<u>Department of Physics</u>
<u>Savitribai Phule Pune University</u>

<u>Two-year M.Sc. (Physics) full-time course</u>
(Credit and Semester based Syllabus to be implemented from Academic Year 2016-17)

Revision of Structure and Syllabi

<u>Preamble</u>

This syllabus has been proposed as per the guidelines of UGC and the Handbook for **CREDIT SYSTEM (CS) For SEMESTER PATTERN of Post Graduate Programs**, prepared by **Professor Vilas Kharat Dr. V. B. Gaikwad**.

All the theory courses have been modified to be of less than or equal to 4 credits. Laboratory courses are of 5 credits. As per the directives of the Handbook,
"Except the credits for practical courses, wherever applicable, a student can register for less number of courses in a semester subject to the condition that such a student will have to complete the degree in a maximum of four years or as per the prevailing rules of the University. This facility will be available subject to the availability of concerned courses in a given semester and with a maximum variation of 25 % credits (in case of fresh credits) per semester."

It was also found that the students have to learn at a slower pace initially. Hence in the first semester, the number of credits has been kept as 23 instead of 25 for all the students.

The project work will start in the third semester and will carry two credits; however, there will be only continuous assessment with no term-end examination at the end of the third semester. Project will continue in the fourth semester and there will be continuous assessment for 8 credits and term-end evaluation for the total of 10 credits of project will be held at the end of the fourth semester.

One of the highlight of our post-graduate program is that a large number of elective courses are available for students which are directly linked to the state-of-the-art research being carried out in the Department. Students can choose two such elective courses in Semester III and IV. There is associated laboratory of 2.5 credits with each of these courses. In the revised syllabus, two more optional courses are made available which can be broadly classified as supplementary to theoretical/computational and experimental streams.

One credit of a theory course will be equivalent to 15 clock hours of teacher-student classroom contact in a semester. For the courses in the first year, the syllabi are designed as per number of lectures and number of tutorials while for the second year courses, apart from lectures, seminars, discussions and tutorials together will make up for the contact hours.

For laboratory courses, although the credits are 5, the total contact hours are 120.

As per the handbook, "among the minimum number of credits to be earned by a student to complete a Post Graduate Degree program (100 credits), the student will have to earn minimum 75% credits from the Department of Physics and the remaining up to 25 % credits could be earned from any subject(s) of any faculty conducted at other PG Department/ PG Center. In any case, a student will have to earn compulsory credits from the Department of Physics over and above.

Other rules related to attendance and evaluation are as per the prevailing rules of the University. Important among them are cited here.

- A student who wishes to register for the third semester should have obtained at least pass or higher grades in at least 50% credits out of the total number of credits offered at the first and second semester of the first year.
- The evaluation of a course means the evaluation of total number of credits of that course. As such, all the credits taken together of a particular course will be evaluated in two parts continuous assessment (CA) and end semester examination (ESE) or term-end examination (TEE). Weightage for CA would be 50% and for ESE (TEE) would be 50%.
- A student will get a pass or higher grade in all the credits of a course after having obtained minimum 40 marks from CA (minimum 15 out of 50) and ESE (TEE) (minimum 15 out of 50) taken together and will get a grade and grade points in the respective course. Otherwise, a student will get grade F (Fail) in that respective course and will not gain any credits or grade points towards that course.
- If a student fails to gain the credits of any course (declared F grade in that course) then the student can reattempt the course with CA (if the course is conducted in that semester) and ESE (TEE) both or with ESE (TEE) only (if one has scored 15 in CA) in the subsequent ESEs (TEEs) within a period of 4 years (or till his/her registration is valid as per the prevailing rules) from the date of admission for the first semester.

M. Sc. (Physics) Semester-wise course structure

- Credits for all theory courses are either 2 or 4 (contact hours per credit = 15)
- Credits for laboratory courses are 5 (contact hours per credit = 24)
- Total number of credits for each semester may be different but sum of all credits of Semesters I to IV = 100

Semester	Course Code	Course Title	No. of Credits	Remarks
Semester I	PHY-T103	Quantum Mechanics-I	4	Compulsory
	PHY-T104	Electronics	4	Compulsory
	PHY-T105	Classical Mechanics	4	Compulsory
	PHY-T106	Mathematical Methods in Physics-I	4	Compulsory
	PHY-T107	Solid State Physics-I	2	Compulsory
	PHY-P101/P102	Basic Physics Laboratory-I / Fortran Programming and Numerical Methods	5	Compulsory
Total			**23**	
Semester II	PHY-T203	Quantum Mechanics-II	4	Compulsory
	PHY-T204	Electrodynamics-I	4	Compulsory
	PHY-T205	Statistical Mechanics	4	Compulsory
	PHY-T206	Mathematical Methods in Physics-II	4	Compulsory
	PHY-T207	Atoms and Molecules	4	Compulsory
	PHY-P201/P202	Basic Physics Laboratory-I / Fortran Programming and Numerical Methods	5	Compulsory
Total			**25**	
Semester III	PHY-T302	Solid State Physics-II	4	Compulsory
	PHY-T303	Electrodynamics -II	4	Compulsory
	PHY-T304/305	Methods of Experimental Physics / Methods of Computational Physics	4	Compulsory
	PHY-T351	Semiconductor Physics	2	Compulsory
	PHY-T352	Special Relativity	2	Optional
	PHY-T 306 to 350	Special paper-I	4	Optional
	PHY-P 306 to 350	Special Laboratory	2.5	Optional
	PHY-P301	Basic Physics Laboratory –II	2.5	Compulsory
	PHY-P300	Project	2#	Optional
Total			25/27	
Semester IV	PHY-T402	Nuclear Physics	4	Compulsory
	PHY-T403/404	Methods of Materials Characterization / Special Topics in Theoretical Physics	4	Compulsory
	PHY-T406 to 450	Special paper-II	4	Optional
	PHY-P406 to 450	Special Laboratory	2.5	Optional
	PHY-P401	Basic Physics Laboratory –II	2.5	Compulsory
	PHY-P400	Project	8#	Optional
Total			27/25	

Project in Semester III is of 2 credits. Evaluation of those credits will consist of continuous assessment only in Semester III. The remaining part of the project is in Semester IV and is for 8 credits. Evaluation for the 8 credits will have continuous assessment. Term-end examination for the project of total 10 credits will be at the end of Semester IV.

PHY-P101/P201 BASIC PHYSICS LABORATORY-I

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/Helmoltz Coil.
2. Magnetic susceptibility measurement using Gouy's Method.
3. Milikan's oil drop experiment.
4. Measurement of Dielectric Constant.

Group D (Optics)

1. Wavelength measurement of Na-source using Michelson interferometer.
2. Study of Fabry Perot interferometer & measurement of Etalon spacing.
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.

Reference Books:

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

PHY-P102/P202 FORTRAN PROGRAMMING AND NUMERICAL METHODS

A. Exercises for acquaintance (only some experiments are listed here): (Using FORTRAN90):

1. To find the largest or smallest of a given set of numbers.

2. To arrange a given set of numbers in ascending/descending order using Bubble sort algorithm.

3. Division of two complex numbers (treating a complex number as an ordered pair of real numbers).

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.

B. Numerical Methods:

1. Lagrange Interpolation, Divided difference interpolation.
2. Root finding methods
   (i) Bisection Method (ii) Regula falsi (iii) Newton-Raphson Method (iv) Method of successive approximations (v) Secant method.
3. To locate the extrema of a function.
4. Evaluation of Bessel Functions.
5. Solution of simultaneous equations : (i) Gaussian Elimination (ii)Gauss-Seidel method.
6. Least Squares Approximation : (i) Linear fit, (ii) Fitting an exponential.
7. Numerical Integration : (i) Simpson's rule, (ii) Gaussian Quadrature. and experiments similar to the above.
8. Numerical solution of a first order differential equations.

(Note: The course is expected to comprise of 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, H. M. Antia (Tata McGraw Hill).
4. Numerical Methods with Fortran IV case studies, Dorn & McCracken (John Wiley and Sons).
5. Numerical Recipes in FORTRAN (2nd Edn.), W. H. Press, S. A. Teakalsky, W. T. Vellerling, B. P. Flannery (Cambridge University Press).
6. Programming in Fortran 90/95 V. Rajaraman (Prentice-Hall of India).

PHY-T103 QUANTUM MECHANICS - I

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

1-D problems in quantum mechanics, Wells and barriers, Harmonic oscillator, Hermite polynomials and their properties, Qualitative plots of wave functions and their interpretation. Formalism of Quantum Mechanics: State Vectors, Observables and operators, Ket space, Bra space and Inner product, Hermitian operators, Eigenvalues and Eigenfunctions, Completeness, Matrix representation of states and operators, Commutability and compatibility, Uncertainty relation for x and p from their commutator, Change of basis, Unitary transformations, Representations in different bases. Time-evolution of a quantum system: Schrödinger, Heisenberg and Interaction pictures, Constants of the motion. Simple harmonic oscillator by operator method, States with minimum uncertainty product.

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

Orbital angular momentum operators, Commutation relations, Raising and lowering operators, Representation of operators and states in spherical coordinates, Spherical harmonics, Plots for spherical harmonics. Spherically symmetric potentials, Solution of hydrogen atom problem, Plots for wave functions.

Intrinsic Spin angular momentum: Pauli matrices and spin 1/2 eigenstates. Addition of angular momenta, Clebsch -Gordan coefficients, Wigner-Eckart theorem(statement). Identical particles: Spin and Statistics. Symmetric and antisymmetric wave functions, Slater determinants and Permanents.

Symmetry in quantum mechanics : Space and time translations. Discrete Parity and time reversal symmetries.

Text Books:

1. Quantum Mechanics, L. I. Schiff (McGraw-Hill).
2. Quantum Physics, S. Gasiorowicz (Wiley International).
3. Modern Quantum Mechanics, J. J. Sakurai (Addison Wesley).
4. Quantum Mechanics, D. J. Griffiths (Pearson Education).

Reference Books:

5. Quantum Mechanics (Non-Relativistic Theory), L.D. Landau and E.M. Lifshitz (Elsevier).
6. Quantum Mechanics : Vols. I & II , C. Cohen-Tannaudji, B. Diu, F. Laloe (John Wiley).
7. Quantum Mechanics: Fundamentals, K. Gottfried and T-Mow Yan (Springer).
8. Introduction to Quantum Mechanics, L. Pauling and E. B. Wilson (McGraw Hill).
9. Quantum Mechanics, B. Crasemann and J.D. Powel (Addison-Wesley).
10. Quantum Mechanics : Vol. I & II, A. P Messiah (Dover) .
11. The Principles of Quantum Mechanics, P. A. M. Dirac (Clarendon Press, Oxford).
12. Quantum Mechanics, I. Levine (Allyn and Bacon).
13. A Modern Approach to Quantum Mechanics, J. Townsend (University Science Books).
14. Essential Quantum Mechanics, G.E. Bowman (Oxford University Press).
15. Quantum Physics, M. Le Bellac (Cambridge University Press).

PHY-T104 ELECTRONICS

Module-1: 1 credit (10 L, 5 T/S/D):
Basic working principles of A.C. and D.C. circuits.
Network theorem: Kirchhoff's law, Superposition theorem, Thevenin's theorem, Norton's theorem, Maximum power transfer theorem, Bi-junction Transistor (BJT): Transistor fundamentals, Transistor biasing circuits.

Module-2: 1 credit (10 L, 5 T/S/D):
Transistor: AC models, Voltage amplifiers, CC and CB amplifiers, Class A and B Power Amplifiers, push pull for PA system, Differential Amplifier, its parameters, Common Mode Rejection Ration (CMRR).

Module-3: 1 credit (10 L, 5 T/S/D):
OPAMP : Op Amp Theory, Linear Op Amp Circuits, Non Linear Op Amp Circuits, applications (Adder, subtractor, active filters, AC voltmeter). 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. IC based oscillators and timer circuits. Regulated power supplies-series, shunt and line filters, Wave shaping circuits.

Module-4: 1 credit (10 L, 5 T/S/D):
Digital Electronics-Logic gates, Arithmetic circuits, Flip Flops, Digital integrated circuits-NAND & NOR gates as building blocks, X-OR Gate, simple combinational circuits, K-Map, Half & Full adder, Flip-flop, shift register, counters, Basic principles of A/D & D/A converters; Simple applications of A/D & D/A converters. Introduction to Microprocessors. Elements of Microprocessors.

Text Books:

1. Electronics Principles, A. P. Malvino (Tata McGraw Hill).

Reference Books:

1. Electronics Fundamentals and Applications, J. D. Ryder (John Wiley-Eastern).
2. Integrated Circuits, J. Milman and C.C. Halkias (Prentice-Hall).
3. Digital Principles and Applications, A. P. Malvino, D.P. Leach (McGraw Hill).

PHY-T105 CLASSICAL MECHANICS

Module-1: 1.6 credits (16 L, 8 T/S/D):
Generalized coordinates and momenta, Phase space, Variational Calculus, Hamilton's principle of least action, Derivation of Lagrangian and Hamilton's equations of motion from principle of least action, Phase portraits of some simple systems, Symmetries and conservation laws, Noether's theorem, Canonical Transformations. Poisson brackets, Hamilton-Jacobi equation. Action-angle variables.

Module-2: 1.6 credits (16 L, 8 T/S/D):
Central forces. Two body problem. Stability of orbits. Classification of orbits.
Application to planetary motion: Kepler's laws.
Scattering in central force fields: centre of mass and laboratory frames of reference, scattering kinematics. Rutherford scattering.
Rigid body dynamics: Euler-Chasle theorems, Moment of inertia tensor. Euler's equation of motion, Euler angles. Symmetric top.
Non-inertial reference frames, Pseudo forces – centrifugal, Coriolis and Euler forces. Applications

Module-3: 0.8 credit (8 L, 4 T/S/D):
Small oscillations. Systems of coupled oscillators. Normal modes and normal coordinates. Generalization to continuum limit.

Text Books:
1. Classical Mechanics, H. Goldstein, C. P. Poole and J. Safko (Pearson).
2. Classical Mechanics, N. Rana and P. S. Joag (McGraw Hill).

Reference Books:
3. Classical Mechanics, J. R. Taylor (University Science Books).
4. Mechanics, L. D. Landau and E. M. Lifshitz (Butterworth-Heinemann).
5. Classical Mechanics, R. D. Gregory (Cambridge University Press).
6. Classical Dynamics of Particles and Systems, S. T. Thornton and J. B. Marion (Cambridge University Press).
7. Classical Mechanics: Systems of Particles and Hamiltonian Dynamics, W. Greiner (Springer).
8. Classical Dynamics: A Contemporary Approach, J. V. Jose and E. J. Saletan (Cambridge University Press).
9. Classical Mechanics, D. Strauch (Springer).

PHY-T106 MATHEMATICAL METHODS IN PHYSICS – I

Module-1: 1.2 credits (15 L, 5 T/S/D):

Vector Spaces: Vector space, Linear independence, Bases, Dimensionality, Isomorphism between vector spaces. Linear transformations and operators in vector spaces, Matrices, Change of basis, Similarity transformations, Diagonalization, Diagonalization of commuting operators, Eigenvalue and Eigenvectors. Inner product, orthogonality and completeness, complete orthogonal set, Gram-Schmidt orthogonalization procedure, self-adjoint and unitary transformations.

Module-2: 2.8 credits (25 L, 15 T/S/D):

Ordinary differential equations: Singularities and classification of singularities of second order linear differential equations, Frobenius series method for the solutions, Power series solutions, applications to Legendre, Bessel, Hermite, Laguerre equations, etc .

Special functions and their properties: Bessel's functions, Legendre and associated Legendre polynomials, Spherical harmonics, Laguerre polynomial and associated Laguerre polynomial, Hermite ploynomials, etc, Generating functions, recurssion relations, integral representations , etc.

Sturm-Liouville systems and orthogonal polynomials: Function space and Hilbert space, Adjoint and Hermitean operators, Eigenvalues and Eigenfunctions of Hermitean operators, Complete orthonormal sets of functions, Weierstrass's theorem (without proof) of approximation by polynomial.

Solutions of inhomgeneous ODE by Green's function method (2/3 lectures).

Text Books:

1. Finite dimensional vector spaces, P. R. Halmos (Springer Verlag).
2. Mathematics of Classical and Quantum Physics, F.W. Byron and R.W. Fuller (Dover).
3. Linear Algebra, K. Hoffman and R. Kunze (Pearson).
4. Differential Equations with Applications, G. Simmons (Pearson).
5. Mathematical Physics, S. Hassani (Springer).
6. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, and F.E. Harris (Academic Press).

Reference books:

1. Algebra, M. Artin (Pearson).
2. Matrix Analysis, R.A. Horn and C.R. Johnson (Cambridge University Press).
3. Fourier series and Boundary value problems, R. V. Churchill (McGraw Hill).
4. Functions of Mathematical Physics, B. Spain and M.G. Smith (Van Nostrand Reinhold).
5. Green's Functions and Boundary value problems, I. Stakgold and M.J. Holst (Wiley).
6. Mathematics for Physicists, Dennery and Krzywicki (Dover).
7. Mathematical Methods in Classical and Quantum Physics, Tulsi Dass and S.K. Sharma (Orient Blackswan).
8. Advanced Engineering Mathematics, E. Kreyszig (John Wiley & Sons).
9. Mathematical Methods of Physics, J. Mathews and R.L. Walker (Addison Wesley).

PHY-T107 SOLID STATE PHYSICS-I

Module-1: 1 credit (15 L/T/S):
Crystal Structure and Diffraction:
Real lattices, packing fraction, reciprocal lattices, Brillouin zones. Diffraction by crystals - Ewald sphere construction, Bragg condition in k-space. Geometric structure factor and atomic form factor. Electron and neutron scattering.
Point defects, line defects and dislocations.

Module-2: 1 credit (15 L/T/S):
Lattice Dynamics:
Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states. Einstein and Debye theories. Anharmonicity and thermal conductivity (qualitative).

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).

PHY-T203 QUANTUM MECHANICS-II

Module-1: 1 credit (10 L, 5 T/S/D):
Time-independent perturbation theory. Non-degenerate and degenerate cases, Fine Structure of the Hydrogen atom. Applications such as the Stark effect, Zeeman effect. Variational method and applications such as the Helium Atom.
WKB approximation: Connection formulas, Bohr-Sommerfeld quantization condition and the Gamow formula for barrier tunneling.

Module-1: 1.5 credits (15 L, 8 T/S/D):
Time-dependent perturbation theory: Interaction picture, Dyson series, Transition probability, Constant perturbation, Fermi's golden rule, Harmonic perturbation, transition probability and interpretation as absorption and emission, principle of detailed balance. Application to ionization of hydrogen atom.
Application to interaction of classical radiation field with matter: Absorption and induced emission, Electric dipole transitions, Selection rules, Decays and lifetime, natural line-width. Transition probability for spontaneous emission, Detailed balance and Planck distribution formula, Einstein A and B coefficients. The Photoelectric effect for H-atom.
Adiabatic and sudden approximations. Aharanov-Bohm Effect.

Module 1 : 1.5 credits (15 L, 7 T/S/T):
Scattering theory: Scattering amplitude, differential scattering cross section and total scattering cross section, the Lippman-Schwinger equation, the Born approximation, Applications and validity of the Born approximation, Optical theorem.
Method of partial waves: Partial wave expansion, Unitarity and Phase shifts; Scattering by a perfectly rigid sphere and square well potential, Ramsauer-Townsend effect; Complex potential and absorption, Collision of identical particles, Levinson's theorem (Statement).

Books:

1. Modern Quantum Mechanics, J. J. Sakurai (Addison Wesley).
2. Quantum Mechanics, L. I. Schiff (McGraw-Hill).
3. Quantum Physics, S. Gasiorowicz (Wiley International).
4. Quantum Mechanics(Non-Relativistic Theory), L.D. Landau and E.M. Lifshitz (Elsevier).
5. Quantum Mechanics, Cohen-Tannaudji, Din, Laloe Vols. I & II (John Wiley).
6. Quantum Mechanics: Fundamentals, K. Gottfried and T-Mow Yan (Springer).
7. Introduction to Quantum Mechanics, L. Pauling and E. B. Wilson (McGraw Hill).
8. Quantum Mechanics, B. Crasemann and J.D. Powel (Addison-Wesley).
9. Quantum Mechanics -Vol. I & II, A.P Messiah (Dover).
10. The Principles of Quantum Mechanics, P. A. M. Dirac (Clarendon Press, Oxford).
11. Quantum Mechanics, I. Levine (Allyn and Bacon).
12. Quantum Mechanics, D. J. Griffiths (Pearson Education).
13. A Modern Approach to Quantum Mechanics, J. Townsend (University Science Books).
14. Essential Quantum Mechanics, G.E. Bowman (Oxford University Press).
15. Quantum Physics, M. Le Bellac (Cambridge University Press).

PHY-T204 ELECTRODYNAMICS-I

Module-1: 1 credit (10 L, 5 T/S/D):
Coloumb's law, Gauss's law, Poisson's equation and Laplace's equation, Electrostatic potential energy, Simple applications, Simple boundary value problems illustrating various techniques such as method of images, separation of variables, Green's functions, Multipole expansion.

Module-2: 1 credit (10 L, 5 T/S/D):
Dielectric materials, Polarization, Electric field of a polarized material, Bound charges, Gauss's law in dielectric materials, Linear dielectric materials, Boundary conditions at the interface of two dielectrics.

Module-3: 1 credit (10 L, 5 T/S/D) :
Steady currents, Biot-Savart law and Ampere's law, Simple applications, Magnetic vector potential, Multipole expansion, Magnetic materials, Magnetization, Magnetic field of magnetized material, Bound currents, Linear magnetic materials, Boundary conditions.

Module-4: 1 credit (10 L, 5 T/S/D):
Electromotive force, Electromagnetic induction: Faraday's law, Inductance, Energy in magnetic fields, Maxwell correction to Ampere's law, Maxwell equations, Wave equations for electric and magnetic fields.

Text Books:
1. Classical Electrodynamics, J. D. Jackson (John Wiley).
2. Introduction to electrodynamics, D. J. Griffiths (Prentice Hall).

Reference Books :
1. Classical theory of fields, L. D. Landau and E. M. Lifshitz (Addison-Wesley).
2. Electrodynamics of continuous media, L. D. Landau and E. M. Lifshitz (Addison-Wesley).
3. Electrodynamics, A. Somerfield (Academic Press, Freeman and Co.).
4. Classical Electricity and Magnetism, W.K.H. Panofsky and M. Phillips (Addison-Wesley).
5. Feynman Lectures Vol. II. R. P. Feynman, Leighton and Sands (Narosa).
6. Berkeley Series Volume II, E.M.Purcell (McGraw-Hill).
7. Electricity and Magnetism, Reitz, Milford and Christy (Pearson).
8. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat (Narosa).

PHY-T205 STATISTICAL MECHANICS

Module-1: 1 credit (10 L, 5 T/S/D):
A brief revision of the laws of thermodynamics. Thermodynamical work for magnetic, dielectric, elastic systems. Legendre transformation, Thermodynamic potentials.
Statistical basis of thermodynamics. Elements of ensemble theory. Microcanonical ensemble. Macroscopic and microscopic states. Classical phase space, phase space density,
Liouville's theorem, Statistical origin of entropy. Application to the ideal gas. Gibbs paradox and Gibbs correction term. Quantum states and the phase space.

Module-2: 1 credit (10 L, 5 T/S/D):
Canonical ensemble, Partition function and thermodynamic variables, Energy fluctuations. Boltzmann distribution. Applications to the thermodynamics of an ideal gas, Specific heat of solids (classical and Einstein models), and Paramagnetism (Langevin and Brillouin models). Equipartition and virial theorem.
Thermodynamics of interacting systems – Van der Waals gas and 1D Ising model.

Module-3: 1 credit (10 L, 5 T/S/D):
Grand canonical ensemble, Partition function and thermodynamical variables,
Density and energy fluctuations, Application to the problem of adsorption.
First order and second order phase transitions, Phase equilibria
Quantum statistics: Density matrix. Pure states and statistical mixtures. Density matrices for microcanonical, canonical and grand canonical ensembles. Representation of density matrices in energy, coordinate and momentum bases, with suitable examples.

Module-4: 1 credit (10 L, 5 T/S/D) :
Ideal Bose gas: Bose-Einstein statistics, Partition function, Thermodynamic behaviour, Bose-Einstein condensation in ideal Bose gas.
Applications : Black body radiation. Planck's law and its limiting cases (Raleigh-Jeans law, Wien's displacement law), Stefan-Boltzmann law. Phonon gas. Specific heat of solids (Einstein and Debye models). Ideal Fermi gas: Fermi-Dirac statistics, Partition function, Thermodynamic behaviour
Applications : Degenerate electron gas (free electrons in a metal), Fermi energy and mean energy, Fermi temperature, Fermi velocity and specific heat . Estimation of the size of white dwarfs.

Text Books:
1. Statistical Mechanics, R. K. Pathria and P. D. Beale (Academic Press).
2. Statistical Mechanics, K. Huang (Wiley).

Reference Books :
1. Statistical Physics of Particles, M. Kardar (Cambridge University Press).
2. Statistical and Thermal Physics, H. Gould and J. Tobochnik (Princeton University Press).
3. An Introduction to Statistical Mechanics and Thermodynamics, R. H. Swendsen (Oxford University Press).
4. Thermodynamics and Statistical Mechanics, W. Greiner, L. Neise and H. Stocker (Springer).
5. Statistical Mechanics, F. Reif (Waveland Press).
6. Statistical Physics (Part 1), L.D. Landau and E. M. Lifhsitz (Elsevier).

PHY-T206 MATHEMATICAL METHODS IN PHYSICS-II

Module-1: 0.8 credit (10 L, 3 T/S/D):
Elementary probability theory**:** Random variable, fundamental probability laws, Binomial, Poisson and normal distributions. Mean, variance, central limit theorem. Higher moments of the distribution function. Applications: Random walk problem.

Module-2: 3.2 credits (30 L, 17 T/S/D):
Complex Analysis: Functions of complex variables, Analytic functions, Cauchy-Riemann conditions, Multivalued functions, elementary discussions of branch cuts, Cauchy's theorem and Cauchy integral formula, Derivatives of analytic functions, Liouville theorem, Power series, Taylor's theorem and Laurent's theorem, Calculus of residues, Evaluation of real definite integrals, Principal value integrals and Dispersion relations, integrals involving branch cuts, Contour integral representations of Special functions, Summation of series using complex integration.
Fourier series, Gibbs Phenomenon and applications. Integral transforms: Fourier transforms, Inverse Fourier transform, Parseval relations, Convolutions. Applicatons. Laplace transform, Inverse Laplace transform (Bromwich integral) and simple applications.
Elementary introduction to tensor analysis: Cartesian tensors, transformation properties and simple applications, Spherical tensors.

Books and References:

1. Mathematics of Classical and Quantum Physics, Byron and Fuller (Dover).
2. Mathematics for Physicists, Dennery & Krzywicki (Dover).
3. Mathematical Physics, S. Hassani (Springer).
4. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, and F.E. Harris (Academic Press).
5. Complex variables and Applications, R. V. Churchill (McGraw Hill).
6 Complex variables, Ablowitz and Fokas (Cambridge Univ. Press).
7. Complex analysis, Ahlfors (Springer).
8. Fourier Series and Boundary value problems, R. V. Churchill (McGraw Hill).
9. Mathematical Methods of Physics, Tulsi Dass and Sharma (University. Press).
10. Functions in Mathematical Physics, Smith & Spain (Van Nost. Reinhold).
11. Advanced Engineering Mathematics, Kreyszig (John Wilely & Sons).
12. Mathematical Methods of Physics, Mathews & Walker (Pearson Addison-Wesley).
13. Differential Equations With Applications, G. Simmons (Pearson Education).
14 Tensors for Physics, S. Hess (Springer)
15 Tensor Calculus for Physics: A Concise Guide, D. Neuenschwander (Johns Hopkins University Press.)
16 Tensor Analysis for Physicists, J. A. Schouten (Dover).

PHY-T207 ATOMS AND MOLECULES

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

Atomic structure and Atomic spectra:

Revision of hydrogen atom (wave functions, orbital and spin angular momentum, magnetic dipole moment, spin-orbit interaction, fine structure, spectroscopic terms).

Multi-electron atoms: Central field approximation, Exchange symmetry of wave functions, electron configurations, Hartree-Fock theory, Self-consistent fields, L-S coupling, J-J coupling, Hund's rules.

Atoms in an electromagnetic field: Spectral lines, Selection rules, Some features of one-and two-electron spectra, fine structure spectra, hyperfine structure spectra, X-ray spectra, Stark effect , Zeeman effect and Paschen-Back effect

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

Molecular Structure and Molecular Spectra : Covalent, ionic and van der Waal bonding, Valence bond and molecular orbital approach for molecular bonding and electronic structure of homonuclear diatomic molecules, pairing and valency, heteronuclear diatomic molecules, hybridization, ionic bonding, electro-negativity, electron affinity.

Electronic structure of polyatomic molecules: hybrid orbitals, bonding in hydrocarbons.

Rotational levels in diatomic and polyatomic molecules: Rigid and non-rigid rotation

Vibrational levels in diatomic and polyatomic molecules. Morse oscillator model for vibrational levels

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

Group theory: Definition and properties of a group, Some examples of groups,

Molecules and symmetry groups: Symmetry elements and operations, General relations among symmetry elements and operations, Symmetry point groups, Classification of molecules,

Simple examples. Representations of groups, Shur's Lemma, The great orthogonality theorem,

Character tables.

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

Masers and Lasers : Spontaneous and stimulated emission, Population inversion, optical pumping,coherence (temporal and spatial), Simple description of ammonia maser and carbon dioxide/helium-neon laser. Application of Lasers in cooling and trapping of atoms.

Atomic and molecular spectroscopic methods: Atomic and Molecular Polarizability, Molecular vibrations and group theoretical selection rules for infra red and Raman transitions,

Infra-red spectroscopy and Raman spectroscopy for vibrational level determination.

Microwave spectroscopy and Rotational Raman spectroscopy for rotational level determination,

Electronic spectroscopy for molecular structure determination (optical spectrophotometry, photoluminescence).

Nuclear Magnetic resonance and Electron spin resonance

Text Books :

1. Physics of Atoms and Molecules, B.H. Bransden and C.J. Joachain (Pearson).
2. Quantum Physics, Robert Eisberg and Robert Resnick (John Wiley).
3. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash (Tata, McGraw Hill) .
4. Molecular Spectra and Molecular Structure, Gerhard Herzberg (D. Van Nostrand Company, Inc.).
5. Molecular Quantum Mechanics, P.W. Atkins and R. Freidman (Oxford University Press)
6. Chemical Applications of Group Theory, F.A. Cotton (Wiley).
7. Quantum Chemistry, I. N. Levine (Wiley).

Reference Books :

1. Group Theory and Quantum Mechanics, M. Tinkham (Dover Publications Inc).
2. Group Theory and its Application to the Quantum Mechanics of Atomic Spectra, E. P. Wigner and J. J. Griffin (Academic Press).
3. Group Theory and its Applications to Physical Problems, M. Hamersmesh (Pergamon Press).
4. Instrumental Methods of Analysis, H.H. Willard, L.L. Merritt, J.A. Dean, and F.A. Settle (CBS Publishers, Delhi) .
5. Instrumental Analysis, D.A. Skoog, F.J. Holler and S.R. Crouch (Cengage Learning, Delhi).
6. Modern Spectroscopy, J.M. Hollas (John Wiley).
7. Introduction to Ligand Fields, B.N. Figgis (Wiley).
8. Lasers and Non-Linear Optics, B. B. Laud (Wiley-Blackwell).

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

Experiments from the following List will be offered :

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

Books :

1. *The Art of Experimental Physics,* D. W. Freston, E. R. Dietz, 1991 (John Wiley).
2. *Advanced Practical Physics for Students,* Worsnop and Flint. (Asia Publishing House).
3. *Modern Physics,* Arthur Beiser (McGraw-Hill Inc).

PHY-T302 SOLID STATE PHYSICS-II

Module-1: 1. 3 credits (20 L/T/S) :
Electronic Band Structure in Crystals: Drude theory of metals. Quantum free electron model of metals (Sommerfeld model). Nearly free electron theory. Brillouin zones. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Tight binding approximation. Band structure (in k-space) of semiconductors crystals – high symmetry points in k-space. Electrons and holes. Effective mass. Hall effect.

Module-2: 1 credit (15 L/T/S):
Dielectric Properties of Solids:
Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Claussius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity.

Module-3: 1 credit (15 L/T/S) :
Magnetism in Solids:
Diamagnetism – Langevin equation. Pauli paramagnetism in metals. Paramagnetism – Brillouin theory. Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Weiss mean field theory of ferromagnetism. Anti-ferromagnetic and ferromagnetic order.

Module-4 : 0.7 credits(10 L/T/S) :
Superconductivity:
Zero resistivity and perfect diamagnetism (Meissner effect). Type-I and Type-II superconductors. London equation. Basic thermodynamics. Energy gap. BCS theory (qualitative). Josephson junctions.

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).

PHY-T303 ELECTRODYNAMICS-II

Module-1: 1 Credit (10 L, 5 T/S/D):
Motion of a charged particle in EM fields, Lorentz force, Motion in uniform, static, electric and magnetic fields and combined static EM fields, some applications**.**

Module-2: 1 Credit (10 L, 5 T/S/D) :
Plane waves, Spherical waves, Phase and group velocities, Electromagnetic plane waves, Continuity equation, Poynting vector and Poynting theorem, Momentum and energy densities associated with electromagnetic wave, Linear, Circular and Elliptic polarizations, Stokes parameters.

Module-3: 1 Credit (10 L, 5 T/S/D):
Reflection and refraction of plane waves, Polarization on reflection and refraction, Propagation in dielectric materials, Propagation in conducting medium, Skin depth.
Wave guides, TE and TM modes, Modes in a rectangular wave guide, Cavities and Modes.

Module-4: 1 Credit (10 L, 5 T/S/D) :
Gauge transformations, Retarded potentials, Lienard-Wiechert potentials of a point charge, Electric dipole radiation, Magnetic dipole radiation, Radiation from half wave and full wave antenna, Radiation from an accelerated point charge, Larmor formula, Bremsstarhlung, Synchrotron radiation.

Text Books:

1. Classical Electrodynamics, J. D. Jackson (John Wiley).
2. Introduction to electrodynamics, D. J. Griffiths (Prentice Hall).

Reference Books:

1. Classical theory of fields, L. D. Landau and E. M. Lifshitz (Addison-Wesley).
2. Electrodynamics of continuous media, L. D. Landau and E. M. Lifshitz (Addison-Wesley).
3. Electrodynamics, A. Somerfield (Academic Press, Freeman and Co.).
4. Classical Electricity and Magnetism, W.K.H. Panofsky and M. Phillips (Addison-Wesley).
5. Feynman Lectures Vol. II. R. P. Feynman, Leighton and Sands (Narosa).
6. Berkeley Series Volume II, E.M.Purcell (McGraw-Hill).
7. Electricity and Magnetism, Reitz, Milford and Christy (Pearson).
8. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat (Narosa).

PHY-T304 METHODS OF EXPERIMENTAL PHYSICS

Module-1: 1.5 credits (15 L, 7 T/S/D):
Improvement in Signal to Noise Ratio: Origin of noise, Hardware devices for noise reduction, Filters, Modulation techniques, Lock-in-amplifier, Software methods to reduce noise level, Ensemble averaging, Box car integrator, Fourier transform, and Impedance matching, Shielding and grounding.
Error and Statistical Data Handling, Error Determination in physical quantities, Propagation of Error, Quantitative estimation of errors, Weighed average, Statistical handling of data, Distribution of data, Principle of maximum likelihood, Fitting of data, Covariance, Chi square test.

Module-2: 1 credits (10 L, 4 T/S/D):
Measurements with Photons, Sources such as Discharge lamps, Lasers, Synchrotron radiation Dispersion elements or wavelength selectors, Monochromators.
Photon detectors, Photodiode, Photomultiplier tube, Charge Couple Device, Fiber Optics,
Line Shape in Spectroscopy Measurements with Electrons, Electron gun, Electron lenses, Electron energy analysers and channelplate, channeltron.

Module-3: 0.75 Credits (8 L, 4 T/S/D):
Basic Vacuum Science
Basic consideration and units, Ultra-high vacuum system, Gas balance, Rotary vane pump
Turbo molecular pump, Diffusion pump, Sorption pump, Getter pump, Sputter ion pump.
Measurements of Vacuum
Introduction, U tube manometer, McLeod guage, Thermal conductivity guage, Penning guage, Hot cathode ionization gauges, Quadrupole mass spectrometer.

Module-4: 0.75 Credit (8 L, 4 T/S/D):
Obtaining Low Temperature
Magic of latent heat, Superfluidity and liquid He, Dilution refrigerator, Magnetic refrigeration, Overview of modern methods to attain low temperature such as Laser cooling.
Low Temperature Thermometry
Primary and secondary temperature measurements, Thermometers, Thermoelectric devices, Electrical resistance devices, Semiconductor devices, and use of SQUID (magnetic measurements) to estimate ultra-low temperature.

Books:

1. Practical Physics, G. L. Squires (Cambridge University Press, Cambridge)
2. An Introduction to Error Analysis, J.R. Taylor (Oxford University Press, University Science Books).
3. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle (CBS Publishers and Distributers).
4. Instrumental Analysis, D.A. Skoog, F.J. Holler and S.R. Crouch (Cengage Learning).
5. Fundamentals of Molecular Spectroscopy, C.N. Banwell and E.M. McCash (McGraw-Hill International Limited, 4th Edition 1996).
6. Fundamentals of Vacuum Technology, W. Umrath (Leybold Vacuum).
7. Vacuum Technology, A. Roth (North Holland).
8. Matter and Methods at Low Temperature, F. Pobell, (Springer Verlag).

PHY-T305 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: 0.5 credit (4 L, 4T/S/D/Lab):
Numerical Methods : Solution of differential equations,
Understanding of special functions, Generation and graphs,

Module-2: 1.75 credits (10 L, 16 T/S/D/Lab):
Random number generators, various tests.
Stochastic processes, Markov chain, Metropolis sampling,
Simple idea of Monte-Carlo integration,
Application to 2D Ising model.

Module-3: 1.75 credits (10 L, 16 T/S/D/Lab):
Hubbard model : Motivation, Representation of Sz basis, Generation of basis states, Construction of Hamiltonian. Exact diagonalization, Calculation of correlation function.

Module-4: 1.75 credits (10 L, 16 T/S/D/Lab):
Lanczos method and applications to tight binding Hamiltonians, Calculation of spectral properties.

Module-5 : 1.75 credits (10 L, 16 T/S/D/Lab):
Numerical solution of Schrödinger equation for spherically symmetric potentials - scattering states, Calculation of phase shifts, Resonance.

Module-6: 1.75 credits (10 L, 16 T/S/D/Lab):
Quantum Monte Carlo, Variational Monte Carlo, Diffusion Monte Carlo.

Module-7: 1.75 credits (10 L, 16 T/S/D/Lab):
Electrons in Periodic Potential, Calculation of band structure using plane wave methods.

Module-8: 1.75 credits (10 L, 16 T/S/D/Lab):
Molecular dynamics, Interacting particles with Lennard-Jones potentials.

Books :

1. A first course in Computational Physics, Paul, L. Pavries (John Wiley & Sons).
2. Monte Carlo Methods, M. H. Kalos and P. A. Whitelock (John Wiley & Sons).
3. Understanding Molecular Simulation, Daan Frenkel and B. Smit (Academic Press).
4. Computational Physics, J. M. Thijssen (Cambridge University Press).
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-T351 SEMICONDUCTOR PHYSICS

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

Basics of semiconductor and p-n junctions: Electrons and holes in an Intrinsic Semiconductor, Conductivity of semiconductor, carrier concentration in intrinsic semiconductor, donar and acceptor impurities, charge density in a semiconductor, Fermi level in intrinsic and extrinsic semiconductor, diffusion, carrier life time, estimation of carrier concentration, Qualitative theory of the p-n junction, p-n-junction as diode and current flow p-n diode, band structure of open circuit and biased p-n junction, I-V characteristics of diode, temperature dependence of p-n characteristics, diode resistance and diode capacitance, estimation of width of the depletion region.

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

Semiconductor Devices: Transistor; Energy level diagram of transistor under open circuit and biased condition. Transistor action, base current, emitter current, collector current and their interrelation, Special types of diodes: breakdown diodes, Zener diode, the tunnel diode, p-i-n diode, point contact diode, schottky diode and their I-V characteristics, junction formation and operatory characteristics of UJT, J-FET, MOS FET, Silicon Control Rectifier (SCR) .

Books:

1) Electronics Fundamental and Applications: J D Ryder (John Wiley-Eastern Publication)
2) Integrated Circuits: Milman and Halkias (Prentice-Hall Publications)
3) Semiconductor Device Physics and Technology , S M, Zee (Wiley India, 2nd edition, 2002).

PHY-T352 SPECIAL RELATIVITY

2 credits (20 L, 10 T/S/D):

Special theory of relativity :

Einstein's Postulates, Lorentz Transformations, Addition of Velocities, Basic kinematic results of Special Relativity, some consequences of special relativity. Geometry of Space-time. Relativistic Mechanics: Proper Time, Proper Velocity, Relativistic Energy and Momentum, Relativistic force law and particle dynamics.

Relativistic Electrodynamics: Transformation of electromagnetic fields under Lorentz transformations. Field strength tensor and its properties, Maxwell's equations in covariant formalism, Gauge transformations – coulomb and Lorentz gauge. Invariance of charge under Lorentz transformations.

Relativistic wave equations: Klein-Gordon and Dirac equation and free particle solutions. particles and antiparticles, Spin in relativity, H-atom fine structure (qualitative discussion).

Books:

1. Classical Electrodynamics, J.D. Jackson, John (Wiley & Sons).
2. Introduction to Electrodynamics, D.J. Griffiths (PHI Learning).
3. Introduction to Special Relativity, R. Resnick, John (Wiley & Sons).
4. Introduction to Special Relativity W. Rindler (Oxford University Press).
5. Relativistic Quantum Mechanics, J. Bjorken and S. Drell (McGraw-Hill).
6. The Classical theory of fields, L.D. Landau & E.M. Lifshitz (Pergamon Press).
7. Principles of Optics, M. Born & E. Wolf (Pergamon Press).

PHY-T306 THIN FILM PHYSICS AND DEVICE TECHNOLOGY-I

Module-1: 1 credit (10 L, 5 T/S/D):
Physical Vapour deposition (PVD) techniques:- Vacuum Evaporation: fundamentals of evaporation, evaporation sources, different types of evaporation methods, Sputtering: fundamentals of sputtering, sputtering yield, sputtering rate, different types of sputtering systems, reactive sputtering, Modified and Hybrid PVD techniques.

Module-2: 1 credit (10 L, 5 T/S/D):
Chemical Vapor Deposition (CVD) techniques:- reaction types in CVD, thermodynamics of CVD, gas transport, growth kinetics, different CVD processes and systems

Module-3: 1 credit (10 L, 5 T/S/D):
Liquid-Phase Chemical Deposition techniques:- Chemical Bath Deposition (CBD), Electroless, Electrochemical deposition, Spray pyrolysis, Sol Gel spin coating, etc.
Epitaxy: Structural aspects of epitaxy, homo- and hetero-epitaxy, lattice misfit and imperfections; Deposition techniques for epitaxial semiconductor thin films.

Module-4: 1 credit (10 L, 5 T/S/D):
Thin Film Growth:- Thin Film Growth Processes, Nucleation, Different types of Growth modes, Capillary theory, Atomistic nucleating processes, Cluster coalescence and depletion, Grain structure of thin films, Structural Consequences of the Growth Process.

Books:

1. Preparation of Thin Films, Joy George (Markel Dekker, Inc).
2. Vacuum Technology, Thin Films and Sputtering, R. V. Stuart (Academic Press).
3. Handbook of Deposition Technologies for Films and Coatings, P. M. Martin (Elsevier).
4. Thin Film Materials Technology Sputtering of Compound Materials, Kiyotaka Wasa, Makoto Kitabatake and Hideaki Adachi (Springer).
5. Handbook of Thin Film Technology, L. L. Maissel and R. Glang (McGraw - Hill).
6. Thin Film Phenomena, K. L. Chopra (McGraw – Hill).
7. Thin Film processes, J. L. Vossen and W. Kern (Academic Press).
8. The Materials Science of Thin Films, M. Ohring (Academic Press) .
9. An introduction to Physics and Technology of Thin Films, A Wagendristel and Y. Wang (World Scientific).
10. Chemical solution deposition of semiconductor films, Gary Hodes (Markel Dekker).
11. Electroplating- Basic Principles, Processes and Practice, Nasser Kanani (Elsevier).

PHY-P306 Experiments based on PHY-T306 (2.5 credits):

1. To study thin film deposition by vacuum evaporation technique.
2. To study thin film deposition by sputtering technique.
3. To study thin film deposition by CVD technique.
4. To study thin film deposition by CBD/electroless technique.
5. To study thin film deposition by electrochemical deposition technique.
6. To study thin film deposition by spin coating technique.

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, Ising model and transfer matrix method of solution. Bose-Einstein condensation.

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).

PHY-P307 Experiments based on PHY-T307 (2.5 credits):

Computational Experiments/Exercises/Mini Projects.

PHY-T309 ADVANCED QUANTUM MECHANICS-I

Module-1: 1.4 credits (15L, 5 T/S/D):
Lorentz transformations in covariant notation, Lorentz and Poincare group, Relation between Lorentz group and SL(2,C) group, Poincare group Generators, algebra, Representations of the Lorentz algebra: Scalar, Vector and Spinor representations, Weyl and Dirac spinors, Bilinear covariants. Relativistic wave equations: Klein-Gordon and Dirac equation, Lorentz covariance of Dirac equation, Free particle solutions, Conserved norm, Positive and Negative energy solutions, Covariant normalization and completeness, Spin and helicity, Energy and spin projection operators, Construction of wave packets of positive and negative energy free particle solutions, Gordon decomposition of the vector current, Zitterbewegung and Klein paradox, Bilinear covariants and physical observables.

Module-2: 1.3 credits (15L, 5 T/S/D):
Classical Relativisitic fields: Canonical formalism: Lagrangian and Action principle, Scalar, Dirac, Weyl fields and vector fields. Symmetries and conservation laws: Noether's theorem, Spacetime and internal symmetries. Gauge invariance of Maxwell's theory, coupling of Maxwell field with Dirac field.

Module-3: 1.3 credits (15L, 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.

References:

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

11. Quantum Electrodynamics Ed. J. Schwinger (McGraw-Hill).
12. A Modern Introduction to Quantum Field Theory, M. Maggiore (Oxford University Press).
13. Group theory in Physics, Wu Ki Tung (World Scientific)

PHY-P309 Experiments based on PHY-T309 (2.5 credits):

Computational Experiments/Exercises/Mini Projects.

PHY-T310 MATERIALS SCIENCE-I

Module-1: 1 credit (10 L, 5 T/S/D):
(A). Introduction and classification of materials: Metals and alloys, Ceramics and glasses, Polymers, etc., a brief introduction to nanomaterials, biomaterials, advance materials, structure–property relationship in materials and modern material needs.
(B) Short review of basic structures: Tetrahedral and octahedral voids (sites), their properties and importance, substitutional and interstitial site occupancy, 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 Zinc Blende, NiAS, Perovskite, Spinel and inverse spinel, Quartz, silicates, glass, polymers etc.

Module-2: 1 credit (10 L, 5 T/S/D):
A. Physical Thermodynamics including Laws of thermodynamics, internal energy, heat capacity, enthalpy, concept of entropy, thermal and configurational entropy (with reference to solid solutions), chemical potential, Maxwell's equations.
B. Phase diagrams of elements (unary systems), Gibb's phase rule, thermodynamics of phase transitions, Clausius-Clapeyron equation, Nucleation and growth kinetics, solidification, crystallization, and grain growth.

Module-3: 1 credit (10 L, 5 T/S/D):
(A) Defects in Solids: Point defects (metals and non-metallic crystals), Line defects (edge and screw dislocations, Burger vector, slip and glide motions of dislocations, strain associated with dislocations, dislocations in ionic crystals), Dislocations and stacking faults in *bcc, fcc,* and *hcp* crystals, Planar defects (grain boundaries), volume defects (voids), Thermodynamic aspects and impact of defects on physical properties of materials
(B) Diffusion in solids: Fick's laws diffusion, Mechanism of diffusion, Kirkendall Effect, Nernst-Einstein equation, concentration profiles, solution to the Fick's second law, importance of diffusion for materials synthesis and processing (examples and applications such as oxidation, corrosion, carborization, decarborization, nitridation, etc.)

Module-4: 1 credit (10 L, 5 T/S/D):
Binary 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 with examples: Binary isomorphous Systems (complete and limited solubility), Interpretation of phase diagrams, Development of microstructures in isomorphous alloys, binary eutectic systems, development of microstructure in eutectic alloys, equilibrium diagrams having intermediate phases or compounds, eutectoid and peritectic reactions, CTT and TTT diagrams and their importance.

Books:

1. Physical Metallurgy, Vol. I and 2 (Fourth Edition) by R. W. Cahn and P. Hassen (North Holland Publishing Company, New York, Fourth Edition, 1996).
2. Materials Science and Engineerin (Sixth Edition) by V. Raghvan (Prentice-Hall Pvt. Ltd., Sixth Edition, 2015).

3. Fundamentals of Materials Science and Engineerin (Ninth Edition by, William Callister (John Willey and Sons 2013).
4. Modern Physical Metallurgy (Fourth Edition) by R. E. Smallman (Butterworths, London 1990).
5. Introduction to the Thermodynamics of Materials (Fourth Edition) by David R. Gaskell (Taylor and Francis, New York, 2003).

PHY-P310 Experiments based on PHY-T310 (2.5 Credits):

1. Cooling curves and Phase diagram of Pb-Sn alloy.
2. Creep: Study of creep phenomenon.
3. Ionic Condctivity.
4. Synthesis of Aluminum thin film by thermal evaporation method.
5. Study of IR spectrum of HCL vapours.
6. Synthesis of Copper thin film by electrochemical method.
7. Synthesis of CNT/RGO thin film by electrophoresis method.

(Any five experiments will be covered)

PHY-T311 ASTRONOMY AND ASTROPHYSICS-I

4 Credit (45 Lectures, 15 T/S/D = 60 contact hours)

OVERVIEW OF THE UNIVERSE:
Interesting astronomy objects: (from planets to large scale structure); Length, Mass and Timescales; Physical conditions in different objects; Evolution of structures in the universe, redshift.
Radiation in different bands; Astronomical Jargon; Astronomical measurements in different bands; Current sensitivities and resolution available.

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.

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.

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.

STELLAR PHYSICS:
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.

GALACTIC PHYSICS:
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. Carroll 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 Astrophysics Volumes I, II and III, T. Padmanabhan, (Cambridge University Press).
5. The Physics of Fluids and Plasmas, Arnab Rai Choudhuri, (Cambridge University Press).

6. Astrophysical Concepts, M. Harwitt, (Springer-Verlag).
7. Galactic Astronomy, J. Binney and M. Merrifeld, (Princeton University Press).
8. Galactic Dynamics, J. Binney and S. Tremaine, (Princeton University Press).
9. Quasars and Active Galactic Nuclei, A. K. Kembhavi and J. V. Narlikar, (Cambridge University Press).
10. An Introduction to Active Galactic Nucleii, B. M. Peterson,
11. The Physical Universe : An Introduction to Astronomy. By Frank H. Shu, (University Science Books).

PHY-T312 NUCLEAR TECHNIQUES-I

Module-1: Credit-1 (10 L, 5 T/S/D):
Interaction of radiation with matter: Origin and basic characterises of X-Rays, beta rays, alpha particles, and gamma-rays. Range –energy relation for beta-rays. Estimation of energies of charged particles from their trajectories in magnetic fields, Interaction of electrons, positrons, heavy ions, gamma rays and neutrons with matter.

Module-2: Credit-2 (10 L, 5 T/S/D):
Radiation detectors: Basic principle of radiation detectors, Gaseous detectors,Ionisation chamber, propotional counter and GM counter, ionization and transport phenomena in gases, avalanche multiplication, cylindrical and multiwire proportional counters, drift chamber, scintillation detectors, general characteristics of organic and inorganic scintillators, detection efficiency for various types of radiations, scintillation detector mounting, photomultiplier gain, stability, semiconductor detectors, basic principle, surface barrier detector, Si(Li), Gel(Li), HPGe and position sensitive detectors.

Module-3: Credit-3 (10 L, 5 T/S/D):
Nuclear Electronics: Pulse processing and related electronics: Preamplifier, amplifier, pulse shaping networks, biased amplifier, pulse stretchers delay lines, discriminator. Pulse height analysis and coincidence technique, D/A, A/D converter, Single channel analyzer, multichannel analyzer, pulse shape discrimination, coincidence units, slow-fast coincidence circuits, anticoincidence circuit.**T**iming 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-4: Credit-4 (10 L, 5 T/S/D):
Dosimetry and radiation protection units: Roentgen, RAD, Gray, Sievert, RBE, BED, REM, REP, kerma, Cema, energy deposit and energy imparted, exposure, absorbed dose, equivalent 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. Estimation of radiation level near a radioactive source using a radiation detector. Estimation of radiation levels near a radioactive source, working principle of pocket dosimeter.

Books :

1. Nuclear radiation detectors, S. S. Kappor and V. S. Rmanurthy (Wiley Eastern Limited).
2. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng (World Scientific).
3. Techniques for nuclear and particle physics, W. R. Len (Springer).
4. Nuclear Measurement Techniques, K. Sriram (Affiliated East-West Press).
5. Fundamentals of surface and thin film analysis, Leonard C. Feldman and James W. Mayer (North Holland).
6. Introduction to nuclear science and technology, K. Sriram and Y. R. Waghamare (A. M. Wheeler).
8. Nuclear radiation detection, W. J. Price (McGraw-Hill).
9. Alphas, beta and gamma-ray spectroscopy, K. Siegbahn (North Holland, Amsterdam).
11. Introduction to experimental nuclear physics, R. M. Singru (John Wiley and Sons).
12. Radioactive isotopes in biological research, Willaim R. Hendee (John Wiley and Sons).

PHY-P312 Experiment based on PHY-T312 (2.5 credits):

To determine resolving/dead time of a GM counter by double source method.

To study Compton scattering using 6.66% MeV gamma-rays.

To determine energy resolution ofa Nal(TI) detector and show that it is independent of the gain of the amplifier.

To determine energy of a given gamma-ray source by calibration method.

To study various operations of 1024 channel analyzer and to calculate energy resolution, energy of gamma ray, area under photopeak etc.

To study beta-ray spectrum of Cs-137 source and to calculate binding energy of K-shell electron of Cs-137.

To estimate the resolving time (T_{rr}) for a given GM counting system using double source method.

(Any five experiments will be covered)

PHY-T313 BIO-PHYSICS-I

Module-1:1 credit (10 L, 5 T/S/D):
Basics of Biophysics : A) General organization of cells, basic cellular components, cell wall structure and function, cell matrix, cytoskeleton, cell growth and division, cell-cell communication
B) Chemical bonding, ionization energy, electron affinity, electron negativity, strong bonds & weak, bond energies with ref. to biomolecules, Interatomic potentials for strong and weak bonds
.

Module-2: 1 credit (10 L, 5 T/S/D):
Cellular mechanics & transport: Mechanical Forces, Physical forces, their magnitude at single molecule level e.g. bacterial motor, protein movement, filament growth, chromosomal forces
Probability distributions: mean, variance, correlations, brief review of statistical thermodynamics
Random walks, Brownian motion, Diffusion equation, friction, Langevin equations, Driven systems
Applications to biological systems: molecular motors, polymers, diffusion inside a cell

Module-3: 1 credit (10 L, 5 T/S/D):
Molecular Biophysics: Amino acids, Protein structure & confirmations, polypeptide chains, potential energy, hydrogen bonding, hydrophobic interactions, disulfide bonds & ways of pairing
Protein stability, chemical & surface denaturation, primary structure sequencing of polypeptide, α and β-helix, Ramchandran plot, protein folding & misfolding
Types of DNA, properties of DNA & RNA, Nucleotide structure, Base pairing, Transcription & translation, Genetic code
Structure & function of water, carbohydrates and Lipids

Module-4: 1 credit (10 l, 5 T/S/D):
Neurobiophysics: Neuron – structure and function, excitable membrane, Ion channels, Resting membrane potential, Depolarization, Hyper-polarization, Nernst equation, Goldman equation, Passive electrical prop. of neuron, action potential-generation & propogation, Nerve conduction, Cell equivalent circuits, Synaptic Integration & transmission, Voltage clamp technique & H-H equations, coding of sensory information

Books:

1. Biology, a human approach, I. W. Sherman and V. G. Sherman (Oxford University Press).
2. Principles of neural science, E. R. Kandel & J. H. Schwatz (Elsevier, North Holland)
3. Neuron to Brain, S. W. Kuffler and J. G. Nichols (Sinacuer Asso. Inc.).
4. The structure and function of proteins, L. Dickerson & J. Geis (Harpes & Row).
5. Biological Physics, Nelson (W.H. Freeman and Company)
6. Biophysics An Introduction, Rodney Cotterill (Wiley)
7. Molecual & Cellualr Biophysics, Mayer & Jackson (Cambridge)

PHY-P313 Experiment based on PHY-T313 (2.5 credits):

1. ECG recording on six leads R-R interval analysis
2. Audiometry
3. Estimation of seed viability by Tetrazonium test
4. Radiation dosimetry
5. Verification of Beer’s & Lambert’s Law
6. Electrophoresis for protein isolation

PHY-T314 BIO-ELECTRONICS-I

Module-1: 1 Credit (10 L, 5 T/S/D):
Signals & classification, Biosignals & origin, volume conduction, Origin, 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 & intracellular 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,Defibrillator, Microschock & Macroschocks

Books:

1. Principles of Neural Science-Kandel & Schwartz (Elsevier, North Holland).
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).
5. Design of Microcomputer based medical Inst, Webster & Tompkins (Prentice-Hall).
6. Encyclopedia of Biomed, Inst. Ed. Webster (Wiley).
7. Digital Principles and Applications, Malvino & Leach (Tata McGraw-Hill).

PHY-P314 Experiment based on PHY-T314 (2.5 credits):

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, Gain, Absorption Coefficient, Stimulated Cross Section, Threshold Condition for Lasing Action. Two Level (Ammonia maser) Three Level and Four Level Systems, Rate Equations, Threshold Pump Power, Relative Merits and De-merits of Three and Four Level System.

Module-2: 1 credit (10 L, 5 T/S/D):
Optical Resonators: Resonator Configurations and its Stability, Characteristics of Gaussian Beam, Transverse and Longitudinal Modes, Mode Selection Techniques (at least two techniques in each case), Losses in a Resonator, Mention of hardware design - laser support structure, mirror mounts, optical coating etc.

Module-3: 1 credit (10 L, 5 T/S/D):
Types of lasers: (A) Gas lasers : Excitation in Gas Discharge via Collisions of 1st and 2nd Kind, Electron Impact Excitation-its cross section, Different Types of Gas Lasers : He-Ne, N_2, CO_2, Metal Vapor Lasers, Excimer Laser
Chemical Laser and Dye Lasers.

Module-4: 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, spectral response etc.

Text Books:

1. Principles of lasers, by Orazio Svelto - Fourth / fifth edition (Plenum Publishing Corporation).
2. Solid state laser engineering, W. Koechner (Springer-Verlag).
3. Principles of Laser and their applications, Callen, O'Shea, Rhodes
4. Laser parameters, Heard

Reference Books:

1. Masers, by A. G. Siegman.
2. Gas lasers, by Garret.
3. Maser Handbook, vol. 1-4, F. T. Arecchi, E. O. Schul Dubois (North Holland).

PHY-P315 Experiments based on PHY-T315 (2.5 credits):

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.

(Any Five per Semester)

PHY-T321 ACCELERATOR PHYSICS-I

Credit-1: 1 credit (10 L, 5 T/S/D):
Introduction and classification of particle accelerators. Sector magnets, lines of force and magnetic field index. Edge focusing effects on charged particles in a dipole magnet. Motion of charged particles in electric and magnetic fields. Axial and radial stability of orbits of charged particles in magnetic field, qualitative and quantitative treatment of weak focussing ,transverse and longitudinal oscillations.

Credit-2: 1 credit (10 L, 5 T/S/D):
Phase stability: Principle of phase stability, momentum compaction, analogy of biased pendulum, phase diagram, synchrotron oscillations.

Credit-3: 1 credit (10 L, 5 T/S/D):
Emittance and admittance for charged particle beams, matching, measurement of emittance of electron and ion beams.Matrix method of studying orbit stability, Working principle of quadrupole lenses. Low energy d.c. accelerators. Electric lines of force in accelerating column.

Credit-4: 1 credit (10 L, 5 T/S/D):
Basic principle and design details of the following types of accelerators ;Electrostatic,
Two stage tandem, cyclotron, Conventional and Race-Track Microtron. High energy ion accelerator-pelletron. Electron synchrotron, 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-T321 (2.5 credits):

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: 2 credits (20 L, 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, Poincare section.
Attractors: Types of attractors, strange attractors, stretching and folding, Lorenz and Rossler attractors.

Module-2: 2 credits(20 L, 10 T/S/D):
Maps : Logistic map, analysis of the logisticmap, 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, ergodicity, invariant measure, Lyapunov exponent, dimensions and their evaluation, K-entropy and symbolic dynamics.

Books:

1. Ordinary Diff. Equations, V. J. Arnold (Springer).
2. Differential Equations, Dynamical Sy stems and an Introduction to Chaos, Hirsch, Smale and Devaney, Academic Press (Elsevier Imprint).
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).
10. Introduction to Dynamics, I. Percival, D. Richards (Cambridge Univ. Press).
11. Berge Pomeo Vidal, Order within chaos (J.Wiley).
12. Chaos in Dynamical System, E. Ott (Cambridge University Press).
13. Chaotic Dynamics, G. L. Baker, J. P. Gollub (Cambridge University Press).

PHY-P323 Experiments based on PHY-T323 (2.5 credits):

Computational experiments/Exercises Mini Projects/

1. Logistic Map :
(a) Bifurcation diagram(1 expt.),
(b) Lyanpunov exponents (1 expt.),
(c) Feigenbaum 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, 5 T/D/S):

Matrix representation of symmetry operations, Representation of a groups ,"Great Orthogonality" theorem, Irreducible representation , Character tables. Representation for Cyclic groups.

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 (SALC) , Projection operators, using projection operator to construct SALC. Illustrative examples of SALCs.

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

Molecular orbital (MO) theory and its applications, Hückel approximation, energy level diagrams, symmetry factoring of secular equation, some simple carbocyclic systems, Hybird orbital and molecular orbitals for AB type molecules. Construct MOs for Naphthalene as an illustrative example.

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

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 Atomic Spectroscopy. The free ion, free ion TERMS, Term wave functions, spin orbit coupling.

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

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 Eastern).
2. Chemical applications of Group Theory, F. A. Cotton (Wiley Eastern Ltd).
3. Introduction to Ligand Fields, B.N. Figgis (Wiley Eastern).

PHY-P324 Experiments based on PHY-T324 (2.5 credits):

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

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

Scientific background and introduction to nano-science, Historical importance, Relation with material science, Atoms, molecules, assembly, clusters, macromolecules- examples, Assembly of atoms ,Chemical bonds-organic and inorganic nature, Crystal structure, Definition of surface, Surface energy, Defects and dislocations, Particles and defects on the surface, Grain boundaries, Surface to volume ratio, Surface related phenomena-chemical reactivity, Mechanical properties, sintering properties, Hardness, Surface related phenomena- and applications, Volume related phenomena-introduction.

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

Quantum confinements, Bond to band approach, Molecular energy levels, HOMO-LUMO, Approach to band theory of solids- continuum and periodicity, Bohr radius, Electronic density of states, Tight binding approximation, Density functional approach, 1D,2D, 3D,0D structures, Effects of quantum confinement in optics, Electronic devices-Semiconductor, Effective mass approximation, Mie theory, scattering, optical properties-colloidal, surface plasmon resonance.

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

Nucleation and growth, Homogeneous and heterogeneous growth, Thermodynamics of growth, Saturation, Supercooling, Gibbs free energy, Wolf construction-faceting, Directional growth, Dendritic growth, 2D growth, 1D growth, Oswald ripening in solution growth, log normal particles size distribution,

Module-4: 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

Books:

1. Physics of Low Dimensional Structures, J. H. Davis (Cambridge Press).
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. H. Kalman, Butterworth-Heinmann, USA, 1993.
5. Experimental Physics, Modern Methods, R. A. Dunlop.
6. Instrumental Methods of Analysis, H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle, (CBS Pub.).
7. Phase transformation in Metals by Porter.
8. Nanomaterials Synthesis and Applications: A.S. Edelstein and R.C. Cammarata,
9. Material Science by Ragawan.
10. Progress in Material Science by Gleiter.

PHY-P325 Experiments based on PHY-T325 (2.5 credits):

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 (10 L, 5 T/S/D):
Introduction to Solar Energy and Energy Storage

Module-2: 1 credit (10 L, 5 T/S/D):
Photo-Thermal Energy and Applications

Module-3: 1 credit (10 L, 5 T/S/D):
Photovoltaic Energy and Applications

Module-4: 1 credit (10 L, 5 T/S/D):
Geothermal Energy

Books:

1) World Energy Resources, Charles E. Brown (Springer Publication, 2002).
2) Handbooks of Solar Radiation, A. Mani (Allied Publishers, 1980).
3) Solar Energy Fundamentals and Applications, H. P. Garg and Satya Prakash (Tata McGraw Hill, 1997).
4) Treatise on Solar Energy, H. P. Garg, Volume 1, 2 and 3 (John Wiley and Sons, 1982).
5) Principles of Solar Engineering, F. Kreith and J. F. Kreider (McGraw Hill, 1978).
6) Solar Energy Thermal Processes, J. A. Duffie and W. Beckman (John Wiley and Sons, 1980).
7) Heat and Thermodynamics, M. W. Zemansky (McGraw Hill Publication, 1989).
8) Principles of Solar Energy Conversion, A. W. Culp (McGraw Hill Publication, 2001).
9) Solar Energy-Principles of Thermal Collection and Storage, S. P. Sukhatme (2nd Edition, Tata McGraw Hill Publication Co. Ltd., 1976).
10) Solar Energy Utilization, G. D. Rai, (Khanna Publishers, 1996).
11) Renewable Energy Sources and Conversion Technology, N. K. Bansal, M. Kleeman and S. N. Srinivas (Tata Energy Research Institute, New Delhi, 1996).

PHY-P 327 LIST of Experiments based on PHY-T327 (2.5 credits):

1) Determination of thickness and refractive index of a semiconductor thin film from reflection and transmission data by using UV-Visible spectrophotoscopy.
2) Determination of band gap of a semiconductor thin film from reflection and transmission data by using UV-Visible spectrophotoscopy.
3) To estimate the activation energy of a given semiconductor thin film sample by using thermally stimulated current method.
4) To study the phenomenon of Hall Effect and magneto-resistance. Determination of Hall coefficient and carrier concentration of the given semiconductor sample.
5) Study of I-V characteristics of solar cell/panel (Variation of intensity, Distance between source and solar cell).
6) Study of power versus load characteristics of series and parallel combination solar photovoltaic systems.
7) Estimation of solar constant
8) To evaluate the performance of parallel flow and counter flow heat exchanger.

PHY-T328 SOFT CONDENSED MATTER-I

Module-1: 1.3 credit (20 L/T/S/D):
Introduction to Soft Matter, Review of concepts of thermal equilibrium, Thermodynamics of solutions., phase separation. Mean Field Theories of phase-transition, Vaan der Waals equation, Critical phenomenon in fluids and Soft Matter systems, Landau Theory of phase transition.

Module-2: 0.9 credit (13 L/T/S/D):
Liquid crystals. Basic definitions and terminology. Liquid crystal phases and phase transitions. Orientational order and order parameters. Mean-field theories of liquid-crystalline order.

Module-3: 0.8 credits (12 L, 10 T/S/D):
Supramolccular self-assembly in soft-condensed matter. Amphiphilic molecules in solutions – aggregation and phase separation. Micellization process. Bilayers, vesicles and membranes.

Module-4: 1 credits (15 L, 10 T/S/D):

Non-equilibrium systems – any two topics from the following
(i) Driven lattice gas models
(ii) TASEP processes (applications in modelling biological transport) .
(iii) Percolation phenomenon.

Books:
1. *Soft-Condensed Matter* by R. A. L. Jones, (Oxford University Press).
2. *Structured Fluids* by T. Witten and P. Pincus, (Oxford University Press).
4. *Soft Matter Physics: An Introduction* by M. Kleman and O. D. Lavrentovich, (Springer).
5. The Colloidal Domain by F. Evans and H. Wennerstrom, (Wiley – VCH).
6. Soft Matter Physics by Masao Doi, (Oxford University Press).
9. *An Introduction to Polymer Physics* by D. I. Bower, (Cambridge University Press).
10. *The Physics of Polymers* by G. Strobl, (Springer).
11. *Scaling Concepts in Polymer Physics* by P. de Gennes, (Cornell University Physics).
12. *Liquid Crystals* by S. Chandrasekhar, (Cambridge University Press).
13. Intermolecular and surface forces (3^{rd} Ed), Jacob N. Israelachvili (Elsevier).

PHY-P328 Experiments based on PHY-T328 (2.5 Credits):

Computational Experiments/Exercises/Mini Projects.

PHY-T329 PLASMA PHYSICS AND TECHNOLOGY - I

Module-1: 1 credit (10 L, 5T/S/D):
Basic processes in plasmas: Collisions in plasmas, significance of small angle scatterings, ionization, recombination, concepts of diffusion, mobility, ambipolar diffusion. Thermal ionisation and the Saha equation, LTE and equilibrium models.

Module-2: 1 credit (10L, 5T/S/D):
Plasma production: Various plasma production techniques, Electrical breakdown in gases using dc, radio frequency, microwave and high frequency fields, Glow and arc discharge,

Module-3: 1 credit (10 L, 5T/S/D):
Plasma diagnostics: Electrical Probes: Probe theory, Langmuir probes, Single and double probe, Emissive probe, magnetic probes, Retarding field analyzer for ion energy analysis,
Spectroscopic methods: Spectroscopic diagnostics (Emission spectra), Verification of Atomic Data, Measurements of Particle Densities, Temperature Measurements, Measurements of the Electron Density, Mass spectrometry

Module-4: 1 credit (10 L, 5T/S/D):
Interaction of plasma with material: Constituents of plasma and their energy (i.e. electron, ions, neutrals, heat, electromagnetic radiations). Interaction of electron from plasma with surfaces, Interaction of ions from plasma with surfaces (sputtering mechanism, buried implantation), Interaction of heat with surfaces, Plasma chemistry and physics. Nucleation and growth phenomena , Homogeneous and heterogeneous nucleation , Dusty plasma , Aerosols.

Books:
1) Glow discharge processes (Sputtering and Plasma etching), Brain Chapmn (A Wiley Interscience Publication).
2) Thermal Plasmas: Fundamentals and Applications, Volume 1, Maher I. Boulos, Pierre Fauchais, Emil Pfender (Springer Science+Business Media).
3) Plasma Diagnostics, Holt Greven (North Holand Publishing Company, Amsterdam).
4) Reactions under Plasma Conditions, M. VenuGopalan (Wiley Interscience).
5) Cold Plasma in Materials fabrication: From Fundamental to Applications, Alfred Grillb (IEEE Press).
6) Introduction to Plasma Spectroscopy, Hans-Joachim Kunze (Springer).
7) Plasma Deposition, Treatment, and Etching of Polymers Edited by Riccardo d'Agostino, (ACADEMIC PRESS, INC).

PHY-P329 Experiments bases on PHY-T329 (2.5 credits):

1) Capacitevely coupled DC plasma reactor, verification of townsend discharge by varying pressure and Voltage.
2) Plasma reactor using AC glow discharge at 50 Hz in capacitively coupled system. Measurements of plasma voltage and plasma current at different voltages . Measurement of plasma power.
3) To study the Inductively coupled plasma devices. Measurement of plasma currents and voltage.
4) Plasma polymerization of poly acrylonitrile nitrile (PPAN). Measurement of physical properties of the plasma polymerized film.
5) Production of microwave plasma in a glass applicator. To study the effect of pressure and microwave power on the plasma glow.
6) Measurement of optical emission spectra from any of plasma devices for any chosen gas in the reactor.

(Any Five per Semester)

PHY-T330 PHYSICS OF SEMICONDUCTOR DEVICES –I

Module-1: 1 credit (10 L, 5T/S/D):
Carrier transport in semiconductors: Valence band model of pure and doped semiconductor, Equilibrium concentration of electrons and holes inside the energy band gap, The Fermi level and energy distribution of carriers inside the bands, temperature dependence of Fermi energy and carrier concentration in an extrinsic semiconductor, Drift, diffusion and injection of carriers; Carrier generation and recombination processes, Carrier lifetime, Relaxation lifetime, Dielectric relaxation lifetime, Recombination of electrons and holes.

Module-2: 1 credit (10 L, 5T/S/D):
Properties of semiconductor: Type of semiconductors, direct and indirect band gap semiconductors, measurements of mobility and diffusivity, Optical and thermal properties of some semiconductors, Four –point probe resistivity measurement, Van-der Pauw method, Hall effect, The Haynes-Shockley experiment: Diffusion constant, temperature dependent electrical properties of some semiconductors.

Module-3: 1 credit (10 L, 5T/S/D):
Metal-semiconductor junction: Metal-semiconductor junction, Formation of barriers, Schottkey barriers, Rectifying contacts, Ohmic contacts, Ideal conditions, Depletion layer, Surface/Interface states, Role of interface States in Junction Diodes, Barrier height adjustment, Current transport processes, Tunneling current, Minority carrier injection, MIS tunnel diode, Measurement of barrier height, photoelectric measurements, Activation energy measurements, Capacitance-voltage measurements, applications of M-S junctions.

Module-4: 1 credit (10 L, 5T/S/D):
Metal-Insulators-Semiconductor: Metal-Insulators-Semiconductor capacitance, Ideal MIS capacitor, Surface space-charge region, Ideal MIS capacitance curves, Interface traps, measurement of interface traps, oxide charges and work function difference, Carrier transport, Non-equilibrium and avalanche, accumulation and inversion layer thickness, brief about classical and quantum model, dielectric breakdown.

Books:

1. An Introduction to Semiconductor Devices, Donald A. Neamen (McGraw-Hill)
2. Solid State Electronic Devices, B.G. Streetman and S K Banerjee (Pearson Education Inc. 6th Edition)
3. Semiconductor Devices: Physics and Technology, S. M Sze (2nd Edition, John Wiley, New York)
4. Introduction to Semiconductor Materials and Devices, M. S. Tyagi (John Wiley & Sons)
5. Fundamentals of Semiconductor Devices, BL Anderson and RL Anderson (McGraw-Hill Higher Education)
6. Principles of Semiconductor Devices, Sima Dimitrijev (OXFORD UNIVERSITY PRESS)
7. Complete Guide to Semiconductor Devices, K.K. Ng (John Wiley & Sons, Inc., New York 2nd Ed.)
8. Modern Semiconductor Device Physics, S M Sze (John Wiley) (1998)
9. Semiconductor Devices: Basic Principles, Jaspreet Singh (John Wiley & Sons)

10. Semiconductor Device Fundamentals" Robert F., Pierret (Addison-Wesley)
11. Physics of semiconductor devices, Dilip K Roy (Universities press).
12. Fundamentals of Photonics, Saleh and Teich (Wiley-Interscience).

PHY-P330 Experiments bases on PHY-T330 (2.5 credits):

1. Fabrication of semiconductor devices (UV-detector, Switches, memory devices, MOS FET’s, photovoltaics solar cells, LED’s. etc) and basic characterization and/or similar experiments.
2. Fabrication and measurements of p-n MS, MIS, MOS, etc. junctions (structures).
3. Studies on optical properties of semiconductor devices.
4. Calculation of electrical parameters such as swing voltages, threshold voltages, on/off ratios, mobility in linear and saturated regions of MOSFET’s.
5. Electric transport properties, Current-Voltage (I-V) measurements on the above prepared semiconductor devices.

PHY-T402 NUCLEAR PHYSICS

Module-1: 1 credit (10 L, 5 T/S/D):
General properties of nuclei, Radioactive decay and Radiation detectors: Nuclear mass, mass defect, binding energy, nuclear radius, angular momentum, magnetic dipole moment and electric quadrupole moment. Basic theory of Alpha, Beta and Gamma-Rays decay. Radioactivity and units of radiation. Interactions of charged particles and gamma-rays with matter. Basic working principle of radiation detectors with details of proportional counter, NaI(Tl) and semiconductor detectors.

Module-2: 1 credit (10 L, 5T/S/D):
Nature of Nuclear Interactions and Nuclear Reactions: Nature and properties of nuclear force. Deuteron problem, Electromagnetic, weak and hadronic interactions. Low energy n-p and n-n scattering, Phase shift and scattering cross section. Q-value and threshold energy of nuclear reactions. Neutron and charged particle induced nuclear reactions, cross section of a nuclear reaction. Compound nucleus formation, nuclear fission and fusion reactions.

Module-3 : 1 credit (10 L, 5T/S/D):
Nuclear Models and Nuclear Reactors: Liquid drop model and Empirical mass formula. Shell Model with details of Magic numbers, Nuclear Energy levels and their applications. Collective Model. Nuclear fission and fusion reactions. Fissile and fissionable nuclei. Classification of nuclear reactors and electric power delivered.

Module-4 : 1 credit (10 L, 5T/S/D):
Elementary Particle Physics: Classification of elementary particles, their masses, spin parity, and life-time. Additive quantum numbers such as strangeness, isospin, baryon number,hyper charge,etc. Classification of quarks, their masses and spins. Quark contents of particles. C.T.P invariances. Parity non conservation in weak interactions, etc. Gell-Mann-Nishijima formula.

Books:
1. Concepts of Nuclear Physics, B.L. Cohen (Tata McGraw Hill).
2. Subatomic Physics, Frauenfelder and Henley (Prentice-Hall).
3. Nuclear Physics. Irving Kaplan (Addison-Wesley Publishing Company. Inc.).
4. Theoretical Nuclear Physics, John Markus Blatt and Victor Weisskopf (Dover Publication, Inc.).
5. Introductory Nuclear Physics, Kenneth S. Krane (Wiley India Pvt. Ltd.)
6. Modern Atomic and Nuclear Physics, Fujia Yang and J.H.Hamilton (McGraw Hill International Editions).
7. Atomic and Nuclear Physics, Shatendra Sharma (Pearson).
8. Nuclear Physics An Introduction, S. B. Patel (New Age International Limited).
9. Introduction to Nuclear Science and Technology, K. S. Ram and Y. R. Waghmare (A.H. wheeler & Co.Ltd).
10. Nuclei and Particles: In Introduction to nuclear and Sub-Atomic Physics, Emilo Segre (W.A. Benjamin Inc.).

PHY-T403 METHODS OF MATERIALS CHARACTERIZATION

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

Methods to Study Structural Properties and Chemical Composition of Solids: X-ray diffraction, Reitvald analysis, effect of temperature on diffraction patterns, Grain size measurements using Scherrer formula, Theory and analysis of few patterns. Comparison with electron and neutron diffraction. Grazing angle x-ray and electron diffraction.

Scanning electron microscopy, Transmission electron microscopy, Dark field and bright field imaging, EDAX, Theory and analysis of few patterns.

Scanning Probe Microscopy, STM, AFM, different modes of operation of STM and AFM Practical analysis

Inductively coupled plasma atomic emission analysis (ICP-AES), Inductively coupled plasma mass spectroscopy (ICP-MS) and SIMS for determination of chemical composition.

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

Methods to Study Electronic Structure, Optical, Electrical and Magnetic Properties of Materials :X-ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES), Theory and Practical analysis

Optical absorption, reflectance, luminescence and scattering from solids to determine the electronic structure, FTIR and Raman spectroscopy.

Magnetization measurements by SQUID and VSM, Mossbauer spectroscopy, Electron paramagnetic resonance, Nuclear magnetic resonance, chemical shift in NMR, Theory and Practical Analysis

Measurements of the electrical parameters (conductivity, mobility and charge carrier concentration) and dielectric constant.

Books:

1. Fundamentals of Molecular Spectroscopy, C.N. Banwell and E.M. McCash (McGraw-Hill International Limited, 4th Edition).
2. Instrumental Methods of Analysis, H.H. Willard, L.L. Merritt, J.A. Dean, and F.A. Settle (CBS Publishers and Distributers).
3. Instrumental Analysis, D.A. Skoog, F.J. Holler and S.R. Crouch (Cengage Learning, Delhi (2007), 11th Indian reprint)
4. Physical Principle of Electron Microscopy, F. Edger (Springer Science).
5. Nanotribology and Nanomechanics, Ed. B. Bhushan (Springer Verlag (2011), Chapter 2)
6. Superconducting quantum interference device, Instruments and Applications, R.L. Fagaly, Rev. Sci. Instrum. 77, 101101 (2011).

PHY-T404 SPECIAL TOPICS IN THEORETICAL PHYSICS

(Any two modules out of 6 will be offered)

Module-1: 2 credits (25 L, 5 T/S/D):
Topology and Differential Geometry:

Topological spaces: definition of topological spaces, Subspace topology, Open and closed sets, limit points and closure, continuous mappings, homeomorphisms, product topology, Metric topology, topological groups.

Connectedness and compactness: connected spaces, connected sets in the real line, compact spaces, compact sets in the real line.

Fundamental groups: Paths and loops, homotopy of paths and loops, First fundamenal group, fundamental group of R^n, S^n, punctured plane, S^2 with anti-podal points identified (RP^2) etc, simple applications.

Manifolds: definition, differentiable manifolds, differentiation of functions on manifolds, orientability.

Calculus on manifolds: vectors and vector fields, tangent and cotangent spaces.

Differential forms: definition and properties, exterior derivatives, exterior algebra, Lie derivative, Integration of differential forms, Stokes theorem.

Cohomology groups OR Riemannian geometry: Frames, connections, curvature and torsion, volumn form, Hodge star operation and Laplacian of forms.

Simple applications.

References:

1. Topology, J. Munkres (Pearson Education).
2. Real Mathematical Analysis, C.C. Pugh (Springer).
3. Basic Topology, M.A. Armstrong (Springer).
4. Lectures on Advanced Mathematical Methods for Physicists, S. Mukhi and N. Mukunda (World Scientific).
5. Algebraic Topology, E. H. Spanier (Springer).
6. Topology and Geometry for Physicists, C. Nash and S. Sen (Dover).
7. Geometrical Methods of Mathematical Physics, B. Schutz (Cambridge University Press).
8. Geometry, Topology and Physics, M. Nakahara (CRC Press).
9. The Geometry of Physics: An Introduction, T. Frankel (Cambridge University Press).
10 Lectures on Differential Geometry, S. Sternberg (American Mathematical Society).
11. Differential Geometry and Lie Groups for Physicists, M. Fecko (Cambridge University Press).
12. Mathematical Methods of Classical Mechanics, V. I. Arnold, K. Vogtmann and A. Weinstein (Springer).

Module-2: 2 credits (25 L, 5 T/S/D):
Green's function in Physics :
Time independent Green's functions - Definition and general formalism: Method of calculation, eigenfunction expansion of Green's function. Application to inhomogeneous differential equations: 1-D, 2-D, 3-D cases, Poisson equation and image problems in electrostatics. Time dependent case - general formalism. Applications: Diffusion equation, wave equation - advanced and retarded Green's functions, causal properties.
Green's functions in one-body nonrelativistic quantum mechanics: Green's function for time independent Schrodinger equation, density of states. Time dependent case- propagator for free particle.

Green's function and perturbation theory: time independent and dependent cases, application to scattering theory. Bound states in shallow potential wells. Analytic properties of Green's function. General remarks about many-body Green's functions.

References:

1. G.F Roach, Green's Functions, Cambridge University Press, 1982
2. G. Barton, Elements of Green's function and Propagation, Clarendon press oxford, 1989
3. I. Stackgold and M.Host, Green's functions and Boundary Value problmes, 3rd ed, Wiley, 2011.
4. P. Dennery, Andre Krzywicki, Mathematics for Physicists, Dover Publications, 1995.
5. S. Hassani, Mathematical Physics, Springer, 1998.
6. E. N. Economou, Green's function in Quantum Physics, 3rd ed. Springer 2005.
7. G. Rickayzen, Green's function and Condensed matter, Dover, 2013.
8. J.D. Jackson, Classical Electrodynamics, 3rd ed, Wiley1998.
9. K. Gottfried, T. M. Yan, Quantum Mechanics: Fundamentals, Springer, 2003
10. J. Sakurai, Modern Quantum Mechanics, Pearson Education India, 2nd ed. 2010.
11. Quantum Mechanics, L. I. Schiff (McGraw-Hill).

Module-2: 2 credits (25 L, 5 T/S/D):

Path Integral Methods:

Path integral: General formalism, Construction of the path integral, Functional integrals and Gaussian integrals, Applications to free particle and harmonic oscillator problem.

Path integral and statistical mechanics, Euclidean path integral, Generating functions and correlation functions.

Nonlinear Path integrals: Quartic potentials, Semiclassical approximation, Effective actions, Instantons and tunneling, Tunneling in a dissipative environment.

Path integral and topological effects: Path integral for spin, other applications.

References:

1. Quantum Mechanics and Path integrals, R. P. Feynman and A.R. Hibbs (Dover publications).
2. Techniques and Applications of Path Integration, L.S. Schulman (Dover Publications).
3. Path integrals and quantum processes, M. Swanson (Dover publications).
4. Field Theory: A Modern Primer, Frontiers in Physics, P. Ramond (Westview press).
5. Field theory: A Path Integral Approach, Ashok Das (World Scientific).
6. Path Integrals in Quantum MechanicsStatistics, Polymer Physics and Financial Markets, H. Kleinert (World Scientific).

Module-3: 2 credits (25 L, 5 T/S/D):

Solitons:

Wave equations that exhibit solitons: KdV equation, sine-Gordon equation, nonlinear-Schrodinger equation, nonlinear lattice equation – Toda lattice, etc. and their applications in physics.

Elementary soliton calculations: one soliton solution and two-soliton solution of KdV equations and sine-Gordon equation, constants of motion and infinite conservation laws, linear stability analysis of the soliton soluton, Backlund and auto-Backlund transformations for integrable hierarchies, KdV as integrable Hamiltonian system, inverse scattering method for soliton solutions.

References:

1. Solitons: An introduction, P.G. Derazin and R.S. Johnson (Cambridge University Press).
2. Solitons, Nonlinear Evolution equations and inverse scattering, M.J. Ablowitz and P.A. Clearkson (Cambridge University Press).

Module-4: 2 credits (25 L, 5 T/S/D):

Renormalization Group and Critical Phenomena :

Phase transition, order parameter, critical exponents, scale invariance, scaling hypothesis, relation between critical exponents, Block spin, Kadanoff block spin construction, block spin transformation, real space renormalization group transformation, RG flow and fixed point analysis, calculations of critical exponents, example of one-dimensional Ising model**.**

References:

1. Phase transition and Crtical Phenomena, Eugene Stanley (Oxford University Press).
2. Statistical Mechnics, K. Huang (Willey).

Module-5: 2 credits (25 L, 5 T/S/D):

Introduction To Non-equilibrium Statistical Mechanics :

Irreversible processes and fluctuations : Diffusion, Master equation, Fokker-Planck-Smoluchowski and Langevin dynamics, Fluctuations and dissipations, Stokes-Einstein relation, Driven diffusive processes. Introduction to transport phenomena, Boltzmann transport equation, Kinetic equations, H-theorem and relaxation to equlibrium.

References:

1. Fundamentals Of Statistical And Thermal Physics, F. Reif (Waveland Press).
2.The Fokker-Planck Equation, H. Risken (Springer).
3. Stochastic Processes, Van Kampen (North Holland).
4. Statistical Mechanics, Kerson Huang (Wiley).
5. Statistical Mechanics Plischke-Bergersen (World Scientific).

Module-6: 2 credits (25 L, 5 T/S/D):

Introduction To Fluid Dynamics:

Fluid Mechanics and Turbulence Continuum hypothesis, Lagrangian and Eulerian frames, equation of continuity, Euler’s equation, Bernoulli’s equation, Incompressible fluids. Viscous fluid 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. Introduction to Turbulence.

References:

1. Fluid Mechanics, Landau-Lifshitz (Butterworth-Heinemann).
2. An Introduction To Fluid Dynamics, G. Batchelor (Cambridge University Press).
3. Fluid Mechanics, P. Kundu, I. Cohen (Academic Press).

PHY-T406 THIN FILMS AND DEVICE TECNOLOGY-II

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

Thin Film thickness and deposition rate measurement techniques:- Gravimetric Methods, Optical Methods, Direct Methods, Film Thickness Measurement by Electrical or Magnetic Quantities.

Analysis of thin film structure, composition and morphology of thin films, Mechanical properties of thin films: - stress in thin films and adhesion. Optical properties of thin films

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

Electrical and magnetic properties of thin films: - Conductivity of continuous and discontinuous thin films, conduction in thin films of metals and insulators, determination of electrical parameters, Hall effect, TEP measurements, Photoconductor, Magnetic film size effect, magnetic thin films for memory applications.

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

Applications of thin films: - Antireflection coating, Optoelectronic applications (photon detectors, photovoltaic devices, thin film displays), microelectronic applications (thin film passive components like resistor, capacitor, etc. and thin film active components like thin film diode and thin film transistor),

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

Thin Film Devices: Sensors, Energy conversion (phototelectrolysis, photovoltaics) and energy storage (supercapacitor), Surface engineering applications of thin films (surface passivation, lubricating layer), Miscellaneous Applications (catalysis, biomedical)

Books:

1. Thin Film Materials Stress, Defect Formation and Surface Evolution, I. B. Freund, S. Suresh (Cambridge University Press, 2004)
2. Thin Film Device Applications, K. L. Chopra and I Kaur (Plenum Press, 1983)
3. Thin Film Analysis by X-ray Scattering, M, Birkholz (Wiley, 2006)
4. Active and Passive thin film devices and applications, T.J. Coutts (Academic Press), 1978.
5. Thin films Solar Cells, K. L. Chopra, S. R. Das (Plenum Press), 1983.
6. Handbook of modern sensors, Jacob Freden (AIP Press 2004)
7. Active and Passive Thin Film Devices, T. J. Coutts (Academic Press, 1978).
8. Light, Water, Hydrogen The Solar Generation of Hydrogen by Water Photoelectrolysis, C. A. Grimes, O. K. Varghese, S. Ranjan (Springer 2008)
9. Energy storage, Robert A Huggins (Springer 2010)
10. Advanced Characterization Techniques for Thin Film Solar Cells, Daniel Abou-Ras, Thomas Kirchartz and Uwe Rau (Wiley 2011)

PHY-P406 Experiments based on PHY-T406 (2.5 credits):

1. To determine thickness of the thin film by different methods.
2. Determination of band gap/carrier concentration of thin films using optical method.
3. To study electrical properties of thin films of metals and oxides.
4. To study photoconductivity/electrochromism of thin films.
5. To find out type of conductivity of thin film using TEP.
6. To study properties of gas/UV sensors.
7. To study phototelectrolysis of thin films.
8. To study thin film as a supercapacitor.

(Any Five per Semester)

PHY-T407 CONDENSED MATTER-II

Module- 1 : 2 credits (20 L, 10 T/S/D):
Harmonic oscillators and phonons, Second quantization for particles. 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. Density functional theory: Hohenberg-Kohn theorem, Kohn-Sham theory, Local density approximation.

Module- 2 : 2 credits (20L, 10T/S/D):
Superconductivity: Phenomenology, London theory, Ginzburg-Landau theory, BCS theory, high temperature superconductor.
Superfluidity: Phenomenology, two fluid model, Landau's theory,
superfluid velocity, superfluid flow, excited states.

References:

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 (Wiley).
5. Solid State Physics, N.W. Ashcroft & N.D. Mermin (Holt, Reinhart and Winston).
6. Many-particle physics, G.D. Mahan (Plenum Press).
7. Quantum theory of many-particle systems, A.L. Fetter and J.D. Walecka (Dover).

PHY-P407 Experiments based on PHY-T407 (2.5 Credits):

Computational Experiments/Exercises/Mini Projects.

PHY-T409 ADVANCED QUANTUM MECHANICS-II

Module-1: 1.3 credits (15 L, 5 T/S/D):
Canonical quantization of free fields: Scalar field, Radiation field, Dirac field.
Continuous symmetries and Conservation laws,
Discrete symmetries: parity, charge conjugation and time reversal.

Module-2: 1.3 credits (15L, 5 T/S/D):
Interacting fields :
Relativistically covariant Lagrangians for various interactions, coupling of Maxwell field with Dirac field, Gauge invariance, covariant derivative. Perturbation theory: Interaction picture, Time evolution and S-matrix, Decay rates and cross sections, Scalar and spinor electrodynamics, Elementary processes and Diagrams, Feynman rules for diagrams.

Module-3: 1.4 credits (15 L, 5 T/S/D):
Cross section and Decay rate calculations: Applications to elementary processes such as Mott scattering, Bhabha scattering, pair annihilation, Compton effect, etc.
Radiative corrections: Electron propagator, vertex function, one-loop renormalization, Lamb shift, self energy. Renormalization, regularization and power counting.

References:

1. Relativistic Quantum Mechanics, J. Bjorken and S. Drell (McGrew-Hill).
2. Quantum Field Theory, F. Mandl and G. Shaw (J. Wiley & Sons).
3. Advanced Quantum mechanics, J. J. Sakurai (Addison-Wesley).
4. Relativistic Quantum Field Theory, J. Bjorken and S. Drell (McGraw-Hill).
5. An Introduction to Relativistic Quantum Field Theory, S. S. Schweber (Row, Peterson).
6. Quantum Electrodynamics, R. P. Feynman (Benjamin Cummings).
7. Quantum Field Theory, L. Ryder (Academic Press).
8. Quantum Field Theory, C. Itzykon and J. B. Zuber (McGraw-Hill).
9. The Quantum Theory of Fields, S. Weinberg, Vol. I (Cambridge).
10. An Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroeder (Addison Wesley).
11. Quantum Electrodynamics Ed. J. Schwinger (McGraw-Hill).
12. A Modern Introduction to Quantum Field Theory, M. Maggiore (Oxford University Press).
13. Field Theory: A Modern Primer, Frontiers in Physics, P. Ramond (Westview press).
14. Group theory in Physics, Wu Ki Tung (World Scientific).

PHY-P409 Experiments based on PHY-T409 (2.5 Credits):

Computational experiments/Exercises/Mini Projects.

PHY-T410 MATERIALS SCIENCE-II

Module-1: 1 credit (10 L, 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 Young modulus, shear modulus, shear strength yield strength, hardness, toughness, ductility, toughness, brittleness, stiffness, , Frenkel model, Peierls-Nabarro relation, Plastic deformation, importance of dislocation movements, sessile dislocations, relation of slip process and crystal structures, Creep, Fatigue in materials, Fracture, Strengthening of materials.

Module-2: 1 credit (10 L, 5 T/S/D):
Electrical properties and its measurements: Metals - Electrical resistivity of metals and commercial alloys, their applications. Semiconductors - Electrical conductivity of intrinsic and extrinsic semiconductors, temperature and charge carrier concentration dependence, practical aspects of doping in semiconductors, electrical conduction in ionic materials, electrical properties of polymers. Dielectric materials - Peizoelectricc, Pyroelectric and Ferroelectric materials their characteristics and applications (examples illustrating the occurrence of Pyro/Piezo/Ferro-electric properties).

Module-3: 1 credit (10 L, 5 T/S/D):
Magnetic and optical properties and their measurements: Examples of Diamagnetic, Paramagnetc, Ferromagnetic, Ferri- and Antiferrimagntic materials (explanation of their corresponding magnetic behaviour), Soft and hard magnetic materials. Magnetic storage.
Optical Properties: Interaction of visible radiation with materials, Photoconductivity, Optical Fibers, types and applications in communication. Various applications based on optical properties of materials (explanation of their corresponding optical behaviour)

Module-4: 1 credit (10 L, 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. Compaction, sintering, calcination, vitrification reactions with examples. Laboratory scale synthesis routes - Solid state reaction, solgel, and combustion synthesis methods.
Thin Films and surface processing: (a) Ion beam processing, features of ion induced phenomenon (low and high energy) (b) Laser processing - Pulsed and CW laser processing, various types of processing, concepts Laser annealing, alloying, laser deposition etc. with examples.

Books:

1. Physical Metallurgy, Vol. I and 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. Fundamentals of Materials Science and Engineering, William Callister (John Willey and Sons).
4. Encyclopedia in Materials Characterization: Surfaces, Interfaces, Thin Films Editors: C. Richard Brundle and Charles A. Evans (Jr. Butterworth-Heinemann publishers, Singapore).

PHY-P410 Experiments based on PHY-T410 (2.5 credits)

1. Morphological investigations using Scanning Electron Microscopy (SEM).
2. Structural investigations using Raman Spectroscopy.
3. Study of optical properties of semiconducting nanostructures using Photoluminescence (PL) Spectroscopy.
4. Study of magnetic properties using Vibrating Sample Magnetometer (VSM).
5. Study of Mangetostriction of Ferrite materials.

PHY-T411 ASTRONOMY AND ASTROPHYSICS-II

4 Credits (45 Lectures, 15 T/S/D= 60 contact hours)

PRINCIPLES OF RELATIVITY:

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

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 membranes, gravitational waves.

COSMOLOGICAL MODELS:

Cosmological principle, 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 neutrinos and the relic neutrino background – nucleosynthesis – decoupling of matter and radiation; Cosmic microwave background radiation – inflation – origin and growth of density perturbations.

References:

- General Relativity and Cosmology, J. V. Narlikar, Delhi: Macmillan Company of India Ltd.
- Classical Theory of Fields, Vol. 2, L. D. Landau and E. M. Lifshitz, Oxford : Pergamon Press.
- First Course in General Relativity, B. F. Schutz, Cambridge University Press.
- Introduction to Cosmology, J. V. Narlikar, Cambridge University Press.
- Structure Formation in the Universe. T. Padmanabhan, Cambridge University Press

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

(Total 2.5 + 2.5 = 5 credits)
(Please note that some of these experiments, involving observations with the telescope, will be covered either in III or IV semester depending on the sky conditions)

List of M.Sc. A & A Experiments : (for associated ½ laboratory, 2.5 credits for each of Sem III and IV):

01. To estimate the temperature of an artificial star by photometry
02. To study the characteristics of a CCD camera
03. To study the solar limb darkening effect
04. To estimate the relative magnitudes of a group of stars by a CCD camera
05. To study the atmospheric extinction for different colours
06. Differential photometry of a programme star w. r. t. a standard star
07. To study the effective temperature of stars by B-V photometry
08. To estimate the night sky brightness with a photometer
09. Faraday Rotation effect in amorphous glass and crystalline media
10. Beam-pattern of various antenna
11. Muon Physics
12. 21-cm spin-flip line of neutral hydrogen
13. Beam pattern and pointing of a parabolic dish antenna

[Out of these there will be 5+5 experiments selected per semester (will have at least 2 Radio and 2 Optical experiments)]
Lectures associated with the experiments will be given on a number of topics including:
Time and Coordinates; Telescopes; Atmospheric effects; Noise and Statistics; Astronomical Detectors; Imaging and Photometry

Books :

1. Telescopes and Techniques, C.R.Kitchin, Springer.
2. Observational Astrophysics, R.C. Smith, Cambridge University Press.
3. Detection of Light: from the Ultraviolet to the Submillimetre, 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.

[Out of these, there will be 5+5 experiments selected per semester (will have at least 2 Radio and 2 Optical experiments)]
Lectures associated with the experiments will be given on a number of topics including:
Time and Coordinates; Telescopes; Atmospheric effects; Noise and Statistics; Astronomical Detectors; Imaging and Photometry

PHY-T412 NUCLEAR TECHNIQUES-II

Module-1: 1 credit (10 L, 5 T/S/D):
Neutron Sources and Reactors: Reactor neutron sources, radioactivity based neutron sources and laboratory neutron sources, Thermal and fast neutron detectors, basics of fission and fusion as a source of nuclear energy, production of radioisotopes. Reactor operation, Power reactors.

Module-2: 1 credit (10 L, 5 T/S/D):
Measurement of Lifetime and Nuclear Levels: Basic concepts of half life, mean lifetime of radioactive nuclei. Excited states of nuclei; Measurement of lifetime of the nuclear excited states, covering range from picoseconds to years using techniques such as recoil distance, delayed coincidence, activity measurement and others. Measurement of beta-beta and beta-gamma coincidence. Study of angular co-relation between the gamma-rays emitted from Co-60 source.

Module-3: 1 credit (10 L, 5 T/S/D):
Nuclear Spectroscopy: Basic principles and applications of (i) Mössbauer effect. (ii) Positron annihilation and (iii) perturbed Angular co-relation (iv) Beta-ray orange spectrometer. Iron and air core magnetic spectrometers, mass and energy resolution, and transmission efficiency for the above spectrometers.

Module-4: 1 credit (10 L, 5 T/S/D):
Applications: Elemental analysis by neutron activation method, proton induced X-ray Emission, Nuclear Reaction analysis, Elastic recoil detection analysis method. Measurement of thermal and fast neutron flux and cross-section by activation method. Practical uses of radioisotopes, Radioactive waste disposal, applications of radioisotopes in medical field, industries and agriculture .dating of archaeological and other ancient object, Carbon-14 and potassium-argon dating 39,40 method trace element studies, radiotherapy for cancer treatment.

Books:

1. Nuclear radiation detectors, S. S. Kapoor and V. S. Ramamurthy (Wiley Eastern Limited, New Delhi).
2. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng (World Scientific).
3. Techniques for nuclear and particle physics, W. R. Leo (Springer).
4. Nuclear Measurement Techniques, K. Sriram (Affiliated East-West Press, New Delhi).
5. Fundamentals of surface and thin analysis, Leonard C. Feldman and James W. Mayer (North Holland, New York).
6. Introduction to nuclear science and technology, K. Sriram and Y. R. Waghamare (A. M. Wheeler).
7. Nuclear radiation detection, W. J. Price (McGraw-Hill, New York).
8. Alpha, beta and gamma-ray spectroscopy, K. Siegbahn (North Holland, Amsterdm).
9. Introduction to experimental nuclear physics, R. M. Singru (John Wiley and Sons).
10. Radioactive isotopes in biological research, William R. Hendee (John Wiley and Sons).

PHY-P412 Experiments based on PHY-T412 (2.5 credits):

To make a short lived isotope Using 14 MeV neutrons and measure its half life time.

To determine resolving time of a coincidence using chance coincidence technique.

To determine activity of a given gamma-ray source using radiation monitor.

Measurement of neutron flux using activation method.

To measure efficiency and energy resolution of a HPGe detector

To study different pulse shaping circuits for > T, = T, < T conditions and combination of differentiation and integration for 'n' number of networks.

To study designing of a D/A converter using R-2R ladder network.

Obtain Fermi-Kurie plot and estimate the end point energy of beta particle emitted from Cs-137 using beta ray spectrometer.

i) To verify inverse square law of radiation in air ii) To estimate mass absorption coefficient for a given concrete brick and iii) Calculate the time and minimum permissible dose per week for which the student can work in the laboratory using Cs-137 source and radiation survey meter.

Measurement of half life of a given radioactive material (MnO2) induced by thermal neutrons. Also, estimate the flux of the Cf-252 neutron source

To determine the mass absorption coefficient for mica, aluminum, copper and estimate the end point energy using different radioactive sources, such as Sr90, Sr90-Y90, Ra226, etc.

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

Bioenergetics: Reversible & Irreversible Thermodynamics, Free energy, Helmoltz free energy, Gibbs free energy, Redox potentials, Photosynthetic pathways (Photosystem I & II), Thermodynamics in photosynthesis, thermoluminescence & glow curves in photosynthesis

Energy consumption, Respiration, ATP synthesis, Chemoenergetics (oxidative phosphorylation)

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

Neurobiophysics: A)Biophysics of Mechanoreception- structure of ear, Auditory transduction, frequency analysis

Biophysics of photoreception – structure of eye, photoreceptors, visual perception, visual pathways- parvo & magnocellular, Receptive field, responces from photoreceptors, LGN & visual cortex, simple, complex, Hypercomplex cells, Blob cells

B) Origin of EEG and its significance, Auditory, Visual and Somatosensory evoked potentials

C) Memory & Learning by Neurons, Brain areas & Cognitive functions

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

Techniques and Methods in Biophysics Centrifugation, chromatography & electrophoresis, Absorption spectroscopy, IR & Raman spectroscopy for biomolecules, NMR spectroscopy for proteins

Scanning Tunnelling Microscopy, Atomic force microscopy for biomolecules & cells

Optical Tweezers- basics & application for piconewton force measurement

Patch clamping technique

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

Radiation Biophysics: Ionizing radiation, Interaction of radiation with cells & biological systems, measurement of radiation (Dosimetry), radioactive isotopes and medical applications,

Biological effects of radiation, radiation protection & therapy

Laser radiation & cell-tissue interactions

Lasers and phototherapy

Books:

1. Biophysics, P.Narayanan (Bhalani Publication)
2. From Neurons To Brain, Stephen W. Kuffler & John G.Micholls (Sinaeur Associates Inc Publishers)
3. Methods in Modern Biophysics, Bengt Nolhrg (Springer)
4. Clinical Biophysics: Principle & Techniques, P.Narayanan (Bhalani Publishing House)
5. Biological Physics, Phillip Melion (W.H. Freeman and Company)
6. Radiation Biophysics, Edward L.Alpen (Prenhce Hall Series)
7. Modelling Biological System, James W. Haefner (Springer)
8. Principle of Neural Science, E.R. Kandel & J.H. Schwartz 4th Edition (Elsevier)

PHY-P413 Experiment based on PHY-T413 (2.5 credits):

1. Recording and analysis of Visual Evoked Potential
2. Mechanotrasnconduction in insect leg & recording of action potentials
3. Fourier analysis of biopotentials
4. Chlorophyll absorption and fluorescence spectra
5. Protein structure and Sequence alignment using software tools

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, Heart rate variability (HRV), Arrthymia analyzer, Power
spectra of EEG, EMG, signals, Averaging of Evoked potential, Real time system for ECG & EMG with DSP hardware, Patient monitoring system,Neurophotonics system.

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.

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 (Oxford: Clarendon Press)
5. Biomedical Signal Analysis, Akay (Academic Press)
6. DSP lab Manual V. R. Udpikar

PHY-P414 Experiments based on PHY-T414 (2.5 credits):

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

(Any Five per Semester)

PHY-T415 LASER-II

Module-1: 1 credit (10 L, 5 T/S/D):
Optically pumped laser systems:- Optical sources, projection geometries, power supply Ruby laser, Nd: YAG laser, Nd:glass Laser Amplifiers for these lasers, their characteristics

Module-2: 1 credit (10 L 5 T/S/D):
Q-switches-pulse reflection mode- Multiple-pulsing in slow Q-switches.
Pulse transmission mode Q-switching- Mode locking-active and passive techniques Passive mode locking using dye cell, Distributed Feedback Lasers (and its importance for short pulse generation) semiconductor lasers, color center laser.

Module-3: 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-4: 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.

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

PHY-P415 Experiments based on PHY-T415 (2.5 credits):

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. Study of oscillator and amplifier systems of Nd: YAG laser,
6. Estimation of gain factor
7. To study magneto-optic rotation and magneto-optic modulation

(Any Five per Semester)

PHY-T421 ACCELERATOR PHYSICS II

Module-1: 1 credit (10 L, 5 T/S/D):
Electric and magnetic lenses for focusing charged particles.Concept of weak and strong focusing in accelerators.Air-core magnetic lenses for focusing electrons.Measurement of charged particle beam profile. Measurement of electron and ion beam energies. Study of focusing properties of a pair of quadrupole lenses. High voltage pulse forming electronic systems for accelerator.

Module-2: 1 credit (10 L, 5 T/S/D):
Equation for describing trajectories of charged vparticles. Linear machine lattices, Hamiltonian formulation, linear machine imperfections, storage ring physics. Techniques for extraction of electron beam from the booster electron accelerator.

Module-3: 1 credit (10 L, 5 T/S/D):
Sources of particle beams, electron gun, ion sources. Techniques for producing pulsed charged particle beams.Basic working principle of pulsed transformers. Induction coil for measurement of pulsed current. Applications of accelerators with special emphasis on industrial and medical fields.

Module-4: 1 credit (10 L, 5 T/S/D):
Design of dipole, quadrupole magnets and its applications in beam optics. Structures of the R.F. cavities used in particle accelerators. Electric fields in the cavity. Mechanism of particle acceleration in a cavity. Range of frequencies in cavities used for electron and ion accelerations

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-P421 Experiments based on PHY-T421 (2.5 credits):

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, Symbolic synamics.

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

References:

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. Statistical Physics, Vol. I, Toda Kubo Saito (Springer Verlag).
8. Quantum Chaos – An Introduction, H.J. Stockmann (Cambridge University Press).

PHY-P423 Experiments based on PHY-T423 (2.5 Credits):

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: 1 credit (10 L, 5 T/D/S):
Hybridization schemes for sigma and pi bonding hybrid orbtials as LCAO , 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.

Module-2: 1 credit (10 L, 5 T/D/S):
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-3: 1 credit (10 L, 5 T/D/S):
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-4: 1 credit (10 L, 5 T/D/S):
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. Discussion of Raman pectra of novel materials such as Graphene, Carbon nanotubes etc.

Books:

1. Chemical applications of group theory, F. A. Cotton (Wiley Eastern Ltd. New Delhi, 1989.)
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 (2.5 credits):

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 (vapors) and ammonia (gas) and study the vibrational modes.
4. To obtain Raman Spectra of some novel materials such as Graphene and interpret the results.

PHY-T425 NANOTECHNOLOGY-II

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

Special mayerials and their characterization

Special Nanomaterials: Graphene, MoS2, CNT, C60, nanorods, nano-porous materials. Clusters. Fullerens, semiconductor and metal clusters. Data analysis of nanostructure material using spectroscopic and microscopic technique: SEM, TEM, AFM, MFM, SNOM, Confocal Microscope, Uv-Vis, Raman, XPS, SAXS.

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

THE SCIENCE OF MINIATURIZATION

Top Down Approach of Nanomaterials Synthesis : Moore's Laws (1,2,&3) and technology' Roadmap–clean rooms Processing Methods: - Cleaning – Oxidation – Lithography – Etching- – CVD - Diffusion – Ion implantation – metallization – state of the art CMOS architectures Photolithography Overview – Critical Dimension – Overall Resolution – Line-Width – Lithographic Sensitivity and Intrinsic Resist Sensitivity (Photochemical *Quantum Efficiency*) – Resist Profiles – Contrast and Experimental Determination of Lithographic Sensitivity – Resolution in Photolithography – Photolithography Resolution Enhancement Technology Conventional lithography and its limitations. Lithography using scanning probes, soft lithography.

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

SPINTRONICS

Analysis of spintronic materials : GMR and CMR, DMS materials. Photonic band gap materials. Spin tunneling devices - Magnetic tunnel junctions- Tunneling spin polarization - Giant tunneling using MgO tunnel barriers - Tunnel-based spin injectors - Spin injection and spin transport in hybrid nanostructures - spin filters -spin diodes - Magnetic tunnel transistor - Memory devices and sensors - ferroelectric random access memory- MRAMS -Field Sensors - Multiferro electric sensors- Spintronic Biosensors.

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

NANOELECTRONIC DEVICES

Electronic transport in 1,2 and 3 dimensions- Quantum confinement - energy subbands - Effective mass - Drude conduction - mean free path in 3D - ballistic conduction - phase coherence length - quantized conductance - Buttiker-Landauer formula- electron transport in pn junctions - short channel NanoTransistor –MOSFETs - Advanced MOSFETs – CMOS devics.

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).
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. H. Kalman (Butterworth-Heinmann, USA, 1993).
8. Nanotechnology, G. Timp, Maple-Vail (Book Man. Group, USA, 1999).
9. Characterization of Materials, J. B. Wachtman and Z. H. Kalman (Butterworth-Heinmann, USA, 1993).

PHY-P425 Experiments based on PHY-T425 (2.5 credits):

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

PHY-T427 ENERGY STUDIES-II

Module-1: 1 credit (10 L, 5 T/S/D):
Wind Energy and Technology

Module-2: 1 credit (10 L, 5 T/S/D):
Hydrogen Energy and Fuel Cells

Module-3: 1 credit (10 L, 5 T/S/D):
Ocean Energy and Technology

Module-4: 1 credit (10 L, 5 T/S/D):
Bio Energy and Its Applications

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 R. H. Bube (Academic Priess).
9) Biomass Energy systems, Venkata Ramala and S. N. Srinivas (Tata Energy Research Institue, New Delhi, 1996).
10) Thin Film Solar Cells, K. L. Chopra and S. R. Das (Plenum Press, 1983).
11) Solar Hydrogen Energy Systems, T. Ohta (Pergamon Press, 1979).
12) Hydrogen Technology for Energy, D. A. Maths (Noyes Data Corp.,1976).
13) Handbook-Batteries and Fuel Cell, Linden (McGraw Hill, 1984).
14) Wind Energy Conversion Systems, L. L. Freris (Prentice Hall, 1990).

PHY-P427 EXPERIMENTS BASED ON PHY-T427 (2.5 CREDITS):

1) Determination of calorific value of wood/cow dung using bomb calorimeter.
2) Performance evaluation of solar still.
3) Performance evaluation of flat plate collector.
4) Performance evaluation of evacuated tube collector.
5) Performance evaluation of box type solar cooker.
6) Performance evaluation of parabolidal type solar cooker.
7) To measure the intensity of solar radiation using Pyranometer and solar intensity meter (Suryamapi) and to estimation of standard deviation.
8) Study of domestic/industry electricity bill

PHY-T428 SOFT CONDENSED MATTER-II

Module -1: 1.3 credits (20 L/T/D):
Brownian Motion and thermal fluctuations : Brownian Motion of free particles, Langevin equation, Einstein Relation, Brownian motion in potential field, Fluctuation dissipation Theorem.

Module-2: 0.7 credits (10 L/T/D) :
Colloidal dispersions. Stability and phase behaviour of colloidal systems. DLVO theory.

Module-3: 1 credits (15 L/T/D):
Polymer physics. Basic definitions and terminology. Statistical properties of polymer chains. The ideal chain and the Gaussian chain. Excluded volume effect. Lattice theory of polymer solutions. Mean field approximation. Polymer dynamics.

Module-4: 1 credits (15 L/T/D) :
Non-Equilibrium Systems: Any two topic from the following:
(i) Physics of Active systems
(ii) Growth models
(iii) Capillarity and Wetting phenomenon.

References:

1. *Soft-Condensed Matter* by R. A. L. Jones (Oxford University Press).
2. *Structured Fluids* by T. Witten and P. Pincus (Oxford University Press).
4. *Soft Matter Physics: An Introduction* by M. Kleman and O. D. Lavrentovich (Springer).
5. *The Colloidal Domain* by F. Evans and H. Wennerstrom (Wiley –VCH).
6. *Soft Matter Physics* by Masao Doi (Oxford University Press).
9. *An Introduction to Polymer Physics* by D. I. Bower (Cambridge University Press).
10. *The Physics of Polymers* by G. Strobl (Springer).
11. *Scaling Concepts in Polymer Physics* by P. de Gennes (Cornell University Physics).
12. *Liquid Crystals* by S. Chandrasekhar (Cambridge University Press).
13 Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls and Waves, by Pierre-Gilles de Gennes, Françoise Brochard-Wyart, and David Quéré (Springer)
14 Intermolecular and surface forces (3rd Ed), Jacob N. Israelachvili (Elsevier).

PHY-P428 Experiments based on PHY-T428 (2.5 Credits):

Computational experiments/exercises/mini/project.

PHY-T429 PLASMA PHYSICS AND TECHNOLOGY – II

Module-1: 1 credit (10 L, 5T/S/D):
Cold Plasma Reactors: Plasma systems, DC reactor, RF reactor, microwave reactor, ECR plasma reactor, Magnetically enhanced reactor, Plasma Enhanced Chemical Vapour Deposition and reactors , Reactor clusters, Merits and de-merits of plasma techniques : Case study (RF & ECR plasma).

Module-2: 1 credit (10 L, 5T/S/D):
Applications of Cold plasma: Plasma polymerization, Plasma etching, Plasma enhanced chemical vapor deposition, hallow cathode discharge for thin film deposition, Examples: Polymer thin films, deposition of amorphous Si, polymer thin film for passivation, discuss the process operative in each case. Ion sources using ECR and RF plasma devices , Inductively coupled plasma for elemental analysis, Plasma ashing , surface cleaning, space application, Plasma display devices , Various other applications .

Module-3: 1 credit (10 L, 5T/S/D):
Thermal plasma Reactors: Thermal plasma interaction with matter, Plasma reactors viz. DC arc plasma, Plasma torches, Transferred and non-Transferred arc plasma torches, RF Plasma torches and based reactors, Laser plasma reactors .

Module-4: 1 credit (10 L, 5T/S/D):
Applications of thermal plasmas: Thermal plasma assisted melting, evaporation and condensation, Nucleation and growth phenomena in thermal plasma reactors , Nano-material synthesis, Plasma spray coating, plasma spherodisation, plasma cutting & welding.

Books:

1. Glow discharge processes (Sputtering and Plasma etching): by Brain Chapmn, A (Wiley Interscience Publication, NY, 1980).
2. Thermal Plasmas: Fundamentals and Applications, Volume 1: by Maher I. Boulos, Pierre Fauchais, Emil Pfender (Springer Science+Business Media New York, 1994).
3. Plasma Diagnostics: Holt Greven (North Holand Publishing Company, Amsterdam, 1968).
4. Reactions under Plasma Conditions: by M. VenuGopalan (Wiley Interscience, (NY), London 1971).
5. Cold Plasma in Materials fabrication: From Fundamental to Applications by Alfred Grillb (IEEE Press, NY 1994).
6. Introduction to Plasma Spectroscopy By Hans-Joachim Kunze (Springer Heidelberg Dordrecht London New York, 2009).
7. Plasma Deposition, Treatment, and Etching of Polymers Edited by Riccardo d'Agostino, (ACADEMIC PRESS, INC., 1990)

PHY-P429 Experiments based on PHY-T429 (2.5 credits):

1. Production and study of open arc thermal plasma. Measurement of current, Voltage and power. Study of evaporation rate of anode.
2. Production and study of transferred arc torch operated thermal plasma and generation of Nano-particles of Metal and Metal oxide
3. Production and study microwave excited Electron Cyclotron Resonance plasma and study its properties.
4. Spectroscopic investigation of thermal plasma and calculate the electron temperature using Bolzman plots.
5. Thermal plasma for alloy preparation
6. Cold plasma for etching application
7. Cold plasma for thin film deposition
8. Cold plasma for polymer surface modification
9. Atmospheric plasma for the degradation of organic pollutants.
10. Study of dielectric barrier discharge (DBD) plasma

(Any Five per Semester)

PHY-T430 PHYSICS OF SEMICONDUCTOR DEVICES –II

Module-1: 1 credit (10 L, 5T/S/D):
Optoelectronic and Sensor devices: Photodiodes, p-i-n and p-n photodiodes, heterojunction photodiode, metal semiconductor photodiode, Phototransistors, Gain Bandwidth and Signal to noise ratio, Variation of photo-detectors, Light emitting diodes, Thermistors, Diode-thermal sensors, Transistor thermal sensors, mechanical sensors, Strain gauge, piezoelectric strain gauge, inter-digital transducer capacitor sensor, Magnetic sensors, Hall plate, magnetoresistor, Chemical sensors, metal oxide sensors,

Module-2: 1 credit (10 L, 5T/S/D):
Transistor based devices: Fabrication of field effect transistors, Transistor as an amplifier, High frequency transistor behavior, Thin film transistor architectures, Concept of Integration and planar technology, Basic device characteristics, Junction field effect transistor (JFET) Metal-semiconductor FET, Metal-insulator FET, MOS Field effect transistor, and output and transfer characteristics, Mobility model, short channel MOSFET I-V characteristics, control of threshold voltage, sub threshold characteristics,

Module-3: 1 credit (10 L, 5T/S/D):
Photvoltaic devices (Solar cells): Spectral distribution of solar radiation, photovoltaic effect, types of solar cells, solar constant, absorption of solar radiation in the atmosphere, crystalline Silicon solar cells, thin film solar cells, and multi-junction (tandem solar cells), hybrid solar cells, Dye sensitized solar cells, perovskite solar cells, quantum dot based solar cells. Dark and illuminated characteristics of solar cells, Effect of light intensity on solar cell parameters(Open circuit voltage, Short circuit current, fill factor, efficiency, etc.), Effect of series and shunt resistance on I-V curves due to defects in materials.

Module-4: 1 credit (10 L, 5T/S/D):
Integrated Circuit (IC) Technology: The integrated circuit approach, A short summary of the planar technology, Pattern generation and photomask making, Photolithography, Epitaxy, Oxidation, diffusion, and ion implantation, metallization and interconnections, encapsulation and circuit testing.

Books:
1. An Introduction to Semiconductor Devices, Donald A. Neamen (McGraw-Hill, 2006)
2. Solid State Electronic Devices, B.G. Streetman and S K Banerjee (Pearson Education).
3. Semiconductor Devices: Physics and Technology, S. M Sze (2nd Edition, John Wiley, New York, 2002)
4. Introduction to Semiconductor Materials and Devices, M. S. Tyagi (John Wiley & Sons, 2008)
5. Fundamentals of Semiconductor Devices, Anderson and Anderson (McGraw-Hill).
6. Principles of Semiconductor Devices, Sima Dimitrijev (OXFORD UNIVERSITY PRESS,)
7. Complete Guide to Semiconductor Devices, K.K. Ng (John Wiley & Sons)
8. Modern Semiconductor Device Physics, S M Sze (John Wiley & Sons)
9. Semiconductor Devices: Basic Principles, Jaspreet Singh (John Wiley & Sons, 2001)
10. Semiconductor Device Fundamentals, Robert F. Pierret (Addison-Wesley,1996)
11. Physics of semiconductor devices, Dilip K Roy (Universities press, 2002).
12. Fundamentals of Photonics, Saleh & Teich (Wiley-Interscience, 2007)

PHY-P430 Experiments based on PHY-T430 (2.5 credits):

1. To study photoelectric properties of the semiconductor devices prepared in SEM III.
2. Frequency dependent Capacitance-Voltage measurements on above prepared semiconductor devices
3. (Flat band potential, Dielectric constant, Carrier concentration, etc.)
4. Studies on optoelectronic properties (dark and illuminated J-V characteristics) photovoltaic devices.
5. The effect of intensity of light and light soaking on the photovoltaic devices.
6. Preparation of IR detector devices and their characterization under Dark and IR light source.

(Any Five per Semester)