COTTON COLLEGE STATE UNIVERSITY

DEPARTMENT OF PHYSICS

Postgraduate Physics Syllabus

DISTRIBUTION OF PAPERS/CREDITS (L+T+P format)

Semester – I

Paper Code	Paper Name	Credits
PHY 701C	Classical Mechanics	3 + 1 + 0
PHY 702C	Quantum Mechanics 1	3 + 1 + 0
PHY 703C	Mathematical Physics 1	3 + 1 + 0
PHY 704C	Electronics	3 + 1 + 0
PHY705C	Physics Laboratory & Workshop	0 + 0 + 3
	An elective paper for selected students (see given list)	2 + 1 + 0

Semester – II

Paper Code	Paper Name	Credits
PHY 801C	Classical Electrodynamics	3 + 1 + 0
PHY 802C	Quantum Mechanics – 2	3 + 1 + 0
PHY 803C	Mathematical Physics – 2	3 + 1 + 0
PHY 804C	Solid State Physics	3 + 1 + 0
PHY 805C	Physics Laboratory	0 + 0 + 3
	An elective paper for selected students (see given list)	2 + 1 + 0

Semester – III

Paper Code	Paper Name	Credits
PHY 901C	Atomic and Molecular Physics	3 + 0 + 1
PHY 902C	Statistical Mechanics	3 + 1 + 0
PHY 903C	Nuclear and Particle Physics	3 + 0 + 1
PHY 904C	Special Paper (to be selected from list-I given here)	3 + 1 + 0
	Elective Paper (see given list)	2 + 1 + 0

Semester - IV

Paper Code	Paper Name	Credits
PHY 1001C	Computational Laboratory	2 + 0 + 3
	Special Paper (to be chosen from list-I given here)	
	Special Paper(to be selected from list-I given here)	
	Elective–1 (see given list)	2 + 1 + 0
	Elective–2 (see given list) --OR-- Dissertation	2 + 1 + 0

List - I (Special Papers):

Paper Code	Paper Name	Credits
PHY 1101C	General Theory of Relativity and Cosmology	3 + 1 + 0
PHY 1102C	Quantum Mechanics - 3	3 + 1 + 0
PHY 1103C	Optoelectronics	3 + 0 + 1
PHY 1104C	High Energy Physics - 1	3 + 0 + 1
PHY 1105C	Condensed Matter Physics - 1	3 + 0 + 1
PHY 1106C	Nuclear Physics - 1	3 + 0 + 1
PHY 1107C	Electronics - 1	3 + 0 + 1
PHY 1108C	High Energy Physics 2	3 + 0 + 1
PHY 1109C	Condensed Matter Physics - 2	3 + 0 + 1
PHY 1110C	Nuclear Physics - 2	3 + 0 + 1
PHY 1111C	Electronics - 2	3 + 0 + 1

A pre-requisite for taking level/part 2 of any special paper is that the student should have taken level/part 1 earlier.

List - II (Elective Papers):

Paper Code	Paper Name	Credits
PHY 1201E	Introductory Astronomy and Astrophysics	2 + 1 + 0
PHY 1202E	Plasma Physics	2 + 1 + 0
PHY 1203E	Atmospheric Physics	2 + 1 + 0
PHY 1204E	Nano Physics	2 + 1 + 0
PHY 1205E	Biophysics*	2 + 1 + 0
PHY 1206E	Physics of the Earth*	2 + 1 + 0

** These papers will be offered only after the current (August-December, 2014) semester*

SEMESTER-I

Paper code: PHY 701C

CLASSICAL MECHANICS

Credits: 4 (3+1+0)

Preliminaries [6 lectures]

Variational principle and Lagrange's equations of motion, non-uniqueness of Lagrangian – simple applications, Lagrangian for systems with dissipation and subject to nonholonomic constraints.

Legendre transformations and Hamilton's equations of motion, the principle of least action, derivation of Hamilton's equations from variational principle: simple applications.

Rigid body [10 lectures]

Kinematics, Infinitesimal rotation, Inertia tensor, eigenvalues of the inertia tensor and the principal axis transformations, Euler's equations of motion, Euler angles, Motion of heavy symmetrical top with one point fixed and stability of motion.

Small Oscillations [6 lectures]

Theory of small oscillations, normal co-ordinates, normal modes, applications to coupled oscillations, diatomic and tri-atomic molecules.

Canonical transformation and Hamilton-Jacobi Theory [8 lectures]

Generating function, Symplectic approach, the Poisson brackets and Canonical invariants, Hamilton-Jacobi theory, Action angle variables, Kepler problem – Staeckel condition.

Continuous systems and Fields [10 lectures]

Lagrangian and Hamiltonian formulation for continuous systems, Symmetry and conservation principles – Noether's Theorem, Classical field theory.

Fluid dynamics [4 lectures]

Perfect fluid motion, Euler's and Bernoulli's equations, vorticity, Navier-Stokes equation

Nonlinear dynamics and Classical Chaos [4 lectures]

Introduction to nonlinear systems, concept of catastrophe, bifurcation, chaos and strange attractors, fractals, physical examples.

Reading List:

1. **Classical Mechanics:** H.Goldstein
2. **Classical Mechanics:** John R Taylor
3. **Classical Mechanics:** Jeol A Shapiro
4. **Classical Mechanics:** Rana and Joag
5. **Mechanics:** Landau and Lifshitz
7. **Introduction to Mathematical Physics, Methods and Concepts:** C.W. Wong
8. **Chaos and Nonlinear Dynamics:** R.C.Hibron

SEMESTER-I

Paper code: PHY 702C

QUANTUM MECHANICS - 1

Credits: 4 (3+1+0)

Wave Particle Duality and Uncertainty Principle [10 lectures]

Wave Particle Duality and Uncertainty Principle: Particles and waves in classical physics, Quantum view of particles and waves (Double slit experiment with wave and particles), de Broglie's hypothesis of matter wave, Probabilistic interpretation of wave function, Uncertainty relation.

Wave packet description of a particle, Gaussian and square wave packets, Wave packet and uncertainty principle, group velocity and phase velocity.

Schrodinger's Equation [10 lectures]

Schrodinger's Equation, eigenfunctions and eigenvalues, time dependent and time independent Schrodinger's equation, probability density and probability current density, Simple application of Schrodinger Equation (i) Particle in a box, Harmonic oscillator, tunnelling through a barrier. Hydrogen atom.

Relativistic quantum mechanics [4 lectures]

Relativistic quantum mechanics. Klein Gordon equation and its physical significance, Klein Gordon equation in the presence of electromagnetic field and its non-relativistic approximation.

Operator Methods [20 lectures]

Introduction to linear vector space, Hilbert space and wave functions, observables and operators, Dirac notations, orthogonality and completeness of eigen states. Commutation of operators, generalized uncertainty principle. Change of basis and unitary transformation.

Postulates of quantum mechanics, probability of outcome of measurement, expectation value. Classical Limit and the Ehrenfest Theorem;

Application of Operator method: The harmonic oscillator, ladder operators, coherent states.

Time evolution of states: [4 lectures]

Evolution of states, unitary time evolution operator, Schrodinger's and Heisenberg picture, Heisenberg's equation of motion.

Reading List:

1. **Quantum Mechanics:** C. Cohen-Tannoudji, B. Diu, and F. Lalö
2. **The Principles of Quantum Mechanics:** P. A. M. Dirac
3. **Quantum Mechanics:** N. Zettili
4. **The Feynman Lectures on Physics:** R. Feynman, R. Leighton and M. Sands
5. **Quantum mechanics:** A. Ghatak and S. Lokanathan
6. **Quantum Mechanics:** A. Arhuldass
7. **Quantum Mechanics:** S. N. Biswas
8. **Introduction to Quantum Mechanics:** D. J. Griffiths

SEMESTER-I

Paper code: PHY 703C

MATHEMATICAL PHYSICS - 1

Credits: 4 (3+1+0)

Complex Variables [20 lectures]

Recapitulation: Complex numbers. Functions of a complex variable – single and multiple valued functions, limit and continuity; Differentiation – Cauchy-Riemann equations and their applications; Analytic and Harmonic functions; Complex integrals, Cauchy's theorem (elementary proof only), Cauchy's Integral Formula; Series – Taylor an Laurent expansion; Classification of singularities; Branch point and branch cut; Residue theorem and evaluation of some typical real integrals using this theorem; Principal value of an integral.

Vector spaces [8 lectures]

Infinite dimensional spaces, examples; Cauchy sequences; completeness; norms; inner products; Hilbert spaces; applications in physics.

Differential equations [8 lectures]

Sturm-Liouville theory; Hermitian operators; Completeness; Simple applications; Inhomogeneous equations, Green's functions and their applications.

Fourier Transforms (FT) [8 lectures]

Fundamental properties; FT of derivatives of a function; shift theorem; change of scale; modulation theorem; convolution theorem; Parseval's identity; FT of complex conjugates of functions.

Elementary Probability Theory [4 lectures]

Random variables; binomial, Poisson and normal distributions.

Reading List:

1. **Mathematical Methods for Physicists :** G. Arfken and H. Weber
2. **Mathematics for Physicists:** P. Dennery and A. Krzywicki
3. **Vector Analysis and an Introduction to Tensor Analysis:** S. Lipschutz, M. Spiegel, S. Lipschutz and D. Spellman.
4. **Applied Mathematics for Engineers and Physicists:** L. Pipes and L. Harvill

SEMESTER – I

Paper code: PHY 704C

ELECTRONICS

Credits: 4 (3+1+0)

Network Analysis [4 lectures]

Network properties of transfer function of linear and lumped systems; Zero input and zero state response; system stability; poles and zeros of network; Routh array and Bode plotting.

MOS and CMOS devices and applications [10 lectures]

Static and dynamic characteristics; depletion and enhancement modes; use of the devices in amplifiers and oscillators.

(a) TUNNEL diode and applications: Tunnelling effect; transfer coefficient; tunnel diode characteristics; use of tunnel diode as oscillator and amplifier.

(b) GUNN diode and applications: Transferred electron effect; TE modes; Gunn diode in oscillation circuit.

(c) IMPATT/AVALANCHE diode and applications: Drift and scattering velocity; relation between field, current and terminal impedance; equivalent circuits of the diodes and their use in amplifiers and oscillators.

OP-AMP applications [6 lectures]

Oscillators: Phase shift, Wien bridge and high frequency and voltage controlled oscillators; saw-tooth generator.

Filters: active low and high pass filters; Butterworth filter (up to 2nd order).

Analog computation: solution of differential equation (up to second order), solution of simultaneous equations.

Digital Circuits [6 lectures]

Mapping of logic expression and function minimization: SOP, POS expressions and circuit configurations; combinatorial logic gates; working and configuration of TTL. DTL, RTL, CMOS, MOSFET, ECL and L2L gates;

Sequential circuits: RS, JK, D and T Flip Flops.

Register: serial, parallel and shift register -- their design.

Counter: synchronous counter and design (up to module-10 counter).

Microprocessor: flow chart; assembly language; solution of simple problems.

Signal Transmission and Devices [8 lectures]

Transmission line: Basic conception of transmission of LF and HF in open wire and coaxial lines; wave equations; characteristic impedance; VSWR; short and open circuit impedance; matching and stub matching.

Waveguides: fundamental concepts of signal propagation through a waveguide; rectangular waveguides; relation between cut-off frequency and waveguide dimension.

Antenna: $\lambda/4$ dipole; antenna arrays; end fire and broadside.

Modulation and De-modulation [6 lectures]

Amplitude modulation: Bandwidth and frequency spectra.

Frequency modulation: Narrow band and wide band; power; bandwidth; improvement of S/N with emphasis and de-emphasis circuits.

Detection: Balanced detector; zero-crossing detector; PLL.

PAM: Basic principles; baseband binary PAM.

PCM: Sampling of signal; quantization of signal; noise and bandwidth.

Digital Communication and Modulation Techniques [8 lectures]

Incoherent ASK (amplitude shift keying), FSK (frequency shift keying), coherent ASK and FSK, differential PSK (DPSK), bandwidth and power requirement, M-ary signalling scheme; QPSK; Block diagrams of transmitters and receivers; types of errors and codes; error control coding methods.

Reading List:

1. **Modern digital electronics:** R. Jain
2. **Electronic Communication System:** G. Kennedy and B. David
3. **Microwaves:** K. Gupta

SEMESTER – I

Paper code: PHY 705C

Physics Laboratory + Workshop

Credits: 3 (0 + 0 + 3)

List of laboratory Experiments:

1. To design an RC-coupled class A amplifier and

    i) Draw the frequency response graph and find the half power points

    ii) Measure the output impedance of the amplifier

    iii) Measure the gain bandwidth product

2. Draw the characteristic curve for a FET and measure the pinchoff voltage

3. Using a IC 741

    i) Design an integrator circuit and a differentiator circuit

    ii) Draw the wave form

    iii) Measure the rise and fall time

    iv) Compare the result with theoretical values

4. Design a Wien Bridge Oscillator and find the frequency of oscillation. Compare the result with theoretical values.

5. Measure the energy band-gap of a given semiconductor material of a PN junction and its junction capacity by reverse-biasing the junction.

6. Determine the wavelength of sodium light by observing the interference pattern formed by Lloyd's mirror.

7. Determine the polarizing angle of air-glass using helium neon laser and verify Brewster's law.

8. Determine the minimum number of lines required in given grating for resolution of sodium lines in first, second, third and fourth (any two) orders and find the separation between the D-lines.

9. Study the atomic levels with Frank and Hertz apparatus.

10. Determine the specific resistance of the given rods by Kelvin's double bridge.

List of Workshop Experiments:

A. Machine Workshop

1. Introduction to machines in workshop.

2. Introduction to safety rules.

3. Sketches of tools and equipments.

4. Demonstration of tools and equipments to be used in practical job.

5. Practical job -- to make nut and bolt from mild steel rod, measuring, hacksaw cutting, lathe turning, drilling, making hexagonal shape by filing and thread cutting with dia and tape.

B. Electronics Workshop

1. Safety precautions

2. Familiarization with Tools and equipments, Electronic components, Power supply

3. Computer hardware overview

C. Job

1. To make a PCB for a required circuit

2. To design transistor regulated power supply, IC regulated power supply, amplifier, oscillator, transmitter etc.

SEMESTER-II

Paper code: PHY 801C

CLASSICAL ELECTRODYNAMICS

Credits: 4 (3+1+0)

Electrostatic Boundary Value Problem [5 lectures]

Poisson and Laplace equations; solutions of Laplace equation in rectangular, cylindrical and spherical polar coordinates; boundary value problems; Green's function approximation.

Maxwell's Equations [10 lectures]

Maxwell's equations and solutions; electromagnetic potentials; gauge transformations, Lorentz and Coulomb gauges; Gauge invariance. Scalar and vector potentials; Gauge transformations.

Propagation of em-waves in free space, non-conducting and conducting media; reflection and transmission at the boundary of two non-conducting media; reflection from a metal surface; propagation of em-waves in bounded media; idea of wave guides.

Relativistic Electrodynamics [5 lectures]

Recap of basic concepts of STR, introduction to 4-vectors, Lorentz transformations in terms of 4-vectors, covariance of Maxwell's equations; electromagnetic field tensor.

Radiation from moving charge [8 lectures]

Retarded potential; Lienard Wiechert potential and fields for a point charge; total power radiated by an accelerated charge; angular distribution of radiation from charged particles in extremely relativistic motion: Cherenkov radiation, Synchrotron radiation.

Scattering of electromagnetic waves [4 lectures]

Scattering of em-waves due to free electrons: Thompson scattering; scattering from bound electrons: Rayleigh scattering, resonance fluorescence; energy loss in radiation.

Conservation Laws [4 lectures]

Energy-momentum tensor and conservation laws.

Motion of charged particles in electromagnetic field [5 lectures]

Non-relativistic motion of a charged particle in uniform fields, in a slowly varying field; gradient drift; magnetic mirror.

Waves in Plasma [7 lectures]

Propagation of plane em-waves in low pressure ionized gases; conductivity of ionized gas; plasma angular frequency; Debye screening length; propagation of transverse waves in a perfectly conducting fluid embedded in a magnetic field; MHD (Alfven) waves; basic idea of plasma confinement

Reading List:

1. **Introduction to Electrodynamics:** D. Griffiths
2. **Classical Electrodynamics:** J. Jackson
3. **The Classical Theory of Fields:** L. Landau
4. **The Feynman lectures on Physics:** R. Feynman, R. Leighton and M. Sands.
5. **Classical Electricity and Magnetism:** W. K. H. Panofsky and M. Phillips.
6. **Electromagnetic Field Theory and Wave Propagation:** Uma Mukherjee
7. **Engineering Electromagnetics:** W. H. Hyat and J. A. Buck
8. **Fundamentals of Electromagnetics:** M. A. Wazed Miah
9. **Electromagnetic Fields and Waves:** P. Lorrain and D. Corson
10. **2000 Solved Problems in Electromagnetics:** S. A. Nasar
11. **Electromagnetics:** B. B. Laud
12. **Elementary Plasma Physics:** C. L. Longmire
13. **Introduction to Plasma Physics and Controlled Fusion:** F. F. Chen

SEMESTER-II

Paper code: PHY 802C

QUANTUM MECHANICS - 2

Credits: 4 (3+1+0)

Angular Momentum I [14 lectures]

The orbital angular momentum operator, general formalism of angular momentum, eigenfunctions of orbital angular momentum, spherical harmonics; Raising and lowering operators for angular momentum using Bra and Ket algebra. Spin angular momentum, experimental evidence for spin (Stern-Gerlach Experiment), spin half and Pauli matrices.

Angular Momentum II [6 Lectures]

Addition of angular momenta and Clebsch-Gordon coefficients.

Indistinguishable and identical particles in quantum mechanics [4 lectures]

Indistinguishable and identical particles in quantum mechanics; combination of wave functions for a system of particles; symmetric and anti-symmetric wave functions, spin statistics connection, exchange interaction and exchange energy.

Relativistic Quantum Mechanics [6 lectures]

Dirac equation and plane wave solutions; electron spin and its relationship with mag netic moment; non-relativistic limit to Dirac equation

Approximation Methods [18 lectures]

Time independent perturbation theory: first and second order non-degenerate , degenerate cases , Stark and Zeeman effects *(6 lectures)*

Variational methods and examples of hydrogen atom, harmonic oscillator *(4 lectures)*

Time dependent perturbation theory: transition probability, transition probability for constant perturbation, transition to a continuum of final states, Fermi's golden rule. Harmonic perturbation. *(6 lectures)*

Adiabatic and sudden approximations *(2 lectures)*

Reading List:

1. **Quantum Mechanics :** C. Cohen-Tannoudji, B. Diu, and F. Lalö
2. **The Principles of Quantum Mechanics:** P. A. M. Dirac
3. **Quantum Mechanics:** N. Zettili
4. **The Feynman Lectures on Physics:** R. Feynman, R. Leighton and M. Sands
5. **Quantum Mechanics:** A. Ghatak and S. Lokanathan

6. Quantum Mechanics: A. Arhuldass

7. Quantum Mechanics: S N Biswas

8. Introduction to Quantum Mechanics: D. J. Griffiths

SEMESTER-II

Paper code: PHY 803C

MATHEMATICAL PHYSICS - 2

Credits: 4 (3+1+0)

Tensor Analysis [12 lectures]

Co-ordinate transformations, scalars, covariant and contravariant tensors; addition, subtraction, outer product, inner product and contraction; Symmetric and anti symmetric tensors; Quotient law; metric tensor; conjugate tensor; Raising and lowering of indices; The Christoffel symbols and their transformation laws; Covariant derivatives of tensors.

Special Functions and Polynomials [16 lectures]

Legendre, Hermite and Laguerre polynomials: Rodrigues' formula; generating functions; recurrence relations; orthogonality; series expansion of a function in terms of a complete set of Legendre functions; Bessel functions: first and second kind; generating function; recurrence formula; zeros of Bessel functions; orthogonality.

Laplace Transforms (LT) [8 lectures]

LT of elementary functions; basic properties; change of scale theorem; shift theorem; LT of derivatives and integrals of functions; derivatives and integrals of LTs; convolution theorem; inverse Laplace Transform (Bromwich Integral); solution of differential equations.

The Dirac Delta function [2 lectures]

Representation and properties; Fourier and Laplace transforms of the Dirac Delta function.

Group theory [10 lectures]

Definition of group; subgroups, cosets, classes, factor group, homomorphism, isomorphism, isomorphism, direct products; group representation – reducible and irreducible representations; symmetry group, unitary group, Lie groups, SU(2) and SU(3), simple applications.

Reading List:

1. Mathematical Methods for Physicists : G. Arfken and H. Weber

2. Mathematics for Physicists: P. Dennery and A. Krzywicki

3. Vector Analysis and an Introduction to Tensor Analysis: S. Lipschutz, M. Spiegel, S. Lipschutz and D. Spellman.

4. **Applied Mathematics for Engineers and Physicists:** L. Pipes and L. Harvill
5. **Group Theory and its Application to Physical Problems:** M. Hamermesh
6. **Classical Groups for Physicists:** B. Wybourne

SEMESTER – II

Paper code: PHY 804C

SOLID STATE PHYSICS

Credits: 4 (3+1+0)

Crystal structure and wave diffraction in crystals [10 lectures]

Bravais lattices; diffraction of electromagnetic waves in crystals; reciprocal lattice and Brillouin zone; atomic and crystal structure factors; neutron and electron diffraction by crystals; defects and dislocations. Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order; quasi crystals.

Crystal Binding [6 lectures]

Crystals of inert gases: Van der Waals-London interaction; repulsive interaction; equilibrium lattice constants; ionic crystals: electrostatic or Madelung energy; Madelung constant and its evaluation.

Phonons [4 lectures]

Crystal vibration: phonons as normal modes -- classical and quantum picture; lattice specific heat.

Free electrons in solids [6 lectures]

Free electron theory and electronic specic heat; Drude model of electrical and thermal conductivities. Motion of electron in a periodic potential; Bloch's theorem in 3 dimensions; nearly free electron.

Electronic band structure of solids [6 lectures]

The nearly free electron approximation; the tight binding approximation; band structure of metals, insulators and semiconductors.

Semiconductors [8 lectures]

Impurity and Fermi level; electron transport; pn-junctions; the Hall effect and thermoelectric power; Fermi surface; de Hass-van Alphen effect; cyclotron resonance; response and relaxation phenomena.

Reading List:

1. **Introduction to Solid State Physics:** C. Kittel
2. **Solid State Physics:** N. Ashcroft and N. Mermin
3. **Solid State Physics:** A. J. Dekker
4. **Intemediate Quantum Theory of Crystalline Solids:** A. O. E. Animalu
5. **Introductory Solid State Physics:** H. P. Myers
6. **Heat and Thermodynamics:** W. Zemansky

SEMESTER-II

Paper code: PHY 805C

PHYSICS LABORATORY

Credits: 3 (0 + 0 + 3)

List of laboratory Experiments:

1. To design 1st and 2nd order low-pass filters using IC 741 and

   i) Draw the frequency response and find the roll-off rate.

   ii) Determine the gain and cut-off frequency and compare with theoretical values.

2. Design wide bandpass and band rejection filters and draw the frequency response curves.

3. Simplify given Boolean equations and verify with NAND/NOR gates.

4. Construct AND, OR, NOT, NOR, XOR and half adder with the help of NAND gates and verify their truth tables

5. Solve simple problems using microprocessor 8085/8086

6. Design a D/A converter using Op Amp and R-2R ladder network

7. Determine spice losses in an optical fibre.

8. Determine the conductivity type and Hall constant of a given semiconductor

9. Determine the constant of a Ballistic Galvanometer (BG) and study I-H and B-H curves

10. Determine e/m for electrons by magnetron method.

SEMESTER – III

Paper code: PHY 901C

ATOMIC AND MOLECULAR PHYSICS

Credits: 4 (3+1+0)

Atomic Physics [15 lectures]

Fine structure of Hydrogen atom; relativistic corrections for energy levels of hydrogen atom: mass correction and LS term spectrum of helium and alkali atoms; Hyperfine structure; effects due to isospin; spectral line-width; LS and JJ coupling; Zeeman effect; Paschen-Bach effect; Stark effect; ESR.

Electron in an atom; electron spin; S hyperfine structure and isotopic shift; width of spectrum lines; LS and JJ couplings; Zeeman, Paschen-Bach & Stark effects; Lande interval rule.

Molecular Physics [13 lectures]

Born-Oppenheimer approximation; electronic, rotational and vibrational structure of diatomic molecules; selection rules; molecular orbits and valence bond method for H_2^+ and H_2. Heterogeneous molecules: correlation diagrams; polyatomic molecules and their structure.

Spectroscopy [10 lectures]

Electronic, rotational, vibrational and Raman spectra; selection rules; electron spin resonance; nuclear magnetic resonance; chemical shift; Frank-Condon principle.

Lasers [10 lectures]

Spontaneous and stimulated emission; Einstein A & B coefficients; optical pumping; population inversion; rate equation; modes of resonators and coherence length.

Reading List:

1. **Introduction to Atomic Spectra:** Harvey Elliott White
2. **Physics of Atoms and Molecules:** B. Bransden and C. Joachain
3. **Modern Atomic Physics:** B. Cagnac and J. Pebay-Peyroula
4. **Fundamentals of Molecular Spectroscopy:** C. Banwell and E. McCash
5. **Molecular Spectra and Molecular Structure:** G. Herzberg

SEMESTER – III

Paper code: PHY 902C

STATISTICAL MECHANICS

Credits: 4 (3+1+0)

Classical Statistical Mechanics [15 lectures]

Statistical basis of thermodynamics: the macroscopic and the microscopic states; postulates of equal a-priori probability; connection between statistical mechanics and thermodynamics.

Elements of ensemble theory: Phase space of a classical system; Lioville's theorem; micro canonical, canonical and grand canonical ensemble; equivalence to other ensembles.

Fluctuations [8 lectures]

Thermodynamic fluctuations; Gaussian distribution; random walk and Brownian motion; diffusion equation; approach to equilibrium: the Fokker-Planck equation; introduction to non-equilibrium processes.

Formulation of Quantum Statistics [15 lectures]

Basic principle; inadequacy of the classical theory; quantum mechanical ensemble theory; density matrix; ensembles in quantum statistical mechanics; Maxwell-Boltzmann statistics; Bose-Einstein statistics; Fermi Dirac statistics; properties of an ideal Bose gas system and ideal Fermi gas system and their equations of state; some application: black-body radiation, white dwarf.

Phase transitions [10 lectures]

Formulation of the problem; the theory of Lee and Yang; first and second order phase transitions; diamagnetism, paramagnetism and ferromagnetism; Ising model; Bose-Einstein condensation (BEC). Liquid helium; two-fluid hydrodynamics: second sound; theories of Landau and Feynman.

Reading List:

1. **Statistical Mechanics:** R. Pathria and P. Beale
2. **Statistical Mechanics:** R. Feynman
3. **Statistical Physics:** L. Landau and E. Lifshitz

SEMESTER – III

Paper code: PHY 903C

NUCLEAR AND PARTICLE PHYSICS

Credits: 4 (3+0+1)

Static Properties of the Nucleus [4 lectures]

Size of the nucleus and its determination from electron scattering; form factors; angular momentum, spin and moments;

Two nucleon system [10 lectures]

Bound state problem: deuteron ground state with square well potential; electric quadrupole and magnetic dipole moments -- experimental values.

Scattering problem: low energy n-p scattering; partial wave analysis; scattering length.

Models of nuclear structure [10 lectures]

Nuclear stability; mass parabolas -- prediction of stability against beta decay; stability limits against spontaneous fission.

Shell model: evidence of shell structure; magic numbers; effective single particle potentials -- square well and harmonic oscillator; Wood-Saxon with spin-orbit interaction; extreme single particle model -- its successes and failures in predicting ground state spin, parity; Nordheim rule.

Nuclear reactions [8 lectures]

Classification; conservation principles; laboratory and center of mass frame of reference -- energy and angle relationship for non-relativistic cases; kinematics and Q-values; exoergic and endoergic reactions; threshold energy.

Basic concepts of flux and cross-sections; attenuation; Coulomb and Rutherford scattering; quantum mechanical and relativistic effects; extended particles; the compound nucleus hypothesis; Ghoshal experiment.

Nuclear beta decay [4 lectures]

Fermi's theory of beta decay; comparative half lives and forbidden decays; Kurie plot; neutrino physics; Reins and Cowen experiment; concept of double beta decay and Majorana neutrino.

Nuclear radiation detectors [4 lectures]

Ionization, proportional and GM counters; scintillation counters; solid state detectors (SSND).

Elementary particles [8 lectures]

Classification of elementary particles and their interactions; conservation laws, symmetry principles and quantum numbers; strangeness and isospin; Gell-Mann Nishijima scheme.

Reading List:

1. **Introductory Nuclear Physics:** K. Krane and D. Halliday
2. **Introductory Nuclear Physics:** S. Wong
3. **Atomic and Nuclear Physics:** S. Ghoshal
4. **Concepts of Nuclear Physics:** B. Cohen

SEMESTER – III

SPECIAL PAPER

Credits: 4

The students should opt for one of the special papers offered by the department from amongst the list provided in this syllabus.

SEMESTER – III

ELECTIVE PAPER

Credits: 3

An elective paper(s) will be offered by the Department from the list given in this syllabus.

SEMESTER – IV

Paper code: PHY 1001C

COMPUTATIONAL LABORATORY

Credits: 5 (2+0+3)

Introduction [4 lectures]

Representation of integers and real numbers in computers; floating point arithmetic; rounding and truncation errors; introduction to simple numerical procedures such as iterations, recursions etc .

High Level programming language with emphasis on FORTRAN 77 [16 lectures in lab]

Introduction to FORTRAN; structured programming; constants and variables; variable declaration; expressions; I/O statements; assignment statements; control statements; subscripted variables; using FORTRAN library functions; subroutines and functions.

Solution to non-linear equations [6 lectures]

Isolation of roots of simple equations; general methods for solving transcendental equations; Newton-Raphson method -- advantages and disadvantages; regula-falsi method; propagation of errors in each of these methods.

Solution of linear systems: Ax = b [4 lectures]

Gauss elimination and Gauss-Jordan elimination.

Interpolation and curve-fitting [6 lectures]

Polynomial interpolation using Lagrange's method; construction of Newton-Gregory forward difference and backward difference tables; error estimation in these methods; curve-fitting and the principle of least square.

Numerical Integration [6 lectures]

Integration as quadrature (or area under the curve); Newton-Cote's formulae: trapezoidal and Simpson's rule; Gaussian quadrature.

Solution of differential equations [6 lectures]

Euler's method for solving first order linear differential equations (initial value problem): limitations and discussion on its accuracy; Runge-Kutta method and its comparison with Euler's method; 4th order R-K method.

Computer Laboratory

1. Basic programming: sorting; matrix operations, string manipulation, reading (and writing) formatted data to (and from) files; Plotting: Interfacing pgplot subroutine library with f77 programs.

2. Interpolation by using difference table and divided difference table

3. Derivative by forward difference and central difference method

4. Integration by Gauss quadrature method

5. Integration by statistical methods (simple and intelligent sampling)

6. Solving ODE by Runge-Kutta and Taylor method

7. Solving wave equation and Laplace equation in two dimensions

8. Monte Carlo methods: (e.g. simulating the value of π)

9. Mini project work.

Reading List:

1. **Introductory Methods of Numerical Analysis:** S. Sastry
2. **Numerical Methods:** E. Balagurusamy
3. **Computer Oriented Numerical Methods:** V. Rajaraman
4. **FORTRAN 77 and Numerical Methods:** C. Xavier
5. **Numerical Recipes:** W. Press
6. **Numerical Recipes Example Book (FORTRAN):** W. Vetterling and W. Press

SEMESTER – IV

SPECIAL PAPER

Credits: 4

The students should opt for one of the special papers offered by the Department from amongst the list provided in this syllabus.

SEMESTER – IV

SPECIAL PAPER

Credits: 4

The students should opt for one of the special papers offered by the Department from amongst the list provided in this syllabus.

SEMESTER – IV

ELECTIVE PAPER

Credits: 3

An elective paper(s) will be offered by the Department from the list given in this syllabus.

SEMESTER – IV

ELECTIVE PAPER
OR
DISSERTATION

Credits: 3

An elective paper(s) will be offered by the Department. Students who take up a dissertation should undertake a project for the dissertation under the guidance of a faculty member of the Department.

SPECIAL PAPER

Paper code: PHY 1101C

GENERAL RELATIVITY AND COSMOLOGY

Credits: 4 (3+1+0)

Introduction [4 lectures]

Limitation of STR and need for a relativistic theory in non-inertial frames of reference; concepts of gravitational and inertial mass and the basic postulate of GTR; gravitation and acceleration and their relation to non-inertial frames of reference; equivalence principle; general co-variance; Minkowski space and Lorentz transformation; recap of 4-vectors.

Basic tensor algebra and tensor calculus [10 lectures]

Co-variant and contra-variant tensors and their transformation; differential geometry; the metric tensor and space-time geometry; affine connection and its relation to metric tensor; Christoffel symbol; the metric tensor and Minkowski tensor; the geodesic equation; parallel transport and curvature; the curvature tensor and Bianchi identities; the Ricci tensor.

Theory of gravitation [18 lectures]

GTR and its Newtonian approximation; Einstein field equation for gravity; gravitational field and isotropic space-time (metric tensor); solution of the field equation in empty space (Schwarzschild solution) -- its physical interpretation and the presence of matter and its relation to curvature; tests of GTR -- advance of perihelion of Mercury; deflection of light by gravitational field.

Cosmology [16 lectures]

Fundamental principles of cosmology (qualitative); geometrical and physical cosmology; the Big Bang model and the early universe; cosmic microwave background radiation

(CMBR); anisotropy of CMBR; helium synthesis.

Einstein's field equation for free space; the gravitational field equation in a non-empty space. Extragalactic distance scale and Hubble's law; cosmic distance ladder; Hubble constant and the age of the universe; the Robertson-Walker metric; red-shift in the Robertson-Walker metric; apparent magnitude and red-shift relation; non-static model of the universe.

SPECIAL PAPER

Paper code: PHY 1102C

QUANTUM MECHANICS -- III

Credits: 4 (3+1+0)

Approximation Methods [12 lectures]

The Wentzel-Kramers-Brillouin Method: general formalism; bound states for potential wells with no rigid walls, one rigid wall, two rigid walls; tunnelling through a potential barrier.

Scattering theory [14 lectures]

i. Review of scattering in classical mechanics *(3 lectures)*

ii. The First Born approximation: applications *(3 lectures)*

iii. Born approximation: second order *(4 lectures)*

iv. Partial wave analysis *(4 lectures)*

Relativistic Quantum Mechanics [6 lectures]

Dirac equation; electron spin and its relationship with magnetic moment; non-relativistic limit to Dirac equation.

LS coupling [4 lectures]

Application to atomic physics.

Path integral formulation [6 lectures]

Path integral formulation of Quantum mechanics: introduction

Quantum Field Theory [6 lectures]

Introduction to QFT.

Reading List:

1. **Quantum Mechanics:** C. Cohen-Tannoudji, B. Diu, and F. Lalö
2. **The Principles of Quantum Mechanics:** P. A. M. Dirac
3. **Quantum Mechanics:** N. Zettili
4. **The Feynman Lectures on Physics:** R. Feynman, R. Leighton and M. Sands
5. **Quantum Mechanics:** A. Ghatak and S. Lokanathan
6. **Quantum Mechanics:** A. Arhuldass
7. **Quantum Mechanics:** S. N. Biswas

SPECIAL PAPER

Paper code: PHY 1103C

OPTOELECTRONICS

Credits: 4 (3+1+0)

Basic Optics

Natural, artificial and specialized light sources, characterization of light sources based on intensity spectrum, emission, spatial distribution, conversion efficiency. Experimental methods for studying these characteristics;

Use of optical filters, their disadvantages and necessity and use of monochromatic source, wave nature of light, reflection and refraction, Snell's law, Total Internal Reflection.

Light Sources

Study of LEDs: variable band-gap semi material idea of hetero-junction, simple and double hetero structure light sources, quantum efficiency, internal and external quantum efficiency, expression for total and internal quantum efficiency, reasons for external quantum efficiency to be less than internal quantum efficiency, intensity distribution of LED, Lambertial sources, encapsulation of LEDs, types of LED surfaces and edge emitting, Burus LED.

Study of LASER: LASER as an amplifier of light and necessary conditions for amplification, special properties of laser: monochromatic, coherent and light power nature, directionality, divergence and attenuation of LASER beams. Study of 3-level LASER (Ruby LASER), study of 4-level LASER, study of tunable LASER, semiconductor LASER and application of high power, low power continuous wave and pulsed LASERs.

Light Detectors

Idea of light detectors and their basic types, natural and specialised light detectors, type of specialised light detectors, thermal, quantum light detectors, types of quantum photo-detectors, photo-resistive, photo-voltaic, photo-emissive detectors. Study of quantum detectors -- photo-electric cell, photo-multiplier tube, photo-diode. Important characteristics of light detectors -- spectral response, viewing angle, efficiency and material used for photo-detectors.

Optical Fibre: Theory and Applications

Action of optical fibre as wave guide, advantages of optical fibre communication over normal medium, necessary conditions for wave-guiding mechanisms of optical fibres. Step-index and graded-index fibres, expression for angle of acceptance and cone of acceptance. Numerical aperture, time dispersion, splicing and fibre connections -- requirements of splicing, practical methods of splicing; Types of optical fibre connectors, losses in optical fibre communication. Losses due to fibres: intrinsic and extrinsic losses, intrinsic losses due to atomic scattering and molecular absorption, expression for loss factor. Extrinsic losses due to mechanical effects, micro bends, cracks etc. Losses due to connectors, core longitudinal, angular misalignment, mismatch of rate indices of fibre material etc.

Expression for electromagnetic wave guided by fibre, modes of transmission, dispersion in optical fibres, wavelength and time dispersion, internodes dispersion.

Optical Fibre Systems and Devices

Optical transmitter/receiver circuits, driver circuits for LED, detector circuit design using photo- diode, photo transistors and fibre choice. Communication over special fibres, DS fibres, NZDS fibre, integrated optics, slab and strip waveguides and electro-optic devices -- phase shifters, interferometer modulators.

Opto-electronic modulation and switching devices: analog and digital modulation, electro-optic modulators, optical switching and logic. Opto-electronic integrated circuits.

Measurement on Optical Fibre

Optical fibre experimental set-up, launching light into fibre, detection etc. Fibre attenuation measurement, dispersion measurement, profile measurement, numerical aperture measurement, diameter measurement.

Practical [Any 5 experiments to be performed]

1. Study of characteristics of:

   i. Photo-diode

   ii. Photo-transistor

2. Study of characteristics of

   i. LDR

   ii. LED

3. Study of characteristics of a solar cell

4. Studies of

   i. Analog signal transmission through fibre

   ii. Digital signal transmission through fibre

5. Study of fibre optics voice communication through fibre with different bending losses

6. PC-to-PC communication using RS232 port over fibre

7. Transmission of modulated signal through optical fibre and its demodulation

8. Time division multiplexing and demultiplexing through optical fibre

9. Study of Gaussian nature of LASER beam and evaluation of beam spot-size

Reading List:

1. **Optical Electronics:** A. K. Ghatak & K. Thyagarajan
2. **An Introduction to Fibre Optics:** A. K. Ghatak & K. Thyagarajan
3. **Semiconductor Optoelectronic Devices:** P. Bhattacharya
4. **Optoelectronics and Fibre Optics Communication:** C. K. Sarka & D. C. Sarkar
5. **Fibre Optics Essentials:** A. K. Ghatak & K. Thyagarajan

SPECIAL PAPER

Paper code: PHY 1104C

HIGH ENERGY PHYSICS - 1

Credits: 4 (3+1+0)

Introduction to Elementary Particles and Quark model of Hadrons

Classification of elementary particles, spin and parity determination of pions and strange particles; properties of particles: C, P, G-conjugation, Gell-Mann and Nishijima scheme, the eight-fold way classification (Gell-Mann and Neeman classification), quark hypothesis (of Gell-Mann and Zweig), properties of quarks and their kinds, elementary idea of Lie groups, spin SU(2) and flavour SU(3) symmetry, colour quantum number, hadron wave functions and classification (spin and flavour).

General Concepts on Nature of Interactions and Gauge Theories

Four fundamental interactions and their characteristics in terms of decay lifetimes, strengths, ranges; conservation laws and decay modes, charged leptonic weak interactions, decay of muons, neutron and chrged pions, neutral weak interactions.

Lorentz transformation properties of bilinear covariants of Dirac fields; examples of forms of Hamiltonians and interaction Hamiltonians; gauge theories of interactions, global and locl gauge transformations, Abelian U(1) (QED) and non-Abelian (Yang-Mills), SU(2) gauge theories, QCD (based on SU(3) color).

Elements of Quantum Field Theory (QFT)

Concept of fields, classical fields as generalized coordinates, Lagrangian of a field, Schwinger's action principle;

Euler Lagrange equation, canonical quantization of a one-dimensional classical system; Fock space states and their eigenvalues; the method of second quantization, canonical quantization of free fields (Hermitian and non-Hermitian scalar fields, electromagnetic field), energy, momentum and charge of the field, vacuum in field theory; C, P, T transformation properties of scalar, electromagnetic fields.

Reading List:

1. **Introduction to Elementary Particles:** David Griffiths
2. **Quarks and Leptons: An Introductory Course in Modern Particle Physics:** Francis Halzen & Alan D. Martin
3. **Gauge Theory of Elementary Particle Physics:** Ta-Pei Cheng & Ling-Fong Li
4. **Quantum Field Theory:** L. H. Ryder
5. **Relativistic Quantum Mechanics (Vol-I & Vol-II):** James D. Bjorken & Sidney D. Drell

SPECIAL PAPER

Paper code: PHY 1105C

CONDENSED MATTER PHYSICS - 1

Credits: 4 (3+1+0)

Phonon Spectrum

Phonon creation and annihilation operators, elastic scattering of electrons, inelastic scattering by phonons, inelastic scattering of neutrons by phonons, inelastic phonon scattering, normal and Umklapp processes.

Electronic Energy Band Calculations

Nearly free electron approximations, tight binding approximation, Wigner-Seitz method.

Optical Properties of Solids

Optical constants, dispersion relation of optical constants from Maxwell's equations, Kramers-Kronig relations, optical absorption and emission in semiconductors, exciton absorption, impurity and inter-band transitions, luminescence, activators, Frank-Condon principle, photoluminescence and thermo luminescence.

Superconductivity

Isotope effect, Frohlich interaction, electron-phonon interaction and BCS theory of superconductivity, flux quantization in a superconductivity ring, superconducting tunnelling-Giaever and Josephson effects (d.c and a.c), superconducting quantum interference device (SQUID), Ginzburg-Landau theory of type-II superconductivity, high temperature superconductivity and superconducting magnets.

Semiconductor Devices

Metal-semiconductor junctions, semiconductor homo and hetero junctions, I-V characteristics of junctions, some opto-electronic devices, photo-generation at p-n junction, photovoltaic effect.

Lattice Imperfections

Imperfections in crystals, equilibrium concentration of point defects, dislocations, diffusion in solids: Fick's law, colour centers, excitons, Mossbauer effect.

Reading List:

1. **Lattice Dynamics:** A. K. Ghatak and L. S. Kothari
2. **Energy band Theory:** W. A. Harrison
3. **Theory of Superconductivity:** J. R. Schriffer
4. **Solid State Physics:** A. J. Dekker
5. **Fundamentals of Solid State Physics:** J. Richard. Christman
6. **Introduction to Solid State Physics:** C. Kittel

SPECIAL PAPER

Paper code: PHY 1106C

NUCLEAR PHYSICS - 1

Credits: 4 (3+1+0)

Nuclear Theory

i. Rotational invariance in three dimensions, angular momentum operator, coupling of two and three angular momenta, Clebsch-Gordon coefficients, Wigner-Eckart theorem with application.

ii. Scattering of particles by central potential, scattering amplitude and cross section, partial waves and phase shift, effective range theory, coherent and incoherent scattering, S-Matrix.

Nuclear Model

i. Shell model: Independent particle model, total spin J for various configurations, configuration mixing, electric dipole and quadrupole moments of various nuclei in the light of extreme single particle shell model.

ii. Collective model: Failure of shell model in understanding the excited states of even-even nuclei, dynamics of collective motion, rotational and vibrational modes, Hamiltonian for collective model of a deformed nucleus -- Nilsson model.

Nuclear Excitation and Decay

i. Nuclear transition matrix elements, electromagnetic interaction of nuclei, multi-pole expansion, transition probability, angular momentum and parity, selection rules, nuclear isomerism, internal conversion, internal pair-creation, angular correlation.

ii. Weak interaction and beta decay, transition rate for beta decay, neutrino mass measurement, polarization of electron and neutrino helicity, two component theory of neutrino, parity violation in weak interactions.

Nuclear Instrumentation

Linear accelerator -- tandem and pelletron, variale energy cyclotron, radioactive ion beam, detectors -- photographic emulsion, solid state nuclear track detectors.

Data acquisition techniques: pre-amplifier, pulse shaping networks in amplifiers, strobe generation using discriminators, gate and display generator (GDG), time to amplitude converter (TAC), analog to digital converter (ADC).

Reading List:

1. **Nuclear Physics:** Roy and Nigam
2. **Introduction to Nuclear Reactions:** G. R. Satchler
3. **Structure of the Nucleus:** M. A. Preston & R. K. Bhaduri
4. **Nuclear Physics -- Principles and Applications:** John Lilley
5. **Nuclear Physics -- Experimental and Theoretical:** H. S. Hans
6. **Nuclear Physics (Vol. I, II, III):** E. Segri
7. **Nuclear and Particle Physics:** W. E. Burcham & M. Jobes

SPECIAL PAPER

Paper code: PHY 1107C

ELECTRONICS - 1

Credits: 4 (3+0+1)

Discrete Time Signal and Systems

Analog filter design: Group delay and phase difference, approximation of ideal filter by practical filters like Butterworth, Bessel, Chebyshev (Type I); (Lecture – 4)

Filter transformation: frequency scaling, transformation from one band to another, transmission band; (Lecture – 4)

Combinational Logic Design

Circuit design of logic circuits with ICs: Combinational logic design with SSI gates, MSI devices (RTL. TTL, CTL, ECL, MOS, CMOS, IIL), threshold voltage, operating speed, power dissipation, noise margin, logic voltage level, fan in and fan out operations.

Synthesis and design of sequential circuits: Analysis and synthesis of synchronous and asynchronous circuits, hazard free asynchronous circuits, sequential machine, flow chart, reduced dimension map state, function synthesis, logic design with SM charts with examples. (Lecture – 12)

Microprocessor and Microcomputer

Microprocessor architecture and microcomputer interfacing, buses, details of microprocessor programming, input/output techniques, modems, higher level languages, microcontrollers. (Lecture – 6)

Servomechanism

Open loop system, first and second order system with derivative and integral control, servomotor and its control circuits. (Lecture – 6)

Electronic Lab: Credit-1

Practical: (Any five from the list)

1. Design a low pass and high pass filters (1^{st} and 2^{nd} order)
2. Design a band pass and band reject filter
3. Microprocessor programming experiment
4. Fourier Transform experiment using DSO
5. Modulation index determination experiment
6. Analog /digital communication experiment
7. Loss in optical fibre with laser kit experiment
8. Microprocessor by GAOKAR

Reading List:

1. Digital Signal Processing: Principles, Algorithms and Applications : J. Proakis, D. Manolakis
2. Digital Signal Processing: P. Ramesh Babu
3. Modern Digital and Analog Communication Systems: B. P. Lathi
4. Electronic Communication Systems: Kennedy and Davis
5. Communication Systems (Analog and Digital): Sanjay Sharma

SPECIAL PAPER

Paper code: PHY 1108C

HIGH ENERGY PHYSICS - 2

Credits: 4 (3+1+0)

Quantum Electrodynamics (QED)

Covariant perturbation theory, Feynman rules in momentum space, reduction of time-ordered products, Wick's theorem, calculation of second order process, Mott scattering, Klein-Nishima formula, Compton scattering, elements of renormalization of charge, mass and vertex.

Electrodynamics of Quarks and Hadrons

Hadron production in e^+ and e^- collision, elastic e^--p scattering and concepts of form factors and charge radii, deep-inelastic scattering and structure function, Parton model, Bjorkin scaling and its violation, QCD evolution equations.

Symmetry Breaking in Gauge Theories

Spontaneous symmetry breaking, Goldstone theorem and Goldstone bosons, Higgs-Kibble mechanism for giving masses to vector bosons, electroweak unification and W^+, W^-, Z^0 bosons.

Beyond standard model: Introductory ideas on grand unified theories (GUTs) and proton decay possibilities, elements of super symmetry and Minimal Super-symmetric Standard Model (MSSM), neutrino puzzles, neutrino oscillations and neutrino masses.

Elementary Idea on Superstring Theories and Extra Dimensions

Introductory ideas only

Reading List:

1. **Introduction to Elementary Particles:** David Griffiths
2. **Quarks and Leptons: An Introductory Course in Modern Particle Physics:** Francis Halzen & Alan D. Martin
3. **Gauge Theory of Elementary Particle Physics:** Ta-Pei Cheng & Ling-Fong Li
4. **Quantum Field Theory:** L. H. Ryder
5. **Relativistic Quantum Mechanics (Vol-I & Vol-II):** James D. Bjorken & Sidney D. Drell

SPECIAL PAPER

Paper code: PHY 1109C

CONDENSED MATTER PHYSICS - 2

Credits: 4 (3+1+0)

Magnetic Properties of Solids

Magneto-conductivity, cyclotron resonance, Landau levels and Landau cylinders, de Haas-van Alphen effect, Fermi surface studies.

Exchange interaction and exchange integral for two-electron system, Heisenberg Hamiltonian for exchange interaction, relationship between exchange energy and molecular field, ferromagnetic spin waves and their dispersion relations, magnons, neutron diffraction and anti-ferromagnetic ordering.

Thin Solid Films

Thin films and preparation by thermal evaporation and sputtering method, condensation, nucleation and growth f thin films, size effect in electrical conductivity: Fuchs and Sondheimmer theory and comparison with experiments; two dimensional electron gas (2DEGS) systems, 2DEGS in hetero-structures, energy relationships, integral quantum hall effect (QHE) and fractional quantum hall effect.

Nanophysics

Idea of nano-structured materials; Quantum dots and quantum wires, variation of bandgap of nano-materials with crystalline size; methods of preparation of nano-materials: ball milling, evaporation, ion beam deposition and chemical method, determination of crystalline size, electronic, spintronic, photonic, thermal and magnetic properties in nano-scale materials.

Reading List:

1. **Fundamentals of Solid State Physics:** J. R. Christman
2. **Magnetism in Solids:** D. H. Martin
3. **Physics of Semiconductor Devices:** S. M. Sze
4. **Handbook of Thin Film Technology:** L. I. Maissel and R. Glang
5. **Physics of Magnetism:** Soshin Chikazumi
6. **Nanotechnology: Molecularly Designed Materials:** Gan-Moog Chow and Kenneth E. Gonlsaves, American Chemical Society, 1996
7. **Nanoparticles and Nanostructured Films: Preparation, Characterization and Applications:** J. H. Ffender (Ed.)
8. **Physics of Low Dimensional Semiconductors:** John H. Davies

SPECIAL PAPER

Paper code: PHY 1110C

NUCLEAR PHYSICS - 2

Credits: 4 (3+1+0)

Nuclear Reaction

i. Optical model for elastic scattering, average interaction potential for nucleons, energy dependence of the potential, spin-orbit coupling, average potential for complex projectiles, imaginary potential and absorption, analysis of scattering experiments.

ii. Compound nucleus resonance: Breit-Wigner dispersion formula for $l = 0$ and for all values of l.

Reaction mechanism -- compound nucleus, continuum theory of cross section, statistical theory, evaporation probability.

iii. Direct reactions: Kinematics of stripping and pick-up reactions, inelastic scattering, transfer reaction with grazing angle concept, plane wave and distorted wave, Born approximation (DWBA)

Fission and Fusion:

i. Characteristics of fission, fission cross-section, spontaneous fission, mass and energy distribution of fission fragments, slowing down of neutrons, rate of energy loss due to successive collisions, Fermi age equation

ii. Particle and nuclear interaction in the early universe, primordial nucleosynthesis, basic fusion processes, characteristics of fusion, stellar nucleosynthesis, s-process and r-process ($A < 60$ & $A > 60$)

Elementary Particles

Strangeness and other quantum numbers, spin and parity determination of pions and strange particles, baryon spectroscopy, structure of nucleons -- quark model, properties of quarks and their classification, elementary ideas of SU(2) and SU(3) symmetry groups and hadron classification, introduction to standard model, electroweak interaction -- W & Z Bosons.

Applications of Nuclear Physics

The technique of NMR, some experiments using NMR; the Mossbauer effect, some experiments on Mossbauer effect.

Diagnostic nuclear medicine, X-radiography, gamma camera, Computed Tomography (CT), positron emission tomography (PET), Magnetic Resonance Imaging (MRI), radiation therapy.

Reading List:

1. **Nuclear Physics:** Roy and Nigam
2. **Introduction to Nuclear Reactions:** G. R. Satchler
3. **Structure of the Nucleus:** M. A. Preston & R. K. Bhaduri
4. **Nuclear Physics -- Principles and Applications:** John Lilley
5. **Nuclear Physics -- Experimental and Theoretical:** H. S. Hans
6. **Nuclear Physics (Vol. I, II, III):** E. Segri
7. **Nuclear and Particle Physics:** W. E. Burcham & M. Jobes

SPECIAL PAPER

Paper code: PHY 1111C

ELECTRONICS - 2

Credits: 4 (3+1+0)

Information Theory

Information, channel and fundamental limits on performance, random signal, noise in communication systems, uncertainty, information and entropy, average information content (entropy) of symbols in long independent and dependent sequences, source encoding theorem, Shanon's encoding theorem, communication, channel discrete with memory and memoryless, continuous channel, Shanon-Hartley theorem and channel capacity.

Modulation Technique for Digital Communication

Description of OOK, ASK, OSK, FSK, coherent ASK, PSK and FSK, non coherent ASK, FSK, differential PSK, bandwidth and power requirement, M-arry signalling scheme, QPSK, transmitter and receivers FSK, PSK and QPSK, multiplexing and demultiplexing: TDM, FDMA, elements of CDMA and spread spectrum techniques and applications, error control coding, methods of controlling errors, types of errors and codes.

Elements of Optical and Microwave Communication

Circular waveguides, reflection and matching in waveguides, elementary discussion on propagation of optical signal through fibre, step-index fibre, graded fibre and propagation and multipath dispersion in graded fibre, attenuation in optical fibre, optical communication by laser, detector and amplifier circuits.

Antenna

Horn antenna, dual mode, E/H plane, directivity, phase error, reflector, cylindrical, doubly curved, lens antenna: single surface dielectric, stepped lenses, metal plate lens antenna, aperture and field, microstrip antenna: cavity model, impedance, radiation pattern;

Introduction to Robotics

Robot components, frame description and degrees of freedom, manipulators, position, orientation & tracking, workspace, translation of frame matrix representation: representation of transformation: pure rotational about an axis, inverse transformation matrix, robot hand, trajectory: path generation (up to 3rd order polynomial), sensors, encoder and tachometer, proximity sensors: magnetic, optical and infrared sensors.

Reading List:

1. **Network Analysis:** M. E. Van Valkenburg
2. **Network Theory and Filter Design:** V. K. Aatre
3. **Digital System Design and Multiprocessor:** J. P. Hayes
4. **Microprocessor Architecture: Programming and Applications:** R. S. Gaonkar
5. **Microelectronics:** J. Milman
6. **Engineering Electronics:** J. D. Ryder
7. **Integrated Electronics:** J. Milman and C.C. Halkias
8. **Digital Circuits and Logic Design:** S. C. Lee
9. **Antenna:** J. D. Kraus
10. **Electronic Communication:** D. Roddy and J. Coolen
11. **Digital Communication:** J. G. Proakisd
12. **Antenna Theory and Design:** R. S. Elliot
13. **Antennas and Radiowave Propagation:** Robert E. Collin

ELECTIVE PAPER

Paper code: PHY 1201E

INTRODUCTORY ASTRONOMY & ASTROPHYSICS

Credits: 3 (2+1+0)

Introduction to Astronomy [4 lectures]

The celestial sphere; coordinate systems; concept of time; magnitude scales and colour index; astronomical telescopes;

Stellar parallax and other methods to measure stellar distances; binary systems and derivation of stellar parameters.

Solar interior, solar atmosphere and the solar cycle.

Stellar structure [4 lectures]

Integral theorems of hydrostatic equilibrium for stars; homologous transformation and the theory of polytropic gas sphere; Virial theorem and stability of polytropes.

Stellar Radiation theory [4 lectures]

Transport of energy in stellar interior; ionization and mean molecular weight; Saha's ionization equation; stellar opacity and Rosseland mean opacity coecient; theory of stellar radiation and equation of transfer; limb darkening; stellar classication and the Hertzsprung-Russel (H-R) diagram.

Nuclear reactions in stars [4 lectures]

Thermonuclear reaction rates; nuclear cross section; non-resonant reaction and resonant reaction rates; hydrogen burning in stars; helium flash; advance stages of nuclear burning and nucleosynthesis of elements.

Star formation and the Interstellar Medium (ISM) [4 lectures]

Physical processes in interstellar dust and gas; Jeans criteria for collapse; free fall collapse; isothermal collapse; pre main-sequence stars and Hayashi track.

Propagation effects: Dispersion, scattering, birefringence etc.

Physics of compact objects [4 lectures]

The end point in stellar evolution; degenerate stars; white dwarf mass and Chandrasekhar's limit; mass-radius relation; collapse of stellar core; electron capture and formation of a neutron star; gravitational binding energy of neutron stars; rotating neutron stars and pulsars; the maximum mass of a neutron star.

Galaxies, Active galaxies and large-scale structure of the Universe [8 lectures]

Classification of galaxies and their properties; active galactic nuclei and their classification; Eddington luminosity; jets; variability and superluminal motion; unification schemes; evidence of black holes; large-scale distribution of galaxies; formation and evolution of the Universe; cosmic microwave background radiation; synthesis of light elements; cosmological models (H_o and q_{o}).

Reading List:

1. **The Physical Universe - An Introduction to Astronomy:** Frank Shu
2. **Observational Cosmology:** Stephen Serjeant
3. **Radio Astronomy:** J. D. Kraus
4. **An introduction to modern astrophysics:** Carrol and Ostlie
5. **Astrophysics: Decoding the cosmos:** Judith Ann Irwin
6. **Astrophysics for physicists:** Arnab Rai Choudhuri

ELECTIVE PAPER

Paper code: PHY 1202E

PLASMA PHYSICS

Credits: 3 (2+1+0)

Introduction [6 lectures]

Recap of non-relativistic dynamics of charged particles in electro-magnetic field; plasma as the 4th state of matter; electron and ion temperature; Debye length; cyclotron frequency; Larmour radius; drift velocity of guiding center; magnetic moment;

Magnetic mirror systems and their relation to plasma contentment devices.

Magneto-Hydrodynamics (MHD) [6 lectures]

Introduction to ideal MHD systems; fundamental equations of magneto-hydro dynamic systems; diffusion and mobility of charged particles in plasma; plasma as a fluid and MHD equations; approximations and linearization of MHD from dimensional considerations; single fluid MHD equation.

Waves and Instabilities in Plasma [10 lectures]

Waves in un-magnetized plasma; energy transport; ion-acoustic waves and MHD waves; plasma stability and the use of normal modes to analyze stability; interaction between plasma particles; perturbation at two uid interface; Raleigh Taylor instability; Kelvin Helmholtz instability; Jeans instability.

Kinetic Theory [10 lectures]

Need for kinetic theory and MHD as approximation of kinetic theory; phase space for many particle motion; velocity and space distribution function; electron-ion plasma oscillation frequency; derivation of Landau damping and Vlasov equations for fluid dynamics.

Reading List:

1. **Introduction to Plasma Physics and Controlled Fusion:** F. Chen and F. Chen
2. **Introduction to Plasma Physics:** R. Goldston and P. Rutherford

ELECTIVE PAPER

Paper code: PHY 1203E

ATMOSPHERIC PHYSICS

Credits: 3 (2+1+0)

Introduction to Atmosphere [4 lectures]

Atmosphere and its composition; Physical and dynamical processes on layer formation: troposphere, stratosphere and ionosphere; vertical variation of temperature; ozone and its spatio-temporal variation; measurement of ionization density and ozone density; temperature, pressure and wind distribution in the atmosphere and general circulation.

Mathematical and Statistical Methods [8 lectures]

First and second order differential coefficients and their applications to atmospheric variabilities; auto-correlation theory; standard statistical distributions: binomial, normal, gamma, student's t and χ^2 distributions; application of auto-correlation and auto regressive processes applied to atmospheric variabilities.

Error analysis; sampling and test of hypothesis; analysis of variance; interpolation and extrapolation techniques; grid-point interpretations; harmonic and spectral analysis and their use in atmospheric science.

Instruments and Observational Techniques [6 lectures]

Working principle, application and circuit block diagrams of instruments: Ionosonde, Radiosonde, Ozonesonde, LIDAR, DIAL, SODAR, AWS, weather satellites and Doppler, ST and MST radars.

Wave Propagation in atmosphere [6 lectures]

Super and sub-refraction conditions and mm and cm radio-wave propagation; rain attenuation of waves in atmosphere; ionosphere and its role in radio communication: Total Internal Reflection.

Atmospheric thermodynamics and radiation budget [8 lectures]

Radiative transfer in the atmosphere; aerosol scattering: Rayleigh and Mie scattering; role of aerosols and atmospheric dust in radiation balance; calculation of radiative heating and cooling and energy balance; energy exchange processes through waves and instabilities.

ELECTIVE PAPER

Paper code: PHY 1204E

NANO PHYSICS

Credits: 3 (2+1+0)

The nano-scale regime

Emergence of nanotechnology; bottom-up and top-down approaches; challenges in nanotechnology.

Synthesis of Thin films

Quantum wells, wires and dots; synthesis of metallic, oxide and semiconductor nano-particles:

Physical: lithographic, scanning probe microscope, melt-spinning, R.F. sputtering, Pulsed laser deposition.

Chemical: Chemical bath deposition, sol-gel, vapour deposition

Thin films

Fundamentals of film growth, method of thin film deposition, vapour evaporation, R.F sputtering, CBD, MBE, size effects in thin films

Characterization of Thin Films

X-ray diffraction technique, broadening of diffraction lines, Scherrer equation, optical absorption spectra;

Basics of electron microscopy: SEM, TEM, AFM, Photoluminescence, electrical and magnetic properties.

Quantum Mechanical Treatment

Quantum wells, widening of bandgap in semiconductor dots, strong and weak confinement, size dependent properties, size dependent absorption spectra, blue shift, size dependent magnetic properties.

Carbon Nanostructures

Nature of carbon bond, small carbon clusters, discovery of, C_{60}; larger and smaller fullerenes; carbon nano-tubes, bulk nano-structured materials and their properties.

Applications of nanomaterials

Nano-electronics, biological applications of nano-particles, bandgap engineered quantum devices, photonic crystals.

Reading List:

1. **Springer Handbook of Nanotechnology:** Bharat Bhushan (Ed.), Springer-Verlag, Berlin 2004.

2. Nanostructures and Nanomaterials: Synthesis, Properties and Applications: Guozhong Cao.

3. Introduction to Nanotechnology: Charles P. Poole Jr. and Frank J. Owens

4. Elements of X-ray Diffraction: B. D. Cullity and S. R. Stock

ELECTIVE PAPER

Paper code: PHY 1205E

BIOPHYSICS

Credits: 3 (2+1+0)

(The department will offer this paper after the August-December, 2014 semester)

ELECTIVE PAPER

Paper code: PHY 1206E

PHYSICS OF THE EARTH

Credits: 3 (2+1+0)

(The department will offer this paper after the August-December, 2014 semester)