

Syllabus for Semesters III to VI For Physics (Hons.) for 2010-2013

I. INTRODUCTION

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 3

1. **MM3a. Mathematical Physics: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. **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-Germer 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.

18 Lectures

3. **TP3a. 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

4. **OP3a. Physical Optics:** Wave theory of light: Huygen's Principle, deduction of laws of reflection and refraction. Interference of light waves: Young's experiment, spatial and temporal coherence, intensity distribution, Fresnel's biprism, interference in thin films, Newton's ring, Michelson interferometer, application in 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.

24 Lectures

5. **TP3b. 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 hydrostatics, 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

6. **EM3a Electrostatics II:** Multipole expansion: calculation of the approximate potential and field at large distances, the monopole, dipole and quadrupole terms, A dipole in a inhomogeneous electric field, dipole-dipole interaction. Conductors: basic properties, force on a surface charge, capacitors. Electrostatic fields in matter: dielectric polarization, the electric displacement \vec{D} , linear dielectrics.

10 Lectures

7. **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, Faraday-Lenz's Laws, inductors, calculation of self and mutual inductances in simple cases.

24 Lectures

8. **EI3a. Analog Devices II: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.

14 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, reading, writing, redirection to and from data

Physics Lab

LP3a. Methods of laboratory measurements:

Demonstration of CRO

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.

Lectures Summary for Sem:3

SL	Module	No. of Lectures
1.	MM3a	24
2.	QM3a	18
3.	TP3a	6
4.	OP3a	24
5.	TP3b	24
6.	EM3a	10
7.	EM3b	24
8.	EI3a	14
Total		144

IV. SEMESTER 4

1. **CM4a. Classical Mechanics: Description of kinematics in locally-orthogonal coordinate systems and the Canonical formalism I:** 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.

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, Hamiltonian formulation.

30 Lectures

2. **MM4a. Mathematical Physics: 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.

24 Lectures

3. **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. 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.

14 Lectures

4. **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, free particle and the Delta-Function potential, finite square well and potential barriers - the concept of tunneling.

24 Lectures

5. **EM4a. Formulation of Maxwell's Equations and Propagation of EM waves:** Maxwell's correction to Ampere's law, displacement current, electrodynamic 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.

24 Lectures

6. **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

Physics Lab

LP4a. Methods of laboratory measurements:

1. To determine the self-inductance of a coil using Anderson's bridge.
2. To determine Fourier spectrum of (i) square, (ii) triangular and (iii) half rectified sinusoidal waveforms.
3. To calibrate a polarimeter and hence to determine the concentration of an unknown solution.
4. To study the resistivity of a semiconductor using the four-probe method.

SL	Module	No. of Lectures
1.	CM4a	30
2.	MM4a	24
3.	TP4a	14
5.	QM4a	24
6.	EM4a	24
7.	SR4a	24
Total		140

V. SEMESTER 5

1. **CM5a.Classical Mechanics: The canonical formalism II and Rigid dynamics and small oscillations:**

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.

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.

24 Lectures

2. **SS5a.Solid State Physics I:** Crystallography: Translational and rotational symmetry, lattice and basis, fundamental types of lattices in two and three dimensions, examples of some basic crystal structures, reciprocal lattice vectors, crystal diffraction by X rays, Laue and Bragg equations, elementary idea about Structure factor, experimental method.

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, Widemann Franz law, Hall effect in metals and semiconductors.

Thermal Properties: Lattice Vibrations and Specific heats.

24 Lectures

3. **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, simple harmonic oscillator, The Central force problem and the Hydrogen atom.

30 Lectures

4. **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.

24 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

Physics Lab

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

1. To study the diffraction and interference patterns of a double slit.
2. To investigate the magnetic field between the pole pieces of an electromagnet using a ballistic galvanometer and calibration of a Hall probe.
3. To draw the B-H loop of a ferro-magnetic material in the form of an anchor ring and to study the energy loss.
4. To determine an unknown wavelength using a Fresnel's biprism.
5. To verify Fresnel's equation.

Lectures Summary for Sem:5

SL	Module	No. of Lectures
1.	CM5a	24
2.	SS5a	24
3.	QM5a	30
4.	TP5a	24
5.	EI5a	25
Total		132

VI. SEMESTER VI

1. **SS6a.Solid State Physics II:** Properties of Dielectric materials: polarization, electronic, ionic and dipolar polarizability, Clausius-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: phenomenological approach.

24 Lectures

2. **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: phase shift, 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. MOS-FET: enhancement and depletion type, operation, drain and transfer characteristics.

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(Qualitative).

20 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 decoupled and the meson octet.

10 Lectures

- IN6a.Instrumentation:** Basic principles of cryogenics. Basic principles of production of high vacuum. Principles of Ultrasonics, Transducers: principles of conversion, examples: including mechanical, pressure and temperature transducers. Basic principles of particle accelerators, GM counter, semiconductor detectors for charged particles and gamma rays; Multiwire proportional chamber, Drift chamber.

16 Lectures

- OP6a.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

- OP6b.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

Physics Lab

LP6a.Methods of laboratory measurements:

- To design a series regulated power supply and to study its performance characteristics.
- 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.
- 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.
- 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.	SS6a	24
2.	EI6a	30
3.	AM6a	20
4.	NP6a	24
5.	NP6b	10
6.	IN6a	16
7.	OP6a	8
8.	OP6b	6
Total		138