

Syllabus for Semesters I to VI

For Physics (Hons.) for 2010-2011 (Final copy as approved by the BOS on 18/12/2009)

I. INTRODUCTION

All recommendations made during the BOS meeting on 18/12/09 has been included in this copy.

II. NOMENCLATURE

The name of each module consists of a topic abbreviation, followed by semester number and an alphabet signifying the submodule number (within the semester). The names of the topics appear in the following list.

MM Mathematical Methods

SS Solid State Physics

CM Classical Mechanics

TP Thermal Physics

EI Electronics and Instrumentation

EM Electricity and Magnetism

OP Optical Physics

WP Wave propagation and related phenomena

NP Nuclear Physics

SR Special Relativity

PM Properties of Matter

QM Quantum Mechanics

AM Atomic and Molecular Physics

LP Laboratory Practices

PC Physical Computation

III. SEMESTER 1

Theory Modules

1. **MM1a.Review of Math Methods:** A very brief review of one-variable calculus highlighting the important application areas, and the successful system of differential modeling. Elementary functions and their special properties. Plotting Graphs of simple functions with their derivative and integral curves. Functions of two variables and their visual representation. An overview of the math methods and their relationship to the whole course.

10 Lectures

2. **MM1b.Vector algebra and Analysis in Cartesian coordinates, delta functions, use of tensor notation:** Brief review of the elementary notions of vector algebra including and upto the notion of cross products. Transformation of vectors:Active Vs. Passive Viewpoints; Orthogonal Transformations: Rotation, Inversion and Mirror Reflections; True and Pseudo Scalars and Vectors, Parity;The notions of Symmetry under a coordinate transformation. Vector Calculus: The differentiation and integration of vectors; applications of vectors to the study of lines and surfaces. Representation of spatially varying physical quantities by Fields and the ideas of

Gradient, Divergence and Curl: Product Rules, The Integral theorems of Gauss, Green and Stoke's (heuristic proof only), Evaluation of Line, Surface and Volume Integral of Fields. The Delta function: properties and simple representations including the divergence of the inverse square field. The use of Index Notation for the representation of various products, the $\epsilon - \delta$ rule and its use for the validation of vector identities.

24 Lectures

3. **MM1c.Theory of probability distributions:** The notion of probability, Random variables: Expectation values, variance. Discrete and continuous probability distributions: binomial, Poisson and Gaussian distribution functions – simple examples.

8 Lectures

4. **MM1d.Fourier Series and Fourier Integrals:** Piecewise continuous functions, Periodic functions and the Diriclet's conditions for Expanding them in harmonic series of sines, cosines and complex exponentials. Fourier integrals and Transforms: Transform of simple pulses like the delta peak or the triangular peak. Wave packets and the bandwidth theorem.

8 Lectures

5. **CM1a.Kinematics and Newtonian dynamics:** Mechanics of single particle: velocity and acceleration of a particle in plane polar, spherical polar and cylindrical polar co-ordinates; Time and path integral of force; Work, energy, conservative force; Concept of potential; Dissipative force. Mechanics of system of particles: Expressions of linear and angular momentum; descriptions of the center of mass motion; Motion of particles in force fields; Conservation laws of momenta and energy. Rigid bodies: Moment of Inertia; radius of gyration; Calculation of Moment of Inertia in simple symmetric systems.

16 Lectures

6. **CM1b.The theory of simple oscillations:** Free and forced oscillations of a Harmonic Oscillator, resonance, sharpness of resonance. Superposition of perpendicular oscillations, Lissajous figures. Vibrational characteristics of a weakly an harmonic oscillator: generation of harmonics and phase shift.

10 Lectures

7. **TP1a.The Kinetic theory of gases:** Towards a Microscopic theory of matter, Basic Assumptions, ideal gas approximations, the perfect gas equation of state. The random nature of molecular collisions, Maxwell's Distribution, Finite size effects: Mean free time and paths, Degree of freedom of molecular configurations and the law of Equipartition of Energy. Intermolecular interaction in real gases: The Virial EOS: virial coefficients and the Van der Waal's equation of state: Critical constants, law of corresponding states, Boyle temperature, Limitations of the Van der Waal's ES. Transport phenomena: Molecular explanation of viscosity thermal conduction, and diffusion in gases; The phenomenon of Brownian Motion and its significance.

20 Lectures

8. **EI1a.Study of electrical transients, networks and electronic devices:** Current and Voltage Sources, D.C Network theorems: analysis of series-parallel networks – potential divider and bridge circuits; applications of KCL and KVL; Sensitivity of wheatstone bridge; Thevenin and Norton's theorems: applications. Capacitors and Inductors as circuit elements: transient response. A.C Circuits, Impedance, differentiators and integrators.

18 Lectures

Computer Lab

PC1a.Visualization of Functions and Datasets: Learning to use Gnuplot to visualize functions and datasets: Cartesian, Polar and Parametric plots, 2-D surface and contour plots, simple nonlinear least squares curve fitting.

15 Classes

Physics Lab

1. **LP1a.Principles of laboratory practice:** Getting Ready, Setting up and performing an experiment, Effective ways to record and present data and analysis, Concept of absolute and relative errors, Estimation of errors contributed by various factors in any specific experiment.

4 Lectures

2. **LP1b.Initiation to different methods of laboratory measurements:** Demonstrations and handling instructions of basic measuring instruments. Practice of simple experiments like:

- (a) Measurements with slide callipers/ screw gauge / travelling microscope / spherometer / Waveform measurements with CRO.
- (b) To draw the current-voltage characteristics of a resistor and a p-n diode / Measurements with a breadboard (including electronic components) / Analog and Digital Meters / Use of rheostat for constructing a potential divider arrangement.
- (c) Determination of the moment of inertia of a regular solid body.
- (d) To measure the focal length of a convex lens by displacement method.
- (e) Spectrometeter(i-d curve).
- (f) Determination of the constants of a ballistic galvanometer.

3. **LP1c.Methods of laboratory measurements:**

- (a) Determination of Young's modulus by flexure method.
- (b) Determination of thermal conductivity by Lees-and-Chorlton method.
- (c) To verify the Thevenin and Norton's theorem and the Maximum Power Transfer Theorem using Wheatstone's bridge.
- (d) Determination of viscosity of water by Poiseuilli's method.
- (e) Verification of Stefan's Law.

Lectures Summary for Sem:1

SL	Module	No. of Lectures
1.	CM1a	16
2.	CM1b	10
3.	EI1a	18
4.	MM1a	10
5.	MM1b	24
6.	MM1c	8
7.	MM1d	8
8.	TP1a	20
Total		116

IV. SEMESTER 2

1. **MM2a.Study of Partial Differential Equations:** Formulation of problems that lead up to the wave, diffusion and the Laplace's Equation in Cartesian coordinates. The solution of Boundary Value Problems belonging to the above class using the method of separation of variables. Formulation and solution of axisymmetric problems in spherical and infinite-cylinder problems in cylindrical polar coordinate systems;Applications:Heat conduction, wave propagation and potential problems.

18 Lectures

2. **MM2b.Series solution of DEs and ODEs:** Applications of first and second order linear differential equations with constant co-efficients. Series solution of the Harmonic Oscillator and other simple equations with constant coefficients. Solution of equations with non-constant coefficients using the Frobenius Method. Orthogonal Functions: Solution of Legendre and Hermite equations about $x = 0$;Legendre and Hermite polynomials.

16 Lectures

3. **CM2a. Central Force theory, Scattering cross-section and impact parameter:** Motion under central force, nature of orbits in an attractive inverse square field, Newton's Laws of Gravitation, Intensity and potential, Kepler's law's of planetary motion. Gauss' theorem in gravitation. Scattering problems: scattering cross section and the impact parameter, calculation of cross sections for the Hard Sphere and Rutherford scattering.

14 Lectures

4. **OP2a. Ray optics:** Limiting form of wave optics: Fermat's Principle. Matrix methods in paraxial optics, lens systems. Dispersion: Dispersive power of prisms, Chromatic aberration. Theory behind the construction of optical systems: methods of reductions of chromatic and seidel aberrations (including a qualitative discussion of their nature and causes). Microscopes, Telescopes and Eyepieces – Ramsden and Huygen.

16 Lectures

5. **WP2a. Study of Wave propagation and phenomena:** The equation of plane progressive waves in 1 to 3 dimensions, characteristic features of a spherical wave, intensity of a plane wave field. Superposition of waves. Stationary waves. Dispersion in wave propagation. Wave packets. Group and phase velocity. Propagation of waves in continuous media: transverse oscillations of stretched string. Wave propagation in periodic structures. The Doppler effect.

18 Lectures

6. **EM2a Electrostatics I:** The potential and intensity in Electrostatics due to discrete / continuous charge distributions: formulation and application of the Gauss' theorem. The unique nature of the inverse-square fields, Gravitational / Electrostatic Potential, Energy of continuous charge distributions, Electrostatic Boundary conditions. Special Techniques for calculating potentials: Laplace's and Poisson's Equation, Solution of the Laplace's Equation in simple symmetric systems, The Method of images.

18 Lectures

7. **PM2a. Elastic Properties of Matter:** Elastic properties, the notion of shear, description of deformation, thermodynamics of deformation, Hooke's law, different moduli of elasticity and their inter-relations for an isotropic solid, Torsion of cylindrical wires. Description and analysis of the bending of beams supported at both ends and the cantilever, energy associated with strain, elastic properties of liquids & gases.

10 Lectures

8. **PM2b. Superficial Properties of Matter:** Molecular model of matter: Surface tension, surface energy, the angle of contact between surfaces, capillary phenomena, excess pressure on a curved liquid membrane, force between two parallel plates separated by thin liquid layer, dependence of surface tension on external factors, Jaeger's method for determination of surface tension.

6 Lectures

9. **PM2c. Fluids and Flows:** Newtonian and non-Newtonian fluids, viscosity, co-efficient of viscosity, critical velocity, Reynold's number, Poiseuille's equation for incompressible fluids, correction terms, Stoke's law, terminal velocity, effect of temperature on viscosity. Ideal Fluids: Streamlines and flowlines; Equations of continuity; Euler's equation of motion; Streamline flow; Bernoulli's equation and its application.

9 Lectures

10. **EI2a. Analog Devices I:** Diodes: Intrinsic and extrinsic semiconductors, current carriers, current conduction (mobility, conductivity, diffusion). P-N junction, space charge and electric field distribution at an unbiased jn, jn capacitance. Forward and reverse characteristics, Schottky relation, diode resistance. Basic circuits including clipper and clamper. Avalanche and Zener breakdown. Zener diode as a voltage regulator. Characteristics of C and L-section filters, Bridge rectifier with C and L filter; BJTs as circuit elements, current components and Characteristic curves.

16 Lectures

Physics Lab

LP2a. Methods of laboratory measurements:

1. To draw the $(\mu - \lambda)$ curve of a prism and to verify Cauchy's dispersion relation.

2. To draw the resonance curve of a series and parallel LCR circuit and hence to determine the Q factors.
3. To study the forward and reverse characteristics of a zener diode and to study the line and load regulation.
4. To study the performance of a bridge rectifier and its regulation characteristics with and without filter.

Lectures Summary for Sem:2

SL	Module	No. of Lectures
1.	CM2a	14
2.	EI2a	16
3.	EM2a	18
4.	MM2a	18
5.	OP2a	16
6.	MM2b	16
7.	WP2a	18
8.	PM2a	10
9.	PM2b	7
10.	PM2c	8
Total		141

V. SEMESTER 3

1. **MM3a.Linear Transformation Theory:** Linear Vector Space:linear independence,basis,closure, Examples of Linear Vector Space, Matrices,linear transformation, eigensystems: Similarity Transformation and diagonalization of real symmetric matrices with non-degenerate eigenvalues. Study of orthogonal, Hermitian and Unitary systems. Study of Hermitian Eigensystems, Function Spaces, Inner product, Operators as linear transformations, Hermiticity. The nature of ortho-normalization in function spaces, eigenfunctions of the multiplication and derivative operators.

24 Lectures
2. **MM3b.Transformations in arbitrary coordinate systems:** Nonlinear transformations as a sequence of infinitesimal linear transformations, covariant and contravariant tensors, identification and validation of transformation properties of indexed quantities.

10 Lectures
3. **QM3a.Emergence of Quantum Physics:** The limitations of the existing theories of blackbody radiation: Planks hypothesis and its successes, Einstein's explanation of the photoelectric effect - validation of the quantum nature of radiation(photon). Existence of discrete energy states within atoms: Frank and Hertz's Experiments, De Broglie's explanation. Electron waves from Davisson's-Garmer's and G.P Thomson's Experiments. Basic statement of the Heisenberg uncertainty principle. Order of magnitude of energies within the nucleus, estimate of First Bohr radius, Basic statement of the Energy-time uncertainty relation: relation with the lifetime of excited states.

16 Lectures
4. **CM3a.Classical Mechanics:The canonical formalism I:** Motivation for studying the canonical formalism: constrained systems; examples of constrained dynamical systems: calculation of their degrees of freedom and the notion of generalized coordinates. Virtual displacements and the D'Alembert's Principle: Deduction of the Lagrange's Equation of motion from D'Alembert's Principle, Illustration of the Lagrange's Equation at work.

16 Lectures
5. **CM3b.Description of kinematics in locally-orthogonal coordinate systems:** Orthogonal Curvilinear Systems:Unit vectors;Spherical and Cylindrical polar systems;Expressions of kinematic quantities in these frames;Non-Inertial frames of reference;Rotating frames;Coriolis and centrifugal forces;simple examples. Force free motion of rigid bodies: free spherical top and the free symmetric top.

10 Lectures

6. **OP3a. Physical Optics:** Wave theory of light: Huygen's Principle; deduction of law of reflection and refraction. Interference of light waves: Young's experiment, spatial and temporal coherence, intensity distribution, Fresnel's biprism, interference in thin films, antireflection coatings, filters, Newton's ring, Michelson interferometer, application in fine structure study, Mach-Zender interferometer, multiple beam interference-reflected and transmitted pattern, Fabry-Perot interferometer and application to fine structure study. Diffraction: Fresnel and Fraunhofer class, Fresnel's half period zones, explanation of rectilinear propagation of light, zone plate, Fraunhofer diffraction due to a single slit, double slit and circular aperture(qualitative). Plane diffraction grating(transmission). Rayleigh criterion of resolution, resolving power of prism, telescope, microscope and grating. Polarization. Different states of polarization, double refraction (explanation from electromagnetic theory), Huygen's construction for uniaxial crystals, polaroids and their uses. Production and analysis of plane, circularly and elliptically polarized light by retardation plates. Optical activity. Fresnel's explanation, biquartz and half-shade polarimeters.

28 Lectures

7. **TP3a. The laws of thermodynamics:** The Macroscopic and microscopic viewpoints, Unchanging states and thermodynamic variables. Thermal equilibrium: Zeroth law and the concept of temperature. Thermodynamic equilibrium: Quasi-static processes; Internal Energy and the First Law; application to hydrostatic; ideal gas; magnetic and other two parameter systems. Real vs. Reversible processes, the Kelvin-Planck and the Clausius statements of the Second Law, Carnot's Cycle and Carnot's Theorem, The Absolute temperature scale, Clausius Inequality, Definition of Entropy, calculation of entropy changes, and the Entropy version of the second law, Thermodynamic Engines: Rankine (External combustion engine); Otto and Diesel Cycles (Internal combustion engines); Unavailable energy.

24 Lectures

8. **EM3a Electrostatics II:** Multipole Expansion: Calculation of the approximate potential and field at large distances, The monopole, dipole and quadrupole terms, A dipole in an inhomogeneous electric field, dipole-dipole interaction. Conductors: Basic properties, force on a Surface charge, capacitors. Electrostatic Fields in matter: Dielectric Polarization, the electric displacement displacement \vec{D} , Linear Dielectrics.

14 Lectures

9. **EM3b. Electricity and Magnetism:** Magnetostatics: Lorentz force, Biot-Savart Law, The Divergence and Curl of \vec{B} Ampere's Law, Magnetic Vector potential, Comparison of Electrostatics and Magnetostatics. The Magnetic vector potential: magnetostatic boundary conditions, Multipole expansions of the vector potential. Magnetostatic fields in matter: Magnetization, Field of a Magnetized object, The Auxiliary field \vec{H} , Linear and Nonlinear Media, Ferromagnetism: Hysteresis. Boundary conditions for \vec{B} and \vec{H} . Current Electricity: Ohm's Law, EMF, Motional EMF and the Faraday-Lenze's Laws: Inductors, Calculation of self and mutual inductances in simple cases.

20 Lectures**Computer Lab**

PC3a. Numerical Computation - I: The Fortran-90 Language Subset: Syntax and semantics, Programming Styles, F90 Specific working style, Declaratives, assignments, Array handling, I/O, Arithmetic and Logical Operators; Logical variables, Looping(Iteration) and Branching(Decision) operations, editing, writing, redirection to and from data files, the simplest format statements and string operations. Practice of writing simple and effective codes: ordering, sorting and searching methods, implementation of matrix operations.

15 Lectures

PC3a. Numerical Computation - I(DD's proposal): Basic concepts of FORTRAN90 and DOS prompt

1. File opening in MS-DOS prompt, Notepad.
2. Assigning .f95/f90 at the filename extension.
3. Introduction to basic input output statement in FORTRAN.
4. Writing a simple hello world program in MS DOS prompt.

5. Use of g95 compiler to compile the file and finally execute the *.exe file.
6. Introduction to simple addition, subtraction multiplication of numbers using fortran.
7. Introduction to variables of different data types (both simple and complex).
8. Writing small program in FORTRAN using the knowledge gained so far.
9. Introduction to loops in FORTRAN.
10. Writing little complex program in FORTRAN using the knowledge gained so far.
11. Introduction to basic input/Output redirection operator in MS DOS prompt and handle external files using them.
12. Write FORTRAN program that will read data from files and write processed data in other file using input/Output redirection operator.
13. Wrap up.

15 Lectures

Physics Lab

LP3a.Methods of laboratory measurements:

1. To determine the mutual inductance between a pair of coils using a ballistic galvanometer.
2. Determination of band-gap in semiconductors.
3. To study transistor characteristics in CE and CB mode.
4. To draw the Calibration curves ($\sin\theta - \lambda$) of optical sources using a plane transmission grating.
5. To find the number of lines /cm of a plane transmission grating and hence to measure an unknown wavelength. To measure the separation between the D1 - D2 lines of sodium.
6. Initiation of project.

Lectures Summary for Sem:3

SL	Module	No. of Lectures
1.	CM3a	16
2.	CM3b	10
3.	EM3a	14
4.	EM3b	20
5.	MM3a	24
6.	MM3b	10
7.	OP3a	28(proposed)
8.	QM3a	16
9.	TP3a	24
10.	WP3a	10
Total		172

VI. SEMESTER 4

1. **CM4a. Classical Mechanics: The canonical formalism II** Variational calculus: simple examples like the brachistochrone problem and the shortest distance between two points in a plane; Idea of a functional and its Extrema, Euler equations for extremal problems. Minimum Principles: The principle of least action: Euler-Lagrange equations of particle dynamics. Basic Canonical transformation theory, Examples.

24 Lectures
2. **QM4a. Quantum Mechanics I:** Classical vs The Quantum Interference of Light, Classical Particles vs. Quantum Particles, Free Particle - Plane wave Correspondence, Dispersion relation for matter waves, Spatially confined matter and wave packets, Equation satisfied by massive particles - Schrödinger's equation. Bandwidth theorem and the Heisenberg uncertainty principle, Evolution of wave packets, Collapse of the wave function. Stationary states: The infinite Square well, The Harmonic Oscillator, Free Particle and the Delta-Function Potential, Finite square well and potential barriers - the concept of tunneling.

26 Lectures
3. **OP4a. Laser Physics:** Laser Theory: Einstein co-efficients and light amplification, threshold condition and rate equations for three level and four level systems. Laser instrumentation: main components, optical resonators, Specific examples: Ruby laser, He-Ne laser, Semiconductor laser.

8 Lectures
4. **OP4b. Fiber Optics:** Introduction, total internal reflection, the optical fiber, reasons for using glass fibers, coherent bundle, numerical aperture, step index and graded index fiber, attenuation in optical fibers, fiber sensors.

6 Lectures
5. **EI4a. Analog Devices:** BJT: Currents components, generalized transistor equation, dependent and independent variables in CB and CE connections, Characteristic curves, α and β of a transistor and their relations. CE output characteristics, load line and Q-point. Transistor biasing and stability factors (Fixed bias and Self-bias). h-parameter analysis of the CE amplifier: current, voltage and power gains, input and output impedances, effect of source resistance; comparison of CB, CE and CC amplifiers, Emitter follower and other transistor circuits. Feedback in Amplifiers: Negative and positive feedback, series and shunt feedbacks, input and output impedances in voltage series feedback. Nyquist criterion. Advantages of negative feedback.

20 Lectures
6. **EM4a. Formulation of Maxwell's Equations and Propagation of EM waves:** Maxwell's correction to Ampere's law, displacement current, Electrodynamics Boundary conditions, Maxwell's Field equations, Poynting theorem, Poynting vector. Wave Equation for the EM fields in vacuum: EM waves in vacuum: transverse nature, Energy and momentum carried by EM waves, Propagation through linear media: reflection and refraction at plane boundary, reflection and transmission coefficients, Fresnel's Formula. EM waves in conductors: attenuation and skin depth, reflection and transmission. Dispersion in Nonconductors: The damped driven electron radiator, normal and anomalous dispersion, Cauchy's formula, Rayleigh Scattering.

28 Lectures
7. **TP4a. Phase Transitions and Formal methods of Thermodynamics:** Legendre Transformations: The approach to thermal equilibrium via different processes and the introduction of thermodynamic potentials; Free Energies. Maxwell's Relations: Simple deductions using these relations. The Theory of Phase transitions: Multicomponent systems, Phase diagrams: Phase equilibrium curves and the triple point. Gibb's phase rule and simple applications. Ehrenfest Criteria and the classification of phase transitions. First Order phase transitions, Latent Heat, Clausius-Clapeyron's Equation. The Joule-Thomson effect: inversion temperature, regenerative cooling, regenerative cooling, principles of refrigeration.

16 Lectures
8. **TP4b. Thermal radiation:** Essential Facts: Spectral emissive and absorptive power; Blackbody; Kirchoff's law; Energy density; Radiation pressure; Stefan-Boltzmann's law; The form of spectral density functions: Planck's law (qualitative).

6 Lectures

9. **SR4a.Special Relativity:** Historical Perspective: Limitation of Galilean Transformation, significance of Michelson-Morley and Fizeau's experiments, Einstein's Postulates, Heuristic deduction of the Lorentz transformation equations, Clock Synchronization, Length contraction and time dilatation, the relativity of simultaneity, velocity addition rule.

The Geometry of Space-time: Coordinates of an event, Invariance of the interval, Space-time Diagrams- World Lines, regions of spacetime, the Lorentz transformation and the velocity parameter. momentum and energy in units of mass / energy, the momentum energy 4 vector, Equivalence of energy and rest mass. Relativistic dynamics: applications to particle interactions.

24 Lectures

Computer Lab

PC4a.Numerical Computation - II: Application of the Fortran-90 Language Subset: Numerical errors, Univariate interpolation, simple root-finding techniques, Linear Least Squares Curve fitting, Elementary statistical analysis of data.

15 Lectures

PC4a.Numerical Computation - II(DD's proposal): Advanced Concepts of FORTRAN 90

1. Recapitulation of semester 3.
2. Introduction to arrays of different data types in FORTRAN90.
3. Writing programs using arrays.
4. Introduction to file handling in FORTRAN 90.
5. Writing complex program to read data from data files and process data according to the need of the user and write the output in different locations.
6. Introduction to Random number generation in FORTRAN 90.
7. Write complex program in FORTRAN 90 using the concepts developed so far.
8. Wrap up.

15 Lectures

Physics Lab

LP4a.Methods of laboratory measurements:

1. To investigate the magnetic field between the pole pieces of an electromagnet using a ballistic galvanometer and calibration of a Hall probe.
2. To determine Fourier spectrum of (i) square, (ii) triangular and (iii) half- and full-rectified sinusoidal waveforms.
3. To calibrate a polarimeter and hence to determine the concentration of an unknown solution.
4. To study the diffraction and interference patterns of a double slit.
5. Project (continued).

Lectures Summary for Sem:4

SL	Module	No. of Lectures
1.	CM4a	24
2.	EI4a	20
3.	EM4a	28
4.	OP4a	8
5.	OP4b	6
6.	QM4a	26
7.	SR4a	24
8.	TP4a	16
9.	TP4b	6
	Total	158

VII. SEMESTER 5

- CM5a. Classical Mechanics: Rigid dynamics and small oscillations:** Kinematics of rigid body motion, angular momentum & kinetic energy of rotation. A pair of linearly coupled oscillators – eigenfrequencies and normal modes. General theory of small oscillations.

16 Lectures

- SS5a. Solid State Physics I:** Crystallography: Crystalline and Amorphous solids, Translational and rotational symmetry, Lattice and Basis, fundamental types of lattices in two and three dimensions, lattice parameters, Examples of some basic crystal structures, Reciprocal lattice vectors, Crystal diffraction by X rays, Laue and Bragg equations, Elementary idea about Structure factor: relationship with experiment, Experimental Methods: Powder Method, Electron Diffraction by Crystals.

Structural Theory of Solid: Binding forces in solids. Band Theory of solids, Kronig-Penny model, Energy band structure of conductors, insulators and semiconductors, effective mass, Free electron theory of metals, drift current, mobility and conductivity, Wiedemann Franz law, Hall effect in metals and semiconductors.

Thermal Properties: Lattice Vibrations and Specific heats.

30 Lectures

- QM5a. Quantum Mechanics II:** The Formalism of Quantum Mechanics: Hilbert space, States and Observables. BraKet Algebra. Postulates : The Generalized statistical interpretation. Momentum space wave function, the uncertainty principle and the minimum uncertainty wave packet. Theory of angular momentum: Spin 1/2, addition of angular momenta The Central force problem and the Hydrogen atom, Study of Semiconductor nanostructures like quantum dots and quantum wells insofar as they illustrate the features of bound state systems.

30 Lectures

- TP5a. Statistical Mechanics: Essentials:** Unique features of Macroscopic Systems: Thermodynamic Vs. Statistical Approach. Phase Space, calculation of phase volumes. Microstates and Macrostates, The Statistical Weight of a macrostate, ensembles: PEAPP. Equilibrium of an isolated system (microcanonical ensemble) – The entropy connection¹. Equilibrium of a system in a Heat Bath (The canonical ensemble), the partition function, averages of thermodynamic quantities, fluctuations, general definition of entropy². Systems with variable particle number (The grand canonical ensemble) – The perfect quantal gas: Bose-Einstein and Fermi-Dirac Statistics (both using partition functions and state counting), The classical limit³ and its region of validity, reduction to Maxwell distribution, comparison between photon, phonon, electron and the ideal gas. Entropy of mixing, Sackur Tetrode formula, Gibb's Paradox.

Applications: A selection from the following topics can be used to illustrate the fundamental concepts.

¹ The variation of the number of Schottky defects with temperature.

² Paramagnetic solid in a heat bath, Negative temperature, Third law of thermodynamics, Adiabatic Cooling, Heat Capacity of solids, Equipartition theorem, Validity of the classical regime, Maxwell velocity distribution.

³ Black Body Radiation, Electronic heat capacity of metals, Perfect gas of bosons of non-zero mass: Bose Einstein Condensation.

28 Lectures

5. **EI5a.Digital Electronics:** Boolean Algebra and Logic Gates: Binary, decimal and hexadecimal system; interconversions; 1's complement and 2's complement of a binary number; binary addition and complemental subtraction. Positive and negative logic. Truth tables of AND, OR, NOT gates. AND and OR circuits using diodes and transistors, NOT gate using transistor. NAND and NOR as universal gate, combination of gates for obtaining different Boolean function. De Morgan's theorem, simplification of boolean expression. Combinational logic: Half adder, full adder, digital comparator, decoder, encoder (ROM), A-D and D-A converter, dual slope integration, D-A ladder network, multiplexer, demultiplexer. Sequential logic: Flip-flops: RS, D,JK,JKMS. Edge triggering and clocked operations, shift registers, counters (asynchronous, synchronous, binary and decade counters). Communication: Modulation, demodulation. AM, FM and Phase Modulation. Diode detector and slope detector.

25 Lectures

Computer Lab

PC5a.Numerical Computation - III: Application of the Fortran-90 Language Subset: Series sums and Numerical Integration. Solution of Simple Differential Equations by the Euler Method: Simple applications involving Newton's II law of motion like motion under dynamic friction, oscillatory / periodic systems, phase plots.

15 Lectures

PC5a.Numerical Computation - III(DD's proposal):

1. Introduction to numerical analysis
 - (a) Introduction to errors
 - (b) Basic numerical methods like Newton Raphson, Bisection, Iteration etc.
 - (c) Simpsons 1/3 rule, Eulers method, differentiation.
 - (d) Method of regression, extrapolation.
2. Combine knowledge of FORTRAN 90 and numerical analysis to write programs to solve physical problems, e.g.
 - (a) Problem of falling parachutist from the sky in presence of air friction both analytically and numerically (without finding the analytical solution for differential equations).
 - (b) Compare how the real Van der Waals gas equation approaches the real gas equation numerically.
 - (c) Different radio active decays
 - (d) Biological cell activity, etc.
3. Simulate real physical systems using FORTRAN 90.

15 Lectures

Physics Lab

LP5a.Methods of laboratory measurements: Instruction on Ideal OPAMP as circuit element.

1. To determine the self-inductance of a coil using Anderson's bridge.
2. To study the resistivity of a semiconductor using the four-probe method.
3. To study the performance characteristics of a temperature controller.
4. To draw the B-H loop of a ferro-magnetic material in the form of an anchor ring and to study the energy loss.
5. To determine an unknown wavelength using a Fresnel's biprism.
6. To verify Fresnel's equation.
7. Completion of project.

Lectures Summary for Sem:5

SL	Module	No. of Lectures
1.	CM5a	16
2.	EI5a	30
3.	QM5a	30
4.	SS5a	30
5.	TP5a	28
	Total	134

VIII. SEMESTER VI

- SS6a.Solid State Physics II:** Properties of Dielectric materials: Polarization, Electronic, ionic and dipolar polarizability, Claussius-Mossotti equation. Magnetic Materials: Classification of Magnetic materials, Dia, Para and Ferro-magnetic properties of materials, Larmor Precession, Langevin's theory of diamagnetism, Classical and Quantum theory of paramagnetism - Curie's law, spin and van Vleck paramagnetism, Spontaneous magnetization and ferromagnetism, Curie Weiss law, Exchange interaction, Domain structure, and Hysteresis. Superconductivity and Superfluidity: Phenomenological approach.

25 Lectures

- EI6a.Analog Devices II:** OPAMPs: Ideal OPAMP characteristics, concept of virtual ground; differential amplifier, CMRR; inverting and non-inverting amplifier; addition, integration, differentiation, comparator, Schmitt trigger. Multistage Amplifiers: Voltage and power gains of multistage amplifiers, gain in decibels. Frequency response of a 2-stage R-C coupled amplifier, gain and bandwidth. Operating points of Class A, B, AB & C amplifiers; simple Voltage and Power amplifiers. Oscillators: Barkhausen criteria for sustained oscillations; Sinusoidal oscillators: Hartley, Crystal and Wien Bridge Oscillators. Relaxation Oscillators: Astable, Monostable and Bistable Multivibrators. FETs: JFET (construction and operation). Static, drain and transfer characteristics, pinch-off, Common-source FET amplifier, small signal low frequency equivalent circuit. MOSFET: enhancement and depletion type, operation, drain and transfer characteristics, elementary idea of CMOS.

30 Lectures

- AM6a.Atomic and Molecular Physics:** Atoms and light in a magnetic field, orbital magnetic moments, Vector atom model: properties of electron spin, magnetic resonance, addition of orbital and spin angular momenta, the spin-orbit interaction, the Zeeman effect: Normal and Anomalous, Empirical evidence of electron spin: Stern-Gerlach Experiment: Orientally quantized states. The Pauli exclusion principle, the ground states of atoms and the periodic table, electron antisymmetry, the helium atom, alkali atoms. Molecules: Binding by quantum tunneling (H_2^+), covalent bonding (H_2), ionic bonding (LiF), Van der Waals interaction, rotation, vibration spectra.

18 Lectures

- NP6a.Nuclear Structure, Properties and Reactions:** Nuclear Facts: sizes and masses, ground state properties of nuclei, Nuclear Force. Models: liquid drop and the shell model (simple features). Nuclear radioactivity: Alpha, Beta and Gamma emissions. Alpha decay and spontaneous fission, excited states of nuclei, nuclear reactions, power from nuclear fission, nuclear fusion, nucleosynthesis in stars.

24 Lectures

- NP6b.Elementary Particles:** Overview of Subnuclear Physics - Qualitative approach. Fundamental forces and Particle interactions: the Standard model: Truly elementary particles: Leptons, Quarks, Mediators and the Higgs. Hadrons: Baryons and Mesons. Antiparticles, Neutrinos, Symmetries and Conservation Laws, Quantum numbers: Parity, Charge Conjugation, Time reversal. Exact Vs. Approximate conservation laws. Strange Particles. The Quark structure of hadrons: Construction of the baryon decuplet and the meson octet.

10 Lectures

- IN6a.Instrumentation:** Production of low temperature, thermodynamics of liquefaction, Joule-Thomson liquefier, Principles of cryogenics. Basic Principles of production of high vacuum. Principles of Ultrasonics, Transducers: Principles of conversion, Examples: including Mechanical, Pressure and Temperature trans-

ducers. Basic theory of cyclotron, synchrotron, electron storage ring and linear accelerator, GM counter, semiconductor detectors for charged particles and gamma rays.

18 Lectures

Physics Lab

LP6a.Methods of laboratory measurements:

1. To design a series regulated power supply and to study its performance characteristics.
2. To measure the offset parameters of an OPAMP. To study the use of an OPAMP as (i) an inverting amplifier, (ii) a non-inverting amplifier, (iii) an adder and (iv) a differential amplifier. To study the performance of an OPAMP (i) integrator, (ii) differentiator and (iii) Schmitt trigger.
3. To construct two input OR, AND and NOT gates using discrete components and to verify their truth tables. To implement these gates using NAND/NOR IC. To verify De Morgan's theorem. To verify a few Boolean expressions using ICs.
4. To determine mid-band gain in the mid-frequency region of a CE amplifier and to find its band-width.
5. To design a Wien-Bridge oscillator of a given frequency of oscillation and to study the stability of the amplitude of oscillation and the performance of the lead-lag network.

Lectures Summary for Sem:6

SL	Module	No. of Lectures
1.	AM6a	18
2.	EI6a	30
3.	IN6a	18
4.	NP6a	24
5.	NP6b	10
6.	SS6a	25
	Total	125