M. Sc Applied Physics

Course Structure and Syllabus (Effective from Monsoon - 2013)

(Three semesters–Theory & One Semester–Project / Dissertation)

S. No.	Paper Code		L	T	P	C
FIRST SEMESTER						
1	SAP 1001	Mathematical Methods in Physics	3	0	0	3
2	SAP 1003	Electrodynamics	3	0	0	3
3	SAP 1005	Classical Mechanics and Relativity	3	0	0	3
4	SAP 1107	Quantum Mechanics	3	0	0	3
5	SAP 2007	Statistical Physics	3	0	0	3
6	SCS 1054	Programming using C & C Programming Lab	1	0	3	3
7	SAP 1004	Physics Lab – I	0	0	3	2
						Total credits: 20 C
SECOND SEMESTER						
8	SAP 2101	Electronics and Instrumentation	3	1	0	4
9	SAP 2203	Quantum Electronics	3	0	0	3
10	SAP 2105	Atomic, Molecular and Modern Spectroscopy	3	0	0	3
11	SAP 2109	Condensed Matter Physics	3	0	0	3
12	SAP 3109	Fibre Optics and Integrated Optics	3	0	0	3
13	SAP 2002	Physics Lab II - Lasers and Advanced Optics Lab	0	0	3	2
14	SAP 2004	Physics Lab III - Electronics and Instrumentation Lab	0	0	3	2
						Total credits: 20 C
THIRD SEMESTER						
15	SAP 3201	Nuclear Physics and Engineering	3	0	0	3
16	SAP 3203	Plasma Physics	3	1	0	4
17	SAP 3005	Materials Science	3	0	0	3
18	SAP 3002	Physics Lab IV - Advanced Materials Science Lab	0	0	3	2
19	SAP 3004	Physics Lab V - Plasma Beams and Application Lab	0	0	3	2
20	Breadth Paper: of PG level of other Departments*		3	0	0	3
	Elective: (Any one paper)					
21	SAP 3107	Nonlinear Optics	3	0	0	3
22	SAP 3011	Nanostructures and Nanomaterials	3	0	0	3
23	SAP 3013	Thin Film and Vacuum Technology	3	0	0	3
24	SAP 3015	Advanced Experimental Techniques	3	0	0	3
25	SAP 3017	Medical Physics	3	0	0	3
26	SAP 3019	Biophysics	3	0	0	3
						Total credits: 20C
FOURTH SEMESTER						
27	SAP 4001	Project / Dissertation				**20 C**
						Total credits: 20 C
		Total credits of all semesters:				**80 C**

L: Lecture, T: Tutorial, P: Practical, C: Credit

*** Should not have been taken earlier by the student in any other programme**

Semester- I

SAP 1001 Mathematical Methods in Physics (3-0-0-3)

Matrix Algebra: Definition, Algebra of matrices, Special matrices, Eigen-values and Eigen-vectors, LU-Decomposition, Solution of Linear system by LU-Decomposition. **(4)**

Complex variables: Analytic functions, Cauchy-Riemann conditions, Cauchy's Integral theorem and Integral formula, Laurent expansion, Singularities, Evaluation of residues, Residue theorem. **(5)**

Second order differential equations: Partial differential equations of theoretical physics, separation of variables – ordinary differential equations, singular points, series solutions – Frobenius' method, **(4)**

Special Functions: Gamma and Beta functions, Relation between Gamma and Beta functions, Duplication formula, Error function, Bessel's Functions of different kinds, Integral representations of Bessel's Functions, Orthogonality of Bessel's Functions, Modified Bessel's Functions, Legendre Polynomials, Recurrence relations, Rodrigue's formula, Orthogonality of Legendre Polynomials, Associated Legendre Function, Hypergeometric Functions and its integral representation. **(12)**

Fourier Series: General Properties, Advantage and uses of Fourier series, Applications of Fourier series. **(4)**

Integral Transform: Laplace Transform, Inversion, Convolution Theorem, Applications of Laplace Transform; Fourier Transform, Inversion, Fourier Sine and Cosine transform, Convolution Theorem, Fourier transforms of derivatives. Applications of Fourier Transform. **(6)**

Textbooks:

1. Hans J. Weber George B. Arfken, *Mathematical Methods for Physicists*, (2005), Academic Press.
2. L. A. Pipes, *Applied Mathematics for Engineering and Physics* (1958) McGraw-Hill.

References:

1. Charlie Harper, *Introduction to Mathematical Physics* (2003), Prentice-Hall India.
2. Erwin Kreyszig, *Advanced Engineering Mathematics* (1999), Wiley.
3. N. P. Bali, A. Saxena and N.C. S. W. Iyengar, *A Text Book of Engineering Mathematics* (1996), Laxmi Publications (P) Ltd.

SAP 1003 Electrodynamics (3-0-0-3)

Electrostatics: The concept of a scalar potential. Poisson's and Laplace's equations for scalar potential. Green's theorem, Electrostatic field energy density. Solutions of Laplace's equation in rectangular, spherical and cylindrical coordinates using the method of separation of variables. Multipole expansion of potential due to a localized charge distribution. Dipole and quadrupole fields. Interaction energy of dipole and quadrupole in an external field. Electrostatics in matter; Polarization and electric displacement vector. Electric field at the boundary of an interface. Clausius - Mossotti equation. **(13)**

Magnetostattics, Time Varying Fields and Maxwell's Equations: Foundations of Magnetostatiscs, Scalar and Vector potentials, Magnetic moment of a current distribution. Macroscopic magnetostatics, Magnetization. M and H vectors, Maxwell's displacement current. Maxwell's equations. Vector and scalar potential. Lorentz and Coulomb gauge. Conservation of energy and momentum of a system of charged particles and electromagnetic fields. Field energy and field momentum. **(13)**

Solutions of Maxwell's Equations and Radiation: Plane waves in dielectrics medium. Polarization, reflection and refraction at a plane interface between dielectrics. Phase velocity and group velocity, spreading of a pulse propagating in a dispersive medium, propagation in a conductor, skin depth. Waveguides and cavity resonator. Radiation due to localized oscillatory source, near and far zones, radiated power due to an electric dipole, magnetic pole, example of a centre - fed linear antenna as an electric dipole radiator. Retarded green's function. Lienard-Wichert potentials and fields for a point charge. Larmor's formula for power radiated by a slowly moving accelerated charge. Thomson scattering, Rayleigh scattering and application to nanoparticles. **(14)**

Textbook:
1. *Classical Electrodynamics,* J. D. Jackson

References:
1. *Introduction to Electromagnetic Fields and Waves*, D. R. Corson and P. Lorrain
2. *Introduction to electromagnetics,* D. J. Griffiths
3. *Electromagnetic Theory,* J. A. Stratton, McGraw Hill

SAP 1005 Classical Mechanics and Relativity (3-0-0-3)

Constrained Motion: Constraints, Classification of Constraints, Principal of Virtual Work, D'Alembert's principal and its applications (**3**)

Lagrangian formulation: Generalized coordinates, Langrange's equations of motion, properties of kinetic energy function, theorem on total energy, generalized momenta, cyclic-coordinates, integrals of motion, Jacobi integrals and energy conservation, Concept of symmetry, invariance under Galilean transformation, velocity dependent potential. **(8)**

Hamilton's formulation: Hamilton's function and Hamilton's equation of motion, configuration space, phase space and state space, Lagrangian and Hamiltonian of relativistic particles and light rays. **(5)**

Canonical Transformations: Generating function, Conditions for canonical transformation and problem. **(5)**

Poisson Brackets: Definition, Identities, Poisson theorem, Jacobi-Poisson theorem, Jacobi identity, (statement only), invariance of PB under canonical transformation. **(4)**

Rotational Motion: Rotating frames of reference, inertial forces in rotating frames, Larmour precision, electromagnetic analogy of inertial forces, effects of Coriolis force, Foucault's pendulum. **(5)**

Central Force: Two body central force problem, stability of orbits, condition for closure, integrable power laws, Kepler's problems, orbits of artificial satellites, Virial theorem. **(5)**

Relativity: Special theory of relativity, Lorentz's transformation, covariant four–dimensional formulations, force and energy equations in relativistic mechanics **(5)**

Textbook:

1. Classical Mechanics by H. Goldstein, Pearson Education Asia.

References:

1. Classical Dynamics of Particles and Systems by Marion and Thornton, Third Edition, Horoloma Book Jovanovich College Publisher.
2. Classical Mechanics by P.V.Panat, Narosa Publishing Home,, New Delhi.
3. Classical Mechanics by N.C.Rana and P.S.Joag, Tata Mc-Graw Hill Publishing Company Limited, New Delhi.
4. Introduction to Classical Mechanics by R.G.Takwale and P.S.Puranik, Tata Mc-Graw Hill Publishing Company Limited, New Delhi.

SAP 1107 Quantum Mechanics (3-0-0-3)

Introduction to quantum mechanics: Schrödinger wave equation, interpretation of wave function, probability current density. Solutions: one dimensional square well and barrier, Linear harmonic oscillator, Heisenberg and quantum mechanical treatments. Spherically symmetric potential in three dimensions, hydrogen atom. **(9)**

Scattering theory and WKB approximation method: Scattering cross sections and coefficients, scattering by spherically symmetric potentials, scattering by a coulomb field. Born approximations, WKB approximations, boundary conditions in the quasi classical case, **(9)**

Angular momentum, spin and identical particles: Angular momentum, various commutation relations, eigenvalues and eigenfunctions of the angular momentum, spin, spin operators, Pauli's spin matrices, spinors, the principle of indistinguishability of identical particles, Pauli's exclusion principle, **(8)**

Perturbation theory: Perturbation independent of time, first and second order, the effect of the electric field on the energy levels of an atom (Stark effect), perturbations depending on time, first order transitions, constant perturbation, Fermi golden rule, interaction of an atom with electromagnetic radiation, the Einstein's A & B coefficients. **(7)**

Relativistic wave equations: Klein-Gordon equation for a free particle and particle under the influence of an electromagnetic potential, Dirac's relativistic Hamiltonian, Dirac's relativistic wave equation, significance of negative energy states, **(7)**

Textbook:

1. Quantum Mechanics by L. I. Schiff. (Tata McGraw Hill, New Delhi)

References:

1. Quantum Mechanics by L. D. Landau and E. M. Lifshitz (Pergamon, Berlin)
2. Introduction to Quantum Mechanics; D. J. Griffith
3. Quantum Mechanics by A. K. Ghatak and S. Lokanathan (McMillan India)
4. A Textbook of Quantum Mechanics by P. T. Mathews (Tata McGraw Hill)

SAP 2007 Statistical Physics (3-0-0-3)

Introduction to Statistical Physics: Need for statistical mechanics, Basic ideas of probability and statistics, Gaussian and Poisson distribution, central limit theorem, Vander Walls equation of state. **(6)**

Formulation of equilibrium statistical mechanism: Concept of phase space, distribution function, Liouville equation, basic postulates of statistical mechanics, equipartition theorem, classical ideal gas, Gibbs paradox **(5)**

Ensembles: micro-canonical, canonical, grand canonical ensembles, partition function, connection to thermodynamics, application of various ensembles **(5)**

Quantum statistics: Bose-Einstein and Fermi-Dirac statistics, Ideal Bose gas, Bose-Einstein condensation, Debye theory of specific heat, ideal Fermi gas, **Imperfect gas**: Many-body problems, imperfect Bose gas, Imperfect Fermi gas **(10)**

Basic ideas of phase transition: Thermodynamics of phase transition, metastable states, Yang-Lee theory, coexistence of phase, second order phase transition, critical phenomena, critical exponent **(6)**

Density matrix formalism: Statistical approach, properties of density matrix, pure states, coherent states, equation of motion, first order theory, reduced density operator **(4)**

Noise: Concept of reservoir, Markov process, Reservoir theory, fluctuation-dissipation theorem, equation of motion under the action of reservoir, damping mechanism **(4)**

Textbook:

1. Statistical Mechanics, Kerson Huang, John Wiley and Sons
2. Statistical Physics, Landau and Lifshitz, Pergamon Press

References:

1. Statistical Mechanics, R. K. Patharia, Pergamon Press
2. Introduction to Statistical Physics, Kerson Huang, Taylor & Francis
3. Statistical Physics, S. K. Ma, World Scientific Publishing, Singapore

SCS 1054 Programming Using C & C Programming Lab (1-0-3-3)

MODULE – I

Problem solving using Algorithms and Flow Charts, Basic Structure and execution of C programmes, Constants, Variables, and Data Types and various type of declarations, Different type operators and Expressions, Evaluation of Expressions, Operator Precedence and Associability, Mathematical Functions.

MODULE –II

Managing Input and Output operations, Decision Making and Branching Decision Making and Looping.

MODULE – III

One – dimensional Arrays and their declaration and Initializations, Two-dimensional Arrays and their initializations, Multidimensional Arrays, Dynamic Arrays, String Variables, Reading and Writing Strings, Arithmetic Operations on characters, Putting Strings together, Comparison of Two Strings, String – handling functions, Table and other features of Strings.

MODULE –IV

Need for user –defined Functions, Definition of Functions, Return values and their types, Function calls and Declaration, Arguments and corresponding return values, Functions that return multiple values, Nesting of functions, Recursion, Passing arrays and strings to functions, The Scope, Visibility and Life time of variables.

MODULE –V

Defining Structure, Declaring Structure Variable and Accessing Structure Members, Initialisation of Structure, Comparing Structure Variables, Operation on Individual Members, Arrays of Structures, Structures within structures, Structures and Functions, Unions, Size of Structures, Bit Fields.

MODULE – VI & VII

Understanding Pointers, Accessing the Address of a Variable, Declaration and Initialisation of Pointer Variables, Accessing a Variable through its Pointer, Chain of Pointers, Pointer Expressions, Pointer Increments and Scale Factor, Pointers and Arrays, Pointers and Arrays, Pointers and Character Strings, Arrays of Pointers, Pointers and Function Arguments, Functions Returning Pointers, Pointers and Structures, File Management in C.

Different assignments based on **C** language will be given to the students.

Textbook:

1. E. Balagurusamy – Programming in ANSI C, 3rd Edn. , TMH, New Delhi ; 2004

Reference:

1. Y.P.Kanetkar – Let us C, 4th Edition, BPB Publication , New Delhi; 2002

SAP 1004 Physics Laboratory-I (0-0-3-2)

1. Determination Band gap of a semiconductor
2. Determination of Planck's constant using white light and colour filter
3. Determination of dielectric constant of a given insulating material
4. Determination of elastic constants of a given material using Hyperbolic & Elliptic fringes
5. Measurement of variation of Electrical conductivity of metals and alloys with temperature using four point probe methods
6. Determination of Wavelength and dλ (between D1 & D2) of sodium vapor light using Michelson Interferometer
7. Thermal expansivity using interferometric technique
8. Measurement of wavelength of light by Fabry Perot Interferometer
9. Understand how a Fabry-Perot Interferometer works and use it to observe the hyperfine splitting of spectral lines. or
10. Assemble and align Fabry-Perot interferometer, and use it to measure differential wavelength for the Na doublet.
11. Measurement of Hall voltage and Hall Coefficient of a semi-conducting material.
12. Current-Voltage characteristics of an anodic vacuum arc with different materials as consumable anode (Cu, Al, Ni)
13. Current-Voltage characteristics of dc glow discharge
14. Breakdown voltage determination of a Zener diode from it characteristic curve
15. FET / MOSFET characteristics and amplifier design
16. Determination of ionization potential of Lithium
17. Determination of half-life of In / Co60
18. Testing the elegance of fit of Poisson distribution to cosmic ray bursts by chi-square test
19. Determination of e/m of electron by Normal Zeeman effect using Fabry-Perot etalon
20. Calibration of a vacuum gauge (Pirani) with the aid of McLeod gauge.
21. Determination of Lande-g factor of a paramagnetic sample using electron spin resonance

Semester – II

SAP 2101 Electronics and Instrumentation (3-1-0-4)

Electronic Devices: Varactor diode, photo-diode, Schottky diode, solar cell, Principle of Operation and I-V Characteristics of FET, MOSFET. (4 classes)

Integrated Analog Electronics: Basics of operational amplifiers, voltage gain, input and output impedance of inverting amplifier, non-inverting amplifier; phase inverter, scale changer, integrator, differentiator. voltage multiplier, limiter, clipper, clamper and peak-to-peak detector, difference amplifier, instrumentation amplifier, active filters (low-pass, high-pass, band-pass, band-reject/ notch), RC phase shift and Wein bridge oscillators. (7 classes)

Advanced applications of op-amps: Comparators, schmitt trigger, multivibrators, AMV and MMV using 555 timer, waveform generation, power supply circuits, analog computation using op-amps. D/A converters, binary weighted, ladder type, A/D converters, simultaneous, counter type, successive approximation type, dual slope converter. (7 classes)

Digital Electronics: Introduction to various logic families; Combinational Circuits, adders, subtracters, multiplexers, demultiplexers, encoders, decoders, Sequential circuits, flip-flops, RS, JK, Master Slaves, T and D Flip-Flops, controlled registers, shift registers, synchronous and asynchronous counters, controlled counters, up/down counters, ring counter; Memories ROM, PROM, RAM (5 classes)

Introduction of measurements and measurement systems: Measurement basics: range, resolution, linearity, hysteresis, reproducibility and drift, calibration, accuracy and precision. Errors and noise in measurements, basic noise reduction techniques. (2 classes)

Electronic Instruments: Classification and principles of operation analog electronic voltmeter, DC voltmeter, advantages of digital over analog processing. Digital voltmeter and frequency meter, Kelvin Double Bridge, Maxwell's Bridge; Signal conditioning. (7 classes)

Transducers: Definition, classification, principle of analog transducer: resistive (strain gauge, thermistor and RTD), capacitive, piezoelectric, thermocouple and LVDT, Actuators: pneumatic cylinder, relay, solenoid. (4 classes)

Textbooks:

1. Electronic Devices: Solid State Electronic Devices – B. G. Streetman, PHI, Physics of Semiconductor Devices – S. M. Sze.
2. Electronics Circuits & Systems: Integrated Electronics - Millman & Halkias, McGraw Hill,
3. Operational Amplifiers and Linear Integrated Circuits - R. F. Coughlin, F. F. Driscoll, PHI.,
4. Operational Amplifiers and Linear Integrated Circuits - R. A. Gayakwad, PHI.
5. Digital Electronics: Digital Electronics – Malvino and Leach, TMH.
6. Instrumentation: Electrical and Electronic Measurements and Instrumentation - A. K. Sawhney,
7. Electronic Instrumentation - H. S. Kalsi, Modern Electronic Instrumentation & Measurement Techniques - Helfrick & Cooper

References:

1. Electronic Devices and Circuits – T.F. Bogart Jr., J.S.Beasley and G.Rico,Pearson Education, 6th edition,2004.
2. Electronics Fundamentals and Applications, J. D. Ryder, Prentice Hall of India , New Delhi , 1987.

3. Electrical and Electronic Measurements and Instrumentation, Sawhney, Dhanpatrai and Sons, New Delhi, 1982.

SAP 2203 Quantum Electronics (3-0-0-3)

1. **Beam Optics:** Paraxial theory, Gaussian beam transmission through optical components, Hermite–Gaussian beams, Laguerre-Gaussian and Bessel beams. [5]

2. **Optical Resonator (cavity)**: Theory of resonator, ABCD matrix, Stable and unstable resonator, Longitudinal and transverse mode of the cavity. [5]

3. **Electro-optics** and magneto-optics: Light propagation in anisotropic media. Theory of electro-optic, magneto-optic and acousto-optic effects and devices. [5]

4. **Laser principle and properties**: Coherence, monochromaticity, divergence .Principle of laser: Absorption and Emission of light, Population inversion, Gain oscillation, Gain saturation, Threshold, Rate – equation, 3 and 4 level systems. [5]

5. **Types of lasers**: Continuous wave, Pulsed, Q- switched and Mode locked laser. Different lasers Systems: Design (in brief) and functioning of different lasers - Ruby Laser, Nd: YAG laser He-Ne laser, CO_2 laser, Argon ion laser, Excimer laser, Semiconductor laser, Fiber laser. [5]

6. **Laser safety and Applications:** Alignment, Targeting, Tracking, Dimension gauging, Velocity Measurement, Surface quality measurement, Contour mapping, Profile detection, Determination and measurement of atmospheric pollution. Holographic non destructive testing (NDT). [5]

7. Interaction of atom with electromagnetic field, Rabi oscillation, linear absorption and amplification- Beer's Law. Introduction to non-linearity of matter towards its optical properties. Brief introductions to harmonic generation and parametric processes. Nonlinear material (Brief discussion). [5]

Textbooks:

1. Elements of Photonics, K. Iizuka
2. Laser Fundamentals, William T. Silfvast, Cambridge University Press (1998)

References:

1. K. Shimoda, Introduction to Laser Physics, Springer Verlag, Berlin (1984)
2. Laser Electronics: J. T. Verdeyen, 3rd Ed, Prentice Hall (1994)
3. Laser Physics, M. Sargent III, M. O. Scully and W. E. Lamb, Jr.

SAP 2105 Atomic, Molecular and Modern Spectroscopy (3-0-0-3)

1. Atomic Physics: Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen; Hyperfine structure and isotopic shift; Spectral terms of two electron atoms, terms for equivalent electrons, L-S and J-J coupling schemes, Singlet-Triplet separation for interaction energy of L-S coupling. Lande Interval rule, Zeeman, Paschen Back & Stark effect; width of spectral lines

2. Molecular Spectroscopy: Rotational, vibrational and electronic spectra of diatomic molecules; Frank–Condon principle and selection rules, Raman Effect, Rotational Raman spectra. Vibrational Raman spectra. Stokes and anti-Stokes lines and their Intensity difference, Rule of mutual exclusion, Importance of neutral hydrogen atom, Molecular hydrogen, Fluorescence and Phosphorescence

3. NMR Spectroscopy: Nuclear spin, nuclear resonance, saturation, chemical shift, de shielding, spin-spin interaction, coupling constant J, basic ideas about instrumentation of NMR, applications.

4. Mass Spectroscopy: Ion production, fragmentation, ion analysis, ion abundance, mass spectroscopy, instrumentation and application.

5. Mossbauer Spectroscopy: Spectral parameters and spectrum display, Isomer shift, quadruple splitting, hyperfine interaction and applications

Suggested Books:

1. "Introduction to Atomic Spectra", H. E. White, McGraw-Hill.
2. "Atomic Physics", G. P. Harnwell & W. E. Stephens, McGraw-Hills Book Company, Inc.
3. "Fundamentals of Molecular Spectroscopy" C. N. Banwell & E. M. McCash, Tata McGraw-Hill
4. "Modern Spectroscopy", J. M. Hollas, John Wiley
5. "Preparation of Molecular Physics" A. Beisen, McGraw-Hill.
6. The Feynman Lectures on Physics by R. B. Feynman, R. B. Leighton, M. Sands, Narosa Publishing House

SAP 2109 Condensed Matter Physics (3-0-0-3)

1. **Crystal Structure:** Revision of concepts, crystal structure, simple crystals, Miller indices, lattice planes, Bragg's law (SS), structure determination, Laue's method, powder crystal method, rotating crystal method, electron diffraction, neutron diffraction, reciprocal lattice, Ewald's construction, symmetry operations [6]

2. **Lattice vibrations:** Lattice specific heat, classical theory, experimental results, Einstein's theory (SS), density of states in 1-D and 3-D, Debye theory of specific heat, thermal conductivity of solids, thermal resistance of solids. Vibrations of a one-dimensional chain of (a) similar atoms and (b) two types of atoms, optical and acoustic modes, concept of phonons. [6]

3. **Energy band theory:** Classical free electron theory of metals, drift current, conductivity, mobility, Hall effect (SS). Wave mechanical treatment of electron in a box, electrons in a periodic potential, Bloch's theorem, Kronig-Penney model, Brillouin zones, energy band structure in conductors, semiconductors, insulators, Fermi-Dirac distribution, Fermi energy density of states, Fermi surface, effective mass. [6]

4. **Magnetism:** Classification of magnetic materials, Langevin's theory of paramagnetism, ferromagnetism, hysteresis, ferromagnetic domains, antiferromagnetism, ferrimagnetism, ferrites, Curie's law, magnetic ordering, Weiss theory of paramagnetism, quantum theory of para & ferromagnetism, paramagnetic resonances, ferromagnetic resonance [6]

5. **Dielectrics and ferroelectrics:** Different types of polarization and polarizability (SS), Clausius-Mossotti relation, dielectric constant, dielectric breakdown, dielectric losses, ferroelectric, piezoelectric, pyroelectric behavior. Frequency dependence of dielectric properties, temperature dependence, ferroelectric-paraelectric phase transitions. [6]

6. **Superconductivity**: History, general properties, measurements, critical field, temperature, current, Meissner effect, type-I and type-II superconductors (SS). London equation, penetration depth, optical properties, Cooper pair, BCS theory (Qualitative), coherence length, electron-phonon interaction, flux quantization, Josephson junction, high T_c superconductors. [6]

7. **Introduction to special materials:**
   Optoelectronic materials; Materials for solar cells; Liquid Crystal [4]

References:

1. Introduction to Solid State Physics: C. Kittel, Wiley Eastern ltd., New Delhi - 1988.
2. Solid State Electronics Engineering Materials, S. O. Pillai, Wiley Eastern ltd. New Delhi, 1992.
3. Solid State Physics: Ashcroft & Mermin
4. Solid State Physics: A. J. Dekker, Macmillan, new Ed, 2011

SAP 3109 Fiber Optics and Integrated Optics (3-0-0-3)

1. **Overview of Optical Fibers**: Structure of optical fibers. Step-index and graded index fibers; light propagation in optical fibers. Single mode, multimode and W-profile fibers. Ray Optics representation, numerical aperture and acceptance angle. **[5]**

2. **Attenuation and Dispersion:** Attenuation in optical fibers - Absorption - Scattering losses - Radiative losses. Dispersion effects, Material dispersion - Combined effect of material and multipath dispersion - RMS pulse widths and frequency response - Model Birefringence **[5]**

3. **Wave Propagation in Step-index Fibers**: Modes in an ideal step-index fiber, Time dispersion - Material Dispersion and Waveguide dispersion in single-mode fibers. **[5]**

4. **Wave Propagation in Graded-index Fibers**: Modes in graded index fibers. No. of propagating modes. Inter model and Intra model dispersion in graded-index Fibers. Mode coupling. **[5]**

5. **Fabrication processes**: Different fiber fabrication methods- chemical vapor deposition method, axial vapor deposition, plasma enhanced modified CVD. **[5]**

6. **Photonic Crystal Fibers**: guiding principle, index guiding and band gap guiding. Types of fibers, dispersion, birefringence, polarization and nonlinear property. Device application**.** **[5]**

7. **Theory of Optical Waveguides**: Planar, rectangular, Channel and strip loaded waveguides; symmetric and asymmetric waveguide. Step-index and graded index waveguides, Electro-optic and acousto-optic waveguide devices. Modulators, Waveguide Couplers and integrated optics devices. **[5]**

Textbooks:

1. Introduction to Optical fibers: A.K. Ghatak and K. Thyagarajan
2. Optoelectronics: AmonYariv

References:

1. Optical Fiber Communication Systems by Gerd Keiser.
2. Optical Communication Systems by John Gowar.

SAP 2002 Physics Laboratory II (Lasers & Advanced Optics Lab) (0-0-3-2)

1. Measurement of screw parameters using a laser beam.
2. Measurement of Electro optic coefficient using Kerr effect.
3. Measurement of Magneto optic effect using Faraday effect
4. Optical characterization of thin film (measurement of thickness, uniformity, surface quality and adhesion).
5. Measurement of thickness of thin films using Michelson interferometer.
6. Measurement of coherence length using Michelson interferometer.
7. Measurement of atomic spectra of discharge lamp (H_2, He, Ne).
8. Construction and reconstruction of an object using holography.
9. Nondestructive testing using double exposure holography.
10. Optimization of Nd-YAG laser for drilling hole with $\phi = 2mm$, h=2mm.
11. Characterization of drill with optical microscope.
12. Micromachining (SS, AL) using Nd-YAG laser.
13. Diffraction of light by straight edge.
14. Reflection of white light from a metal surface and determination of n and k.
15. Resolving power of a plane transmission grating.

SAP 2004 Physics Laboratory III (Electronics & Instrumentation Lab) (0-0-3-2)

1. Design and performance study of two stage CE, RC coupled BJT amplifier with feedback
2. Determination of operational amplifier parameters: open loop gain, input impedance and output impedance, offset voltage and CMRR
3. Design and performance study of regulated dc power supply
4. Design and performance study of inverting, non-inverting and unity gain, differentiator, integrator amplifier using op-amp
5. Design and performance study of a constant current source
6. Design and performance study of a voltage controlled oscillator
7. Design and performance study of Schmidt trigger circuit
8. Design and performance study of astable multivibrator and mono-stable multivibrator
9. Design and performance study of function generator, RC phase shift oscillator, Wien bridge oscillator
10. Design and performance study of active filters (Low pass, high pass, band pass, band reject)
11. Design and performance study of logarithmic and anti-logarithmic amplifier for linearization of nonlinear measuring instruments.
12. Design and performance study of 8-bit ADC using ADC-0808
13. Design and performance study of thermocouple based temperature controller
14. Combinational circuits: Adders, multipliers, magnitude comparators.
15. Sequential circuits : Flip flops, counters, shift registers.(ripple counter with D type flip-flops; J-K flip-flop and its application to counting)
16. Experiment on multiplexing and de-multiplexing
17. Design of resistive bridge with error amplifier

∗ All the above mentioned experiments should preferably be simulated using MultiSIM before breadboarding and their performance may be compared with those obtained by simulation.

Semester III

SAP 3201 Nuclear Physics and Engineering (3-0-0-3)

1. **Nuclear Models**
   Liquid drop model, semi-empirical mass formula, transitions between odd A isobars, transitions between even A isobars, odd-even effects & magic numbers, shell model

2. **Two nucleon problem**
   Ground state of deuteron, excited state of deuteron, nature of nuclear forces, spin-dependence of nuclear force tensor forces, meson theory of nuclear force

3. **Scattering**
   Neutron-proton scattering at low energies, cross-section, scattering cross-section, scattering length, proton-proton scattering at low energies,

4. **Interaction of radiation with matter**
   Interaction of charged particles with matter, stopping power of heavy charged particles, energy loss of heavy ions and electrons, Cerenkov radiation, absorption of gamma rays, photoelectric effect, Compton effect and pair production

5. **Accelerators & Detectors**
   Electron source, ion source, linear accelerator, synchrotron, introduction to advance accelerator (LHC)
   Ionization chamber, scintillation counter, semiconductor counter, Cerenkov detectors

6. **Elementary particles**
   Classification of elementary particles, particles and anti particles, fundamental interactions (response of particles to strong, electromagnetic and weak interactions), elementary particles quantum numbers, conservation laws and symmetry, the CPT theorem

Books Recommended:

1. Nuclear Theory- Roy and Nigam
2. Nuclear Physics-D C Tayal
3. Nuclear Physics : D. Halliday
4. Nuclear Physics: I. Kaplan
5. Physics of Particle Accelerators:-Kalus Wille
6. Elementary Particles: I S Hughes

SAP 3203 Plasma Physics (3-1-0-4)

1. Introduction to Plasma: The fourth state of matter, collective behaviour, charge neutrality, space and time scales, Concept of plasma temperature, Debye length, plasma frequency, plasma parameters and criteria for plasma state. Debye Shielding, Plasma sheath, Plasmas in nature and laboratory [6]

2. Basic Processes in plasmas: Collisions in plasmas, Ionization and the Saha equation, LTE and equilibrium models, Recombination, Concepts of diffusion, mobility and electrical conductivity, Ambipolar diffusion, Effect of magnetic field on the mobility, diffusion of plasma in presence of magnetic field. [8]

3. Plasma Theory: Motion of charged particles in Electric and magnetic fields, Concepts of elementary kinetic theory of plasmas, Boltzmann and Vlasov equation, Fluid theory of plasma, single & multi fluid approximations, generalized Ohm's law, MHD equations [8]

4. Plasma Oscillations and waves: Langmuir oscillations, ion waves, electromagnetic waves along and perpendicular to B_o, Alfven waves. [4]

5. Plasma production: Electrical discharges, Electrical Breakdown in gases, glow discharge, self-sustained discharges, Paschen curve, high frequency electrical discharge in gases, electrode less discharge, Capacitively and inductively coupled plasmas, Electrical arcs. [6]

6. Plasma diagnostics: Langmuir probe, Spectroscopic diagnostics. [4]

7. Plasma Applications: Controlled thermonuclear fusion, tokamak, MHD generator, plasma display, industrial applications of plasmas, hazardous waste disposal. [4]

Textbooks:

1. Introduction to Plasma Physics and Controlled Fusion, Francis F. Chen , Springer; 2nd ed. 1984. latest edition. 2006.
2. Fundamentals of plasma physics, J. A. Bittencourt, 3rd Edition Springer-Verlag New York Inc., 2004
3. The Physics of Plasmas, T. J. M. Boyd and J. J. Sanderson, Cambridge University Press, 2003
4. Cold Plasma in Materials Fabrication from Fundamentals to Applications, A. Grill, (IEEE Press, New Jersey, 1994)
5. Reactions under Plasma conditions Vol. I and II, Venugopalan

SAP 3005 Materials Science (3-0-0-3)

Introduction: Metallic materials, Polymeric materials, Ceramic materials, Composite materials, Electronic materials, New materials. **(2)**

Imperfections in solids: Types of imperfections, Point defects. Dislocations: Edge dislocation & Screw dislocation, Burger's vector, Concepts of dislocation density, Surface defects, Volume defects, vibrational defects. **(4)**

Mechanical Properties of Materials: Elastic and plastic deformation, effects of temperature, effect of grain size, creep fracture and fatigue, factors affecting mechanical properties of solids, defects in crystalline solids, dislocations, strengthening mechanics, cold working and annealing, solute-solution hardening, precipitation hardening, diffusion hardening, strain hardening, dispersion hardening. **(6)**

Phase Equilibrium: Concept, phase stability, diagrams, rules. Fe-C phase transformations in ferrous alloys, properties of ferrous and non-ferrous alloys and their applications, Techniques for phase diagrams, Single & Binary phase diagram, Lever's rule, Gibbs phase rule. **(4)**

Glasses, ceramics, composite and Polymeric materials: Ceramic and refractories, glassy state, clay products, characterizations, properties and applications of glass-ceramic materials. Composites: particle- reinforced composites, fibre – reinforced composites, their applications.

Polymers: Molecular shape, structure and configuration, crystallinity, copolymers, thermoplastic and thermosetting polymers, mechanical behavior of polymers, elastomers, polymer additives, Applications of different types of polymers. **(9)**

Superconducting materials: Basic phenomena, Meissner effect, Magnetic properties of type-I and type-II superconductors, Energy gap, London equations, Coherence length, Cooper pairs, BCS theory (qualitative), Josephson effect, SQUID, Flux quantization, Introductory information about high-temperature superconductors, applications. **(5)**

Introduction to new materials: Smart materials, Nanomaterials & Biomaterials - definitions, classifications, examples and applications. **(3)**

Advanced experimental techniques: Introduction to RBS, SIMS, FTIR, ESR & Mossbauer spectroscopy and their applications for identifications of materials. **(7)**

Textbook:
1. Materials Science and Engineering, An Introduction, W.D. Callister, Wiley

References:

1. Solid state physics, N.W. Ashcroft and N. D. Mermin, Saunders College.
2. Principles of the solid state, H. V. Keer, Wiley Eastern.
3. Material Science, J. C. Anderson, K. D. Leaver, J. M. Alexander, R. D. Rawlings, ELBS.
4. Handbook of Liquid Crystal by Kelker and Hatz, Chemie-Verlag.

SAP 3002 Physics Lab IV - Advanced Material Science Laboratory (0-0-3-2)

1. Stress-strain properties of materials
2. Deflection test of metal beams.
3. Mechanical testing of materials
4. Preparation of high T_c compounds and T_c measurements.
5. Hall voltage measurement
6. Contact angle measurement
7. Experiment on piezoelectric effect
8. To study hysteresis property of ferromagnetic material.
9. To find out the surface morphology and roughness of a treated and untreated film by using Atomic Force Microscope (AFM) in its semi – contact mode
10. To study the variation of mass with temperature with the help of TGA (Thermogravimetric Analysis) setup
11. To study the morphology of a sample using SEM and to study elemental analysis by EDX method.
12. To determine the thermodynamic constants and glass transition temperature of a given polymer sample using Deferential Scanning Calorimeter (DSC)
13. To measure the frequency dependence of dielectric constant of a ferroelectric material (BaTiO3) using an ‘Impedance meter’.
14. To characterize the given sample (e. g. Benzoic acid) using Fourier Transform Infrared Spectroscopy (FTIR) technique.
15. To find the band gap of a wide band gap semiconductor film by measuring its absorbance of light using UV-visible spectrophotometer.

SAP 3004 Physics Lab V - Plasma Beams and Applications Laboratory (0-0-3-2)

1. Verification of Paschen curve and find out ionization law
2. Current-Voltage characteristics of a Cascaded Plasma Arc Generator
3. Estimation of plasma torch efficiency using energy balance.
4. Measurement of plasma parameters of a dc glow discharge using single and double probe
5. Measurement of conductance of cylindrical pipe with the help of rotary pump.
6. Measurement of electron temperature using spectroscopic method.
7. Study of wave propagation in a glow discharge plasma
8. Study of anodic vacuum arc characteristics and deposition of thin film.
9. Determination of compound formation and grain size using XRD.
10. Study of dc magnetron thin film deposition unit.
11. Sputtering of target using magnetron
12. Characterization of thin films using AFM and determination of rms roughness of films.
13. Characterization of thin films using SEM / EDX, determination of average grain-size and composition of a thin film.
14. Characterization of thin films using XRD and grain-size determination using Scherrer's formula
15. Measurement of resistivity of thin films using four probe.

Breadth Paper of PG level of other Department

*** Should not have been taken earlier by the student in any other programme**

Electives

SAP 3107 Nonlinear Optics (3-0-0-3)

1. **Origin of Nonlinear Optical Phenomena:** Introduction to nonlinear optics, description of nonlinear optical interaction, phenomenological theory of nonlinearity, nonlinear optical susceptibilities, second and third order optical susceptibilities. [5]

2. **Second harmonic Generation:** Sum and difference frequency generation, second harmonic generation (SHG), phase matching of SHG, quasi phase matching, electric field induced SHG (ElFISH), optical parametric amplification. **[5]**

3. **Two level atoms:** Nonlinear Optics in two level approximations, Density matrix equation, closed and open two level atoms, steady state response in monochromatic field, Rabi oscillations, dressed atomic state, optical wave mixing in two level systems. **[5]**

4. **Optical phase conjugation**: Principle, Aberration correction by OPC, Application of OPC in signal processing. [5]

5. **Intensity dependent phenomena:** Intensity dependent refractive index, self focusing, self phase modulation and spectral broadening, optical continuum generation by short optical pulse. Self induced transparency. Spatial and temporal solitons, solitons in Kerr media. Pulse compression. Applications. **[5]**

6. **Bistability:** Optical bistability, Steady state bistability, absorptive bistability, Dispersive bistability, Optical switching. **[5]**

7. **Ultra fast Phenomena:**
   Ultra fast pulse generation with and without mode locking, Generation of femto second pulses, Coherent transients, Optical Nutation, Free induction decay, photon echo. **[5]**

Textbook:

1. Nonlinear Optics: Robert Boyd, Academic Press

References:

1. Nonlinear Optics in signal processing: W.Easan and A.Miller, Chapman and Hall
2. Physics of Nonlinear Optics: Guang- Sheng -He and Song-Hao Lin, World Scientific
3. Flytzanis and L.Oudar; Nonlinear Optics: Device and Applications, Springer Verlag, (1986)

SAP 3011 Nanostructures and Nanomaterials (3-0-0-3)

Module-I

Introduction to Nanotechnology & Nanomaterials, Nanoscale, Effect of Nanoscale on Material Properties: Thermal, Mechanical, Electrical, Magnetic and Optical Properties. 10

Module-II

New Behaviour: Size confinement, Interfacial Phenomena, Surface to Volume Ratio, Surface Tension, Quantum Mechanics (Importance of Nanomaterials & its effect on Bulk Properties, Nanomaterials. 07

Module-III

Nanostructured Materials: Properties and Applications of Nanocrystals, Nanoparticles (Emphasis on Surface to Volume Ratio, Surface Tension, Surface Energy), Nanowires, Nanotubes, Oxide Nanostructures, Nanorods, Biomolecules, Nanostructured Polymers, Nanostructured Coatings & Nanocatalist. 10

Module-IV

Introduction to Nanomaterials Fabrication Techniques: Top-Down Process, Bottom-Up Process & Self Assembly. 04

Module-V

Introduction to Nanomaterials Characterization Methods: AFM, Scanning Probe Microscopy, Nanoindentation, Raman Spectroscopy, XPS & FTIR. 06

Module-VI

Applications of Nanomaterials: Structural and Functional Applications, Electronics Applications & Biological Applications. 03

Textbook:

1. C. P. Poole Jr. and F J Ownes, Introduction to Nanotechnology, Wiley (2003).

Reference:

1. D. Tomanek and R. J. Enbody, Science and Applications of Nanotubes, Kluwer (2003).
2. Davies, Introduction to semiconductor Devices, Wiley (2002).

SAP 3013 Thin Film and Vacuum Technology (3-0-0-3)

Module-I
Thermodynamics and Thin Film growth

Module-II
Vacuum Technology: Gas Laws, Kinetic Theory of Gases, Conductance and Throughput, Gas Sources in a Vacuum Chamber, Vacuum Pumps.

Module-III
Physical Vapor Deposition: Sputtering (Plasma Physics (DC Diode), rf Plasmas, Magnetic Fields in Plasmas, Sputtering Mechanisms), Evaporation.

Module-IV
Chemical Vapor Deposition: Mechanisms, Materials, Chemistries, Systems.

Module-V
Etching: Wet Chemical Etching (Mechanisms, Materials and Chemistries), Dry Plasma Etching/Reactive Ion Etching (Mechanisms, Materials and Chemistries).

Module-VI
FILM Formation and Structure: Capillarity Theory, Atomistic Nucleation processes, Cluster Coalescence, Grain Structure of Films.

Module-VII
Thin Film Characterization: Structural, Chemical

Textbook:

1. R. K. Waits, Thin Film Deposition and Patterning, American Vacuum Society, 1998.

References:

1. M. Ohring, The Materials Science of Thin Films, Academic Press, Boston, 1991.
2. Ludmila Eckertova, Physics of Thin Films, 2nd Plenum Press New York, 1986
3. Kasturi L. Chopra, Thin Film Phenomena (McGraw-Hill, 1969)

SAP 3015 Advanced Experimental Techniques (3-0-0-3)

X-ray Diffraction Methods: (8)
Classification of crystal system, Bragg's law and Laue conditions, Powder methods, crystal size analysis, Rietveld method of structural analysis, X-ray fluorescence spectroscopy, applications of emission spectra for compounds and alloys, Applications of absorption spectra for solid solutions and transitional metal compounds, Neutron spectroscopy. X-Ray Reflectivity

Spectroscopy (6)
Atomic absorption spectrophotometer and its application to environmental analysis, UV-visible spectroscopy and its application, IR-spectroscopy and its application, AES, XPS, Introduction to RBS, SIMS, and its applications. Raman Spectroscopy (UV and Vis)

NMR, EPR spectroscopy (7)
Principles of magnetic resonance, Instrumentation and specimen preparation techniques, chemical shift, spectral analysis, basic principles of ESR. Some applications to simple solids and liquids. An Introduction to Mossbauer spectroscopy.

Microscopy & Optical Microscopy (4)
Optical microscopy, metallurgical microscope, TEM, SEM and AFM, specimen preparation, instrumentation and applications, Electron Energy Loss Spectroscopy, Nano indenter and NanoTribometer

Thermochemical analysis (4)
Thermoanalytical techniques, Instrumentation and applications of TGA, DTA, DSC.

Electrochemical Techniques (6)
Electrochemical Instrumentation, Coulometry, polarography, cyclic voltametry, application to oxidation-reduction reaction, pulse technique and stripping voltametry.

Vacuum Technology & Thin film Deposition Technique (6)
Application to Vacuum Technology, Types of vacuum pumps, different technique of thin film deposition CVD, PVD, MBE, MOCVD.

Mass spectrophotometric technique, TLC, HPLC, GC-MS etc. (4)

Textbook:

1. Mossbauer Effect: An Introduction to Inorganic and Geo Chemist by G. M. Banchroft, McGraw Hill, 1973

References:

1. Spectroscopy, Vol. I, II and III, ed. By Straughan and Walker, John Wiley.
2. Analytical Chemistry by G. D. Christian, 6th edition, John Wiley & Sons.
3. Analytical Chemistry by D. Kealey & P. J. Haines, Viva Books Pvt. Ltd.

SAP 3017 Medical Physics (3-0-0-3)

Atomic Physics: (9)
Traditional definition of atom, periodic system of elements, mechanical properties of atom, emission of light and its frequencies. Electromagnetic spectra. Principles of Nuclear Physics Natural radioactivity, Decay series, type of radiation and their applications, artificially produced isotopes and its application, accelerator principles; Radionuclides used in Medicine and technology.

Interaction With Living Cells: (7)
Target theory, single hit and multi target theory, cellular effects of radiation, DNA damage, depression of Macro molecular synthesis, Chromosomal damage.

Sometic Effect of Radiation: (7)
Radio sensitivity protocol of different tissues in human, LD 50/30 effect of radiation on skin, blood forming organs, lenses of eye, embryo and Endocrinal glands.

Genetic Effects of Radiations: (9)
Threshold of linear dose effect, relationship, factors affecting frequency of radiation induced mutation, Gene controlled hereditary diseases, biological effect of microwave and RF wave. Variation in dielectric constant and specific conductivity of tissues. Penetration and propagation of signals effects in various vital organs, Protection standards.

Photo Medicine: (08)
Synthesis of Vitamin D in early and late cutaneous effects, Phototherapy, Photo hemotherapy, exposure level, hazards and maximum permissible exposures. LASER PHYSICS – Characteristics of Laser radiation, Laser speckle, biological effects, laser safety management.

Textbooks:
1. Moselly, ‘Non ionising Radiation’ Adam Hilgar Brustol 1988
2. Branski.S and Cherski.P ‘Biological effects of Microwave’ Hutchinson & ROSS Inc. Strondsburg 1980

References:
1. Glasser.O.Medical Physics Vol.1,2,3 year Book Publisher Inc Chicago, 1980

SAP 3019 Biophysics (3-0-0-3)

Introduction: Laws of Physics and Chemistry, introduction to crystallography, Introduction to chromatorgraphy, electrophoresis. (5)

Physico-Chemical Techniques to study Biomolecules: hydration of macromolecules, diffusion of osmosis, sedimentation, ultracentrifuge, rotational dissusion, light scattering, small angle X-scattering, Mass spectrometry. (10)

Spectroscopy: UV spectroscopy, circular dichroism, Fluorescence spectroscopy, IR, Raman and Electron spin spectroscopy, NMR spectroscopy. (5)

Molecular Modeling & Macromolecular Structure: building the structure of H_2O_2, , nucleic acid structure, monomers, polymers, double helical structure of DNA, Polymorphism and nanostructure of DNA, structure of RNA, protein structure: amino acids, virus structure (5)

Energy Pathways in Biology: free energy, couple reactions, group transfer potential, pyridine nucleotides, photosynthesis, energy conversion pathways, membrane transport. (5)

Biomechanics: strained muscles, mechanical properties of muscles, cardiovascular system. (5)

Neurobiophysics: nervous system, physics of membrane potentials, sensory mechanisms. (5)

Origin and evolution of life: prebiotic earth, theories of origin and evolution of life, laboratory experiments on formation of small molecules. (5)

Textbooks:

1. "Cell and Molecular Biology-Concepts and Experiments" by G.Karp, 2nd ed. John Wiley & Sons, Inc. Singapore, 1999.
2. "Principles of Physical Biochemistry " by K.van Holde, W.C. Johnson, and P.S.Ho. Prentice Hall, 1998.

Semester – IV

SAP 4001: Thesis / Dissertation (20)