraw Hill).
2. *Advanced Quantum Mechanics,* J. J. Sakurai (Addison-Wesley)
3. *Relativistic Electron Theory,* M. E. Rose (John-Wiley & Sons).
4. *An Introduction to Relativistic Quantum Field Theory,* S. S. Schweber (Row, Peterson).
5. *Quantum Mechanics,* L. I. Schiff (McGraw Hill).
6. *Quantum Electrodynamics,* R. P. Feynman (Benjamin Cummings).
7. *Lectures on Quantum Mechanics*, G. Baym (Benjamin).
8. *Quantum Field Theory,* L. Ryder (Academic).
9. *Quantum Field Theory,* C. Itzykson & J. B. Zuber (McGraw Hill)
10. *The Principle of Quantum Mechanics,* P. A. M. Dirac (Cambridge).
11. *The Quantum Theory of Fields,* S. Weibherg, Vol. I (Cambridge).
12. *An Introduction to Quantum Field Theory,* M. E. Peskin and D. V. Schroeder, Addison.

PHY-P309 : Experiments based on PHY-T309 (3 Credits, 72 lab hours)

Computational Experiments/Exercises/Mini Projects.

PHY-T310 : MATERIALS SCIENCE-I (Elements of Materials Science)

Module 1 : 1 Credit (10 Lectures, 5 T/S/D)

Short review of basic structures, Tetrahedral and octahedral sites and their properties and importance, substitutional and interstitial solid solutions (only definitions), coordination number and Pauling rules, Crystal Structures of metallic alloys, Ceramics, polymers, silicates, composite materials etc. This include structures such as NaCl, CsCl, Rutile, flurite, corrundum, Hexagonal and cubic zink Blende, NiAS, Perovskine, spinel and inverse spinel, quartz, silicates (linkages of tetrahedral and octahedral units), glass, polymers etc.,

Module 2 : 1 Credit (10 Lectures, 5 T/S/D)

Physical Thermodynamics including topics such as Laws of thermodynamics, internal energy, reversible and irreversible reactions (with reference to materials phase transitions), heat of formation, concept of entropy, derivation of expression for configurational entropy using concept of multiplicity, micro and macrostates etc., free energies, chemical potential, derivation of various thermodynamical expressions, concepts of eqillibrium and metastability, Phase diagrams of elements, applications of thermodynamics, Clapeyron and Clauses-Clapeyron equations for phase transitions, vapor pressures, effect of temperatures, its importance to vacuum systems and materials evaporation for thin films.

Module 3 : 1 Credit (10 Lectures, 5 T/S/D)

Defects in Materials : point defects, line defects (dislocations), surface defects (grain boundaries), volume defects (voids), defects formation energies, their impact on physical properties of materials, formation energies, defect creation and annihilation, thermodynamic aspects such as concentration and interactions, stress fields, Burger vector, slip and glide motions of dislocations, calculation of surface energies and its importance etc.

Module 4 : 1 Credit (10 Lectures, 5 T/S/D)

Phase Diagrams : Concepts of solid solubility, Hume-Rothery rules, concept of formation of phase diagrams on basis of entropy and free energy changes for compositions, Phase diagrams of various categories such as that of limited solubility, eutectic, peritectic etc. with examples, intermetallic alloys etc.

Module 5 : 1 Credit (10 Lectures, 5 T/S/D)

Diffusion in solids : concentration gradients, steady state non steady state flow, Fick’s laws, error functions, diffusivity (macroscopic and microscopic diffusion models), importance of diffusion for materials synthesis and processing, examples and applications such as oxidation, corrosion, carborization, decarborization, nitridation, Nernst-Einstein equation, concentration profiles, etc. Heat Treatment and Phase transformations in solids : Variation of free energies, nucleation and growth, surface and volume free-energies, Quenching, Nucleation rate, growth rates derivation of related expressions, T-T-T diagrams, applications of nucleation and growth and precipitation reactions.

Books :

1. *Physical Metallurgy,* Vol. 1 and Vol. 2 by R. W. Chan and P. Hassen North Holland Publishing Company, New York, 1983.
2. *Materials Science and Engineering,* V. Raghvan, (Prentice-Hall Pvt. Ltd.), 1989.
3. *Introduction to Materials Science for Engineers,*
4. J. F. Shackelford, (Macmillan Publishing Company, New York), 1985.
5. *Physical Metallurgy,* Smallman.
6. *Thermodynamics,* Swalin.

PHY-P310 : Experiments based on PHY-T310 (3 Credits, 72 lab. hours)

1. Cooling curves and Phase diagram of Pb-Sn alloy system.
2. Working of Rotary-diffusion vacuum system and Synthesis of silver film by thermal evaporation and DC plasma methods.
3. Oxidation of Bismuth films.
4. Synthesis of conducting oxide films by pyrolysis method.
5. Ionic conductivity.

PHY-T311 : ASTRONOMY AND ASTROPHYSICS-I

Module 1 : 3 Credits (30 Lectures, `5 T/S/D)

Overview of the Universe : Qualitative description of interesting astronomical objects, (from planets to large scale structures), Length, Mass and Timescales, Physical conditions in different objects, Evolution of structures in the universe, red-shift. Radiation in different bands, Astronomical Jargon; Astronomical measurements in different bands, current sensitivities and resolution available.

PHYSICS OF ASTROPHYSICS

A. Gravity : Newtonian gravity and basic potential theory, Simple orbits – Kepler's laws and precession, flat rotation curve of galaxies and implications for dark matter, virial theorem and simple applications, role of gravity in different astrophysical systems.

B. Radiative Processes : Overview of radiation theory and Larmor formula, Different radiative processes : Thomson and Compton scattering, Bremsstrahlung, Synchrotron [detailed derivations are not expected] Radiative equilibrium, Planck spectrum and properties; line widths and transition rates in QT of radiation, qualitative description of which radiative processes contribute in which waveband/ astrophysical system, distribution function for photons and its moments, elementary notion of radiation transport through a slab, concept of opacities.

C. Gas Dynamics : Equations of fluid dynamics; equation of state in different regimes [including degenerate systems]; Models for different systems in equilibrium, Application to White dwarfs/Neutron stars, Simple fluid flows including supersonic flow, example of SN explosions and its different phases.

Module 2 : 1 Credit (10 Lectures, 5 T/S/D) Stellar System

Basic equations of stellar structure, Stellar energy sources; qualitative description of numerical solutions for stars of different mass, homologous stellar models, Stellar evolution, Evolution in the HR-Diagram.

Module 3 : 1 Credit (10 Lectures, 5 T/S/D)

Milky Way Galaxy, Spiral and Elliptical galaxies, Galaxies as self gravitating systems; spiral structure, Supermassive black holes, Active galactic nuclei.

Books :

1. *Modern Astrophysics,* B. W. Carroo and D. A. Ostlie, (Addison-Weseley).
2. *The physical universe,* F. Shu, (University Science books).
3. *The Physics of Astrophysics,* Volume I and II, F. Shu, (University Science books).
4. *Theoretical Astophysics,* Volumes I, II and III,
5. T. Padmanabhan, (Cambridge University Press).

6. *The Physics of fluids and plasmas,* Arnab Rai Choudhuri, (Cambridge University Press).
7. *Astrophysical concepts,* M. Harwitt, Springer-Verlag.
8. *Galactic Astronomy,* J. Binney and M. Merrifeld, (Princeton University Press).
9. *Galactic dynamics,* J. Binney and S. Tremaine, (Princeton University Press).
10. *Quasars and Active Galactic Nuclei,* A. K. Kembhavi and J. V. Narlikar, (Cambridge University Press).
11. *An Introduction to Active Galactic Nucleii,* B. M. Peterson.

PHY-T312 : NUCLEAR TECHNIQUES-I

Module-1 : 1 Credit (10 L, 5 T/S/D)

Interaction of radiation with matter : General description of interaction processes, interactions of directly ionizing radiation, stopping power, linear energy transfer, range of particles, interaction of indirectly ionizing radiation attenuation coefficient, energy transfer, build up factor.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Relation detectors Gaseous ionization, ionization and transport phenomena in gases, avalanche multiplication, cylindrical and multiwire proportional counters, drift chamber, scintillator detectors, general characteristics of organic and inorganic scintillators, detection efficiency for various types of radiation, scintillators, detection efficiency for various types of radiation, scintillation detector mounting, photomultiplier gain, stability, semiconductor detectors, basic principle, surface barrier detector, Si(Li), Gel(Li), HPGe and position sensitive detectors.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Pulse processing and related electronics : Preamplifier, amplifier, pulse shaping networks, biased amplifier, pulse stretchers delay lines.

Pulse height analysis and coincidence technique : Single channel analyzer, multichannel analyzer, pulse height spectroscopy, pulse shape discrimination, coincidence units, slow-fast coincidence circuits.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Timing methods and systems : Walk and fitter, time pick off methods, digital timing methods, introduction to CAMAC systems. Multichannel Analyzer Applications of radiation, gamma-ray and neutron radiography.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Dosimetry and radiation protection : Units kerma, Cema, energy deposit and energy imparted, absorbed dose, main aims of radiation protection, dose equivalent and quality factor, organ dose, effective dose equivalent effects and dose limits, assessment of exposure from natural man-made sources.

Books :

1. *Nuclear radiation detectors,* S. S. Kappor and V. S. Rmanurthy. (Wiley Eastern Limited, New Delhi,) 1986.
2. *Introduction to radiation protection dosimetry,* J. Sabol and P. S. Weng, (World Scientific), 1995.
3. *Techniques for nuclear and particle physics,* W. R. Len (Springer), 1955.
4. *Nuclear Measurement Techniques,* K. Sriram, (Affiliated East-West Press, New Delhi), 1986.
5. *Fundamentals of surface and thin film analysis,* Leonard C. Feldman and James W. Mayer,

(North Holland, New York), 1988.

6. *Introduction to nuclear science and technology,*
7. K. Sriram and Y. R. Waghamare, (A. M. Wheeler), 1991.
8. *Nuclear radiation detection,* W. J. Price, (McGraw-Hill, New York), 1964.
9. *Alphas, beta and gamma-ray spectroscopy,*
10. K. Siegbahn, (North Holland, Amsterdam), 1965.
11. *Introduction to experimental nuclear physics,* R. M. Singru, (John Wiley and Sons), 1974.
12. *Radioactive isotopes in biological research,* Willaim
13. R. Hendee, (John Wiley and Sons), 1973.

PHY-P312 : Experiment based on PHY-T312 (3 Credits, 72 lab. hours)

1. To determine resolving/dead time of a GM counter by double source method.
2. To study Compton scattering using 6.66% MeV gamma-rays.
3. To determine energy resolution ofa Nal(TI) detector and show that it is independent of the gain of the amplifier.
4. To determine energy of a given gamma-ray source by calibration method.
5. To study various operations of 1024 channel analyzer and to calculate energy resolution, energy of gamma ray, area under photopeak etc.
6. To study beta-ray spectrum of Cs-137 source and to calculate binding energy of K-shell electron of Cs-137. (Any five experiments will be covered)

PHY-T313 : BIOPHYSICS-I

Module-1 : 2 Credits (20 L, 6 T, 4 D)

Part (A)

Cellular Basis of life : Cell components-structure and function, plant and animal cells, Bio Molecules, General idea about structure and function-H_2O, Proteins, carbohydrates, Fats and nucleic acids, Introduction to Biological energy, Energy consumption, Respiration, Energy production, Photosynthesis, ATP synthesis.

Part (B)

Essential physical principles related to life processes, Chemical bonding, Ionization energy, Electron affinity, Electro-negativity, strong bonds and weak bonds, Inter atomic potentials, Non central processes, Bond energy, Spring constituents, Free energy, Internal energy, Thermodynamic principles, water, acids, basis and aqueous reactions, Transport process, Diffusion, Viscosity, thermal conduction.

Module-2 : 1 Credit (10 L, 3 T, 2 D)

Protein structure : 4 levels, Ramachandran plot, Interpretations, Classification (by structure, function)

Nucleic acids, Types of DNA, Properties, RNA, Base pairing Transcription & Translation

Conformation Analysis : Asymmetric Carbon, Fisher conventions, L-D type systems, Torsion angle, Newmann projection, Cis-trans peptide,

Module-3 : 1 Credit (10 L, 3 T, 2 D)

Neurobiophysics : Structure & Function of Neuron, Types of synapses, Resting potential, Local depolarization, Action potential : Generation & propagation, Equivalent circuit of cell, Voltage clamp, Na-K pump, Equivalent circuits.

Module-4 : 1 Credit (10 L, 3 T, 2 D)

Biophysical Techniques :

X-ray crystallography : X-ray, Bragg’s Law, Types of crystals

Thermoluminescence (TL) : TL origin, detection and utility.

Electrophoresis : Coulmb’s Law, How it separates

molecule of different molecular weight and configuration.

UV-visible, IR and Fluorescence spectroscopy

Circular Dichroism (CD)

NMR - Theory, applications, (Briefly),

Reference Books :

1. *Biology, a human approach,* I. W. Sherman and V. G. Sherman, (Oxford University Press), 1979.
2. *Principles of neural science,* E. R. Kandel & J. H. Schwaz, (Elsevier, North Holland), 1982.
3. *Biophysical plant physiology and exology,* P. S. Nobel, (University of California, Los Angeles and W. H. Freeman & Co., Sanfranscisco), 1983.
4. *Neuron to Brain,* S. W. Kuffler and J. G. Nichols, (Sinacuer Asso. Inc.) 1995.
5. *The structure and function of proteins,* L. Dickerson & J. Geis, (Harpes & Row), 1975.

PHY-P313 Experiment based on PHY-T313 (3 Credits, 72 lab. hours)

1. Electroretinogram of Cockroach.
2. Audiometry.
3. Chlorophyll absorption.
4. Radiation dosimetry
5. Verification of Beer’s & Lamber’s Law.

PHY-T314 : BIO-ELECTRONICS-I

Module 1 : 1 Credit (10 L, 5 T/S/D)

Signals & classification, Biosignals & origin, volume conduction, Time & frequency domain, characteristics of biosignals such as ECG, EEG, EP, EMG, MEG Signal acquisition & processing basics.

Module 2 : 1 Credit (10 L, 5 T/S/D)

Electrode + electrode interface, polarization, Electrode behavior & circuit model, Electrode skin interface, Body surface electrodes, internal electrodes, Microelectrodes, electrode arrays, Displacements, resistive, capacitive, piezoelectric sensors, temperature measurement, fiber-optic sensors, radiation sensors for biomedical uses.

Module 3 : 1 Credit (10 L, 5 T/S/D)

Bioelectric amplifiers, Basic requirements, Differential amplifier, Instrumentation amplifier, Integrators, differentiators, active filters, ECG amplifier, right leg driven system, EEG multichannel amplifiers & filters, noise filtering & transient protection, Amplifiers for use with glass electrodes & inracellular electrodes.

Module 4 : 1 Credit (10 l, 5 T/S/D)

Stimulators : Constant current & constant voltage stimulator, internal external stimulators Pacemaker types & circuits, Photo-stimulator for vision, Acoustic stimulators for hearing, Wave shaping circuits & waveform generator,

Module-5 : 1 Credit (10 L, 5 T/S/D)

Recording System : Complete recording system for ECG, EMG, EEG, EP & specifications, Cardiac monitors, defibrillator, ventilator systems, hemodiatctar system, microshock, macroshock hazards, Basic approach for shock protection.

OPTIONAL

Module 6 : 1 Credit (10 L, 5 T/S/D)

Medical Imaging Systems : Information content of an Image, Modulation Transfer function, Noise equivalent Bandwidth, Computed radiography, CT, MRL, PET ultrasonography-basics of above systems.

Books :

1. *Principles of Neural Science-Kandel & Schwartz* (Elsevier, North Holland), 1981.
2. *Op-Amps & linear Integrated Circuits-Gaikwad,* (EEE Prentice Hall).
3. *Biomedical Instrumentation*, (EEE Prentice Hall).
4. *Introduction to Biomedical Equipment Technology-Carr & Brown* (John Wiley & Sons), 1981.

5. *Design of Microcomputer based medical Inst,* Webster & Tompkins
6. *Encyclopedia of Biomed,* Inst. Ed. Webster
7. *Digital Electronics,* Malvino & Leach

PHY-P314 : Experiment based on PHY-T 314 (3 Credits , 72 lab. hours)

Experiments :

1. ECG-Preamplifier-instrumentation amplifier design & testing
2. Active filters for biosignals-design & testing
3. Wave shaping circuits for cardiac pacemaker
4. Recording of action potentials with extra cellular electrodes
5. ECG signal recording with surface electrodes
6. Blood pressure measurement with transducer/pressure differentiation circuits
7. Acoustic impedance measurement
8. Piezo-resistive Strain gauge-and experiments of similar type

PHY-T315 : LASER-I

Module-1 : 1 Credit (10 L, 5 T/S/D)

Interaction of radiation with matter : Absorption, spontaneous and stimulated emission, Einstein's Coefficients, population inversion, metastable states, gain, absorption coefficient, stimulated cross section, threshold condition.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Two level system (Ammonia maser-Physical separation of excited species from those in ground state). Three and Four level system, Rate equations for three and four level system, threshold pump power, relative merits and de-merits of three and four level system.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Optical resonators : Resonator configurations, Stability of resonators, Characteristics of Gaussian beam, Transverse and longitudinal modes, mode selection techniques (at least two techniques in each case), losses in a resonator, Hardware design-laser support structure, mirror mounts, optical coating etc.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Gas and dye lasers : excitation in gas discharge, collisions of 1st and 2nd kind, electron impact excitation-its cross section, different types of gas lasers : He-Ne, N_2, CO_2, Metal vapour lasers, Excimer and chemical laser, dye laser.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Laser Parameters and their measurement : Near field and Far field regimes, Internal and external parameters in the near and far field, Detectors and their operational mechanism including specific properties like rise time, spectal response etc.

Text Books :

1. *Principles of lasers,* Fourth edition-by Orazio Svelto
2. (Plenum Publishing Corporation, New York, USAISBN 0-306-454748-2).
3. *Solid state laser engineering,* first and second edition,
4. walter Koechner *Springer series in Optical Sciences,* (Springer-Verlag, New York, USA ISBN).
5. *Principles of Laser and their applications,* Callen, O'shea, Rhodes
6. *Laser parameters*, Heard *Reference Books :*
7. *Masers,* A. G. Siegman.
8. *Gas lasers,* Garret.
9. *Maser Handbook,* vol. 1-4, F. T. Arecchi, E. O. Schul Dubois, (North Holland).

PHY-P315 : Experiments based on PHY-T315 (3 Credits, 72 lab. hours)

1. Determine the spot size and hence the divergence of given He-Ne laser
2. Estimate the diameter of the given wires using He-Ne laser
3. Estimate the wavelength of the He-Ne laser using the diffraction pattern formed due to the grooves of a scale.
4. Estimate the E/P ratio of the Excimer laser. Comment on its importance.
5. Determine some of the vibrational bands of the given sample (HDPE) using the IR spectrophotometer. Determine the force constant for the C-C, C-H bonds.
6. Determination of Brewster Angle and estimation of refractive index of the given transparent material
7. Power distribution within the He-Ne beam Similar experiments will also be thought of from time to time.

PHY-T321 : ACCELERATOR PHYSICS-I

Module-1 : 1 Credit (10 L, 5 T/S/D)

Motion of charged particles in electric and magnetic fields, concept of field index, edge focusing, dipole, quadrupole lenses.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Axial and radial stability of orbits, qualitative and quantitative treatment of weak focussing trasverse and longitudinal oscillations, resonances.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Phase stability : Principle of phase stability, momentum compaction, analogy of biased pendulum, phase diagram, synchrotron oscillations.

Module-4 : 1 Credit 10 L, 5 T/S/D)

Emittance, admittance, concept of matching, measurement of emittance.

Matrix method of studying orbit stability

Module-5 : 1 Credit (10 L, 5 T/S/D)

Basic principle and design details of the following types of accelerators viz, electrostatic, electrodynamic, resonant, induction with special emphasis on microtron, pelletron and cyclotron, synchrotron radiation, synchrotron radiation sources, spectrum of the emitted radiation and their applications.

Books :

1. *Physics of cyclic accelerators,* J. J. Livingood (D. Van Nostrand Co.)
2. *Particle Accelerators,* J. P. Blewett, (McGraw-Hill Book Co.)
3. *Transport of Charged Particle Beams,* A. P. Banford (SPON, London).
4. *The Microtron,* S. P. Kapitza, V. N. Melekhin, (Harwood Academic Publishers).
5. *Recirculating, electron accelerators,* Roy. E. Rand, (Harwood Academic Publishers).
6. *Particle accelerators and their uses,* W. Scharf, (Harwood Academic Publishers).
7. *Theory of resonance linear accelerators,* I. M. Kapchinsky, (Harwood Academic Publishers).
8. *Linear Accelerators,* P. Lapostole and A. Septier, (North Holland)

PHY-P321 : Experiment based on PHY-T 321 (3 Credits, 72 lab. hours)

1. Study of characteristics of microwave components (ferrite isolates, directional coupler, magic-T, 90 bent and twist).
2. Measurement of the quality factor Q of a microwave resonator.
3. Electrolytic tank method for plotting equipotentials of an electron gun.
4. Measurement of field index of a double focusing magnet.
5. Cockroft-Walton generator.

PHY-T323 : Nonlinear Dynamics-I

Module-1 : 1 Credit (10 L, 5 T/S/D)

Introduction : Oscillator system : harmonic oscillator, phase space motion in phase space, oscillator as integrable system, pendulum conservation and non-conservation of areas in phase space, damped harmonic oscillators, dissipation, forced oscillator, stability of solutions sensitivity to initial conditions.

Module-2 : 2 Credits (20L, 10 T/S/D)

Ordinary differential equation, linear ODE, S+N decomposition. Linearization of nonlinear equations, stable and unstable manifolds Hortmon Grobman theorem, stable manifold theorem. Flows & maps, Periodic system, Floquet multipliers, Poincore section. Attractors: Types of attractors, strange attractors, stretching and folding, Lorenz and Rossler attractors.

Module-3 : 2 Credits(20 L, 10 T/S/D)

Maps : Logistic map, analysis of the logistic map, period doubling, intermittency Feigenbaum universality circle map, standard map, Henon map.

Elements of bifurcation theory, routes to chaos.

Characterization of chaotic solutions and attractors, power spectrum, ergo-dicity, invariant measure, Lyapunov exponent, dimensions and their evaluation, K-entropy and symbolic dynamics

Books :

1. *Ordinary Diff. Equations,* V. J. Arnold.
2. *Differential Equations, Dynamical Systems and an Introduction to Chaos,* Hirsch, Smale and Devaney, Academic Press, (Elsevier Imprint), 2004.
3. *Int. to applied nonlinear dynamical ststems & Chaos,* Wiggins (Springer Verlag).
4. *Nonlinear Oscillations, Dynamical Systems and bifurcations of vector fields, Springer Verlag,*
5. Guckenheimer and Holmes, (Springer Verlag).
6. *Chaotic Evolution and Cambridge,* D. Ruelle. (Uni. Press),
7. *Nonlinear Ordinary diff. Eq.,* Jordan & Smith, (Oxford Univ. Press).
8. *Nonlinear dynamics & Chaos,* Strogatz, (Addison Wesley).
9. *Chaos and integrability in Nonlinear Dynamics, An introduction,* M. Tabor, (J. Wiley), 1989.
10. *Introduction to Dynamics,* I. Percival, D. Richards, (Cambridge Univ. Press).
11. Berge Pomeo Vidal, *Order within chaos*, J.Wiley, 1984.
12. *Chaos in Dynamical System,* E. Ott, (Cambridge University Press).
13. *Chaotic Dynamics,* G. L. Baker, J. P. Gollub, (Cambridge University Press).
14. *Chaotic Dynamics of Non-linear Systems,* S. Neil Rasband, (John Wiley).

PHY-P323 : Experiments based on PHY-T323 (3 Credits, 72 lab, hours)

Computational experiments/Exercises Mini Projects/

1. Logistic Map :

    (a) Bifurcation diagram(1 expt.),

    (b) Dyanpunov exponents (1 expt.),

    (c) Fergenbaum constants (1 expt.)

2. Circle map : Arnold tongues (3 expts.)
3. Henon map : Generate attractor and show self similarity (2 expts.)
4. Lorenz map : To generate the Lorenz attractor and study no sensitivity to initial condition (12 expts.)
5. Dimensions and their evaluation :
6. Box counting algorithm (3 expts.)
7. Grassberger Procaccia algorithm (5 expts.)
8. Pendulum, Elliptic functions.

PHY-T324 : Chemical Physics - I

Module -1 : 1 Credit (10 L, 5T/S/D)

Abstract Group Theory : Definition of Groups, Groups of transformation, Group multiplication table, the rearrangement theorem, Generators of finite group, conjugate elements and classes, subgroup cyclic group, isomorphism, direct product of group.

Representation theory of finite groups: Representations, invariants subspaces and reducible representations and related theorems, irreducible representations, Schur's Lemmas without proofs, orthogonality theorem, characters of a representation, orthogonality of characters, reduction of

a reducible representation, direct product of representations, character table, representation for cyclic groups.

Module-2 : 1 Credit (10 L, 5T/S/D)

Molecular symmetry and the symmetry groups: Symmetry elements and operations, symmetry elements and optical isomerism and its experimental demonstrations, the symmetry point groups, linear molecules, the five platonic solids, a systematic procedure for symmetry classification of molecules, illustrative examples, classes of symmetry operations. Symmetry in long chain molecules; polymeric systems.

Module-3 : 1 Credit (10 L, 5T/S/D)

Group theory and quantum mechanics : Wave functions as bases for irreducible representations, the direct product and its importance in physics, identifying nonzero matrix elements, spectral transition probabilities.

Symmetry adapted linear combinations: projection operators, illustrative examples of SAL Cs.

Module-4 : 1 Credit (10 L, 5T/S/D)

Introduction to ligand fields: The concept and the scope the *p* and *d* orbitals, qualitative demonstration of the Ligand field effect, the physical properties by Ligand fields, crystal fields and ligand fields.

Quantitative basis of crystal fields: Crystal field theory: the octahedral and tetrahedral crystal field potential. Its effect on *d* wave functions, evaluation of 10 Dq (This topic should be covered in Seminars).

Atomic Spectroscopy. The free ion, free ion TERMS, Term wave functions, spin orbit coupling (to be partly covered in seminars.)

Module-5 : 1 Credit (10 L, 5T/S/D)

Ligand field theory : Splitting of levels and terms in a chemical environment p-octahedral, tetrahedral and others, construction of energy level diagrams, the method of descending symmetry, Tanabe-Sugano diagrams. Free ion in weak crystal fields: effects of cubic crystal field on S,P,D,F,G,H and I terms (to be partly covered in seminars).

Thermodynamical aspects of ligand field: Crystal field stabilization energy, signatures in other physics properties. Seminars/Tutorials per module. Total 15 Seminars/Tutorials.

Books :

1. *Elements of Group Theory for Physicists,* A. W. Joshi (Wiley Easterm Ltd., N. Delhi), 1985.
2. *Chemical applications of Group Theory,* F. A. Cotton, (Wiley Eastern Ltd., New Delhi), 1986.
3. *Introduction to Ligand Fields,* B.N. Figgis, (Wiley Eastern Ltd., New Delhi), 1976.

PHY-P324 : Experiments based on PHY-T324 (3 Credits, 72 lab. hours)

1. To determine specific rotation of a given solution at different wavelengths (or different solution at a given wavelength).
2. To obtain the crystal field stabilization energy and the value of the crystal field parameter 10 Dq for the given transition metal complexes.
3. To obtain the heat of ligation of the given transition metal complex for the given ligands.
4. To obtain the lattice energy of NaCl by X-ray diffraction and by measuring the heat of dissolution (and using the Born-Haber Cycle).
5. To obtain the ligand field parameter 10 Dq for Cu_2^+ ions in water and in Ammonia.

PHY-T325 Nanotechnology-I

1. Module-1 : 1 Credit (10 L, 5 T/S/D)

Low dimensional materials. Application in electronics, communication, medicine etc. Electron states in a potential well, spherically symmetric potential, Coulomb potential and periodic potential. Tunneling through a potential barrier. Excitons, biexcitons, dark excitons.

2. Module-2 : 1 Credit (10 L, 5 T/S/D)

Clusters. Fullerens, semiconductor and metal clusters, cluster stability. Nanotubes.

3. Module-3 : 1 Credit (10 L, 5 T/S/D)

Electron states in nanoparticles, effective mass approximation, weak confinement, strong confinement, size dependent oscillator strength.

4. Module-4 : 1 Credit (10 L, 5 T/S/D)

Synthesis of nanomaterials (bottom up approach) by physical techniques. Introduction to vacuum techniques (pumps, gauges, materials). Physical vapour deposition, electron beam evaporation, sputter deposition, laser ablation, ion beam mixing, plasma deposition.

5. Module-5 : 1 Credit (10 L, 5 T/S/D)

(Synthesis of nanomaterials by chemical, biological and hybrid routes). Concepts of colloids, LaMer diagram, L.B films, Miceller route, self assembly, biosynthesis, electrophoresis, immobilization in glass, zeolites, polymers.

6. Module-6 : 1 Credit (10 L, 5 T/S/D)

Analysis Techniques. UV-VIS-IR spectroscopy, Luminescence techniques, X-ray, electron and neutron Diffraction, Small Angle X-ray and Neutron Scattering, photon correlation spectroscopy, Extended X-ray Absorption Fine Structure (EXAFS), X-ray Photoelectron Spectroscopy, Auger Electron Spectroscopy.

Recommended Books :

1. *Physics of Low Dimensional Structures,* J. H. Davis, (Cambridge Press), 1998.
2. *Semiconductor Quantum Dots,* L. Banjaj and S. W. Koch.
3. *Low Dimensional Semiconductors,* M. J. Kelly, Clarendon,1955.
4. *Characterization of Materials,* J. B. Wachtman and Z.
5. H. Kalman, Butterworth-Heinmann, USA, 1993.
6. *Experimental Phyysics,* Modern Methods, R. A. Dunlop.
7. *Instrumental Methods of Analysis,* H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle, (CBS Pub.), 1986.

PHY-P325 Experiments based on PHY-T325

1. Synthesis of metal nanoparticles.
2. Synthesis of porous silicon.
3. Absorption by metal nanoparticles.
4. X-ray Diffraction of nanoparticles.
5. Photoluminescence of nanoparticles.

PHY-T327 Energy Studies-I

Module-1 : 1 Credit (10L, ST/SD) Indian Energy Scenario

Role of energy in economic development and social transformation, Energy and gross domestic product (GDP), Gross national product (GNP) and its dynamics.

Various types of energy sources : Energy sources and overall energy demand, Availability of energy sources, Energy consumption in various sectors and its changing pattern, Projected energy demands.

Energy Sources : Coal, Oil, Natural gas, Nuclear power, Hydro-electricity, Solar and other renewable sources, Depletion of energy sources and impact of exponential rise in energy consumption on economics of India and on international relations.

Energy Security : Energy for security and security of energy, Energy consumption and its impact on environmental climatic change.

Future Energy Options : Sustainable development, Energy crisis, Transition from carbon rich and nuclear energy to carbon free technologies, Parameters of transition.

Mocule-2 : 1 Credit (10L, ST/SD) Solar Energy and Its Conversion

Importance of Solar Energy : Nature of solar radiation, Sun as a fusion reactor, Spectral distribution of extraterrestrial radiation, Estimation of extraterrestrial solar radiation, Radiation on horizontal and tilted surfaces, Beam, diffuse, global radiation and their measurement, Available solar radiation, Measurement of beam, diffuse, global radiation.

Conversion of Solar Energy in different forms : Various ways to convert solar energy into different forms, Pyranometer, Pyrhelimeter, Sunshine duration recorder Angstrom relation.

Module-3 : 1 Credit (10L, ST/SD) Basics of Heat transfer

Heat and Thermodynamics : Basic units, dimensions, Concept of heat, energy and work, Ideal gas law, 1st and 2nd law of thermodynamics, Types of heat transfer.

Conductive Heat Transfer : Fourier's law, Stefan-Boltzmann relation and IR heat transfer between gray surfaces.

Radiative Heat Tranfer : Sky radiation, Radiative heat transfer coefficient.

Convective Heat Transfer : Natural and forced convection, Natural convection between parallel plates, Non-dimensional numbers, Conductive heat transfer coefficient, Heat transfer due to wind.

Module-4 : 1 Credit (10L, ST/SD) Energy Storage

Types of energy storage systems : Sensible and latent heat storage system, Electric energy storage systems, Chemical energy storage systems, Heat exchanges, Hydro-storage, Solar pond as a energy storage.

Hydrogen Energy : Storage, Transportation and utilization of Hydrogen, OTEC concept.

Module-5 : 1 Credit (10L, ST/SD) Solar Passive Systems and Green House

Solar Passive Systems : Solar active and passive systems, Types of solar passive systems, Design aspects of solar passive systems, f-Chart method.

Green House : Solar green House, Design and control mechanism.

Reference Books :

1. *TEDDY Year Book,* (Tata Energy Research Institute (TERI) Publication, New Delhi).
2. *World Energy Resources,* Charles E. Brown, (Springer Publication), 2002.
3. *Energy Policy for India,* B. V. Desai, (Weiley Eastern Publication).
4. *Handbooks of Solar Radiation,* A. Mani, (Allied Publishers), 1980.
5. *Solar Energy Fundamentals and Applications,* H. P. Garg and Satya Prakash, (Tata McGraw Hill), 1997.
6. *Treatise on Solar Energy,* H. P. Garg, Volume 1, 2 and 3, (John Wiley and Sons), 1982.
7. *Principles of Solar Engineering,* F. Kreith and J. F. Kreider, (McGraw Hill), 1978.
8. *Solar Energy Thermal Processes,* J. A. Duffie and W. Beckman, (John Wiley and Sons), 1980.
9. *Heat and Thermodynamics,* M. W. Zemansky, (McGraw Hill Publication).
10. *Principles of Solar Energy Conversion,* A. W. Culp (McGraw Hill International Publication).
11. *Solar Energy-Principles of Thermal Collection and Storage,* S. P. Sukhatme, 2nd Edition. (Tata McGraw Hill Publication Co. Ltd.,), 1976.
12. *Solar Energy Utilization,* G. D. Rai, (Khanna Publishers), 1996.
13. *Solar Thermal Engineering,* J. A. Duffie, (Academic Press).
14. *Renewable Energy Sources and Conversion Technology*, N. K. Bansal, M. Kleeman and S. N. Srinivas, (Tata Energy Research Institute, New Delhi), 1996.

PHY-E327 : Experiments based on PHY-T327 List of Experiments :

1. Determination of Calorific value of Wood/Cow dung.
2. Study of Optical Properties of Selective Coatings.
3. Study of Photovoltaic a Characteristics of Solar Cell (Variation of Intensity, Distance between Source and Solar Cell, and Load).
4. Study of Power versus Load Characteristics of Solar Photovoltaic Systems and Study of Series and Parallel Combination of Solar Photovoltaic Panels.
5. Study of Solar Collector (Efficiency versus $\Delta T/I$).

PHY-T 402 : Nuclear Physics

Module-1 : 1 Credit (10 L, 5 T/S/D)

Basic concepts of General properties of nuclei: Masses and relative abundances, mass defect, size and shape, binding energy, angular momentum, magnetic dipole moments and electric quadrupole moments. Nuclear radius, Radioactivity, units of radiation, Alpha, Beta and Gamma-Rays decay.

Module-2:1 Credit (10 L, 5T/S/D)

Constituents of nuclei : Nature of interactions: Electromagnetic, weak interactions and Hadronic interactions. Nucleon - Nucleon scattering, scattering cross section, low energy neutron-Proton scattering, Phase shift, proton-proton scattering, high energy nucleon-nucleon scattering. Theory of nuclear forces, Measurement of nuclear parameters, the Mössbaur effect.

Module-3 : 1 Credit (10 L, 5T/S/D)

Nuclear Models : Liquid drop model, Fermi Gas Model, Shell Model, Collective Model, Single particle model of nucleus Magic numbers, spin-orbit coupling prediction of angler momenta of nuclear ground states, Nuclear Energy levels and their applications.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Reaction dynamics, the Q of Nuclear reaction, Compound nucleus formation and brekup, nuclear fission and heavy ion induced reactions, fusio reactions, types of nuclear reactors. Theory of striping reactions. Basic principls of (i) electron accelerator and (ii) ion accelerators. Linear accelerator, cyclic accelerator Pelletron Electron gun, Radiation detectors; Gas detectors, Nal(Te) detectors Semiconductor detectors, Bubble chamber, Cloud chamber, Spark chamber.

Module-5 : 1 Credit (10 L, 5T/S/D)

Elementary particle physics, Hadrons and leptons, their masses, spin parity decay structure, quarks and gluons. Anti proton production in laboratory. Radiation detector's Gas detectors, Nal(Te) detector, Semiconductor detector. Gell-mann-Nishijima formula, C, P and T invariance and applications of symmetry arguments to particle reactions, parity non conservation in weak interactions etc.

Books :

1. *Concepts of Nuclear Physics,* B.L. Choen (Tata McGraw Hill)
2. *Subatomic Physics,* Frauenfelder and Henley. (Prentice-Hall)
3. *Nuclei and Particles,* E. Segre.
4. *Atomic Nucleus,* R.D. Evans

PHY-T406 : Thin Films and Device Technology

Module-1 : 1 Credit (10L, 5T/S/D)

Electrical conduction in thin films metals and insulators, determination of electrical parameters, Hall effect, TEP measurements, DLTS, thin film diodes, transistors, capacitors and resp.

Module-2 : 1 Credit (10L,5T/S/D)

Optical properties of thin films determination of optical constants, ellipsometry, SERS, nonlinear optics of 2D structures, devices-optical fibers, optical switches.

Module-3 : 1 Credit (10L,5T/S/D)

Optoelectronic devices-solar Cells, heterojunction lasers, photodetectors, electrochromic devices.

Two dimensional structures and high speed quantum devices, semiconductor quantum wells, quantum Hall effect stepped superlattices, MOSFET, BET, HEMT, HET.

Module- 4 : 1 Credit (10L, 5T/S/D)

Magnetic propertices of thin films, magnetic recording and storage.

Superconducting properties of thin films, high T. superconductors, Josephson effect, SQUID and applications.

Module- 5 : 1 Credit (10 L, 5T/S/D)

Photothermal converters, photoelctrochemical cells.

Transducers and sensors, thermal sensors, pyrometes, radiations sensors, pH sensors, gas sensor and strain gauges, multiplexing action, Piezoelectric, pyroelectric and ferroelectric properties of thin films, Use of piezoelectric properties in devices.

Books :

1. *Handbook of thin film technology,* L. I. Maissel and R. Glang. (McGraw-Hill), 1970.
2. *Thin film phenomena,* K. L. Chopra (McGraw-Hill), 1969.
3. *Active and Passive thin film devices and applications,*
4. T.J. Coutts (Academic Press), 1978.
5. *Solid State Physics,* H.Ibach and H, Luth (Norosa Publishers), 1992.
6. *Thin films Solar Cells,* K. L. Chopra, S. R. Das (Plenum Press), 1983.
7. *Electronic Instrumentation and Measurement Techniques,* W. D. Cooper (Prentice Hall), 1979.
8. *Sensors and Transducers,* M. J. Usher (Macmillan Publishers).
9. *AIP Handbook for Modern Sensors,* J. Fradon, (AIP), 1993.
10. *Physics of Thin Films,* Lckertova Plenum, 1977.
11. *Thin Films : Trends and New Applications,* Vol. 2 H. Hoffmann, (Elsevier), 1989.

PHY-P406 : Experiments based on PHY-T406 (2 Credit, 48 lab. hours)

1. Determination of band gap using optical method.
2. Determination of carrier concentration by optical method.
3. To study infra-red properties of photothermal coatings
4. Determination of relative humidity by thick film sensors.
5. To study properties of gas sensors.
6. To study photoelectric properties of films.
7. To study electrical properties of thin films of metals and oxides.

PHY-T407 : Condensed Matter-II

Module- 1 : 2 Credits (20L, 10T/S/D)

Electron Gas: the Hartree-Fock approximation, dielectric theory and screening, Thomas Fermi theory, Lindhard theory, Friedel Oscillation, electron phonon interaction, effective electron phonon- resistivity of metals.

Module- 2 : 2 Credits (20L, 10T/S/D)

Superconductivity: Phenomenology, London theory, Ginzburg-Landau theory, B-C-S theory, high temperature superconductor.

Module- 3 : 1 Credit (10L, 5T/S/D)

Superfluidity: Phenomenology, two fluid model, Bose-Einstein condensation, Landau’s theory, superfluid velocity, superfluid flow, excited states.

or Density functional theory: Hohenberg-Kohn theorem, Kohn-Sham Theory, Local density approximation.

Books :

1. *Superconducitivity of Metals and Alloys*, P.de Gennes, (Benjamin).
2. *Superfluidity,* Vol. 1 & 2, F. London, Dover.
3. *Density Functional Theory,* R.G. Par and W.T.Yang, (Oxford).
4. *Quantum Theory of Solids,* C. Kittel.
5. *Solid State Physics,* Ashcroft & Mermin.

PHY-P407 : Experiments based on PHY-T407 (2Credits, 48 lab. hours)

Computational Experiments/Exercises/Mini Projects.

PHY-T408 : Radiowave Applications

Module-1: 1 Credit (10L, 5T/S/D)

Antennas : Characteristics of Radio waves and radiating system, Antennas, Characteristics of antenna systems, wire aerials, arrays, yagi and TV aerials loop aerials, D.F. systems, reflectors, horn, parabolic dish, TV transmitting antenna Feeder lines.

Module-2 : 1 Credit (10L, 5T/S/D)

Modulation of transmitters : Radiowave modulation, transmitters and applications in communication system, Theory of frequency and phase modulation, A.M. and F.M.,

P.M. modulation systems, S.S.B. system, vestigial sideband modulation and filters, pulse modulation, TV transmitters, scanning, synchronization of pulses, composite video signal, TV camera tubes.

Module-3 : 1 Credit (10L, 5T/S/D)

Receiver & Communication Systems : Detection and receivers: Demodulation of A.M. & F.M., block diagram of TV receiver tuner and mixer stage, IF amplifier detection, video amplifier, sync separation, deflection circuits.

TV communication systems : TV chains, microwave links, satellite communication technique, use of frequency multiplexers and demultiplexers, negative polarity in TV transmission, Information content channel capacity and signal to noise ratio.

Module-4 : 1 Credit (10L, 5 T/S/D)

Propagation : Space, ionosphere and radiowave propagation: Ground and space wave propagation, effect of earths curvature and troposphere, ionospheric propagation Chapman's theory of layer production and important ionospheric parameters.

Module-5 : 1 Credit (10L, 5T/S/D)

Modern Communication System : Digital communication systems. Basics of mobile, cellular systems, LAN, WAN etc.

Books :

1. *Kraus-''Antennas'',* McGraw Hill, 1950.
2. *"Electronics and Radio Engineering",* (McGraw Hill), Termann F. E., 1951.
3. *Ionosphere Propagation,* Keslo, (McGraw Hill), 1964.
4. *Electronic Communication Systems,* George Kenndy, (Tata McGraw-Hill).
5. *Future Trends in communications,* R.J. Horrocks-R.W. Scarr, (Willey Publishers).
6. *Mobile Cellular Telecommunications Systems,* William, C.Y. Lee, (McGraw Hill Books Co.), 1989.

PHY-P408 : Experiments based on PHY-T408 (2 Credits, 48 lab. hours)

1. Simulation of radiation patterns of various antennas.
2. Study of Horn and Patch antenna.
3. To study Amplitude modulation and Demodulation.
4. To study FM Communication limit.
5. To study Video pattern generator.
6. To design and study graphic equalizer.
7. To study time Domaon mltiplexing.
8. To design and study graphic equalizer.
9. To study time Domaon multiplexing.

PHY-T409 : Quantum Mechanics-IV

Module-1 : 1 Credit (10L, 5/S/D)

Classical Theory : Canonical formalism, symmetries and conservation laws, Noether's theorem, internal symmetries.

Module-2 : 2 Credits (20L, 10T/S/D)

Canonical quantization of free fields: Scalar field, Radiation field, Dirac field, Interacting field, Perturbation theory- Interaction picture, S-matrix. Scalar and spinor electrodynamics, Elementary processes and Diagrams, Feynman rules for diagrams.

Module-3 : 1 Credit (10L, 5T/S/D)

Cross section calculation, Applications to such as Compton effect, pair annihilation.

Module-4 : 1 Credit (10L, 5T/S/D)

Radiative corrections : Electron propagator, vertex function, one-loop renormalization, Lamb shift, self energy. Renormalization, regularization and power counting.

Books :

1. *Relativistic Quantum Mechanics,* J. Bjorken and S. Drell (McGrew-Hill).
2. *Advanced Quantum mechanics,* J. J. Sakurai (Addison-Wesley).
3. *Relativistic Quantum Field Theory,* J. Bjorken and S. Drell (McGraw-Hill).
4. *An Introduction to Relativistic Quantum Field Theory,* S. S. Schweber (Row, Peterson).
5. *Quantum Electrodynamics,* R. P. Feynman (Benjamin Cummings).
6. *Quantum Field Theory,* L. Ryder (Academic).
7. *Quantum Field Theory,* C. Itzykon and J. B. Zuber (McGraw-Hill).
8. *The Quantum Theory of Fields,* S. Weinberg, Vol. I (Cambridge).
9. *An Introduction to Quantum Field Theory,* M. E. Peskin and D. V. Schroeder, (Addison Wesley), 1955.

PHY-P409 : Experiments based on PHY-T409 (2 Credits, 48 lab. hours)

Computational experiments/Exercises/Mini Projects.

PHY-T410 : MATERIALS SCIENCE-II

(Material Synthesis and Characterization)

Module 1 : 1 Credit (10 Lectures, 5 T/S/D)

Mechanical response of Materials : Elasticity, model of elastic response, inelasticity, viscoelasticity, stress-strain curves, concept of various mechanical properties such as hardness, yield strength, toughness, ductility, yield toughness, ductility, brittleness, stiffness, young modulus, shear modulus, shear strength, Frenkel model, Peierls-Nabarro relation, Plastic deformation, importance of dislocation movements, sessile dislocations, relation of slip process and crystal structures, Franck reed source for dislocation etc, Creep, fatigue in materials, Fracture, Strengthening of materials

Module 2 : 1 Credit (10 Lectures, 5 T/S/D)

Materials Synthesis: Concept of equilibrium and nonequilibrium processing and their importance in materials science.

Synthesis of Bulk materials: Metallic and non metallic, Ceramics and other materials. Only basic elements of powder technologies, compaction, sintering calcination, vitrification reactions,with different example, phenomenon of particle coalescence, porosity. Quenching : concept, glass formation, splat quenching,

Processing of Thin Films and surface layers of solids : Ion beam processing, features of ion induced phenomenon, low induced phenomenon in materials, Laser types, CW and pulsed laser processing, various types of processing, concepts Laser annealing, alloying cladding, metallurgy reactive processing, laser deposition etc. with examples. Other methods: Sputtering and chemical CVD processing (basic concepts)

Module 3 : 1 Credit (10 Lectures, 5 T/S/D)

Basic concepts of characterization : Use of various probe beams such as γ-rays, X-rays, Microwave, IR, UV-visible radiation, electrons, protons, neutrons and ions, their energies, penetration depths, and interaction with materials.

Exposure to Different characterization techniques such as based on the above probes. This typically includes X-ray (diffraction, topology, micrography), XPS, AES, RBS, ISS STM.

Module 4 : 1 Credit (10 Lectures, 5 T/S/D)

Electrical properties and its measurements, metallic semiconducting and electroceramic materials, case studies on synthesis and electrical measurements.

Module 5 : 1 Credit (10 Lectures, 5 T/S/D)

Magnetic and optical properties and its measurements : case studies on synthesis and measurements of Magnetic and optical materials.

Books :

1. *Physical Metallurgy,* Vol. I and Vol. 2 by R.W. Cahn and P. Hassen (North Holland Publishing Company, New York), 1983.
2. *Materials Science and Engineering,* V. Raghvan, (Prentice-Hall Pvt. Ltd.), 1989.
3. *Fundametals of Molecular Spectroscopy,* C. N. Banwell and E. M. McCash, (Tata MacGrawhill Publishing Company, New Delhi), 1994.

PHY-P410 : Experiments based on PHY-T410 (2 Credits, 48 lab. hours)

1. Creep study in Pb-Sn alloy wire.
2. Synthesis of oxide materials by compaction and sintering.
3. Surface area measurements of nano-particle power.
4. Band gap measurements of oxide film using Uv-Vis Spectroscopy.
5. Study and understanding the AES, XPS and RBS spectra of materials.

PHY-T411 : Astronomy and Astrophysics-II

Module-1 : 3 Credits (30 Lectures, 15 T/S/D) General Relativity

Principles of Relativity : Overview of Special Relativity, space-time diagrams, Lorentz metric, cones, electrodynamics in 4 dimensional language. Introduction to general relativity (GR), equivalence principle, gravitation as a manifestation of the curvature of space-time.

Geometrical Framework of General Relativity : Curved spaces, tensor algebra, Metric, affine connection, covariant derivatives, Physics in curved spacetime, Curvature-Riemann tensor, Bianchi identities, Action Principle, Einstein's field equations, Energy momentum tensors, energy-momentum tensor for a perfect fluid, connection with Newton's theory.

Solutions to Einstein's Equations and their Properties : Spherical symmetry, derivation of the Schwarzschild solution, test particle orbits for massive and massless particles.

The three classical tests of GR, black holes, event horizon-one way memberanes, Gravitational Waves.

Module-2 : 2 Credits (20 Lectures, 10 T/S/D) Cosmolgy

Cosmological Models : Cosmological Principles, Robertson-Walker metric, cosmological redshift, Hubble's law, Observable quantities-luminosity and angular diameter distances. Dynamics of Friedmann-Robertson-Walker models.

Solutions of Einstein's equations for closed, open and flat Universes.

Physical Cosmology and the Early Universe: Thermal History of the Universe: Temperature-redshift relation, distribution functions in the early Universe-relativistic and non-relativistic limits. Decoupling of neutrions and the relic neutrino background-Nucleosynthesis. Decoupling of matter and radiation; Cosmic microwave background radiation. Inflation-Origin and growth of Density Perturbations.

Books :

1. *General Relativity and Cosmology,* J. V. Narlikar, (Macmillan company of India Ltd., Delhi).
2. *Classical Theory of Fields,* Vol. 2, L. D. Landau and E. M. Lifshitz, (Pergamon Press, Oxford).
3. *First course in general relativity,* B. F. Schutz, (Cambridge University Press).
4. *Introduction to Cosmology,* J. V. Narlikar, (Cambridge University Press).

PHY-P311, PHY-P411 : Experiments based on Physics-T311 and PHY-T411

Experiments for Astronomy and Astrophysics I and II

(Total 5 credits, 120 Lab. Hours) Any 10 of these experiments will be covered. (5 in semester III and 5 in Semester IV)

(Please note that some of these experiments, involving observations with the telescope, will be covered either in IIIrd or IVth semester depending on the sky conditions).

List of M.Sc. A & A Experiments :

1. To estimate the temperature of an artificial star by photometry.
2. To study the characteristics of a CCD camera.
3. To study the solar limb darkening effect.
4. To polar align an astronomical telescope.
5. To estimate the relative magnitudes of a group of stars by a CCD camera.
6. To study the atmospheric extinction for different colors.
7. Differential photometry of a program star w.r.t. a standard star.
8. To study the effective temperature of stars by B. V. photometry.
9. To estimate the night sky brightness with a photometer.
10. To estimate the distance to the moon by parallax method.
11. Calibration of a 1420 MHz radio reciever and spectrometer.
12. Detection of 21-cm line of neutral hydrogen from our galaxy.
13. To estimate the distance to a Cepheid variable.
14. To study the variability of delta Scuti type stars.
15. To study the variability of RS CVn binaries.
16. To measure the polarization of day/moon light.

Lectures associetd with the experimets will be given on a number of topics including : Time and Coordindates; Telescopes; Atmospheric effects; Noise and Statistics; Astronomical Detectors; Imaging and Photometry.

Books for above lectures :

1. *Telecopes and Techniques,* C. R. Kitchin, (Springer).
2. *Observational Astrophysics,* R. C. Smith, (Cambridge University Pres).
3. *Detection of Light : from the Ultraviolet to the Submillimeter,* G. H. Rieke, (Cambridge University Press).
4. *Astronomical Observations,* G. Walker, (Cambridge University Press).
5. *Astronomical Photometry,* A. A. Henden & R. H. Kaitchuk, (Willmann-Bell).
6. *Electronic Imaging in Astronomy,* I. S. McLean, (Wiley-Praxis).
7. *An introduction to radio astronomy,* B. F. Burke & Francis, Graham-Smith, (Cambridge University Press).
8. *Radio Astronomy,* John D. Kraus, (Cygnus-Quasar Books).

PHY-T 412 : Nuclear Techniques

Module - 1 : 1 Credit (10 L, 5 T/S/D)

Basic concepts of half life, mean lifetime of nuclei. Measurement of lifetime of nuclear excited states covering range from picoseconds, microsecond, millisecond to years using techniques such as conversion line shift recoil distance, delayed coincidence, activity measurement and other methods. Measurement of Beta-Beta and Beta-gamma coincidence.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Basic principles and applications of (i) Mössbauer effect. (ii) Positron annihilation and (iii) perturbed angular

correlation (iv) orange spectrometer for beat particles and electrons.

Magnetic spectrometers, mass and energy resolution, transmission efficiency for the above spectrometers.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Neutron sources, neutron detectors, measurement of cross-sections for nuclear reaction, thermal and fast reactors, production of radioisotopes. Reactor operation, thermal neutrons, neutron scattering and applications.

Module-4 : 1 Credit (10 L. 5 T/S/D)

Nuclear reaction analysis : Elemental analysis by neutron activation analysis, proton induced X-ray emission, Rutherford backscattering, Resonance nuclear reaction, ERDA, channeling, ion scattering and other such methods.

Module-5 : 1 Credit (10, L 5T/S/D)

Practical uses of radioisotopes, Radioistopes, Radioactive waste disposal applications of radioisotopes dating of archeological and other ancient object, Medical uses of radioisotopes and electron beams, radiotherapy, Carbon-14 and potassium-argon dating 39,40 method trace element studies.

Books :

1. *Nuclear radiation detectors,* S. S. Kapoor and V. S. Ramamurthy. (Wiley Eastern Limited, New Delhi), 1986.
2. *Introduction to radiation protection dosimetry,* J. Sabol and P. S. Weng, (World Scientific), 1995.
3. *Techniques for nuclear and particle physics,* W. R. Leo. (Springer), 1995.
4. *Nuclear Measurement Techniques,* K. Sriram, (Affiliated East-West Press, New Delhi), 1986.
5. *Fundamentals of surface and thin analysis,* Leonard
6. C. Feldman and James W. Mayer, (North Holland, New York), 1988.

7. *Introduction to nuclear science and technology,* K. Sriram and Y. R. Waghamare, (A. M. Wheeler), 1991.
8. *Nuclear radiation detection,* W. J. Price, (McGraw-Hill, New York), 1964.
9. *Alpha, beta an gamma-ray spectroscopy,* K. Siegbahn, (North Holland, Amsterdm), 1965.
10. *Introduction to experimental nuclear physics,* R. M. Singru (John Wiley and Sons), 1974.
11. *Radioactive isotopes in biological research,* William
12. R. Hendee, (John Wiley and Sons), 1973.

PHY-P412 : Experiments based on PHY-T412 (2 Credits, 48 lab, hours)

1. To make a short lived isotope Using 14 MeV neutrons and measure its half life time.
2. To determine resolving time of a coincidence using chance coincidence technique.
3. To determine activity of a given gamma-ray source using radiation monitor.
4. Measurement of neutron flux using activation method.
5. To measure efficiency and energy resolution of a HPGe detector
6. To study different pulse shaping circuits for > T, = T, < T conditions and combination of differentiation and integration for 'n' number of networks.
7. To study designing of a D/A converter using R-2R ladder network.
8. Design study of different modes of scalar using IC 7490 and observe the output of an oscilloscope.

(Any five experiments will be covered)

PHY-T413 : Biophysics-II

Module-1 : 2 Credits (20L, 6T,4D)

(A) Neuroscience : Higher functions of brain : Origin of EEG, Signal characteristics, Physiological significance, Auditory, Visual and somatosensory evoked potenitals

(B) Nerve communications : (1) Understanding visual system : Visual field, receptive field, receptor response, Response from ganglion, Lateral geniculate, simple, complex, hypercomplex, Cell and their receptive field receptive field formation.

(C) Signal processing : Fourier series, transform, correlations (auto and cross, transfer function).

Module-2 : 1 Credit (10L, 3T, 2D)

(A) Membrane Biophysics & Transport :

(B) Structure & function of membrane, membrane proteins, Transport across membrane, Processes, Chemical potential, Flux equation, Nernst Equation, Using-Teorell unidirectional flux ration, Osmotic pressure, Osmotic phenomena in leaky membrane, The Donnan equilibrium-Goldman equation

Medule-3 : 1 Credit (10L, 3T, 2D)

Bioenergetics : Entropy in biological systems, Information, Processing Photosyntheitc pathways, Redox potentials, glow curves, Order of Kinetics, Thermodynamics in phyotosynthesis-Thermoluminessence, Mitochondriul Bioenergetics

Enzyme Kinetics : Classification of exzymes, Activation energy barrier, substrate concentration, Vmax,km, Competitive & Nocompetitive inhibition, Allosteric exzymes

Module-4 : 1 Credit (10L,3T,2D)

Computational biology : Introduction, Protein sequences & database concept. Sequence Alignments: Local/global(details) Protein structure predictions: Methods, Utility Neural Networks : Introduction, theory Application.

Reference Books :

1. *Biophysics : An Introduction by Rodney,* M. J. Colteril (John Willey and Sons Ltd.,), 2002.
2. *Biophysics : Vasantha Pattabhi,* N. Gautham, Narosa Publication House), 2002.
3. *Principles of Biochemistry,* Lehninger
4. *Molecular Biology of the Cell,* Bruce Alberts, Debbis Bary, (Garland Publishing N.Y, London).
5. *Biophysics and Physiology of excitable membrane,* Adleman (Van Mostrand Rcihold Co.), 1971.
6. *Membrane ions and impulses,* K.S. Cole.
7. *Principles of neural science,* Kandel and Schawartz, (Elesvier North Holland), 1982.

8. *Problems of biological physics,* L.A. Bluemenfeld, (Springer-Verlag, Berlin), 1977.
9. *Walter Hopper and Other (ED), Bioplysics,* (Springer Verlag Berlin, 1983).

PHY-P413 Experiments based on PHY-t413 (2 Credits, 48 lab. hours)

1. Recording and Analysis of Visual Evoked Potential
2. Recording and Analysis of Auditory Evoked Potential
3. Recording of Electroneutogram (ENG), Motor Nerve Conduction.
4. Recording of ENG (Electrocardiogram).
5. Thermoluminescence in Biomolecules.
6. RASMOL
7. Sequence alignment using BLAST
8. Sequence alignment (local, global) using FASTA
9. Use of CLUSTAL to plot phylogenetic tree.

PHY-T414 : Bioelectronics - II

Module-1 : 1 Credit (10 L, 5T/S/D)

Basics of Biosignal Analysis Continuous discrete signals, classification of biosignals, random processes and random signal characterization (statistical averages, probability distribution functions Gaussian process) Sampling, Aliasing Quantization, D to A converters, A to D converters, Laboratory interface, programmed data transfer, interrupt driven data transfer, Direct memory access data transfer continuous sampling to disc, selection of lab.

Interface interfacing micro computers/PC to standard biomedical instruments.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Frequency Domain analysis, representation and properties of FT (convolution theorem, FT of periodic, periodic signals) DET, FFT, power spectral density function auto correlation, Cross-correlation power spectral density function.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Special techniques for biosignal analysis, Hear rate variability (HRV), Arrthymia analyzer, Power spectra of EEG, EMG, signals, Averaging of Evoked potential, Real time system for ECG & EMG with DSP hardware.

Module-4 : 1 Credit (10 L 5 T/S/D)

Linear systems: Modeling of physiological systems, system identification, transfer function sensory receptors. Current techniques in biosignal analysis, Neural networks application for biosignal classification, multiresolution analysis of biosignal using wavelet trasform.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Computer in biomedical equipment hardware & software languages-basic review, LAN, WAN in clinical setups, computer in automated medical information systems (MIS), computer analysis in patient monitoring, computer analysis of cardiac & pulmonary functions, computer evaluation of clinical lab tests, computerized axial tomography, telemedicine-basice & application.

Books :

1. *Principles of Neurobiological Signal Analysis,* Glasser & Ruchkin (Academic Press), 1982.
2. *Biomedical Signal Processing,* Arnon Cohen (CRC Press).
3. *Signals & Systems,* Oppenheim (Wily & Young EEE prentice-Hall)
4. *Microcomputers in Neuroscience,* Kerkut
5. *Biomedical Signal Analysis,* Akay (Academic Press)
6. *DSP lab Manual* V. R. Udpikar

PHY-P414 : Experiments based on PHY-T414 (2 Credits, 48 lab. hours) EXPERIMENTS :

1. Fourier analysis of biopotentials.
2. Nerve conduction velocity measurement.
3. R-R interval analysis of ECG under various conditions.
4. Splice train analysis (are, entropy, autocorrelation, CNSS-correlation).
5. Signal conversion (ADC) & sample & hole circuit.
6. Digital filter design-finite impulse response & IIR filters. and similar experiments in digital signal processing.

PHY-T415 : Laser II

Module-1 : 1 Credit (10 L, 5 T/S/D)

Optically pumped laser systems, Optical sources projection geometries, power supply Q-switches-pulse reflection mode, Multiple-pulsing in slow Q-switches. Mode locking.

Module-2 : 1 Credit (10 L 5 T/S/D)

Roby laser, Nd: YAG laser, Nd:glass, Amplifiers for these lasers, their characteristics, semiconductor lasers, color center laser. **Module-3 : 1 Credit (10 L 5 T/S/D)**

Pulse transmission mode Q-switching, Mode locking-active and passive techniques Passive mode locking using dye cell, Distributed Feedback Lasers (and its importance for shoprt pulse generation)

Module-4 : 1 Credit (10 L, 5 T/S/D)

Non-linear optics: interaction of radiation with matter, optical susceptibility, propagation of E-M radiation in a medium/non linear medium, S.H. generation, T.H. generation, wave mixing optical parametric oscillation, non linear materials.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Laser applications: (i) Holography, (ii) Optical communications/optical fiber (iii) Laser spectroscopy, (iv) Material processing welding cutting etc. (v) Medical applications, (vi) Doppler free two photon absorption, (viii) Isotope separation.

Text Books :

1. *Laser in Industry,* S.S. Charschan, (Vol Nostrand), 1972.
2. *Solid State Laser Engineering,* Walter Koechner, (Springer-Verlag), 1976.
3. *Applied non-linear optics,* Fzernik and J. Midwinte, (John Wiley), 1973.
4. *Laser Handbook*, Vol.1-4, F.T. Arechi, E.O. Schul Dobois, (North Holland), 1973.
5. *Application of lasers,* John F. ready.

PHY-P415 : Experiments based on PHY-T415 (2 Credits, 48 lab. hours)

1. Laser induced reactive quenching at the liquid solid interface-study of phase formation by XRD.
2. Relative intensity in different diffraction orders.
3. Estimation of band gap of ZnO by UV-Visible spectroscopy
4. Study of Relaxation oscillation in solid state lasers
5. Stduy of oscillator and amplifier systems of Nd: YAG laser,
6. estimation of gain factor
7. to show that the temporal parameters are independent of amplifier.
8. To study magneto-optic rotation and magneto-optic modulation
9. Demonstration of the spatial coherence of the laser beam. Similar experiments will also be thought of form time to time.

PHY-T421 : Accelerator Physics-II

Module- 1 : 1 Credit (10 L, 5 T/S/D)

Liouville's theorem, beam filamentation due to nonlinear forces and effective emittance, linear beam ellipse transformations, envelope equation envelope representation of trajectories.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Particle motion in magnet systems: beam motion in magnet systems, weak and strong focussing and their applications.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Linear machine lattices, Hamiltonian formulation, linear machine imperfections, storage ring physics.

Module-4 : 1 Credit (10 L, ST/S/D)

Sources of particle beams, electron gun, ion sources. Applications of accelerators with special emphasis on industrial and medical fields.

Module-5 : 1 Credit (10 L, ST/S/D)

Design of dipole, quadrupole magnets and its applications in beam optics

R.F. accelerating structures and their applications.

Books :

1. *Physics of cyclic accekerators,* J. J. Livingood
2. (D. Van Nostrand).
3. *Particle Accelerators,* J. P. Blewett, (McGraw-Hill Book Co.).
4. *Particle Accelerators and their uses,* W. Scharf, (Harwood Academic Publishers).
5. *Frontiers of particle beams,* Ed. M. Month and S. Turner, (Springer Verlag).
6. *Physics with intersecting storage rings Ed. Bruno Touschek,* (North Holland Publishing)

PHY-P421 : Experiments based on PHY-T421 (2 Credits, 48 lab. hours)

1. I/V characteristics of R.F. ion source.
2. Measurement of peak and average current of a beam delivered by an accelerator.
3. Measurement of radiation level around an accelerator using pocket doesimeter.
4. Characteristics of pulse modulator used in accelerators.
5. Study of quadrupole lenses OR similar experiments will be provided.

PHY-T423 : Nonlinear Dynamics-II

Module-1 : 3 Credits (30 L, 15 T/S/D)

Hamiltonian systems Introduction : Hamiltonian phase flow and integral invariants, canonical formalism, Hamilton-Jacobi methods, Generating functions, integrable systems, Liouville Arnold integrability Central force problem, Harmonic oscillators, Toda chain, action variables.

Perturbation Theory : Adiabatic invariance, Averaging KAM theorem Resonances, variational calculation of Tori, Stochastic motion. Diffusion other area preserving systems: Maps Baker's transformation, Cat map, Stmbolic synamics.

Module-2 : 2 Credit (20 L, 10 T/S/D)

Any two of the following topics :

1. Quantum Mechanical Systmes : Chaotic behavior of quantum systems, level spacing and statistics of random matrices, kicked oscillator.
2. Ergodic properties of physical systems: Birkhoff, Hopf and mean ergodic theorems (no proof), Metric transitivity, mixing, k-systems, C-systems, Ergodic invariants, Sinai billiards, stadium problem.
3. Fluid Mechanics and Turbulence Continuum hypothesis, Lagrangian and Eulerian frames, equation of continuity, Euler's equation, Bernoulli's equation, Streamlines, Navier-Stokes equation, Flow in a pipe, Couette flow, Law of Similarity, Reynolds number, Stability of steady flows and instabilities Quasiperiodic flow and frequency locking, Landau's theory of Turbulence, Ruelle-Takens Scenario, Fully developed turbulence, Kolmogorov and Obukov scaling law.
4. Solitons L. KdV equation, inverse scattering transform, other soliton systems.

Books :

1. *Chaos and Integrability in Nonlinear Dynamics,* M. Tabor, (J. Wiley), 1989.
2. *Introduction to Dynamics,* Cambridge, Percival, D. Richards, (Univ. Press).
3. *Regular and Stochastic Motion* A. J. Lichtenburg and M. A. Libermann, (Springer-Verlag.)
4. *Chaos in Classical and Q-systems,* M. C. Gutzwiller, (Springer-Verlag).
5. *Mathematical Methods in Classical Mechanics,* V. I. Arnold (Springer Verlag).
6. *Classical Dynamics,* Jose and Saleton, (Cambridge Univ. Press).
7. *Drazin and Johnson : Solitons,* (Cambridge Univ. Press).
8. *Elements of Soliton Theory,* G. L. Lamb, (J. Wiley), 1980.
9. *Ablowitz and Clarkson,* Solitons : (Cambridge Univ. Press).
10. *Statistical Physics,* Toda Kubo Saito, Vol. I, (Springer Verlag).
11. *Quantum Chaos - An Introduction,* H. J. Stöckmann, (Cambridge Univ. Press), 1999.

12. *Intermediate Classical Mechanics,* Michellotti, (J. Willey).
13. *Classical and Quantum Dynamics,* Dittrich and Reuter, 3rd Edition, (Springer Verlay), 2003.
14. *Ergodic problems of Classical Mechanics,* V.I Arnold and A. Avez Benjamin.
15. *Fluid Mechanics,* L. Landau and I.M. Lifshitz, (Pergamon Press).

PHY-P423 Experiments based on PHY-T423 (2 Credits, 48 lab. hours.)

Computational experiments/exercises/mini/project.

1. Symplectic integrators, Fermi pasta problem.
2. Study of Henon-Heiles system.
3. Study of parametric resonances.
4. Coupled map lattice systems.
5. Analysis of the Lorenz system.

PHY-T424 : Chemical Physics -II

Module-1 : 3 Credits (30 L, 15T/S/D)

Symmetry aspects of molecular orbital (MO) theory LCAO, the Hückel approximation, energy level diagrams, symmetry factoring of secular equation, some simple carbocyclic systems, napthalene as an illustration Hybird orbital and molecular orbitals for AB type molecules: Hybridization schemes for sigma and pi bonding hybrid orbtials as LCDA , MO theory for AB_n type molecules, the relationship of the molecular orbital and the hybridization treatments, molecular orbitals for regular octahedral and tetrahedral molecules.

Electronic spectra of complex ions: selection rules and bandwidths, band intensities, spin-orbit coupling departure form cubic symmetry (Jahn-Taller effect), band shapes spectra in solids, spectra of aqueous solution of metals ions, band assignments, spectra of spin free transition metal ligand octahedral complexes, spectra of spin paired transition metal ligand octahedral complexes, spectra of distorted octahedral complexes, spectra of tetrahedral complexes, the spectro-chemical and nephelauxetic series, charge transfer spectra.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Magnetic properties of complex ions: magnetic susceptibility, the magnetic properties of free ions, quenching of orbital angular momentum by ligand field, the magnetic properties of A,E and T terms, the magnetic of complexes with A and E ground terms and T ground terms. Experimental methods for magnetic measurements (Susceptibility, Magnetization, ESR, NMR in brief)

Module-3 : 1 Credit (10 L, 5 T/S/D)

Molecular vibrations: Group theoretical analysis of various modes of vibration of molecules, IR and Raman active modes, F and G matrices (introduction only). R and Raman spectroscopy): Experimental details, Analysis of IR and Raman Spectra of simple molecules.

Books :

1. *Chemical applications of group theory,* F. A. Cotton, (Wiley Eastern Ltd. New Delhi), 1986.
2. *Introduction to Ligand fields,* B.N. Figgis, (Wiley Eastern Ltd. New Delhi), 1976.
3. *Magnetism and Transition metal complexes,* F. E. Mabbs, D. J. Machin, (Chapman and Hall, London), 1973.
4. *Introduction to Ligand field theory,* C. J, Ballhausen, (McGraw Hill, New York), 1962.
5. *Symmetry and Spectroscopy,* D. C. Harris and M. D. Berrtolucci, (Oxford University Press, Oxford), 1978.

PHY-P424 : Experiments based on PHY-T424 (2 Credits, 48 lab. hours)

1. To obtain electronic spectra of transition metal octahedral complexes in water and obtain 10 Dq. And B for the metal ions (equivalent to 2 expts.)
2. To obtain electronic spectra of transition metal tetrahedral complexes and obtain 10 Dq and B for the metal ions (equivalent to 2 expts).
3. To obtain vibrational spectra of Carbon Tetrachloride (vapours) and ammonia (gas) and study the vibrational modes.

PHY-T425 Nanotechnology-II

Module-1 : 1 Credit (10 L, 5 T/S/D)

Analysis using Microscopies : SEM, TEM, AFM, MFM, SNOM, Confocal Microscope.

Module-2 : 1 Credit (10 L, 5 T/S/D)

Properties of Nanomaterials : Mechanical, thermal, structural, optical, electrical, magnetic. Properties of carbon nanotubes, nanorods, nano-porous materials.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Top Down Approach of Nanomaterials Synthesis : Conventional lithography and its limitations. Lithography using scanning probes, soft lithography.

Module-4 : 1 Credit (10 L, 5 T/S/D)

Spintronics and Photonics : Atomic origin of magnetism. Diamagnetism, paramgnetism, ferromagnetism and anti ferromagnetism, spin glass, magnetic bubbles, domain walls, magnetic multilayers, magnenites, GMR and CMR, DMS materials. Photonic band gap materials.

Module-5 : 1 Credit (10 L, 5 T/S/D)

Analysis of spintronic materials : Magnetoresistance, VSM, SQUID, Faraday and Kerr rotation.

Module-6 : 1 Credit (10 L, 5 T/S/D)

Nano Devices/systems : Coulomb blockade, single electron transistor, magnetic tunnel junction, spin valve, biological labels, DNA detection using nanomaterials, sensors using nanomaterials.

Recommended Books :

1. *Quantum Dots, L. Jacak,* P. Hawrylak, A. Wojs, (Springer), 1997.
2. *Optical Properties of Semiconductor Nanocrystals,* S. V. Gaponenko. (Cambridge Press), 1997.
3. *Physics and Applications of Semiconductor Microstructures,* M. Jaros. Clarendon, 1989.
4. *Nanoparticles and Nanostructured Films,* J. H. Fendler (ed.) (Wiley-VCH), 1998.
5. *Nanostructured Materials and Nanotechnology,* H. S. Nalwa (Ed.) (Academic Press), 2002.
6. *Nanotechnology,* G. Timp, Maple-Vail (Book Man. Group, USA), 1999.
7. *Characterization of Materials,* J. B. Wachtman and Z.
8. H. Kalman, Butterworth-Heinmann, USA, 1993.

PHY-P425 Expeiments based on PHY-T425

1. Alloy nanoparticles using ball milling and X-ray Diffraction of alloy.
2. +3. Granular thin film deposition and SEM+EDAX analysis of thin films.
3. Magnetoresistance Analysis.
4. Lithography.

PHY-T426 : Physics of Nanostructures/Nanotechnology

Module-1 : 1 Credit (10 L, 5 T/S/D)

Why nanoscale technology : Survey of metals, insulators and semiconductors. Free electron and band theories bending and Bravais lattice., Low dimensional structures: Quantum wells, quantum wires quantum dots, particle in a box. Strong and weak confinement, excitons, biexcitions, optical transmissions, photoluminescence, electroluminescence, Fullerenes, nanotube porous silicon and other special nanomaterials.

Module-2 : 1 Credit (10 L,5 T/S/D)

Properties of nanomaterials : Mechanical, thermal, structural, optical, magnetic and electrical

Nanopatterning : Optical-electron-X-ray-ionlithography, SPM, dip pen litho, self assembly, templets.

Module-3 : 1 Credit (10 L, 5 T/S/D)

Synthesis of nanomaterials : Physical, chemical, biological, arc deposition, cluster beam, laser deposition, MBE, MOCVD, glasses, zeolites, polymer, media, chemical, self assembly

Module-4 : 1 Credit (10, L, 5 T/S/D)

Analysis of nanostructures : Microcopies - TEM, STM, AFE, Diffraction : XRD, Optical : UV-VIS, IR, XPS, Magnetomistance, Kerr and Faraday rotations.

Module-5 : 1 Credit (10 L 5 T/S/D)

Photonics and Magnetonics : GMR, CMR, Spintronics, Photonics.

Module-6 : 1 Credit (10 L 5 T/S/D)

Applications : LED, SET, GMR, Display panels, sensors, medical.

Books :

1. *Quantum Dots, L. Jacak,* P. Hawrylak, A. Wojs Springer (1997).
2. *Optical Properties of semiconductor nanocrystals,* S. V. Gaponenko Cambridge Press, (1977).
3. *Physics of low dimensional structures,* j. H. Davis Cambridge, (1998).
4. *Semiconductor Quantum Dots,* L. Banjaj and S. W. Koch.
5. *Low dimensional semiconductors,* M. J. Kelly Clarendon, (1995).
6. *Physics and application of semiconductor microstructures,* M. Jaros Clarendon (1989)

PHY-P426 : Experiments based on PHY-T426 (2 Credit, 48 lab, hours)

1. Synthesis of semiconductor nanoparticles by chemical method.
2. Optical absorption of nanoparticles (observation of Blue shift with size of particles).
3. Photoluminescence of nanoparticles (Luminecence decay time).
4. X-ray diffraction studies of nanoparticles (effect of temperature).
5. Density of states claulation of small clusters (experiments on computer).

PHY-T427 Energy Studies-II

Module-1 : 1 Credit (10L, 5 T/SD) Solar Photovoltaics (SPV)

Solar Photovoltaic (SPV) Conversion : Basic principle of solar photovoltaic conversion, Types of solar cell materials, Fabrication of solar photovoltaic cells, Solar cell parameters and characteristics, Modules.

Solar Photovoltaic (SPV) Conversion Systems : Block diagram of general SPV conversion system and their characteristics, Different configurations, Solar photovoltaic conversion system components and their characteristics, Application (such as street light, water pumps, Radio/TV, Small capacity power generation).

Solar Photovoltaic (SPV) Systems Designing : Load estimation, Selection of inverters, Battery sizing, array sizing.

Hybrid Solar Photovoltaic (SPV) Systems.

Module-2 : 1 Credit (10L, 5 T/S/D) Photothermal applications of Solar Energy

Selective coatings : Ideal characteristics of selective coating for various applications, Types of selective coatings, materials and techniques for selective coatings, Effect of selective coating on the efficiency of solar collectors.

Solar Thermal Devices and Systems : Different types of collectors, Flat plate collector (Basic principle, Construction, Energy balance equation of steady state, Testing, Methods to reduce losses), Solar cookers, Domestic hot water system, Solar dryers, Solar pond, Solar still, Solar furnace, Solar refrigeration, Solar concentrator, Systems based on use of solar concentrators.

Module-3 : 1 Credit (10L, 5 T/SD) Hydrogen Energy

Hydrogen Fuel : Importance of Hydrogen as a future fuel, Sources of Hydrogen, Fuel of vehicles.

Hydrogen Production : Production of Hydrogen by various methods, Direct electrolysis of water, Direct thermal decomposition of water, Biological and biochemical methods of hydrogen production.

Hydrogen storage : Gaseous, Cryogenic and Metal hydride.

Utilization of hydrogen : Fuel cell-Principle, construction and applications.

Module-4 : 1 Credit (10L, 5 T/SD) Wind Energy

Wind Energy : Introduction, Basic principle of wind energy conversion, Extraction of maximum power from wind and its dependence on various parameters.

Wind Mills : Types of wind mills, Vertical axis and Horizontal axis wind mills-their performance, Merits and Demerits, Limitations of wind energy conversions.

Module-5 : 1 Credit (10L, 5 T/SD) Bio Energy

Biomass : Generation and utilization, Properties of biomass, Agriculture crop and Forestry residues used as fuels, Physical, chemical and biological conversion of biomass into useful form of energy, Gasification, Biomass gasifiers and types.

Biogas : Introduction, Generation of biogas, Aerobic and anaerobic bioconversion process, Substances used to produce biogas (Cow dung, Human and other agricultural waste, Municipal waste etc). Digesters and their designs, Pyrolysis and gasification, Fermentation process.

Biofuels : Types of biofuels, Production processes, Biofuel applications, Ethanol as a biofuel.

Reference Books :

1. *Climatological and Solar data for India, Seshadri,* (Sarita Prakashan), 1969.
2. *Solar Energy Utilization,* G. D. Rai, (Khanna Publishers), 1996.
3. *Energy Technology,* S. Rao and B. B. Parulekar, (Khanna Publishers), 1995.
4. *Terrestrial Solar Photovoltaics,* Tapan Bhattacharya, (Namsa : Publication House, New Delhi), 1998.
5. *Solar Cells-Operating Principles, Technology and System Applications,* Martin A. Green (Prentice Inc., U.S.A.).
6. *Solar Thermal Engineering,* J. A. Duffie, (Academic Press).
7. *Renewable Energy Sources and Conversion Technology,* N. K. Bansal, M. Kleeman and S. N. Srinivas, (Tata Energy Research Institute, New Delhi), 1996.
8. *Fundamentals of Solar Cells,* F. A. Faherenbruch and
9. R. H. Bube, (Academic Priess).
10. *Biomass Energy systems,* Venkata Ramala and S. N. Srinivas, (Tata Energy Research Institue, New Delhi), 1996.
11. *Thin Film Solar Cells,* K. L. Chopra and S. R. Das, (Plenum Press), 1983.
12. *Solar Hydrogen Energy Systems,* T. Ohta, (Pergamon Press), 1979.
13. *Hydrogen Technology for Energy,* D. A. Maths, (Noyes Data Corp.),1976.
14. *Handbook-Batteries and Fuel Cell,* Linden, (McGraw Hill), 1984.
15. *Wind Energy Conversion Systems,* L. L. Freris, (Prentice Hall), 1990.

PHY-P427 : Experiments based on PHY-T427 List of Experiments :

1. Study of Hot Water System.
2. Determination of heat Loss Coefficients in Flat Plate Collector.
3. Study of Solar Dryer (Hot Air Collector).
4. Study of Solar Still.
5. Performance Evaluation of Box Type and Concentrating Type Solar Cooker.