Structure and Syllabus

for

2 Year M. Sc. in Physics (CBCS)

ALIAH UNIVERSITY

(Effective from the session 2021-2022)

Department of Physics

Aliah University

New Town, Kolkata

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1. Introduction

- These regulations shall be for the Two-year Postgraduate Degree Programme namely M. Sc in Physics (Choice Based Credit System) of Aliah University
- These regulations shall come to effect from 2021-2022 session
- These regulations shall remain valid till further amendment by the concerned authorities

2. Duration of the Programme

The 2-Year Master's Degree Programme (under CBCS) shall be for a minimum duration of 04 consecutive semesters of 06 months each, *i.e.* two (02) academic years and will start as notified by University authority

A candidate shall have to clear all the semesters within four years from the academic year of his/her first admission to the University failing which enrolment of the candidate shall remain cancelled.

3. Programme Structure

The postgraduate Degree Programmenamely M. Sc in Physicsof Aliah University consists of:

1. **Core Course (CCT** and **CCP):**A discipline specific compulsory basic course.Total 13 papers (10 theory papers each of 4 credit*i.e.* totalling10x4 = 40 credit points and 3 lab papers each of 4 credit *i.e.* totalling 3x4 = 12 credit points)are considered.

2. **Discipline Specific Elective Course (DET and DEP):**A discipline specific elective course (choice based) which is more advanced orspecialized is offered in the Semester- III and IV. Total 4 papers (2 theory and 2 lab paperseach of 4 credit totalling4x4 = 16 credit points)are considered.

3. **Generic Elective Course (GEC):** Aninter-disciplinary elective course (choice based) to be opted from a discipline otherthan ones main discipline(s) of choicein the Semester-III and IV. (2 papers each of 4 credit totalling 2x4 = 8 credit points).

4. **Aliah University Compulsory Course (AUC):**ACompulsoryCourse on "Elementary Arabic and IslamicStudies" having no credit points only in Semester-I.

5. **Ability Enhancement Compulsory Course (AEC):**ACompulsoryCourse on Disaster management/ Human Rights/ Value Education/ Yoga/ Soft Skills having no credit points only in Semester-II.

6. **Project and Dissertation (PRJ):**Students have to work on a specific project and will write a dissertation on it followed by a presentation in Semester IV. (1 paper of 4 credit totaling 1x4 = 4 credit point).

4. Overall credit points and marks distribution

Name of the course	Code	No of Paper x credit	No of Paper x full marks
Core Course	CCT/CCP	13 x 4 =52	13 x50 =650
Discipline Specific Elective Course	DET/DEP	4 x 4 =16	4 x50 =200
Generic Elective Course	GEC	2 x 4 = 8	2 x 50 =100
Project and Dissertation	PRJ	1 x 4 = 4	1 x 50 = 50
Aliah University Compulsory Course	AUC	0	0
Ability Enhancement Compulsory Course	AEC	0	0
		Total Credit= 80	Total marks= 1000

5. Question Pattern for Examinations

Each Course will be evaluated through an Internal Assessment (IA) of 10 marks and a Semester End Examination of 40 marks.

6. Syllabus structure for Department of Physics

Semester I

Course Title	Course Code	Credits	Marks
Mathematical and Computational Physics	PHYPGCCT01	4	50
Classical Mechanics	PHYPGCCT02	4	50
Quantum Mechanics I	PHYPGCCT03	4	50
Solid State Physics	PHYPGCCT04	4	50
Physics Lab I	PHYPGCCP01	4	50
Elementary Arabic and Islamic Studies	PGAUC01	Non-Credit	---
		20	250

*PGAUC01 - Aliah University Compulsory Course

Semester II

Course Title	**Course Code**	**Credits**	**Marks**
Electrodynamics	PHYPGCCT05	4	50
Quantum Mechanics II	PHYPGCCT06	4	50
Nuclear and Particle Physics	PHYPGCCT07	4	50
Semiconductor Physics and Electronics	PHYPGCCT08	4	50
Computational Physics Lab	PHYPGCCP02	4	50
Disaster Management/ Human Rights &Value Education/Yoga/Soft Skills (Any one of the above)	PGAEC01	Non-Credit	
		20	250

* PGAEC01 -Ability Enhancement Compulsory Course

Semester III

Course Title	**Course Code**	**Credits**	**Marks**
Statistical Mechanics	PHYPGCCT09	4	50
Physics Lab II	PHYPGCCP03	4	50
Material Physics I/ General Theory of Relativity/ Advanced Nuclear and Particle Physics	PHYPGDET01	4	50
Advanced Physics Lab I	PHYPGDEP01	4	50
Basic Astronomy and Astrophysics	PHYPGGEC01	4	50
		20	250

*PHYPGDET01- Discipline Specific Elective

PHYPGGEC01- GE-Generic Elective

Semester IV

Course Title	**Course Code**	**Credits**	**Marks**
Atomic and Molecular Physics	PHYPGCCT10	4	50
Project work and dissertation	PHYPGPRJ01	4	50
Material Physics II/ Astrophysics and Cosmology/ Advanced Atomic and Laser Physics	PHYPGDET02	4	50
Advanced Physics Lab II	PHYPGDEP02	4	50
Physics at different length scales	PHYPGGEC02	4	50
		20	250

*PHYPGDET02- Discipline Specific Elective

PHYPGGEC01-Generic Elective

PHYPGPRJ01- Project and Dissertation

Semester: I

PHYPGCCT01: Mathematical and Computational Physics

Credit: 4, Full marks: 50, Lectures: 60

1. **Complex analysis** [10 lectures]

   Analytic functions, Cauchy-Riemann equation; Cauchy's integral formula; Taylor's expansion, Laurent's expansion; Singularities, Poles and Branch points; Residue formulae.

2. **Linear vector space and operators** [12 lectures]

   Basics of abstract algebra *e.g.* Set, Group, Ring, Field. Group multiplication table, Conjugates elements and classes, Isomorphism & Homomorphism, Vector space, Inner product space, Schmidt's orthogonalisation method, Schwartz inequality. Linear operators, Matrix representation of operators. Special operators-conjugate operators, Adjoint and Self adjoint operators, Unitary operators, Orthogonality.

3. **Tensors** [8 lectures]

   General definition, Contravariant, Covariant and Mixed tensors and their ranks; outer product of tensors, Contraction of Tensors, Inner product of tensors; Symmetric and anti-symmetric tensors; Isotropic tensors, Metric tensor, raising and lowering of indices; Cartesian tensors.

4. **Integral transformation** [10 lectures]

   Fourier and Laplace transformation, Respective inverse transformations; Bromwich integral, Solution of differential equation using Fourier transforms and Laplace transformation

5. **Theory of differential equations** [8 lectures]

   Second order linear homogeneous differential equations, Singular points, Frobenius method; Fuch's theorem; Hypergeometric and confluent hypergeometric differential equations; Linear independence of solutions, Wronskian, second solution. Sturm-Liouville theory; Hermitian operators; Completeness, solution of Inhomogeneous differential equations by Green's functions technique.

6. **Computations using FORTRAN 77/90 programming language**[12 lectures]

   Basic Linux commands and vi editor commands, Constants and variables; variable types and declarations. Assignment and arithmetic expressions. Read and write statements, logical expression. IF, Arithmetic IF, IF THEN ELSE statements. GO TO, Computed GO TO statements. DO loops, nested DO loops. Functions and subroutines. Multidimensional arrays. Formatted input/output statements. Precision: single, double, quadruple. Algorithm and flowchart, Application to different numerical problems.

Reference Books

1. Mathematical Methods for Physics, Arfken & Weber
2. Introduction to Mathematical Physics, C. Harper
3. Mathematical Methods, M. C. Potter and J. Goldberg
4. Mathematical Methods of Physics, J. Mathews and R.L. Walker
5. Mathematics for Physicists, P. Dennery and A. Krzywicki
6. Vector Analysis, M. R. Spiegel, (Schaum's Outline Series)
7. Complex variables and Applications, R.V. Churchill and J.W. Brown
8. Theory and Problems of Complex Variables, M.R. Spiegel
9. Matrices and Tensors in Physics, A.W. Joshi
10. Elements of Group Theory for Physicists, A.W. Joshi
11. Differential Equations, S.L. Ross
12. A Text book of Mathematical Physics, Suresh Chandra
13. Fortran 77, Xavier
14. Fortran 90, Balaguruswamy

PHYPGCCT02: Classical Mechanics

Credit: 4, Full marks: 50, Lectures: 60

1. **Lagrangian and Hamiltonian Formulation** [15 lectures]

   Review of D'Alembert's principle, Calculus of variations, Euler-Lagrange's equations, concept of symmetry, homogeneity and isotropy, conservation principles, Lagrange's equations for non holonomic systems, Lagrange's equations for impulsive forces, invariance under Galilean transformation, Hamiltonian formulation-simple applications.

2. **Canonical Transformation and Hamilton-Jacobi Theory** [15 lectures]

   Canonical transformations, generating functions, example of canonical transformation. Poisson Bracket, relations of P.B., Conservation theorems in P.B. Formulation. Hamilton-Jacobi equation, separation of variables, cyclic variables and the Kepler problem, Action angle variables, harmonic oscillator and Kepler problem in action-angle variables.

3. **Rigid Body Dynamics** [10 lectures]

   Euler angles, finite and infinitesimal rotations, inertia tensor, motion of a heavy symmetric top rotating about a fixed point in the body under gravity.

4. **Small oscillations** [8 lectures]

   Condition of stability near equilibrium, the eigenvalue equation & principal axes transformation, normal modes and coordinates, vibrations of molecules.

5. **Continuous systems and fields** [7 lectures]

   Lagrangian and Hamiltonian formulation for continuous systems, symmetry and conservation principles, Noether's theorem, classical field theory.

6. **Introduction to autonomous systems** [5 lectures]

   Non-linear systems, Lyapunov exponents, Basic idea of chaos.

Reference Books

1. Theoretical Mechanics, M. R. Spiegel, (Schaum's Outline Series)
2. Mechanics, K. R. Symon
3. Classical Mechanics, J. Goldstein
4. Classical Mechanics, N. C. Rana and P. S. Joag
5. Padarther Dharma, D. P. Ray Chaudhuri
6. An Introduction to Mechanics, D. Keppner and R.J. Kolenkow
7. Mechanics, H. S. Hans and S. P. Puri
8. Classical Mechanics, A. K. Roychaudhuri
9. Classical Mechanics, J. C. Upadhyaya

PHYPGCCT03: Quantum Mechanics I

Credit: 4, Full marks: 50, Lectures: 60

1. **Three-dimensional problems** [6 lectures]

   Three dimensional problems in Cartesian and spherical polar coordinates, 3-d well and Fermi energy; Radial equation of free particle and 3-d harmonic oscillator; Eigenvalue of a 3-d harmonic oscillator by series solution, Review of hydrogen atom

2. **Operator and Matrix method in Quantum Mechanics** [14 lectures]

   Linear vector space; Linear operators; Hilbert space; Hermitian and unitary operators; Completeness; Matrix representation, change of basis; Formulation of Quantum Mechanics in vector space language; Uncertainty principle for two arbitrary operators; co-ordinate and momentum representation.

3. **Quantum dynamics** [8 lectures]

   Equation of motion in Schrödinger, Heisenberg and interaction picture; One dimensional harmonic oscillator by operator method, time development of the oscillator, coherent state.

4. **Angular momentum** [12 lectures]

   Angular momentum operators, spherical harmonics, commutation relations between angular momentum operators, angular momentum by operator method, raising and lowering operators, matrix representation for j=1/2 and j=1, Pauli spin matrices, addition of two angular momenta, Clebsch-Gordan coefficients; Construction of spin eigen-functions, Wigner D functions.

5. **Approximation methods for bound states-I**

Time independent perturbation theory [10 lectures]

First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory. Application to one-electron system - Relativistic mass correction, Spin-orbit coupling (L-S and j-j), Zeeman effect and Stark effect.

Variational method [5 lectures]

Trial wavefunction, application to He atom as example, Exchange degeneracy; Ritz principle for excited states for Helium atom, Hylleraas-Undheim theorem.

WKB Approximation [5 lectures]

Quantization rule, tunnelling through a barrier, qualitative discussion of alpha-decay and related problems.

Reference Books

1. Quantum Mechanics, J. L. Powell and B. Crasemonn (Narosa)
2. Quantum Mechanics, F. Schwabl (Narosa)
3. Quantum Mechanics, A. K. Ghatak and S. Lokenathan (Macmillan, Delhi)
4. A Textbook of Quantum Mechanics, P. M. Mathews and K. Venkatesan (Tata Mc Graw Hill)
5. Modern Quantum Mechanics, J. J. Sakurai (Persian Education)
6. B. H. Bransden and C. J. Joachain : Quantum Mechanics

PHYPGCCT04: Solid State Physics

Credit: 4, Full marks: 50, Lectures: 60

1. **Imperfections in Crystals** [10 lectures]

   Lattice defects, Point defects, Schottky defects, Frenkel defects, Dislocation, Surface imperfections, Volume defects.

2. **Theory of Semiconductors** [10 lectures]

   Intrinsic and Extrinsic semiconductors; Compound semiconductors; direct and indirect semiconductors; drift velocity, mobility and conductivity of Intrinsic semiconductors; Carrier concentration in N and P type semiconductors; Charge neutrality equation; Carrier transport in semiconductors.

3. **Dielectrics** [15 lectures]

   Electronic, Ionic and Orientation Polarization, Internal field, Clausius-Mossotti equation, Ferro and Piezo electricity, Frequency dependence of dielectric constant, temperature dependence of dielectric constants and permanent molecular dipole moment, response of dielectric to an alternating fields.

4. **Magnetism** [15 lectures]

Dia, para and ferro-magnetic properties of solids. Langevin's theory of diamagnetism and paramagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism: spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie-Weiss law, explanation of hysteresis. Magnetic exchange interaction-Ferro, Antiferro & Ferrimagnetism. ESR and NMR.

5. **Superconductivity** [10 lectures]

Basic phenomenology, Meissner effect, London's phenomenological theory and penetration depth, critical magnetic field, coherence length, type-I and type-II superconductors, magnetic flux quantization, entropy and specific heat, isotope effect, cooper pairs, BCS theory, ac and dc Josephson effects, high temperature superconductors.

Reference Books

1. Introduction to Solid State Physics, C. Kittel
2. Solid State Physics, A. J. Dekker
3. Solid State Physics, Ashcroft and Mermin
4. Solid State Physics, S. O. Pillai
5. Elements of Solid State Physics, J. P. Srivastava
6. An Introduction to Solid State Physics and Application, R. J. Elliot and A. F. Gibson
7. Solid State Physics, D. W. Snoke

PHYPGCCP01: Physics Lab I

Credit: 4, Full marks: 50

1. Interferometry with Michelson interferometer
2. Interferometry with Fabry Perrot interferometer
3. Study of polarization of light
4. To verify Fresnel's equations for reflection of electromagnetic waves
5. Molecular absorption spectroscopy (Iodine absorption)
6. Experiments with optical fiber
7. Measurement of velocity of light
8. Microwave diffraction
9. Photoelectric effect: Measurement of Planck's constant
10. Verification of Coulomb's Law (by method of image charge): Measurement of permittivity of air
11. To find the e/m of an electron

Semester: II

PHYPGCCT05: Electrodynamics

Credit: 4, Full marks: 50, Lectures: 60

1. **Recapitulation of electrodynamics** [15 lectures]
   Recapitulation of field equations, scalar & vector potentials, Lorentz and Coulomb gauge, Conservation laws, Tensors in Minkowski space, electromagnetic field tensor, covariance of electrodynamics, transformation of electromagnetic fields, Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

2. **Field of moving charges and radiations** [25 lectures]
   Retarded potentials, Lienard-Wiechert potentials, Field produced by arbitrary moving charged particle at low velocity and at high velocity, Larmor's formula, Radiation loss from an accelerated charge particle (for linear and circular accelerator), Angular distribution of radiation emitted by an accelerated charge, Total power radiated by an accelerated charge, cyclotron and synchrotron radiation, Electromagnetic field due to a uniformly moving relativistic charge, virtual photon, Energy transfer in a coulomb collision, Cherenkov radiation.

3. **Radiating System** [10 lectures]
   Oscillating electric dipole, radiation from an oscillating electric dipole, Magnetic dipole and electric quadrupole radiation, radiation due to a small current element, radiation from a linear antenna.

4. **Scattering of radiation** [10 lectures]
   Differential scattering cross-section, Thomson and Rayleigh scattering, Radiation reaction, Abraham-Lorentz model, Line width of radiation spectrum due to radiation reaction.

Reference Books

1. Classical Electrodynamics, J.D. Jackson
2. Introduction to Electrodynamics, D. J. Griffith
3. Classical Electrodynamics, W. Panofsky and M. Phillips
4. The Classical Theory of Fields, L.D. Landau & E.M. Lifshitz
5. Electromagnetic Theory and Electrodynamics, Satya Prakash
6. Foundations of Electromagnetic Theory (3rd Edi.), J.R.Reitz, F.J.Milford & R.W.Christy
7. The Feynman Lectures on Physics, Vol. II
8. Electromagnetism and Classified Theory, A. D. Barut
9. Introduction to Electrodynamics, A. Z. Capri and P. V. Panat

PHYPGCCT06: Quantum Mechanics II

Credit: 4, Full marks: 50, Lectures: 60

1. **Approximation methods for bound states-II** [8 lectures]

   Time-dependent Perturbation Theory

   Interaction picture; Constant and harmonic perturbations; Fermi's Golden rule; Sudden and adiabatic approximations; Radiative transitions and Einstein's A & B coefficients

2. **Symmetric in quantum mechanics** [10 lectures]

   Conservation principles and degeneracy associated with symmetry, Continuous symmetries-spatial translation, rotation and time evolution, Discrete symmetries- Parity, time reversal and permutation, Rotation matrices, Spherical tensor operators, Wigner-Eckart theorem, Symmetry group and group representation.

3. **Identical Particles** [6 lectures]

   Meaning of identity and consequences, symmetric and antisymmetric wavefunctions, Slater determinant, symmetric and antisymmetric spin wavefunctions of two identical particles, collisions of identical particles.

4. **Quantum theory of potential scattering** [10 lectures]

   Laboratory and center of mass frames, scattering cross-section amplitude, partial wave analysis, phase shift and resonance, scattering length, optical theorem, scattering by attractive square well and hard sphere, integral equation of scattering, Green's function, Lippmann-Schwinger equation, Born approximation, scattering by Yukawa potential, Coulomb scattering, introduction to S and T matrices

5. **Relativistic Quantum Mechanics** [16 lectures]

   Klein-Gordon equation and its inadequacies, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles, free particle Dirac equation, Dirac matrices, plane wave solution and its interpretation, negative energy states and hole theory, spin, helicity, chirality and magnetic moment of a Dirac particle, Dirac particle in central potential, relativistic angular momentum, radial Dirac equation and its solution for H-atom, non-relativistic limit of the Dirac equation, covariant formulation of Dirac equation, properties of gamma matrices, charge conjugation, normalization and completeness of spinors, bilinear covariant and their transformations under parity and infinitesimal Lorentz transformation, Weyl representation and chirality projection operators

6. **Field quantization** [10 lectures]

   Basic ideas, construction of conjugate momentum from Lagrange density, commutation relations for bosonic and anti-commutation relations for fermionic fields in terms of field and momentum or creation and annihilation operators, quantization of scalar and complex scalar fields, Quantization of non relativistic Schrodinger equation, Occupation number representation, Radiation field theory- electromagnetic field as oscillators, and vacuum quantization and its application in Lamb shift, energy and momentum of field quantum, interaction of atom with quantized radiation field, spontaneous and induced emission.

Reference Books

1. Quantum Mechanics, L.I. Schiff
2. Modern Quantum Mechanics, J.J. Sakurai
3. A Text Book of Quantum Mechanics, P.M. Mathews and K. Venkatesan
4. Relativistic Quantum Mechanics, J.D. Bjorken and S.D. Drell
5. Relativistic Quantum Mechanics, W. Greiner
6. A First Book of Quantum Field Theory, A. Lahiri and P.B. Pal
7. Quantum Mechanics, B. H. Bransden and C. J. Joachain
8. Quantum Mechanics, A. K. Ghatak and S. Lokenathan
9. Introduction to Field Theory, S. Weinbrg

PHYPGCCT07: Nuclear and Particle Physics

Credit: 4, Full marks: 50, Lectures: 60

1. **Nuclear Interactions and Nuclear Reactions** [10 lectures]
   Nucleon interaction, exchange forces and tensor forces, Meson theory of nuclear forces, nucleon-nucleon scattering, effective range theory, spin dependence of nuclear forces, charge independent and charge symmetry of nuclear forces, isospin formalism, Yukawa interaction.

2. **Direct and compound nuclear mechanisms** [8 lectures]
   Cross-sections in terms of partial wave amplitudes, compound nucleus, scattering matrix, reciprocity theorem, Breit-Wigner one level formula, resonance scattering.

3. **Alpha decay** [4 lectures]
   Gamow's theory.

4. **Beta and Gamma decay** [12 lectures]
   Angular momentum and parity selection rules, allowed and forbidden transitions, selection rules, parity violation, two component theory of neutrino decay, detection and properties of neutrino, Gamma decay, multiple transitions in nuclei, angular momentum and party selection rules, internal conversion, nuclear isomerism.

5. **Two-body nuclear problem** [8 lectures]
   Deuteron ground state, nuclear scattering, sources on neutrons, its detection, measurement of energy, neutron diffraction application, interaction of neutron with matter.

6. **Elementary Particle Physics** [10 lectures]

Symmetry and conservation laws, elementary ideas of CP and CPT invariance, classification of hadrons, Lie algebra, SU(2), SU(3) multiplets, quark model, Gell-Mann-Okubo mass formula for octet and decuplet hadrons, charms, bottom and top quarks.

7. **Particle Accelerators** [4 lectures]

Introduction, Linear accelerators, Drift tube and Wave guide accelerators, Low energy circular accelerators, Cyclotron and Betatron.

8. **Nuclear Astrophysics** [4 lectures]

Primordial nucleosynthesis, energy production in stars, pp chain, CNO cycle, Production of elements (qualitative discussion).

Reference Books

1. Nuclear Physics, Cottingham and Greenwood (Cambridge University Press)
2. Nuclear and particle Physics, W.E. Burcham and M. Jobes
3. Introduction to Elementary Particles, D.J. Griffiths
4. Nuclear Physics, R.R. Roy and B.P. Nigam
5. Atomic and Nuclear Physics (Vol. 2), S.N. Ghoshal
6. Nuclear Physics: Principles and applications, J. S. Lilley
7. Introduction to High Energy Physics, D.H. Perkins
8. Nuclear Physics, Kaplan
9. Introductory Nuclear Physics, K. S. Krane

PHYPGCCT08: Semiconductor Physics and Electronics

Credit: 4, Full marks: 50, Lectures: 60

1. **Fundamentals of semiconductor** [8 lectures]

Idea of energy band, the Fermi level and energy distribution of carriers inside bands, temperature dependence of carrier concentration, carrier transport in semiconductors, generation and recombination process of excess carriers in semiconductor and idea of quasi Fermi levels, basic equation of semiconductor device operations.

2. **P-N junction devices** [8 lectures]

p-n junction physics- Fabrication steps, thermal equilibrium condition, depletion capacitance; current-voltage characteristics, charge storage and transient behaviour, junction breakdown, Majority carrier diodes, Tunnel diodes: principle of operations & I-V characteristics. Schottky barrier diodes: Metal semiconductor contacts, Schottky-Mott theory & surface states, Schottky effect, current flow mechanism, I-V characteristics, Rectifying contacts, Ohmic contacts.

3. **Field effect transistors (FET)** [8 lectures]

Classification of various types of FETs, construction of junction FET, Principle of operation drain characteristics, biasing, operating region, pinch-off voltage. Structure and principle operation of MOSFET, depletion & enhancement type, I-V characteristics.

4. **Semiconductor devices** [8 lectures]

Photoconductor, Solar cell, Photodiode, LED, Semiconductor laser, Phototransistor, Thyristor, p-n-p-n switch, Gunn diode, IMPATT diodes-basic principle, GaAs-InP.

5. **Power Amplifier** [8 lectures]

Multistage amplifier, gain, band width and their product, operating point of power amplifier: Class A, Class B and Class C power amplifiers, and analysis of single tuned voltage amplifier, requirement of power amplifiers, Push pull and tuned power amplifiers.

6. **Coupled Amplifier** [4 lectures]

RC-coupled amplifier and its frequency response.

7. **Elements of Communication Electronics** [16 lectures]

Review of modulation and detection, Principles of analog modulation; comparison among different techniques; power, bandwidth and noise. Principle of amplitude modulation (AM) and frequency modulation (FM), AM spectrum and FM spectrum, channel band width and signal band width, side band frequency, Generation of transmitted carrier and suppressed carrier type AM signals with necessary circuits, Principles of detection of different types of modulated signals (TC and SC types), principle of generation of F.M. wave with necessary circuits, Detection of F.M. wave. Modulation techniques in some practical communication systems: AM and FM radio.

Reference Books

1. S.M. Sze: Physics of Semiconductor Devices
2. B.G. Streetman and S. Banerjee: Solid State Electronic Devices
3. Integrated Electronics, J. Millman and C. C. Halkias
4. Electronics Fundamentals and Applications, J. D. Ryder
5. Electronic Device and Circuit Theory, R. Boylestad and L. Nashelsky
6. Digital Logic and Computer Design, M. Moris Mano
7. Microelectronics, Milman and Grable
8. Analog Electronics, B. C. Sarkar and S. Sarkar
9. Radiation, Detection and Measurement, G.F. Knoll
10. Electronic Circuit analysis, Chattopadhyay and Rakshit,
11. Electronic and Radio Engineering, F. E Terman
12. Networks lines and fields, John D. Ryder
13. Radio Frequency Principles and applications, A. A Smith
14. Electronic communications, D. Roody J.Coolen

PHYPGCCP02: Computational Physics Lab

Credit: 4, Full marks: 50

1. Plotting of functions and data; fitting etc. using gnu plot.
2. Revision of numerical methods for integration, finding roots of equation, solving simultaneous linear differential equations, least squares fitting, interpolation, solving differential equations (Euler method).
3. Use of standard subroutines:
   (i) Runge Kutta method for solving differential equations (example : anharmonic oscillator)
   (ii) Matrix diagonalisation; matrix inversion (eigenvalue problem)
4. Monte Carlo methods. Applications in
   (i) Random number generation from different distributions: uniform, Gaussian etc.
   (ii) Numerical integration.
   (iii) 1D and 2D Ising model.

Reference Books

1. Fortran 90/95 Programming Manual, Tanja van Mourik
2. Fortran 90 Course Notes, A. C. Marshall, J. S. Morgan and J. L. Schonfelder
3. Computer Oriented Numerical Methods, V. Rajaraman
4. Numerical Methods in Fortran, J.M. McCulloch and M.G. Salvadori
5. Numerical Methods, R. L. Burden and J. D. Faires

Semester: III

PHYPGCCT09: Statistical Mechanics

Credit: 4, Full marks: 50, Lectures: 60

1. **Recapitulation** [4 lectures]
   Macrostate, microstate, phase space, volume in phase space, phase cells, density of states and Liouville's theorem, counting the number of microstates in phase space, ensembles. Principle of equal priori probability, Ergodic hypothesis. MB, BE, FD distribution function, partition function. Entropy of ideal gas: Sackur-Tetrode equation and Gibb's paradox. Idea of Microcanonical ensemble**,** calculation of internal energy, entropy and chemical potential of a perfect gas.

2. **Canonical Ensemble** [6 lectures]
   System in contact with a heat reservoir, canonical distribution, canonical partition function and its correlation with thermodynamic quantities- expression of entropy, Helmholtz free energy,

total energy, specific heat (C_v), fluctuation of internal energy. Canonical partition function for perfect monatomic gas and calculation of entropy, Helmholtz free energy and internal energy.

3. **Grand Canonical Ensemble** [6 lectures]
   System in contact with a particle reservoir, chemical potential, grand canonical distribution, grand canonical partition function, grand potential, fluctuation of particle number, chemical potential of ideal gas. Chemical equilibrium and Saha ionisation equation.

4. **Classical non-ideal gas** [6 lectures]
   Mean field theory and Van der Waal's equation of state; Cluster integrals and Mayer-Ursell expansion.

5. **Quantum statistical mechanics** [10 lectures]
   Indistinguishability and quantum statistics, exchange symmetry of wave functions, symmetric and anti-symmetric wave functions, average value in quantum statistics. Density matrix, density operator in statistical mechanics, quantum Liouville's theorem. Density matrices for microcanonical, canonical and grand canonical ensembles, simple examples of density matrices- one electron in a magnetic field, particle in a box, linear harmonic oscillator. Statistics of identical and indistinguishable particles, Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics- a comparison, Pauli's exclusion principle.

6. **Ideal Bose and Fermi gas** [8 lectures]
   Calculation of energy and pressure of ideal Bose gas, gas degeneracy, Bose-Einstein condensation, calculation of entropy and specific heat of Bose gas, superfluidity. Calculation of energy and pressure of ideal Fermi gas, weak and strong degeneracy, Fermi gas at finite T, calculation of entropy, specific heat, free energy. Pauli's theory of paramagnetism.

7. **Phase Transition and critical phenomena** [10 lectures]
   General theory of phase transition, examples of phase transition and critical phenomena, magnetic phase transitions. Ising model: partition function for one dimensional case and exact solution in one dimension; Bragg-Williams approximation theory; Critical exponents, calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension.

8. **Non-equilibrium Statistical Mechanics** [10 lectures]
   Time dependent correlation functions, Fluctuation and thermodynamic properties, Brownian motion, Langevin theory, Fokker-Planck Equation, Fluctuation-Dissipation Theorem.

Reference Books

1. Statistical Mechanics, R. K. Pathria
2. Statistical Physics, Berkeley Physics Course, F. Reif
3. Fundamentals of Statistical and Thermal Physics, F. Reif
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich

5. Statistical Mechanics, K. Huang
6. Statistical Physics, F. Mandle
7. Statistical Physics, J.K. Bhattacharyya
8. An Introductory Course of Statistical Mechanics, Palash B. Pal (Narosa)
9. Statistical Mechanics, Gupta & Kumar (Pragati)

PHYPGCCP03: Physics Lab II

Credit: 4, Full marks: 50

1. Determination of Lande-g factor using ESR spectroscopy
2. Measurement of the Hall coefficient of a given sample and its temperature dependence using four probe method
3. Saturation magnetization of ferromagnetic substance using hysteresis loop tracer
4. Measurement of magnetic susceptibility by Guoy's Method
5. Dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibration
6. Determination of dielectric constant of different materials
7. Study of Amplitude Modulation and demodulation
8. Design and characterization of a stable multi-vibrator
9. Square and Triangular wave generator
10. Experiment with FET and MOSFET
11. Performance of Passive pi type and T type high pass and low pass filters

PHYPGDET01:

Credit: 4, Full marks: 50, Lectures: 60

Material Physics I

Electronic Structure of Materials [30 lectures]

Basics

Electrons in periodic potentials: Bloch's theorem, Kronig Penney model, concept of energy bands, NFE model, TB model

Electron Ion Problem

Adiabatic approximation (Born Oppenheimer); Classical nuclei approximation (Ehrenfest Theorem).

Many Electron Problem

Hartree approximation, LCAO method**;** Hartree Fock approx: Slater determinantal wavefunction & its properties, Hartree Fock equation, Fock operator, Energy of the ground state, Koopman's theorem; Going beyond Hartree Fock (introductory), absence of correlation in H-F theory.

Electronic characterization of material: Advances in X-ray/Electron Spectroscopy for electronic structure of materials [15 lectures]

X-ray sources and detectors

X-ray sources, synchrotron radiation, X-ray optics, monochromatizating, collimation and focusing, X-ray detectors, point, linear and area detectors, physical and geometrical factors affecting X-ray intensity.

X-ray and electronic structures

X-ray photoelectron spectroscopy (XPS), Ultra-violet photoelectron spectroscopy (UPS), Auger electron spectroscopy (AES), and inverse photoelectron spectroscopy; ARPES, Theory of Photoemission, Core-level and valence level photoemission, three step consideration, Photoexcitation and photoionization, Core Levels (XPS) and Final States, Photoemission spectroscopy to measure the elemental composition, empirical formula, chemical state, and electronic state of the elements in a compound. Depth profiling, Instrumentation, Applications

X-ray Absorption

Theory of inner shell excitation and X-ray absorption spectroscopy, near edge X-ray absorption. Its application to electronic structures

Charge-Excitation Final States

Satellites, Continuous Satellites and Plasmon Satellites, Resonance photoemission spectroscopy.

Electronic properties of Organic materials and devices [15 lectures]

General Overview of Organic Semiconductors, Structural and Electronic Properties of Organic Semiconductors: recapitulations of BO approximation, Atomic and Molecular Orbitals, LCAO, Bonding and antibonding orbitals, Orbital hybridization, HOMO and LUMO levels.

Charge transport in Organic Semiconductors materials**;** Exciton Processes in Organic Solids, Charge-transfer Exciton, Electronic Conduction in Organic Solids Conductivity: (carrier concentration versus mobility), Carrier generation, Hopping transport, Mobility measurements, Traps etc.

Some basic organic Electronics devices; Organic Light Emitting Diodes, Organic Solar Cells and organics Thin Film Transistors.

Reference Books

1. Photoelectron Spectroscopy, Principles and Applications, Stefan Hüfner
2. X-Ray Scattering from Soft Matter Thin Films, Springer Tracts in Modern Physics; M. Tolan
3. Electrical Characterization of Organic Electronic Materials and Devices, Peter Stallinga
4. Electrical Properties of Materials, Laszlo Solymar, Donald Walsh
5. Organic Electronics: Materials, Manufacturing, and Applications, Hagen Klauk
6. Physics of Organic Semiconductors, edited by W.Brütting and C. Adachi
7. Solid State Physics, Ashcroft &Mermin
8. Solid State Theory, Grosso & Pastore-Parravicini
9. Electronic Structure of Solids, Kaxiras
10. Electronic Structure of Materials, Sutton
11. Lecture Notes on Electron Correlation and Magnetism, Patrik Fazekas
12. Electronic Structure, Richard M. Martin

General Theory of Relativity

1. **Principles of relativity** [10 lectures]

   Overview of Special Relativity, Unit conversion between SI and GR units, space-time interval and Lorentz metric, proper time, action for free particle, relativistic dynamics, four vectors, electrodynamics in 4 dimensional language. Introduction to general relativity (GR), equivalence principle, gravitation as a manifestation of the curvature of space-time

2. **Geometrical framework of General Relativity** [10 lectures]

   Curved spaces, tensor algebra, Metric tensor, it's properties and affine connection, Geodesics, covariant derivatives and parallel transport, Curvature-Riemann tensor, Bianchi identities, Ricci tensor, Energy momentum tensors, Einstein's field equations

3. **Solutions to Einstein's equations and their properties** [10 lectures]

   Spherical symmetry, derivation of the Schwarzschild solution, test particle orbits for massive and massless particles. Inner most stable circular orbit (ISCO), Precession of the Perihelion, Schwarzschild Embedding Diagram, Deflection of Light, Gravitational lensing, Image Brightness.

4. **Applications of GTR** [30 lectures]

   Alternative co-ordinates

   Event horizon, Tortoise co-ordinates, Eddington-Finkelstein co-ordinates, Kruskal-Szekeres metric

   Black holes

   Kerr metric in Boyer-Lindquist co-ordinates, Energy extraction from a rotating black hole- Penrose process, Reissner-Nordstrom black hole, Kerr-Newmann blackhole (no derivation of the metric required), Blackhole thermodynamics and Hawking radiation.

Gravitational Waves

Linearized field equations - Gravitational Waves-polarization, helicity, energy momentum; Generation of Gravitational waves; effect on a test particle; Binary pulsar; detection of gravitational radiation.

Reference Books

1. Gravity: An introduction to Einstein's General Relativity, James B. Hartle
2. Gravitation and Cosmology, Steven Wienberg
3. Gravitation, Misner, Thorne and Wheeler
4. An introduction to Relativity, J.V. Narlikar
5. Gravitation, Vol 1, 2, 3, T. Padmanavan
6. A General Relativity Workbook, Thomas A. Moore
7. A Student's Guide to Vectors and Tensors, Daniel A. Fleisch
8. Lecture Notes on General Relativity, Sean M. Carroll

Advanced Nuclear and Particle Physics

Nuclear Models & Reactions

Models of Nuclei [10 lectures]

1. Collective model: especially for odd-A, emphasis on coupling of particle and collective motions, ground state, β and γ bands (rotational).
2. Degenerate gas-model
3. Nilsson model.
4. Nuclei far away from the stability valley: drip line, extremely neutron rich nuclei, superheavy nuclei.

Nuclear reactions [10 lectures]

1. **Introduction**

   Survey of reactions of nuclei: Strong, electromagnetic and weak processes, Types of reactions and Q-values, Threshold energy, Reaction mechanisms: Energy and time scales for direct and compound reactions, Experimental observables: Cross sections-- definitions and units; Angular distributions, Excitation functions
2. **Thermonuclear reactions**

   Reaction rates. Low energy behaviour and astrophysical S-factors, Forward and reverse reactions, Nonresonant and resonant reactions, Maxwell-Boltzmann distribution of velocities, Gamow peak.
3. Neutron Physics

Models for nuclear reactions [10 lectures]

1. **Direct reactions**

   Optical Model: From Hamiltonian to cross sections for elastic scattering; partial waves, phase shifts, scattering amplitudes, **o**ptical potential.

2. **Nuclear Fission**

   Spontaneous fission, Mass energy distribution of fission fragments, Bohr-Wheeler theory, Fission isobars, Super-heavy nuclei.

3. Compound nuclear reactions. Breit-Wigner one-level formula.
4. Reactions involving exotic nuclei

Particle Physics [30 lectures]

1. **Preliminaries**

   Different types of symmetries and conservation laws. Noether's theorem

2. **Symmetry groups and Quark model**

   SU(2) and SU(3): root and weight diagrams, Composite representation, Young's tableaux, quark model, colour, heavy quarks and their hadrons.

3. **Hadron structure**

   Elastic e-p scattering, electromagnetic form factors, electron-hadron DIS, structure functions, scaling,sum rules, neutrino production.

4. **Strong interactions**

   QCD, asymptotic freedom, gluons and jets in $e^+ e^- \rightarrow$ hadrons, Scaling violation

5. **Low energy weak interactions**

   Fermi theory, calculation of decay widths of muon and π^+

6. **Neutrino physics**

   Theory of two-flavouroscillation. Solar and atmospheric neutrino anomalies. Neutrino experiments.

7. **Flavour physics**

   Quark mixing, absence of tree-level FCNC in the Standard Model, the CKM matrix, oscillation in K and B systems, CP violation.

8. **HEP experiments**

   Relative merits and demerits of $e^+ e^-$ and hadronic colliders, LEP, LHC, B-factories.

Reference Books

1. Physics of the Nucleus, M.A. Preston
2. Theory of Nuclear Structure, M.K. Pal
3. Nuclear Physics, R.R. Roy and B.P. Nigam

4. Atomic and Nuclear Physics (Vol. 2), S.N. Ghoshal
5. Introduction to High Energy Physics, D.H. Perkins
6. Introduction to Elementary Particles, D.J. Griffiths
7. Nuclear Physics- Principles and Applications, John Lilley
8. Nuclear Astrophysics- A Course of Lectures, Md. A. Khan

PHYPGDEP01: Advanced Physics Lab I

Credit: 4, Full marks: 50

1. Absorption / Transmission of thin films by using UV/Vis spectrophotometer.
2. Determination of susceptibility of paramagnetic solution (Ferric chloride and Manganese sulphate)
3. Dielectric and Curie temperature measurement of ferroelectric ceramic (Barium Titanate- $BaTiO_3$)
4. To measure the transition temperature of a high temperature superconductor and demonstrate the Meissner-Ochsenfeld effect
5. Photo-conductivity experiment
6. Preparation and V-I characterization of Thin film
7. Study of Dielectric Polarization and Dielectric spectroscopy
8. Preparation of Nano-particle
9. Determination of band gap using four probe method

PHYPGGET01: Basic Astronomy and Astrophysics

Credit: 4, Full marks: 50, Lectures: 60

Astronomy [30 lectures]

Introduction of stars, galaxies, clusters, black holes, dark matter, dark energy;Different type of galaxies including Milky Way galaxy, Super massive black holes in galaxies, Active galactic nuclei; Mass, length, time and magnitude scales in astronomy; Measurement of stellar parameters: distance parallax, Cepheid variables, nova and supernovae, red shift, stellar spectra, spectral lines; Thermal radiation and thermodynamic equilibrium, Boltzmann and Saha equation, black body radiation. Observational tools: telescope as a camera, optical telescopes (refracting and reflecting telescopes), radio telescopes, astronomical instruments and detectors, observations at other wavelengths (infrared, ultraviolet, X-ray and Gamma ray astronomy).

Astrophysics [30 lectures]

Properties of stars (distance, brightness, size, mass, temperature, luminosity); The Hertzsprung-Russell diagram, luminosity and radius, binary system and mass determination, Main Sequence; Hydrostatic equilibrium and the virial theorem, radiative and convective energy transport inside stars, nuclear energy production; Star formation, pre-main-sequence collapse (gravitational instability and mass scales, collapse of spherical cloud, contraction onto the Main Sequence, Brown Dwarfs), evolution of high-mass and low-mass stars (core and shell hydrogen burning, helium ignition), Jeans Criterion, evolution of Sun-like stars and solar system; Stellar models, Polytropic Stars, Compact object like white dwarfs (electron-degeneracy pressure, mass-radius relation, Chandrashekhar mass limit), neutron stars (mass limit of neutron stars, neutron stars observable as pulsars), black holes as end point of stellar evolution, supernovae.

Reference Books

1. Modern Astrophysics, B. W. Carroll and D. A. Ostlie
2. Introductory Astronomy and Astrophysics, Zeilikand Gregory
3. The Physical Universe, F. Shu
4. The Physics of Astrophysics, Volume I and II, F. Shu
5. Theoretical Astrophysics, Volumes I, II and III, T. Padmanabhan (For advanced learners)
6. Astrophysics: K D Abhayankar

Semester: IV

PHYPGCCT10: Atomic and Molecular Physics

Credit: 4, Full marks: 50, Lectures: 60

1. **One electron atoms** [4 lectures]

   a) Review on quantum states, atomic orbital, Parity of the wave function, angular and radial distribution functions. b) one-electron atom (hydrogen) in an electromagnetic field: Review on transition rates, absorption, stimulated emission, spontaneous emission, density of states, Einstein's coefficients, selection rules, allowed and forbidden transitions, dipole approximation, spectrum of one electron atoms. Atomic life-time and metastable states, line shapes and line width- natural line width, Doppler broadening, pressure broadening.

2. **Fine and hyperfine structure of one electron atoms** [10 lectures]

   Fine structure of hydrogen atom- relativistic corrections to the kinetic energy, spin-orbit term and Darwin corrections, fine structure splitting, selection rules and spectral lines, Lamb shift. Hyperfine interaction and isotope shift; hyperfine splitting of spectral lines and selection rules. Effect of external magnetic field- Strong, moderate and weak field.

3. **Spectra of two-electron atoms** [4 lectures]

   Review on identical particles, symmetric and anti-symmetric wavefunction, wave functions for bosons and fermions, Pauli's exclusion principle, Slater determinant. Singlet and triplet states, para and ortho states. Schrodinger equation of two electron atoms, spin wave functions and role of Pauli's exclusion principle, level scheme of He atom. Calculation of ground state energy of He atom- perturbation theory.

4. **Many-electron atoms** [12 lectures]

Central field approximation-independent particle model, electron states in central field-configurations, shells and sub-shells. Energy levels and spectra for many electron atoms- LS and j-j couplings, equivalent and nonequivalent electrons, spectroscopic terms, Hunds rule, Lande interval rule. Spectra of alkali atoms- effective central potential, fine and hyperfine structures.

5. **Molecular Electronic States** [10 lectures]

Concept of molecular potential, separation of electronic and nuclear wave functions and, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions; Shapes of molecular orbital; π and σ bond; Term symbol for simple molecules.

6. **Spectra of Diatomic Molecules (Rotation and vibration of molecules)** [10 lectures]

Solution of nuclear equation; Molecular rotation: rigid and Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential. Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions

7. **Electronic Spectra** [5 lectures]

Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra5 Lectures

8. **Raman spectroscopy** [5 lectures]

Rotational, Vibrational, Rotational-Vibrational, electronics Raman spectra. Stokes and anti stoke Raman lines. Selection Rules. Spectral structures. Nuclear spin and its effect on Raman spectra.

Reference Books

1. Atomic Spectra and atomic structure, G. Hertzberg
2. Introduction to atomic spectra, H. White
3. Optics and Atomic Physics, B. P. Khandelwal (SiblalAgarwala)
4. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain
5. Atoms, Molecules and Lasers, K. P. R. Nair

6. Physics of the Atom, M. R. Wehr, J. A. Richards, T. W. Adair
7. Introduction to Atomic & Molecular Spectrocopy, V. K. Jain
8. Molecular Physics (Kinetic Theory and Thermodynamics), S. K. Sinha, T. K. Dey
9. Molecular Spectroscopy, Suresh Chandra*
10. Atomic Physics, C. J. Foot
11. Fundamentals of Molecular Spectroscopy, C. B. Banwell
12. Molecular Spectroscopy, G. M. Barrow
13. Atomic and Molecular Spectra,R. Kumar

PHYPGPRJ01: Project work and dissertation

Credit: 4, Full marks: 50

Each student has to carry out a project work on a topic related to recent research interest in physics under the supervision of one supervisor. In the project work the student is expected to perform some theoretical/experimental/computational investigation. In some exceptional cases the project may concentrate on an extensive review of a suitable advanced topic related to the curriculum but well beyond the scope of the M. Sc. syllabus. The student has to submit a dissertation (both soft and hard copies) presenting the findings of the work. The student, at the end of the course, has to defend the Project work carried out by the student in the form of an oral presentation

PHYPGDET02:

Credit: 4, Full marks: 50, Lectures: 60

Material Physics II

1. **Physics at low dimensions** [10 lectures]
   Reviews of quantum mechanics in reduced dimensions and solid state physics, Background to Nanoscience: Definition of Nano, Scientific revolution-Atomic Structure and atomic size, emergence and challenges of nanoscience and nanotechnology, carbon age-new form of carbon (CNT to Graphene), influence of nano over micro/macro, size effects and crystals, large surface to volume ratio, surface effects on the properties. Transport in low-D systems, Nano-scale phenomena and the related chemical, physical and transport properties, Dirac materials

2. **Nanostructured Materials and their Applications** [15 lectures]
   Physics of thin film deposition, adsorption, surface deposition, nucleation growth and structure development; Surface structure, role of surfaces in nanoscience; Epitaxial growth, lattice mismatch and strain, growth modes, self organization, self aligned nanostructures, heterostructures; Growth of quantum structures, Q-wells, Q-wires and Q-dots, Multilayer

superlattice structures, single photon sources, Bulk nanostructured materials, porous silicon, Metal Nanoclusters, Semiconducting Chalcogenide and oxide based nanocrystals and nanoparticles, nanowires, applications; Carbon clusters, Carbon nanotubes, applications; Polymers and polymer based composites, conducting polymers.

3. **Design and synthesis of nanostructure materials** [10 lectures]

   Physics of nanoscale engineering, nanofabrication, Processing of organic, inorganic and bio-based nano particles, nano composites. Common techniques for nano-structure fabrication, Top down and bottom up approach, Chemical process: Sol-gel method, plating, ion exchanged and reduction electro deposition technique, Langmuir-Blodgett (L-B) technique; Templated self assembly Electrochemical approaches, Spin coating, Physical process: vaporization, sputtering, chemical vapour deposition (CVD), Vapor- liquid - solid (VLS) technique, molecular beam epitaxy and laser ablation and related theories and technology for thin film growth, factors on properties of thin films, columnar structure and epitaxial growth.

4. **Advanced Characterization Techniques for nano materials** [5 lectures]

   Microscopy: Compound microscopes, Electron microscopes, Scanning Electron microscope (SEM), Scanning Tunnelling microscope (STM), Transmission Electron Microscope (TEM), Atomic force microscope (AFM), X-ray Diffraction (XRD), theory and method of particle size analysis, Scherrer equation, Reitveldt analysis

5. **Dielectric and optical properties of materials** [10 lectures]

   Theory of electronic polarization and optical absorption, ionic polarization; Optical phonon mode in an ionic crystal; Interaction of electromagnetic waves with optical modes, Polariton, Dispersion curves of Transverse Optical (TO) phonon and optical phonon in diatomic ionic crystal, LST relation, Dielectric function of the electron gas: Plasmon, Exciton, Metal-insulator transition.

6. **Ferroelectric crystal** [10 lectures]

   Theory of ferro-electric transition: first and second order phase transitions; Anti-ferroelectricity, Pizo-electricity, Electrostriction; Luminescence, Fluorescence, Phosphorescence, Raman scattering, spectroscopic techniques

Reference Books

1. Materials science and Engineering, V. Raghavan
2. Materials Science & Engineering, William D. Callister
3. Engineering Materials by Kenneth G. Budinski
4. Handbook of nanoscience, Engg and Technology, W. Gaddand, D.Brenner, S.Lysherski and G.J.Infrate
5. Naostructures and Nanomaterials, Synthesis, properties and applications, G.Cao
6. Nanocrystals: Synthesis, properties and applications, C. N. R. Rao, P. J. Thomas, G. U. Kulkarni
7. Nanostructures and Nanomaterials, Synthesis, Properties, and Applications, G. Cao, Z. Wang

8. Diffraction analysis of the microstructure of materials by E. J. Mittemeijere and P. Scardi
9. Modern techniques of surface science, D. P. Woodruff & T. A. Delchar
10. Electron Microscopy and Analysis (3rd Ed.), P. J. Goodhew, J. Humphreys, R. Beanland
11. Transmission Electron Microscopy: A Textbook for Materials Science, D. B. Williams and C. B. Carter

Astrophysics and Cosmology

Astronomy [20 lectures]

Introduction of stars, galaxies, clusters, black holes, dark matter, dark energy ; Different type of galaxies including Milky Way galaxy, Super massive black holes in galaxies, Active galactic nuclei; Mass, length, time and magnitude scales in astronomy; Measurement of stellar parameters: distance parallax, Cepheid variables, nova and supernovae, red shift, stellar spectra, spectral lines; Radiative transfer (emission, absorption, radiative transfer equation, mean free path, optical depth); Thermal radiation and thermodynamic equilibrium, Boltzmann and Saha equation, Thermodynamics of black body radiation. Observational tools: telescope as a camera, optical telescopes (refracting and reflecting telescopes), radio telescopes, astronomical instruments and detectors, observations at other wavelengths (infrared, ultraviolet, X-ray and Gamma ray astronomy).

Stellar Physics [25 lectures]

Properties of stars (distance, brightness, size, mass, temperature, luminosity); The Hertzsprung-Russell diagram, luminosity and radius, binary system and mass determination, Main Sequence; Hydrostatic equilibrium and the virial theorem, radiative and convective energy transport inside stars, nuclear energy production. Equation of state, opacity, Derivation of scaling relations; Star formation, pre-main-sequence collapse (gravitational instability and mass scales, collapse of spherical cloud, contraction onto the Main Sequence, Brown Dwarfs), evolution of high-mass and low-mass stars (core and shell hydrogen burning, helium ignition), Jeans Criterion, late-stage evolution of stars, evolution of Sun-like stars and solar system; Relativistic Hydrodynamic equilibrium, Tolman-Oppenheimer-Volkoff equation, Degeneracy of matter, Stellar models, Polytropic Stars, Lane-Emden equation, Compact object like white dwarfs (electron-degeneracy pressure, mass-radius relation, Chandrashekhar mass limit), neutron stars (mass limit of neutron stars, neutron stars observable as pulsars), black holes as end point of stellar evolution, supernovae.

Cosmology [15 lectures]

Introduction, Olber's paradox, Hubble's law and the expanding Universe, Big Bang theory, cosmological redshift, scale factor, Cosmological principle, homogeneity and isotropy, Robertson-Walker metric, Dynamics of Friedman- Robertson-Walker models: Solutions of Einstein's equations for sources with p = ω ρ and ω = −1, 0, 1/3, discussion of closed, open and flat Universes. The Cosmic Microwave Background Radiation(CMBR), Problems on standard cosmology, Inflation and present accelerated universe.

Reference Books

1. Modern Astrophysics, B. W. Carroll and D. A. Ostlie
2. Introductory Astronomy and Astrophysics, Zeilik and Gregory
3. The Physical Universe, F. Shu
4. The Physics of Astrophysics, Volume I and II, F. Shu
5. Theoretical Astrophysics, Volumes I, II and III, T. Padmanabhan
6. Astrophysics, K D Abhayankar
7. Modern Cosmology, S. Dodleson
8. Introduction to Cosmology, J.V. Narlikar
9. General Relativity and Cosmology, Benerji & Benerjee
10. A General Relativity Workbook, Thomas A. Moore

Advanced Atomic and Laser Physics

1. **Explicitly correlated methods for few-body systems** [10 lectures]

   Separation of centre-of-mass, coordinate from N-body Schrodinger equation; Hatree-Fock method; Configuration Interaction method (CI); Hylleraas-CI method; Symmetrization and Anti-symmetrization of wavefunction; Construction of spin eigenfunctions; Reduced anti-symmetrizer; Generalized eigenvalue equation; Optimization techniques; Jacobi Coordinates; Hyperspherical method; Hyperspherical harmonics.

2. **Atomic photoionization** [5 lectures]

   Atomic photoionization, calculation of cross-section for one-electron atoms or ions, resonances in photoionization and photo-detachment

3. **Electron-atom and atom-atom collisions** [7 lectures]

   General features, elastic and inelastic electron-atom collisions at low energies, estimation of scattering amplitude and differential cross-section of electron collision with atomic hydrogen, Elastic and inelastic electron-atom collisions at high energies, The Born series, Bethe-Born approximation, electron-impact ionization of atoms, Atom-atom collisions at very low energies, The semi-classical theory of atom-atom collision, rainbow scattering, Non-elastic collision between atoms, symmetrical resonance, atom-atom collision at high velocities, excitation and ionization, charge exchange

4. **Semi-classical theory of atom-light interaction** [8 lectures]

   a) Coherent interaction of two-level atom with light under weak and strong field cases, rotating wave approximation (RWA), Rabi oscillation/flopping, π-pulse, broadening of spectral lines-natural broadening, Doppler broadening, collisional broadening

b) Density matrix, rate equations for density matrix, inclusion of decay phenomena, vector model solution of density matrix equations, optical Bloch equations, Bloch sphere.

5. Laser Spectroscopy [18 Lectures]

Physical effects of strong fields on atomic matter: basic concepts of light-induced effects on atomic matter, inclusion of phenomenological aspects of population and depopulation in a two-level system. A stationary two-level atom in a standing wave, A moving two-level atom in travelling wave, A moving two-level atom in a standing wave. Physical significances of saturation phenomena, Bennett hole/hole burning, Lamb dip, crossover resonance dips. Fine and hyperfine transitions of Rb atom, absorption and saturation absorption spectroscopy in Rb atomic medium-hyperfine and crossover resonance transitions. Three-level systems with two laser fields: pump-probe spectroscopy, concepts and approach.

6. **Laser cooling and trapping** [12 Lectures]

Dynamics of an atom in a laser field, light forces on atoms, radiation pressure forces, dipole force, optical potential, Doppler cooling, optical molasses, Doppler cooling limit, sub-Doppler cooling: Sisyphus cooling, magnetic trap, optical trap, magneto-optical trap (MOT), brief discussion on experimental technique of laser cooling and trapping.

Reference Books

1. Laser Physics, M. Sargent, M.O. Scully and W.E. Lamb
2. Foundations of Laser Spectroscopy, S. Stenholm
3. Atom Optics, P. Meystre
4. Laser Cooling and Trapping, H. Metcalf and P. Straten
5. Elements of Quantum Optics, P. Meystre and M. Sargent III
6. Elements of Quantum Optics, R. Loudon
7. Laser Physics and Spectroscopy, P.N. Ghosh
8. Lectures on Light: Nonlinear and Quantum Optics using Density Matrix, S Rand
9. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain

PHYPGDEP02: Advanced Physics Lab II

Credit: 4, Full marks: 50

1. Study of Zeeman effect.
2. Study of Faraday effect.
3. Study of Kerr effect.
4. Study of surface Plasmon resonance.
5. Experiment with optical fiber.
6. Characteristic study of a diode laser.

7. Determination of the gamma and beta ray absorption coefficients by using a G.M. counter.
8. Study the principle and working of various antennas.

PHYPGGEC02: Physics at different length scales

Credit: 4, Full marks: 50, Lectures: 60

1. Discovery of Subatomic Particles, A historical perspective The Discovery of the Electron: Cathode Rays, Thomson's Experiment, Measurement of electric charge. The Nucleus: Radioactivity, Rutherford's experiment and the discovery of the nucleus, the Neutron. More particles: Neutrinos, Positrons, Other antiparticles, Muons and Pions, Strange particles, Quarks. [15 lectures]

2. Electronic States of Materials Free electrons and the Fermi energy in an arbitrary spatial dimensions, Importance of Fermi energy in electronic specific heat, Computation of Bulk modulus for nonrelativistic and ultra-relativistic system; Density of States in an arbitrary dimension; Variation of low temperature specific heat with temperature in power law dispersion relation, Importance of Nanomaterials, Various processes of preparing nanomaterials, Effective Bohr radius, Variation of band gap with average crystalline size, Understanding Direct band gap and Indirect band gap from absorption spectra, Nanomagnetism, Brief introduction of qualitative features of graphene and other 2D materials, Computation of dispersion relation from tight-binding Hamiltonian, Future and perspective of 2D materials. [20 lectures]

3. Introduction to complex fluids, liquid crystals, macromolecules. Liquid Crystals: Structure and classification of mesophases; introduction to molecular theories of liquid crystals; symmetry and order parameter. Macromolecules: Random walk and polymers; DNA denaturation process. [10 lectures]

4. Electrical Conductivity Electrical conductivity and classification of materials; Metal, Semiconductor and insulator. Electrical conductivity of metal; classical derivation by virtue of relaxation time, the Boltzmann transport equation, Sommerfeld theory of electrical conductivity of metal. Electrical conductivity of semiconductors; types of semiconductors intrinsic, p-type and n-type semiconductors, density of electronic energy states across band gap, electron and hole concentration in an intrinsic semiconductor, calculation of electrical conductivity at a finite temperature. [15 lectures]

Reference Books

1. The Physics of Low-dimensional Semiconductors: An Introduction, John H. Davies
2. Superconductivity Of Metals And Alloys, P. G. De Gennes
3. Concepts of modern physics, A. Beiser