BANGALORE UNIVERSITY

Department of Physics
Jnana Bharati
Bangalore-56

Revised Syllabus for M.Sc. Physics
CBCS Scheme
Effective from 2014-2015 Academic Year

Details of the Courses and Credits for the four Semesters:

Semester	Theory (Hard core)	Credits	Theory Soft/ Open elective	Credits	Labs	Credits	Total
I	4	4 x 4 = 16	Soft core-1	1 x 2 = 2	2	2 x 4 = 8	26
II	4	4 x 4 = 16	Soft core-1	1 x 2 = 2	2	2 x 4 = 8	26
III	4	4 x 4 = 16	Open elective-1	1 x 4 = 4	1	1 x 4 = 4	24
IV	4	4 x 4 = 16	-	-	2	2 x 4 = 8	24
Total number of credits for the 4 Semester M.Sc. course							**100**

Total Marks for the 4 semester:

I Semester	–	700 marks
II Semester	–	700 marks
III Semester	–	600 marks
IV Semester	–	600 marks
Total		**2600** marks

Course Details:
I Semester : 4Theory (Hardcore)+ 1Theory (soft core) + 2 Labs = 26 credits

Paper code	Paper Title	Credits	Exam Max. marks	Internal Assessment marks	Total
P101	Classical Mechanics	4	70	30	100
P102	Electronic Circuits and Devices	4	70	30	100
P103	Quantum Mechanics- I	4	70	30	100
P104	Mathematical Methods of Physics- I	4	70	30	100
P105	Soft Core Experimental Techniques in Physics	2	70	30	100
P106	General Physics Lab-1	4	70	30	100
P107	Electronics Lab	4	70	30	100
				Total marks	**700**

II Semester :4Theory (Hardcore)+ 1Theory (soft core) + 2 Labs = 26 credits

Paper code	Paper Title	Credits	Exam Max. marks	Internal Assessment marks	Total
P201	Statistical Mechanics	4	70	30	100
P202	Electrodynamics	4	70	30	100
P203	Quantum Mechanics-II	4	70	30	100
P204	Mathematical Methods of Physics -II	4	70	30	100
P205	Soft Core Elementary Biophysics	2	70	30	100
P206	General Physics Lab-2	4	70	30	100
P207	Optics Lab	4	70	30	100
				Total marks	**700**

III Semester :4Theory (Hardcore)+ 1Theory (Open elective) + 1 Lab = 24 credits

Paper code	**Paper Title**	**Credits**	**Exam Max. marks**	**Internal Assessment marks**	**Total**
P301	Nuclear and Particle Physics (General)	4	70	30	100
P302	Condensed Matter Physics (General)	4	70	30	100
P303	Elective(one course to be opted from the group) P303-E1: Stellar Astrophysics P303-E2: Lasers and Optics P303-E3: Atmospheric Physics	4	70	30	100
P304	Elective (One course to be opted from the group) P304-E4 : Soft and Living Matter P304-E5 : Material Science P304:E6: Application of Theoretical Concepts in Physics	4	70	30	100
P305	Open elective Physics and our World	4	70	30	100
P306	Advanced Physics Lab-1	4	70	30	100
				Total marks	**600**

IV Semester :4Theory (Hardcore)+ 2 Labs = 24 credits

Paper code	**Paper Title**	**Credits**	**Exam Max. marks**	**Internal Assessment marks**	**Total**
P401	Atomic and Molecular Physics (General)	4	70	30	100
P402	Numerical Analysis and Computational Physics	4	70	30	100
P403	Elective (One course to be opted from the group) E403-E7: Atomic and Molecular Spectroscopy P403-E8: Physics of Solids P403-E9: Nuclear Reactions and Particle Physics P403-E10:Observational Astronomy and Cosmology	4	70	30	100
P404	Electives (One course to be opted from the group) P404-E11: Astro and Space Physics P404-E12: Advanced Electronics P404-E13: Physics of Nanomaterials P404-E14: Crystal and Semiconductor Physics P404-E15: Nuclear Models and Reactor Theory	4	70	30	100
P405	Advanced Physics Lab-2	4	70	30	100
P406	Computer lab	4	70	30	100
				Total Marks	**600**

I Semester

P 101: Classical Mechanics (4 credits, 4 lectures per week)

Unit-I

System of particles: Center of mass, total angular momentum and total kinetic energies of a system of particles, conservation of linear momentum, energy and angular momentum.

Lagrangian Formulation: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the second kind, uniqueness of the Lagrangian, Simple applications of the Lagrangian formulation: 1. Single free particle in (a) Cartesian co-ordinates, (b) plane polar co-ordinates; 2. Atwood's machine; 3.bead sliding on a uniformly rotating wire in a force-free space; 4. Motion of block attached to a spring ; 5. Simple pendulum.

Symmetries of space time: Cyclic coordinate, Conservation of linear momentum, angular momentum and energy.

(13 hours)

Unit- II

Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion), equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force).

Scattering in a central force field: general description of scattering, cross-section, impact parameter, Rutherford scattering, center of mass and laboratory co-ordinate systems, transformations of the scattering angle and cross-sections between them.

Motion in non-central reference frames: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum.

(13 hours)

Unit -III

Rigid body dynamics: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body, precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body, notions of spin, precession and nutation of a rigid body.

Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule, (iii) oscillations of two linearly coupled plane pendula.

(13 hours)

Unit- IV

Hamiltonian formulation: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion, Examples of (a) the Hamiltonian of a particle in a central force field, (b) the simple harmonic oscillator, cyclic co-ordinates and conservation theorems, derivation of Hamilton's equations from variational principle.

Canonical transformation: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (antisymmetry, linearity and Jacobi identity), Poisson brackets of angular momentum, The Hamilton-Jacobi equation, Linear harmonic oscillator using Hamilton-Jacobi method

(13 hours)

References

1. Classical mechanics, H. Gldstein, C. Poole, J. Saflco, 3rd edition, Pearson Education Inc. (2002).
2. Classical mechanics, K. N. Srinivasa Rao, University Press (2003).
3. Classical mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill (1991).
4. Classical dynamics of particles and systems, J. B. Marian, Academic Press (1970)
5. Introduction to classical mechanics, Takwale and Puranik, Tata McGraw-Hill (1983).
6. Classical mechanics, L. D. Landau and E. M. Lifshitz, 4th edition, Pergamon press (1985).

P102: Electronic Circuits and Devices(4 credits, 4 lectures per week)

Unit- I

Physics of devices: p-n junction , abrupt junction – band structure – thermal equilibrium – depletion region – depletion capacitance – current and voltage characteristics – BJT – band structure - transistor action – static characteristics. JFET structure, working, characteristics. MOS structure – MOSFET working – MOSFET characteristics – width of depletion region – junction capacitance-threshold voltage. Metal semiconductor contacts – ohmic and Schottky contacts. Principle of operation of photoelectronic devices: photoconductor – efficiency, current gain, response time. Effect of light on I-V characteristics of a junction photo device, principle and working of a photodiode, Light emitting devices, principle , working and factors affecting the efficiency of LED

(13 hours)

Unit -II

Operational amplifiers: Block diagram of an operational amplifier – Characteristics of an ideal operational amplifier – comparison with 741 – Operational amplifier as a open loop amplifier - Limitations of open loop configuration – Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain. Applications of op-amp: Linear applications – Phase and frequency response of low pass, high pass and band pass filters(first order), summing amplifier – inverting and non-inverting configurations, subtractor, difference summing amplifier, ideal and practical Differentiator, Integrator. Non - linear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers.

(13 hours)

Unit -III

Digital circuits: Review of gates (AND,OR,NAND,NOR,NOT,EX-OR), - Boolean laws and theorems – simplification of SOP equations – Simplification of POS equations - Simplification using Karnaugh Map technique (4 variables)- conversion of binary to Grey code - Flip flops: Latch using NAND and NOR gates- RS flip flop , clocked RS flip flop, JK flip flop, JK master slave flip flop - racing –Shift Registers basics - Counters: Ripple counters-truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter.

(13 hours)

Unit- IV

Digital to Analog converters: ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter. Application of DACs and ADCs. Read Only Memory (ROM) and applications, Random Access Memory (RAM) and Applications. Microprocessors and Microcontrollers basics.

(13 hours)

References

1. Semiconductor Devices Physics and Technology, S M Sze, (Second Edition, 2002), John Wiley and Sons Inc. Asia.
2. Solid State Electronic Devices, Ben G Streetman, Sanjay Banerjee, (Fifth edition, 2000), Pearson Education, Asia.
3. Semiconductor Optoelectronic Devices, Pallab Bhattacharya, (Second Edition, 1997), Pearson education, Asia.
4. The art of electronics, Paul Horowitz and Winfield Hill, (Second Edition, 1992), Foundation Books, New Delhi.
5. Electronic Principles, A P Malvino, (Sixth Edition, 1999), Tata McGraw Hill, New Delhi.
6. Op-Amps and Linear Integrated Circuits, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.
7. Operational Amplifiers with Linear Integrated Circuits, William Stanley, (1988), CBS Publishers and Distributors.
8. Linear Integrated Circuits, D Roy Choudhury and Shail Jain, ((1991), New Age International (P) Limited.
9. Digital principles and applications, Donald P Leach and Albert Paul Malvino, (Fifth Edition, 2002), Tata McGraw Hill.
10. Digital systems, Principles and applications, Ronald J Tocci and Neal S Widmer, (Eighth Edition, 2001), Pearson Education.
11. Physics of Semiconductor Devices, Shur, PHI

P103: Quantum Mechanics-I (4 credits, 4 lectures per week)

Unit-I

Introductory concepts

Empirical basis, wave-particle duality, electron diffraction, Wave packets, Gaussian wave packet, Spreading of Gaussian wave packet, Heisenberg uncertainty principle for position and momentum, Schrodinger equation, conservation of probability, probability interpretation of wave function, expectation values, Ehrenfest theorem, measurement in quantum theory, time-independent Schrodinger equation, stationary states, momentum space representation.

(13 hours)

Unit-II

One-dimensional problems

Free-particle solution, momentum eigen functions, box normalization, particle in square well potential, transmission through a potential barrier, simple harmonic oscillator.

(13hours)

Unit-III

General formalism of quantum theory: operator methods

Hilbert space and observables, linear operators and observables, Dirac notation, degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables, Unitary dynamics, projection operators and measurements, time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method.

(13 hours)

Unit-IV

Angular momentum

Orbital angular momentum commutation relations, Eigen values and eigen functions, Central potential, separation of variables in the Schrodinger equation, the radial equation. The Hydrogen atom.

General operator algebra of angular momentum operators J_x, J_y, J_z. Ladder operators, Eigen values and eigenkets of J^2 and J_z, Matrix representations of angular momentum operators, Pauli matrices, Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch-Gordan coefficients in simple cases ($j_1 = j_2 = 1/2$).

(13 hours)

References

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Mechanics – V.K. Thankappan, Second Edition, Wiley Eastern Limited, 1993.
3. Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977.
4. Quantum Mechanics- L.I. Schiff, Third Edition, Mc Graw Hill Book Company, 1955.
5. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
6. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
7. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.
8. Quantum Mechanics – E. Merzbacher, John Wiley and Sons, 1998.
9. Quantum Physics – S. Gasiorowicz, John Wiley and Sons.

P104 : Mathematical Methods of Physics-I (4 credits, 4 lectures per week)

Unit-I

Linear vector spaces and operators: Vector spaces and subspaces, Linear dependence and independence, Inner product, Orthogonality, Gramm-Schmidt orthogonalization procedure, Basis and Dimensions, linear operators, Matrix representation, Similarity transformations, Characteristic polynomial of a matrix, Eigen values and eigenvectors, Self adjoint and Unitary transformations, Eigen values and eigenvectors of Hermitian and Unitary transformations, Minimal polynomial and diagonalization.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 6; Mathematical Methods for Physicists, Arfken and Weber, Ch. 3; Linear Algebra – Seymour Lipschutz, Schaum Outlines Series, A.W. Joshi, Matrices and Tensors in Physics, Matrices and Tensors in Physics, M. R. Spiegel)

Unit-II

Vector analysis and curvilinear co-ordinates Gradient, Divergence and Curl operations, Vector Integration, Gauss' and Stokes' theorems, Curvilinear co-ordinates, tangent and normal vectors, contravarient and covariant components, line element and the metric tensor, Gradient, Curl, divergence and Laplacian in spherical polar and cylindrical polar co-ordinates.

Definition of tensors, contravariant and covariant components of tensors, raising and lowering of tensor indices, sum, outer, inner products and contraction of tensors, Quotient law, symmetric, antisymmetric tenors, Pseudo and dual tensors, Levi civita symbol, Covariant differentiation and Christoffel symbols. Brief discussion of moment of inertia tensor, Minkowski four vectors, electromagnetic field tensor.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 15; Mathematical Methods for Physicists, Arfken and Weber, Ch. 2; A.W. Joshi, Matrices and Tensors in Physics, M. R. Spiegel)

Unit-III

Calculus of variations and Non-linear methods: Concept of variation, Euler's equation, Missing dependent variables, Applications of the Euler equation, Several independent variables, Hamilton's principle and Lagrange's equations, Lagrangian multipliers, Examples.

Autonomous and non-autonomous systems, fixed points, their classification, phase space trajectories, limit cycle motion, logistic map.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 12; Mathematical methods for Physicists, Arfken and Weber, Ch. 17, 18; Introduction to Dynamics, I Percival and D. Richards, Cambridge University Press, Classical Mechanics, Goldstein, Poole and Safko.)

Unit-IV

Ordinary differential equations and Special Functions: Linear ordinary differential equations, Separation of Poisson and Helmholtz equations in spherical polar and cylindrical polar coordinates, Series solutions – Frobenius'method, Series solutions of the differential equations of Bessel, Legendre, Leguerre and Hermite polynomials, Generating functions, Some recurrence relations, orthogonality properties of these functions, Brief discussion of spherical Bessel functions and spherical harmonics.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 7; Mathematical methods for Physicists, Arfken and Weber, Ch. 9, 11, 12, 13)

References

1. Mathematical Methods of Physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley
2. Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
3. Matrices and Tensors in Physics - M. R. Spiegel, Schaum Series
4. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series
5. Matrices and Tensors in Physics - A.W. Joshi, Wiley Eastern Ltd, 1975
6. Vector Analysis - M. R. Spiegel, Schaum Series
7. Introduction to Dynamics – I. Percival and D. Richards, Cambridge University Press.
8. Classical Mechanics, Goldstein, Poole and Safko.

Soft core Paper

P105: Experimental Techniques in Physics (4 credits, 3 lectures per week)

Unit-I

Safety measures in Experimental Physics

Occupational health and safety, chemical substances, radiation safety, general electrical testing standards, General laboratory and workshop practice.

Physical measurement

Measurement, result of a measurement, sources of uncertainty and experimental error, Systematic error, random error, Reliability- chi square test, Analysis of repeated measurement, Precision and accuracy, Elementary data fitting.

Instrumentation Electronics

Transducers, Transducer characteristics, selection of a instrumentation transducer, Transducer as an electrical element, modelling external circuit components, circuit calculations, ac and dc bridge measurements.

(13 hours)

Unit-II

Vacuum techniques

Units of pressure measurement, characteristics of vacuum, applications of vacuum, Vacuum pumps: Rotary, oil diffusion, turbo molecular pumps, Ion pumps. Vacuum gauges: Pirani and Penning gauges. Pumping speed of a vacuum pump.

Thin film techniques

Thin film techniques(overview), film thickness monitors, film thickness measurement.

Measurement of low temperature

Resistance thermometers, thermocouples.

(13 hours)

Unit-III

Landmark experiments in Physics

Familiarization of certain landmark experiments in Physics through original papers:

1. Mossbauer effect
2. Parity violation experiment of Wu et al.
3. Quantum Hall effect-integral and fractional
4. Josephson tunnelling
5. Laser cooling of atoms
6. Bose-Einstein Condensation

(13 hours)

References

1. Measurement, Instrumentation and Experimental desigh in Physics and Engineering- Michael Sayer and Abhai Mansingh, Prentice Hall of India 2005
2. Data Reduction and Error Analysis for the Physical Sciences, P.R. Bevington and K.D Robinson, McGraw Hill, 2003
3. Electronic Instrumentation- H.S. Kalsi, TMH Publishing Co. Ltd. 1997
4. Instrumentation Devices and Systems-C.S. Rangan, G.R. Sharma, V.S.V. Mani, 2nd Edition, Tata McGraw Hill, New Delhi, 1997
5. Instrumentation Measurement Analysis-B.C. Nakra, K.K. Chaudhary.

II Semester

P201: Statistical Mechanics (4 credits, 4 lectures per week)

Unit-I
Thermodynamics
Postulates of equilibrium thermodynamics, Intensive and extensive variables, Thermodynamic definition of Entropy –Calculation of entropy changes in reversible processes, Equilibrium between two thermodynamic systems, Thermodynamic potentials –Enthalpy, Helmholtz and the Gibbs functions, The Maxwell relations, Variational principles in thermodynamics

(13 hours)

Unit-II
Classical statistical mechanics
Basic postulates of statistical mechanics, Macro-and micro states – Statistical equilibrium--Phase space, Ensemble: microcanonical, canonical, grand canonical; Density function -– Liouville's theorem, Canonical distribution function: Evaluation of mean values in a canonical ensemble, Partition function--connection with thermodynamics; Statistical definition of entropy—Boltzmann equation and its significance; Ideal monoatomic gas, Gibbs' paradox, Equipartition theorem, specific heat of solids.

(13 hours)

Unit-III
Quantum statistical mechanics
Basic concepts – Quantum ideal gas, Identical particles and symmetry requirements, Quantum distribution functions, Bose-Einstein statistics, Ideal Bose gas, black body radiation, Bose- Einstein condensation, specific heat, Fermi-Dirac statistics, Ideal Fermi gas, properties of simple metals, Pauli paramagnetism, electronic specific heat, Quantum statistics in the classical limit.

(13 hours)

Unit-IV
Irreversible processes and fluctuations
Random walk in one dimension, Brownian motion, Langevin equation, Fluctuation dissipation theorem, Einstein relation, Fourier analysis of random functions, Wiener-Khintchine relations Nyquist's theorem, Fluctuations and Onsagar relations.

(13 hours)

References

1. K. Huang, Statistical Mechanics ,Wiley Eastern Limited, New Delhi, (1963).
2. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill, Singapore(1985).
3. R.K. Pathria, Statistical Mechanics, Bufferworgh Heinemann (2nd Edition)
4. Silvio R A Salinas, Introduction to Statistical Physics, Springer, (2001)
5. B.B.Laud, Fundamentals of Statistical Mechanics, New Age International Publication (2003).

P202: Electrodynamics (4 credits, 4 lectures per week)

Unit-I

Electrostatics
Coulomb's law, Electric field, Gauss's law, applications of Gauss's law, Electric Potential, Poisson's equation and Laplace's equation, Work and energy in electrostatics
Techniques for calculating potentials: Laplace's equation in one, two and three dimensions, boundary conditions and uniqueness theorems, Method of Images, Multipole expansion
Electrostatic fields in matter: Dielectrics, Polarization, Field inside a dielectric, Electric displacement, Linear dielectrics.

(13 hours)

Unit-II
Magnetostatics
Biot-Savart Law, Divergence and Curl of B, Ampere's law and applications of Ampere's law, Magnetic vector potential, Multipole expansion.
Magnetostatic fields in Matter: Magnetization, field of a magnetized object, magnetic field inside matter, linear and non linear magnetic media
Electrodynamics
Time dependent fields, Faraday's law, Maxwell's displacement current, Differential and integral forms of Maxwell's equations.

(13 hours)

Unit -III
Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics.

Electromagnetic waves
Electromagnetic waves in non conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws*;* Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media Dispersion: Dispersion in non conductors, free electrons in conductors and plasmas. Guided waves.
Electromagnetic radiation
Retarded potentials, Electric dipole radiation, magnetic dipole radiation.

(13 hours)

Unit-IV
Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, power radiated by a point charge.
Electrodynamics and Relativity: Review of special theory of relativity, Lorentz transformations, Minkowski four vectors, energy-momentum four vector, covariant formulation of mechanics
Transformation of electric and magnetic fields under Lorentz transformations, field tensor, invariants of electromagnetic field, Covariant formulation of electrodynamics, Lorentz force on a relativistic charged particle.

(13 hours)

References

1. Introduction to Electrodynamics – David J. Griffiths, Second Edition, Prentice Hall India, 1989.
2. Classical Electrodynamics – J.D. Jackson, Fourth Edition, John Wiley & Sons, 2005.
3. Classical Electromagnetic Radiation – M.A. Heald and J.B. Marion, Saunders, 1983.

P203: Quantum Mechanics –II (4 credits, 4 lectures per week)

Unit-I

Approximation methods for stationary problems

Time independent perturbation theory***:*** Time independent perturbation theory for a non degenerate energy level, time independent perturbation theory for a degenerate energy level, Applications: (1) one dimensional harmonic oscillator subjected to a perturbing potential in x, x^2 and x^3 (2) the fine structure of the hydrogen atom (3) Zeeman effect.

(7 hours)

Variational Method*:* Bound states (Ritz Method), Expectation value of the energy. Applications: (1) ground state of Helium (2) van de Waals interaction.

(3 hours)

WKB approximation: the "classical region", connection formulae, tunnelling. (3 hours)

Unit -II

Time dependent perturbation theory

Statement of the problem, approximate solution of the Schrodinger equation, constant perturbation, harmonic perturbation, transition to a continuum, the Fermi golden rule

(5 hours)

Scattering theory: The scattering experiment, relationship of the scattering cross section to the wave function, scattering amplitude and scattering cross-section, Born approximation, scattering by a spherically symmetric potential, cross-section for scattering in a screened coulomb potential, validity of Born's approximation.

(5 hours)

Method of partial waves: Expansion of a plane wave in terms of partial waves, scattering by a central potential, optical theorem.

(3 hours)

Unit-III

Symmetry principles and conservation laws

Continuous symmetries: Spatial translation symmetry and conservation of linear momentum, time translation symmetry and conservation in energy, Rotations in Space: Conservation of angular momentum

(6 hours)

Discrete symmetries: Parity, Time reversal, Permutation symmetry, symmetric and antisymmetric wave functions, Slater determinant, scattering of identical particles, ortho and para helium.

(7 hours)

Unit-IV

Relativistic quantum mechanics

Klein-Gordan equation for a free relativistic particle, Plane wave solutions, probability density and probability current density.

(3 hours)

Dirac Hamiltonian for a free relativistic particle, properties of alpha and beta matrices, probability density and probability current, positive and negative energy solutions, orthogonality and completeness of the solutions, intrinsic spin of the Dirac particle, Negative energy sea, gamma matrices, covariant form of Dirac equation, Non-relativistic approximation of Dirac equation in the presence of central potential and spin-orbit energy, Dirac particle in an external magnetic field, magnetic moment

(10 hours)

References

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Mechanics – V.K. Thankappan, Second Edition, Wiley Eastern Limited, 1993.
3. Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977.
4. Quantum Mechanics- L.I. Schiff, Third Edition, Mc Graw Hill Book Company, 1955
5. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
6. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
7. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.
8. Quantum Mechanics – E. Merzbacher, John Wiley and Sons, 1998.
9. Quantum Physics – S. Gasiorowicz, John Wiley and Sons.

P204: Mathematical Methods of Physics – II (4 credits, 4 lectures per week)

Unit-I

Fourier series integral transforms

Fourier Series : Definition, Properties, Convergence, Application of Fourier series, Fourier Integral and Fourier transform, Convolution theorem, Parseval's theorem, Laplace transform and its properties, convolution theorem, inverse Laplace transforms, solution of differential equations using Laplace transforms, Fourier transform & Laplace transform of Dirac Delta function

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 2; Mathematical Methods for Physicists, Arfken and Weber, Ch. 9,10, 14)

Unit-II

Green's functions and integral equations: Boundary value problems, The Sturm-Liouville differential operator, Green's function of one-dimensional problems, discontinuity in the derivative of Green's functions, Properties of Green's functions, Construction of Green's functions in special cases and solutions of inhomogeneous differential equations, Eigen function expansion of Green's function.

Examples of linear integral equations of first and second kind, Relationship between integral and differential equations, Solution of the Fredholm and Volterra integral equations by Neuman series method (method of successive approximations), Separable kernels, Fredholm alternate method.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 9 and 11; Mathematical Methods for Physicists, Arfken and Weber, Ch. 9, 10, 16; P.K. Chattopadhyay, Mathematical Physics)

Unit-III

Complex analysis: Functions of a complex variable, Analytic functions, Cauchy-Riemann relations, Conjugate and harmonic nature of the real and imaginary parts of an analytic function, Cauchy's theorem, Cauchy's integral formula, Taylor and Laurent expansions, analytic continuation, classification of singularities, residue theorem, Evaluation of definite integrals, Dispersion relations and causality, method of steepest descents.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 3; Mathematical Methods for Physicists, Arfken and Weber, Ch. 6, 7; M. R. Spiegel, Complex functions)

Unit-IV
Group theory
Basic definitions, Multiplication table, Subgroups, Cosets and Classes, Permutation Groups, Homomorphism and isomorphism, Reducible and irreducible representations, Schur's lemma, Elementary ideas of Continuous groups GL(n), SO(3), SU(2), SO(3,1), SL(2,C).

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 16; Mathematical Methods for Physicists, Arfken and Weber, Ch. 4; Linear Algebra and Group theory for Physicists, K. N. Srinivasa Rao)

References

1. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley.
2. Mathematical methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012.
3. Complex functions – M. R. Spiegel, Schaum Series.
4. Mathematical Physics - P.K.Chattopadhyay, Wiley Eastern Ltd.1990.
5. Linear Algebra and Group theory for Physicists – K. N. Srinivasa Rao,

Soft Core Paper

P205: Elementary Biophysics (4 credits, 3 lectures per week)

Unit-I
Foundations of Biophysics: Biophysics as an interdisciplinary science, aim and scope of biophysics. Chemical and physical forces between atoms and molecules: Atomic and molecular forces. Inter-atomic molecular bonds: Ionic, covalent and Van der Waals bonds, coordinate bonds and hydrophobic interaction. Mechanism of bond formation based on electronic orbitals. Formation of molecular orbitals, Sigma and Pi bonds, Hybridization. Examples of bond formation between C-C, C-N and carbon and other atoms.

(13 hours)

Unit-II

Physical methods of investigation of macromolecules: Biological macromolecules, General classification, Physical methods of determining size and shape of molecules. Separation methods: Diffusion, Sedimentation and osmosis. Viscosity and surface tension measurements.

Instrumental methods of analysis of biological systems: Light scattering by macromolecules. Optical activity, Absorption spectroscopy and spectrophotometry, Calorimetry, IR and Raman spectroscopy for study of biomolecules. NMR spectroscopy for studying interactions and identification of biomolecules. X-ray diffraction and microscopy for studying living matter (general treatment).

(13 hours)

Unit-III

Isotopes and radioactivity: Radioactive decay laws, production of radioisotopes (radio nuclides), allocation of radioactive traces, isotopic tracer method. Assay using radioactive substances, Labelling and detection methods using fluorescent molecules (a few examples).

Radiation biophysics: Radiation sources, Interaction of radiation with matter (general discussion), energy transfer process, measurement of radiation, Dosimetry, Biological effects of radiation, effect of radiation on living systems, radiation protection and radiation therapy.

(13 hours)

References

1. Essential of Biophysics – P. Narayanan, 2nd Edn., New Age International Publications, 2008.
2. Aspects of Biophysics- William Hughes, John Wiley and Sons, 1979
3. Biochemistry of Nucleic acids- Adams et al. Chapmann and Hall, 1992
4. Biophysics- Vasantha Pattabi and N. Goutham, Narosa Publishing House, New Delhi, 2002.
5. Biophysics- Cotterill.

III Semester

P301: Nuclear and Particle Physics (General)

Unit -I

Interaction of nuclear radiation with matter: (a) Interaction of charged particles: Energy loss of heavy charged particles in matter, Bethe-Bloch formula, energy loss of fast electrons, Bremsstrahlung. (b) Interaction of gamma rays: Photoelectric, Compton, and pair production processes.

Nuclear forces: Characteristics of nuclear forces, Ground state of the deuteron using square-well potential, relation between the range and depth of the potential, Inadequacies of the central force, experimental evidence for the tensor force, magnetic moment and quadrupole moment of the deuteron, deuteron ground state as an admixture of s and d states.

(13 hours)

Unit- II

Nuclear detector sand Nuclear electronics

Nuclear detectors: Scintillation Detectors-NaI(Tl), Scintillation spectrometer, Semiconductor detectors: Surface barrier detectors, Li ion drifted detectors, relation between the applied voltage and the depletion region in junction detectors.

Nuclear electronics: Preamplifiers: voltage and charge sensitive preamplifiers, Linear pulse amplifier, Schmitt trigger as a discriminator, differential (single channel analyzer) & integral discriminators, Analog to digital converters (ADC), multichannel analyzer (MCA): functional block diagram and its working and use in data processing.

(13 hours)

Unit -III

Nuclear models and Nuclear decay

Nuclear models: Liquid drop model: Semi-empirical mass formula, stability of nuclei against beta decay, mass parabola, Shell model: Evidence for magic numbers, prediction of energy levels in an infinite square well potential, spin-orbit interaction, prediction of ground state spin, parity and magnetic moment of odd-A nuclei, Nordheim's rules.

Beta decay: Fermi's theory of beta decay, Kurie plots and "ft" values, selection rules.

Gamma decay: Multipolarity of gamma rays, Selection rules, Internal conversion (qualitative treatment).

(13 hours)

Unit -IV

Elementary particle physics: Types of interactions between elementary particles, hadrons and leptons, detection of neutrinos.

Symmetries and conservation laws: conservation of energy, momentum, angular momentum, charge and isospin, parity symmetry, violation of parity in weak interactions - handedness of neutrinos, Lepton number conservation, Lepton family and three generations of neutrinos. Charge conjugation symmetry, CP violation in weak interactions, Strange particles, conservation of strangeness in strong interactions, Baryon number conservation, Gell-Mann Nishijima formula, eight fold way (qualitative only), quark model, quark content of baryons and mesons.

(13 hours)

References

1. Atomic and Nuclear Physics, S N. Ghoshal: Vol. II.,2000.
2. The Atomic Nucleus, Evans R. D.: Tata McGraw Hill, 1955.
3. Nuclear Physics, R. R. Roy and B. P. Nigam: Wiley-Eastern Ltd. 1983.
4. Nuclear Physics- an Introduction, S.B.Patel: New Age international (P) Limited, 1991.
5. Radiation Detection and Measurements, G.F. Knoll: 3rd edition, John Wiley and Sons, 2000.
6. Nuclear Radiation Detectors, S.S. Kapoor and V.S. Ramamurthy: Wiley-Eastern, New Delhi, 1986. Nuclear Interaction, S. de Benedetti: John Wiley, New York, 1964.
7. Nuclear Radiation Detection, W.J. Price: Mc Graw Hill, New York, 1964.
8. Introduction to Elementary particles, D. Griffiths: John Wiley, 1987.
9. Elementary Particles, J. M. Longo, II Edition, Mc Graw-Hill, New York, 1973.
10. Introduction to Nuclear Physics, Wong, PHI

P302: Condensed Matter Physics (General) (4 credits, 4 lectures per week)

Unit-I

Crystal structure: Crystalline state - periodic arrangement of atoms-lattice translation vectors The basis and crystal structure, primitive and non-primitive lattice cell-fundamental types of lattice, -2d and 3-d Bravias lattice and crystal systems. Elements of symmetry operations-points and space groups-nomenclature of crystal directions and crystal planes-miller indices,

X-ray diffraction: Scattering of x-rays, .Laue conditions and Bragg's law, atomic scattering factor, geometrical structure factor, Reciprocal lattice and its properties.

(13 hours)

Unit-II

Free electron theory of metals : Free electron model, Electrons moving in one dimensional potential well, three dimensional potential well, quantum state and degeneracy, the density of states, Fermi-Dirac statistics, effect of temperature on Fermi distribution function, the electronic specific heat. Electrical conductivity of metals, relaxation time and mean free path, electrical conductivity and Ohm's law, Thermal conductivity, Wiedemann - Franz law, thermionic emission, Hall effect.

Band theory of solids: Elementary ideas of formation of energy bands. Bloch function. Kronig-Penney model, number of states in a band, Energy gap. Distinction between metals, insulators and intrinsic semiconductors.concept of holes, equation of motion for electrons and holes, effective mass of electrons and holes.

(13 hours)

Unit-III

Semiconductors: Introduction to semi conductors, band structure of semi conductors, Intrinsic and extrinsic semiconductors, expression for carrier concentration (only for intrinsic), ionization energies, charge neutrality equation, conductivity-mobility and their temperature dependence, Hall effect in semiconductors.

Superconductors: Critical temperature-persistent current-occurrence of super conductivity-ideal and non-ideal superconductors-Destruction of super conductivity by magnetic field - Meissner effect- heat capacity-energy gap-microwave and infrared properties- Isotope effect-BCS theory (qualitative)-Josephson tunneling-exotic superconductors- high T_c super conductors.

(13 hours)

Unit IV

Dielectrics: Introduction, Review of basic formulae, Dielectric constant and displacement vector -different kinds of polarization-local electric field-Lorentz field-Clausius-Mossatti relation- expressions for electronic, ionic and dipolar polarizability, Ferroelectricity and peizo electricity.

Magnetism: Review of basic formulae -classification of magnetic materials-Langevin theory of diamagnetism, para-magnetism and Ferromagnetism –domains-Weiss molecular field theory (classical)-Heisenberg exchange interaction theory-. Antiferro-magnetism and ferrimagnetism.

(13 hours)

References

1. A.R.Verma and O.N. Srivastava: Crystallography Applied to Solid State Physics, 2nd edition, New Age International Publishers, 2001
2. Solid State Physics- A. J. Dekker, Macmillan India Ltd., Bangalore, 1981.
3. Solid State Physics- C. Kittel, V Ed., Wiley Eastern Ltd., 1976.
4. Elementary Solid state physics,- M.A. Omar, Addissonwesley, New Delhi,2000.
5. Solid state Physics- S.O. Pillai. New Age International Publication. – 2002.
6. Solid state Physics- M.A. Wahab, Narosa Publishing House, New Delhi.- 1999.
7. Modern theory of Solids- Seitz.
8. Semiconductors Devices-Physics and Technology- S.M. Sze.
9. Introduction to Solids – L. Azoroff.
10. Solid State Physics- H.C. Gupta- Vikas Publishing House, New Delhi.-2002

Elective Papers

Elective-1 (One course to be opted out of a group of 3)

P303.E1: Stellar Astrophysics (4 credits, 4 lectures per week)

Unit-I

Basic concepts of Astronomy: Co-ordinate system, Time system-Solar and Sidereal times, Apparent and Absolute magnitudes, Trigonometric Parallax, Atmospheric extinction, Optical telescopes and their characteristics, Modern Optical telescopes, Astronomical Instruments – Photometer, Photographic plates, Spectrographs, Charge Coupled Detector (13 hours)

Unit-II

Stellar properties: Observational properties of stars – spectral and luminosity classification of stars- H-R Diagram, Saha Equation, , Star Formation - Jeans mass, Jeans Length and Free fall timescale, Main Sequence Evolution, Mass- luminosity relation, White Dwarfs – Chandrasekhar's Limit, Neutron Stars, Pulsars, Supernovae, Stellar Black holes

(13 hours)

Unit-III

Solar system: Overview of Sun, Solar Interior structure- Core, Radiative zone and Convective Zone, solar atmosphere-photosphere, Chromospheres, Properties of Interior planets and exterior planets satellites of planets, Kuiper Belt objects, Oort Cloud, Theories of formation of the solar system. (13 hours)

Unit-IV

Stellar structure: Hydrostatic Equilibrium, Mass conservation, Luminosity gradient equation, Temperature gradient Equations, Lane – Emden equation for polytrophic stars and its physical solution, estimates of central pressure and temperature, Radiation pressure, equation for generation and luminosity, equation of temperature gradient for radiative and convective equilibrium, Schwarzschild criterion, gas pressure and radiation pressure, Linear Model and its properties, Volt – Russell theorem, Zero age main sequence, Mass – Luminosity relation.

(13 hours)

References

1.Ostlie and Carroll: Introduction to Modern Astrophysics, Addison Wesley (II Edition), 1997
2. Kristian Rohlf : Tools of Radio Astronomy, Springer
3. John D. Krauss : Radio Astronomy, II Edition, Signet,
4. F. Shu : The Physical Universe, University So Press, 1987.
5. M. Schwarzschild : Structure and Evolution of Stars, Dover.
6. R. Kippenhahn and Weigert A.: Stellar Structure and Evolution, Spinger Verlag, 1990.
7. C.J. Hansen and Kawaler S.D.: Stellar Interiors: Physical Principles, Structure and Evolution, Spinger Verlag, 1994.
8. M. S. Longair : High Energy Astrophysics, CUP.
9. Kitchin C R : Stars, Nebulae and the Interstellar Medium, Taylor and Francis Group, 1987.

P303-E2: Lasers and Optics (4 credits, 4 lectures per week)

Unit-I

Lasers: Review of Einstein's coefficients, Light amplification, Spatial and temporal coherence, Threshold condition, Rate equations for 2 and 3 level systems, Laser pumping requirements, Output coupling, Cavity modes, quality factor, Mode selection and mode locking, Q-switching. Some laser systems: He-Ne, Nd:YAG, Dye lasers, Semiconductor lasers. Optical fibre waveguides, Numerical aperture, Multimode and single mode fibres, Optical fibre communication.

(13 hours)

Unit-II

Propagation of light in optical media: Dispersion: dispersion in dilute and dense gases, group and signal velocities. Anisotropic media: Fresnel's equation, uniaxial and biaxial crystals, double refraction, polarizing prisms.

Jones vector and linear, circular, elliptic states of polarization, Malus' law, Jones matrices and linear optical devices, phase retarders, quarter and half wave plates, Stokes parameters.

Geometric optics: Paraxial approximation, Matrix formulation of geometric optics, optical system matrix, focal length and principal planes, some examples of simple optical elements.

(13 hours)

Unit-III

Wave optics: Interference: Planar wave description of light, two-beam interference, Michelson interferometer, Multi-beam interference, Fabry-Perot interferometer.

Diffraction: Kirchhoff's diffraction theory, regimes of diffraction, Fresnel and Fraunhofer diffraction, rectangular slit, circular aperture, single and multiple slit diffraction.

(13 hours)

Unit-IV

Non-linear Optics: Interaction of radiation with a dielectric medium, dielectric susceptibility, Harmonic generation, Second harmonic generation, Phase matching criterion, coherence length for second harmonic radiation, optical mixing, third harmonic generation, self focussing of light, parametric generation of light.

(13 hours)

References

1. Optical Electronics by A. Ghatak and K. Thyagarajan, Cambridge University Press, 2004
2. Optics – Principles and Applications by K. K. Sharma, Academic Press, MA, 2006
3. Optics 4th Ed. by E. Hecht, Addison-Wesley, NY, 2001
4. Introduction to Modern Optics(2nd Ed), by G. R. Fowles, Dover
5. Principles of Optics by Born and Wolf.
6. Schaum's Outline of Theory and Problems of Optics**,** E. Hecht, McGraw-Hill
7. Laser Fundamentals, Silfvast, Cambridge Press, 1998
8. Lasers and Nonlinear Optics: B.B,. Laud, 2/e, New Age International (P) Publishers, 2002

P303-E3: Atmospheric Physics (4 credits, 4 lectures per week)

Unit – I

Elements of earth's atmosphere: Review of origin and composition of the atmosphere, major components- nitrogen, oxygen, argon; minor components-water vapour, dust particles, ozone; vertical variations in compositions – homosphere, heteorosphere, ionosphere; auroras; thermal structure of the atmosphere – troposphere, stratosphere, mesosphere, thermosphere; horizontal distribution of temperature, pressure and density, distribution of winds, horizontal and vertical winds, land breeze and sea breeze.

Atmospheric observations: Importance of meteorological observations, measurement of temperature and humidity, measurement of wind and pressure, measurement of precipitation, upper air observations - radiosonde, rawinsonde, rocketsonde, pyrgeometer, pyrheliometer, Radar, Doppler weather radar, applications. (13 hours)

Unit – II

Radiation and energy budget: Electromagnetic spectrum of radiation, black body radiation – Planks law, thermodynamical equilibrium, radiometric quantities, atmospheric absorption of Solar radiation – absorption and emission of radiation by molecules, absorptivity and emissivity, Kirchhoff's law, reflectivity and transmitivity, absorption of solar radiation by the atmosphere, Beer's law, indirect estimate of solar radiance at the top of the atmosphere, vertical profile of absorption; scattering of solar radiation, atmospheric absorption and emission of infrared radiation.

Global energy balance: Atmospheric energy balance – global energy balance requirement for the Earth's atmosphere, global energy balance at the earth's surface, estimates of the global energy balance for the earth-atmospheric system, energy processes in the upper atmosphere, internal potential and kinetic energy, conversion of potential and internal energies to kinetic energy, general and frictional dissipation of kinetic energy, atmosphere as heat engine.

(13 hours)

Unit – III

Atmospheric dynamics: Large scale motions, vorticity and divergence, streamline and trajectories, dynamics of horizontal flow – apparent and real forces, equation of motion, geostrophic wind, effect of friction, gradient wind, thermal wind, suppression of vertical motions, conservation law for Vorticity, potential vorticity; primitive equations – pressure as a vertical coordinate, hydrostatic balance, thermodynamic energy equation, solution of the primitive equations, applications; atmospheric general circulation.

Monsoon over India: Morphology of monsoon circulation, symmetric and asymmetric monsoon, Formation of monsoon disturbances, Structure of monsoon disturbances, Wind, temperature and pressure distribution over India in the lower, middle and upper atmosphere during pre, post and mid-monsoon season; Intra-seasonal variability of monsoon, Inter-annual variability of monsoon – anomalous over India and Asia, El Nino Southern Oscillation and dynamical mechanism for their existence. (13 hours)

Unit – IV

Space physics:Basics of ionosphere formation, D-, E- and F-layers, composition of the ionosphere, effect of terrestrial and solar radiation on earth's atmosphere, photochemical processes, currents in ionosphere, electrical conductivity, techniques of ionosphere measurements – ionosonde and Langmuir probes; Earth's magnetic field and its extension into space, structure of magnetosphere, polar and equatorial cross sections, potential drops in magnetosphere, interaction of solar wind with the geomagnetic field, magnetospheric tail, radiation belts, trapping of charged particles, trajectory of charged particles, trapped radiation.

Remote sensing: Concepts of remote sensing, Energy interaction with earth's surface features, Signatures of vegetation, soil and water bodies of the earth's surface, Classification of remote sensors, Spectral, spatial and temporal resolution, IR and microwave sensors, Data reception and products, Application of Remote sensing for earth's resource management, Indian Remote sensing programme.

(13 hours)

References

1. Basics of Atmospheric Science, A Chandrasekar, PHI Publications, 2010.
2. Atmospheric Science-An Introductory Survey, John M Wallace and Peter V Hobbs, Academic Press, Elsevier, 2006.
3. The atmosphere, Frederick K Lutgens and Edward J Tarbuck, Pearson Prentice Hall, 2007.
4. Radar Meteorology by S Raghavan, Kulwer Academic Publishers, 2003
5. An introduction to Dynamic Meteorology, Holton JR, Academic Press NY 2006.
6. A course in Dynamic meteorology, Naval Pandarinath, BS Publications, 2006.
7. The Physics of Monsoons, RN Keshvamurthy and M Shankar Rao, Allied Publishers, 1992.
8. Ionospheres: Physics, Plasma Physics and Chemistry, RW Schunk and AF Nagy, Cambridge University Press, 2000.
9. Basic Space Plasma Physics: W Baumjohann and RA Treumann, Imperial College Press, 1997.
10. Fundamentals of Remote Sensing, George Joseph, University Press Pvt. Ltd. Hyderabad, 2002.

Elective-2(one course to be opted from a group of 3)

P304-E4: Soft and Living Matter (4 credits, 4 lectures per week)

Unit-I

Soft matter: Introduction and Overview

Forces, energies and time scales in condensed matter: Gases, liquids and solids – intermolecular forces, condensation and freezing. Viscous, elastic and viscoelastic behaviour – response of matter to a shear stress, mechanical response of matter at a molecular level. Liquids and Glasses – practical glass forming systems, relaxation time and viscosity in glass forming liquids, glass transition – experimental signatures and theories.

(13 hours)

Unit –II

Random walks, friction and diffusion: Brownian motion, other random walks: conformation of polymers, diffusion in the sub cellular world, equation for diffusion, precise statistical prediction of random processes, biological applications of diffusion.

Colloidal dispersions: Introduction, single colloidal particle in a liquid, Stokes' law, Brownian motion and Stokes-Einstein equation. Forces between colloidal particles – interatomic forces and interparticle forces, van der Waals forces, electrostatic double layer forces, stabilizing polymers with grafted polymer layers, depletion interactions

(13 hours)

Unit- III

Polymers: Introduction, variety of polymeric materials, random walks and dimension of polymer chains, theory of rubber elasticity, viscoelasticity in polymers and the reptation model.

Supramolecular self assembly in soft condensed matter: Introduction, self assembled phases in solutions of ampiphilic molecules, Self assembly in polymers.

Soft matter in nature: Biological polymers, Nucleic acids, nucleic acid conformation – DNA, RNA, Proteins, Protein folding.

(13 hours)

Unit- IV

Biological membranes: Membrane chemistry and structure, membrane physics.

Movement of organisms in low Reynolds-Number world- Friction in fluids, Low Reynolds number, bacterial motion – swimming and pumping.

Techniques and methods employed: X Ray diffraction and Molecular structure, Nuclear Magnetic Resonance, Scanning Tunnelling Microscopy, Atomic Force Microscopy, Optical Tweezers ; Patch clamping, Molecular Dynamics, Potential Energy Contour Tracing.

(13 hours)

References

1. Soft Condensed Matter – Richard A.L. Jones, Oxford Master Series in Condensed Matter Physics; Chapters 1, 2, 4, 5 and 9.
2. Biophysics – An Introduction – Rodney Cotterill; Chapters 6, 7, 8 & 10
3. Principles of Condensed Matter Physics – P.M. Chaikin and T.C. Lubensky.
4. Biological Physics - Energy, Information, Life - Philip Nelson; Chapters 4 and 5

P304 –E5: Material Science (4 credits, 4 lectures per week)

Unit-I

Formation and structure of materials: Introduction to Materials Science- Engineering materials - structure - property relationship, Review of ionic, covalent and molecular bindings, bond angle, bond length and bond energy, lattice energy - Madelung constant-cohesive energy, van der Waal's Interaction- Lennard- Jones Potential, closed packed structure-packing efficiency and density of materials.

Crystal imperfections: Review of crystalline imperfection, Schottky and Frenkel defects-Equilibrium concentrations, edge and screw dislocations, surface imperfections.

(13 hours)

Unit -II

Elastics and plastics behavior of materials:

Atomic model of elastic behavior-rubber like Elasticity-anelastic behavior, viscoelastic behavior, fracture of materials-Ductile and brittle fracture – Ductile brittle transition-protection against fracture

Plastic deformation by slip-shear strength of perfect and real crystals- CRSS ratio, maximum stress to move dislocation, methods of strengthening crystalline materials against plastic deformation-strain hardening, grain refinement, solid solution strengthening, precipitation strengthening.

(13 hours)

Unit- III

Composite materials: Classification of composite materials, matrix materials- polymer, metals, ceramics, rein forcing materials- fibers, particles, concrete-concrete making materials, structure, composition, properties and applications, polymer-concrete composites, fabrication, structure, application of polymer matrix composites, metal matrix composites, ceramic matrix composites, metal matrix composites, ceramic-matrix composites, carbon-fibre composites, fibre reinforce, particle reinforce composites with properties and applications.

(13 hours)

Unit -IV

Elements of polymer science: Monomers- Polymers- classification polymers, synthesis of polymers-chain polymerization, step polymerization, Industrial polymerization methods, Average molecular weight- weight, number & viscosity, size of polymer molecule.

Microstructure of polymers- chemical, geometric, random, alternating and block polymers.

Phase transition-Polymer melting and glass transition, stereo isomerism, degree of crystallinity.

Process of plastic materials: Moulding- compression, injection, blow, extrusion, spinning.

(13 hours)

References

1. Elements of Materials Science and Engineering: Lowrence H. Van Vlack, Addison Wesley, (1975).
2. Introduction to Ceramics: W D Kingery, H K Bower and VR`uhlman, John Wiley, (1960)
3. Foundations of Materials Science and Engineering-William F. Smith, McGraw Hills International Edition, (1986)
4. Materials Science and Engineering, V. Ragharan, Prentice Hall (1993)
5. Structure & Properties of materials-vol I-IV Rose, Shepard and Wulff (1987)
6. Polymer Science, V. R Gowariker, N.V. Vishwanathan, Joydev Shreedhar, Wiley Eastern (1987)
7. Text of Polymer Science, Fred. W.Billmeyer, John Wiley and Sons, Inc. (1984)

P304:E6: Applications of Theoretical Concepts in Physics (4 credits, 4 lectures per week)

Preamble: *Core physics courses taught in I and II semester M.Sc., physics focus mainly on developing a deeper theoretical understanding of concepts with a much needed emphasis on abstract mathematical training. Essentially the theoretical contents learnt in core courses of physics should, in principle, be put to use by students to solve exercises/problems encompassing a wide-range of areas of physics. Apparently, there remains a gap on how/where the theoretical notions are rigorously applied to solve problems in physics. This elective course is designed to bridge the gap existing between learning core theoretical concepts and applying them effectively to solve relevant exercises in physics. Main focus in this course is on solving multi-faceted exercises/problems by combining and extending theoretical skills. A sample set of ten exercises is attached with the syllabus.*

Unit-I
Mathematical Concepts

Vector algebra and vector calculus**:** Finding the volume of a parallelepiped given some of its edge vectors; finding the area of a regular/irregular polygon when vectors corresponding to some of its edges given; finding the normal vector to a given surface; evaluating volume, surface and line integrals of vector fields; applying vector algebra to find the vector representing the refracted ray in optics; integral of $\oint \vec{r} \times \overrightarrow{d\theta}$over a contour in a plane and its connection with finding the magnetic moment of a current distribution.

Matrices, Eigenvalues and eigenvectors, Cayley-Hamilton Theorem: Minimal polynomial of a matrix and diagonalizability; canonical forms of matrices (Diagonal form, Jordan form, Triangular form); predicting the nature of the eigenvalues of some special kinds of matrices (real and odd dimensional, triangular, antisymmetric, normal) without solving the eigenvalue equations; finding functions of the eigenvalues of a matrix in terms of trace, sum of principal minors, determinant; application of cyclicity of trace involving a product of matrices; matrix exponentials; finding trace of the exponential of an anti-hermitian matrix in terms of the determinant of the anti-hermitian matrix. (6 hours)

Hermite, Bessel, Laguerre and Legendre functions: Using recurrence relations and orthogonality relations to find some special integrals; applications of (i) Bessel functions in diffraction (ii) expansion of functions $f(x);\ -1 \leq x \leq 1$in terms of Legendre polynomials and its connection with partial wave analysis in scattering theory; special properties of spherical harmonic functions and their connection with angular momentum. Fourier and Laplace transforms: Finding the Fourier transform of $e^{-|x|}$ and its connection with the wave-function of a particle bound in delta function potential; Fourier transform of $e^{-X^T G X}$, where $X^T = (x_1, x_2, \ldots, x_n)$ is a row and G is a $n \times n$ positive matrix; Fourier and Laplace transforms of a function and its derivatives. Complex analysis: Using residue theorem to evaluate the integral $\int_{-\infty}^{\infty} \frac{dk}{k^2 - a^2}$ using residue theorem and its applications in scattering theory; dispersion relations. Group theory: SU(2) and O(3) groups and their connection with rotations in three dimensional space; symmetry under rotations

(7 hours)

Unit-II

Classical Mechanics

Central forces: Finding maximum and minimum orbital speeds of an object bound in a Kepler orbit; relation between kinetic energies of the object moving in a closed elliptic orbit under gravity when it is at closest and farthest distances; evaluating the angular momentum of an object moving in a central potential; a charged particle moving under uniform vertical gravitational field and a uniform horizontal electric field; constraint on the velocity of a particle (under gravity) so that it stays on a rippled surface $y(x) = d\ \cos kx$. (3 hours)

Rigid bodies: Evaluation of principal moments of inertia; finding the Euler angles to transform body fixed system to space fixed system; Specific forms of precession and nutation.

Small oscillations: Time period and frequencies of oscillations about the equilibrium position of two identical atoms interacting under a potential$V(r) = \frac{a}{r^n} - \frac{b}{r^k}; n > k,$ a, b are real, positive integers; small oscillations of a particle of mass m subjected to a potential $V(x) = \frac{1}{2}kx^2 + \frac{\lambda}{4}x^4$ (4 hours)

Applications of Lagrangean and Hamiltonian formulation: Examples of non-conservative systems: damped harmonic oscillator, charged particle in an external electromagnetic fields: Velocity dependent potentials; uniqueness of the Lagrangeans $L(x,\ \dot{x}), L' = L((x,\ \dot{x}) + \alpha\, \dot{x}$, Evaluating extremized action, symplectic transformations and linear canonical transformations. (6 hours)

Unit-III

Quantum Theory

One dimensional exactly solvable potentials: Delta function potential, Infinite Square Well, Harmonic Oscillator Potential; identifying the special feature that the bound state wave functions of one dimensional potentials are real, position momentum uncertainty relation for a particle confined to (i) a 1-d harmonic Oscillator (ii) Infinite Square Well (iii) Delta function potential; coherent states and minimum uncertainty relations;

Normalization of the wave function and evaluating expectation values in Gaussian wave functions, Calculating expectation values of functions of position and momentum of a harmonic oscillator potential, infinite square well and delta function potentials; Normalization of the ground state wave function of the Hydrogen atom and expectation values of r^n in Hydrogen atom; Virial theorem relating expectation values of kinetic and potential energies; non-classical regions of a particle in quantum harmonic oscillator. Momentum space wave functions of a particle in the ground state of harmonic oscillator and delta function potentials; Tunnelling in a delta function potential.

Time-evolution: Finding the time taken by a quantum particle to evolve to a state orthogonal to the initial state; evolution of uncertainty relations as a function of time when a quantum particle prepared in a Gaussian wave function initially.

Approximation methods: Achieving a lower value of ground state energy by subjecting a two level system to time-independent perturbation; finding the effect of shrinking and expanding the width of the infinite square well potential on the energy levels and wave functions; Subjecting a charged particle bound in a harmonic oscillator potential to external uniform electric and magnetic fields; finding the optimal value of first excited state energy using variational method; identifying symmetric and antisymmetric wave functions of two or more particles; Pauli Hamiltonian and the Schrodinger equation of a quantum particle moving in an external electric and magnetic fields.

Electrodynamics

Electrostatics: Identifying given electric field profile with corresponding static charge distribution; evaluation of the work done on/by a charged particle subjected to an external uniform electric field; evaluating electric dipole and quadrupole moments of a given charge distribution; multipole expansion of a static system of two parallel infinite line charges; Magnetic field of an infinitely long ideal solenoid, Identification of magnetic field profiles with current distributions; evaluation of magnetic fields in the Z direction associated with the current carried by a circular loop in the XY plane; balancing magnetic forces carried by two infinitely long parallel wires under gravity; evaluation of the electric field to be switched on so as to maintain the trajectory of a charged particle moving parallel to two infinitely long parallel wires carrying currents in the same direction; evaluation of magnetic dipole moment; evaluation of angular momentum of an electron moving in a circular orbit when it is subjected to an external magnetic field; trajectories of a charged particle in uniform electric and magnetic fields – non-relativistic and relativistic cases. Lorentz invariants of electromagnetic field. (13 hours)

Unit- IV
Thermodynamics and Statistical Physics

Work done on an ideal gas going from a state with pressure and volume (P_1 V_1) through states (P_1,V_2), (P_2, V_2), (P_2 ,V_1) to (P_1 V_1); maximum work done in the expansion of air when it obeys the law PV^n = constant; temperature change of a thermodynamic system under adiabatic expansion; finding the relation between initial and final pressure and volume of a system of diatomic gas at a given temperature T, when the number of diatomic gas molecules is doubled by maintaining the same temperature; finding the efficiency of a reversible engine from the given T-S diagram; evaluating partition function and average energy of identical particles of mass *m* subjected to a potential (i) $V(x)=0$ (ii) $V(x)=k\,x^2/2$ (iii) $V(x)=ax^2+b(y^2+z^2)^{1/2}$ where a and b are constants; relation between number density and temperature of a gas consisting of non interacting particles to be described by quantum statistics; distributing N particles in M (which is larger than N) number of boxes according to Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics; estimating the number of particles when they are distributed in finite number of energy levels, when the values of energies of each level and the average energy are given; evaluating density of states, exercises on random walk. (7 hours)

Electronics

Semiconductor devices (diodes, junctions, transistors, field effect devices, homo and hetero junction devices), equilibrium charge carrier concentrations in intrinsic semiconductors and extrinsic semiconductors, Fermi energy in intrinsic and extrinsic semiconductors, diode built in voltage, junction capacitance, transistor device structure, device characteristics, illustrative characteristics of basic amplifier configurations, frequency dependence and applications, Opto-electronic devices (solar cells, photo-detectors, LEDs), calculation of cut-off wavelength in photo conductors. Operational amplifiers and their applications: Examples involving Inverting and non inverting amplifier configurations, low pass, high pass and band pass filters design calculations. Digital techniques, Basic logic gates and their truth tables, Boolean laws, simplifications of digital circuits using Boolean algebra. Applications (registers, counters, comparators and similar circuits), A/D and D/A converters, resolution, output calculations for analog/digital circuits, Microprocessor and microcontroller basics (mostly 8085), registers, simple programs. (6 hours)

References

1.Mathematical Methods of Physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley
2.Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
3.Matrices and Tensors in Physics - M. R. Spiegel, Schaum Series
4. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series
5. Vector Analysis - M. R. Spiegel, Schaum Series
6. Complex functions – M. R. Spiegel, Schaum Series.
7. Classical mechanics, H. Gldstein, C. Poole, J. Saflco, 3rd edition, Pearson Education Inc. 2002.
8. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
9.Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Interscience Publication, 1977.
10. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
11. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.
12.Quantum Mechanics – E. Merzbacher, John Wiley and Sons, 1998.
13.Quantum Physics – S. Gasiorowicz, John Wiley and Sons.
14.Fundamentals of Statistical and Thermal Physics -- F. Reif, McGraw Hill, Singapore 1985.
15.Introduction to Statistical Physics -- Silvio R A Salinas, Springer, 2001
16.Introduction to Electrodynamics – David J. Griffiths, Second Edition, Prentice Hall India, 1989.
17. Electronic Principles, A P Malvino, Sixth Edition, Tata McGraw Hill, New Delhi, 1999
18.Operational Amplifiers with Linear Integrated Circuits, William Stanley, CBS Publishers and Distributors, 1988.
19.Op-Amps and Linear Integrated Circuits, Ramakant A Gayakwad, Third Edition, Eastern Economy Edition, 2004.
20.Digital principles and applications, Donald P Leach and Albert Paul Malvino, Fifth Edition, Tata McGraw Hill, 2002.

Sample Exercises

1) Find the equation of The equation of the path joining the origin to the point P(1, 1) in the XY plane that makes the integral $\int_0^P (y'^2 + y\,y' + y^2)\,dx$ stationary. (Here $y' = \frac{dy}{dx}$).
2) Find the volume of a sphere of radius 1 in four dimensions.
3) A mass m is in equilibrium at a distance r_0 from the origin in a spherical potential given by $V(r) = V_0\,[(r/R)+a^2(R/r)]$ where V_0 , R, and a are some positive constants. Find the angular frequency of oscillations when the mass is set into oscillations about the equilibrium position.
4) Suppose we have two non-interacting particles both of mass m in the 1d infinite square well $0 \leq x \leq a$, where a denotes the width of the well. If it is told that the particles are Bosons, how would you write the wave function $\Psi(x_1, x_2)$ of the first excited state?
5) Find the ground state energy of a positronium (a bound system of electron and its antiparticle positron).

6) An observer at rest measures the magnitude of an electric field to be 4 units. And an astronaut, who is moving with relativistic velocity with respect to the stationary observer, measures the magnitude of the same electric field to be 5 units and also a magnetic field of magnitude 3 units. How would you explain it?
7) Three infinitely long wires are placed equally apart on the circumference of a circle of radius a, perpendicular to the plane of the circle. Two of the wires carry current I in the same direction, while the third carries a current of $2I$ in the opposite direction. Find the magnitude of the magnetic field of this system at a distance r from the centre of the circle, for $r>a$.
8) A sealed and thermally insulated container of total volume V is divided into two equal parts with an impermeable wall. The left half of the container is initially occupied by n moles of gas at temperature T. Find the change in entropy when the wall is suddenly removed and the gas expands to fill the entire volume.
9) In a group of 40 people, how would you find the probability that at least two of them share the same date of birth?
10) A system of gas molecules subjected to a three dimensional harmonic oscillator potential are said to be in thermal equilibrium at temperature T. Find the average total energy of the system in terms of kT (here k denotes the Boltzmann constant)

Open Elective course

P305: Physics and our World (4 credits, 4 lectures per week)

Preamble to the course

This is a course that assumes no quantitative background and is meant as an introduction to a physicists' way of understanding the world we inhabit. It is a survey of the hierarchical structuring of the universe in categories of space, time, matter and energy, from the very small to the gigantic. Rather than providing a simplified treatment of the subjects and categories by which the physicists seeks to understand the physical universe the course seeks to take the participant on a path that provides a glimpse of the process by which this understanding is sought.

Unit-I

Space and Time

A discussion on length scales and dimensions, Galaxies, The solar system and Planet Earth, Rotation and revolution of the Earth, Seasons, Calendars in history and the recording of time.
Laws of nature – a discussion of principles, theories and models, Gravitation, Planetary motion and Kepler's laws, The laws of motion in the eyes of Galileo and Newton.

(13 hours)

Unit-II

The relationship between space and time: A basic account of the theory of relativity, Does nature differentiate between Left and Right?- The notion of Parity
Is there an "arrow" of time? Entropy and the laws of thermodynamics
The size of the universe - Is the universe expanding?

(13 Hours)

Unit-III

Matter and Energy

Discrete and continuous matter- a brief historical survey, Atoms and molecules: Structure of atoms, the nucleus, Elementary particles, Unification of forces
Equivalence of matter and energy, Nuclear energy and thermonuclear power. The Periodic table of elements, Chemical bonds and molecules, Large molecules and living matter.

(13 hours)

Unit-IV

Waves and oscillations, Electromagnetic radiation and spectrum, Propagation of waves
Energy in the atmosphere- Wind and solar energy, Weather predictability and chaos, Indeterminacy, The quantum world -- an introduction, Debates on the conceptualisation of physical realities – is nature unreasonably mathematical?

(13 hours)

References

1. The Evolution of Physics- Einstein and L. Infeld, Toughstone 1967.
2. The Ascent of Man- J. Bronowski, Liffle and Brown Company, 1976.
3.Cosmos- Carl Sagan, McDonald and Company, 2003.
4. In search of Schrodinger's Cat- John Gribbin, Random House, 2012
5. Chaos- James Gleick, Viking Penguin, 1987
6. Doubt And Certainty – Tony Rothman and George Sudarshan (Helix books, Cambridge, 1998)

IV Semester

P401: Atomic and Molecular Physics (General) (4 credits, 4 lectures per week)

Unit-I

Absorption and emission of radiation: Interaction of radiation with matter: Einstein's coefficients, Beer's law for attenuation and amplification of light. The width and shape of spectral lines: natural broadening, Doppler broadening-estimation of half width, General treatment of other broadening mechanisms-collision and power broadening.

(13 hours)

Unit-II

Atomic Physics: Brief review of early atomic models. Hydrogenic atoms: Energy levels and selection rules, Relativistic corrections and fine structure, hyperfine structure, Lamb shift and isotope shift. Interaction with external fields: Zeeman effect, Paschen-Back effect, Stark effect. Two electron atom: Ortho and para states and role of Pauli's exclusion principle, level schemes of two electron atoms. Many electron atoms: LS and JJ coupling schemes, Lande interval rule.

(13 hours)

Unit-III

Molecular Physics-A:Born-Oppenheimer approximation, Rotational spectroscopy: Classification of rotors. Diatomic molecule as a rigid rotator, Centrifugal distortion and non – rigid rotator, energy levels and spectra, Intensity of rotational lines, experimental techniques. Raman scattering, Polarizability, Rotational Raman spectroscopy (diatomics). Experimental technique.

(13 hours)

Unit-IV

Molecular Physics-B: Diatomic molecule as a simple harmonic oscillator, anharmonicity, effect of anharmonicity on vibrational terms, energy levels and selection rules. Vibrating rotator-energy levels and rovibrionic spectra, Experimental technique and IR spectrometry. Applications of IR spectroscopy. Mutual exclusion principle.

Electronic spectra of diatomic molecules: vibrational coarse structure and rotational fine structure in electronic spectra, intensity of vibrational bands in electronic spectra – Frank-Condon principle. Dissociation and pre-dissociation.

(13 hours)

References

1. Physics of atoms and molecules**,** Bransden and Joachain, (2^{nd} Edition) Pearson Education,2004
2. Fundamentals of Molecular Spectroscopy, Banwell and McCash, Tata McGraw Hill, 1998.
3. Modern Spectroscopy, J.M. Hollas, John Wiley, 1998.
4. Molecular Spectroscopy, Jeanne L. McHale, Pearson Education, 2008
5. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 3^{rd} Edition, Oxford Press(Indian Edition), 2004.
6. Molecular Structure and Spectroscopy: G. Aruldhas, Prentice Hall of India, New Delhi, 2001

P402: Numerical Analysis and Computational Physics (4 credits, 4 lectures per week)

Unit-I
Numerical methods
Interpolation, solution of linear algebraic equations using Gauss elimination method, Curve fitting by least square fit method, Numerical integration, Trapezoidal and Simpson's rules, Numerical differentiation, Euler and Runge-Kutta methods, Finding roots, bisection method, Newton-Raphson method.

(13 hours)

(Mathematical Methods of Physics, Mathews and Walker Ch. 13)

Unit-II
Probability and statistics
Random variables, Fundamental probability laws, permutations and combinations, binomial distribution, Poisson distribution, Gauss' normal distribution, general properties of distributions, multivariate Gaussian distributions, Errors of observation and measurements, Fitting of experimental data

(13 hours)

Unit-III
Programming-I
Elementary information about digital computer principles, compilers, interpreters and operating systems, Constants and variables, arithmetic expressions, data types, input and output statements, control statements, switch statements, the loop statements, format specifications, arrays, algorithms, flowcharts, functions and some simple programming examples in C.

(13 hours)

Unit-IV
Programming -II
C program for (i) finding roots using Newton-Raphson method, Bisection method, (ii) solving simultaneous linear algebraic equations, (iii) evaluating integrals using Simpson's and trapezoidal rules, (iv) solving ordinary differential equations using Euler and Runge-Kutta method, (v) least square fitting (vi) Lagrange's interpolation

(13 hours)

References

1. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley
2. Mathematical methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
3. Introductory Methods of Numerical analysis – S.S. Sastry, Third Edition, Prentice – Hall of India, 2003
4. Programming in ANSI – C, E. Balaguruswamy, Second Edition, Tata McGraw Hill, 1992
5. Computational *Physics* - The University of Texas at Austin
6. Web link: http://www.phys.unsw.edu.au/~mcba/phys2020/#numint

Elective-3 (One course to be opted from a group of 4)

P403-E7: Atomic and Molecular Spectroscopy (4 credits, 4 lectures per week)

Unit-I

Vibrational and electronic spectroscopy of polyatomics: Elements of molecular symmetry, Point Groups, Character tables for C_{2v},C_{3v} and $C_{\infty v}$ groups, symmetry and dipole moments, Polyatomic vibrations, Normal modes, Vibrational selection rules for IR and Raman spectra. Molecular Orbitals, Electronic states and Hund's coupling cases, Vibrational structure in electronic spectra (diatomics), Dissociation and pre-dissociation-mixing of Born-Oppenheimer states.

(13 hours)

Unit-II

Spin resonance spectroscopy-A: Basic principles NMR absorption and resonance condition, Relaxation processes: concepts of spin-lattice relaxation and spin-spin relaxation, Line broadening and dipolar interaction, MASS experiment, chemical shift, spin-spin coupling, First order spectra, nomenclature for spin systems, Chemical equivalence and magnetic equivalence of nuclei. Techniques for observing nuclear resonances in bulk materials, continuous wave, pulsed and FT NMR, chemical analysis using NMR.

(13 hours)

Unit-III

Spin resonance spectroscopy-B: Electron spin and magnetic moment, Basic concepts of ESR, characteristics of g-factor and its anisotropy, nuclear hyperfine interaction, Spin Hamiltonian, ESR of organic and inorganic radicals: equivalent and non-equivalent set of nuclei, experimental technique. Basic principles of NQR, nuclear quadrupole interaction, fundamental requirements of NQR. Electron Nuclear Double Resonance(ENDOR)-general treatment.

(13 hours)

Unit-IV

Precision spectroscopy of atoms: Sub Doppler laser spectroscopy- Molecular beams and reduction of Doppler width using collimator, Lamb dip and Saturation Absorption spectroscopy, Elementary ideas of laser cooling of atoms- Doppler cooling, polarization gradient cooling, MOT

Ion Traps- Penning and RF traps, Single ion motion in a Penning trap, Side band cooling, Quantum jumps

(13 hours)

References

1. Physics of atoms and molecules**,** Bransden and Joachain, (2nd Edition) Pearson Education, 2004
2. Fundamentals of Molecular Spectroscopy, Banwell and McCash, Tata McGraw Hill, 1998.
3. Modern Spectroscopy, J.M. Hollas, John Wiley, 1998.
4. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 3rd Edition, Oxford Press(Indian Edition), 2004
5. Spectra of Atoms and Molecules, *P*. Bernath, Oxford Press, 1999
6. Molecular Spectroscopy, *J.L. McHale*, Pearson Education, 1999
7. Atomic Physics, C.J. Foot, Oxford University Press, 2008

8. Introduction to Magnetic Resonance Spectroscopy: ESR, NMER NQR, II Edition, D. N. Sathyanarayana, I.K. International Publishing House Ltd. 2014.
9. Basic Principles of Spectroscopy: Raymond Chang, McGraw-Hill Kogakusha Ltd.

P403-E8: Physics of Solids (4 credits, 4 lectures per week)

Imperfections in crystals

Classification of imperfections, crystallographic imperfections, point defects - concentrations of Schotky and Frenkal defects, line defects- edge dislocations, screw dislocation, Burger vectors, dislocation motion, stress fields around dislocations, observation of dislocations, plane defects- grain boundaries, tilt and twin boundaries –surface imperfections-role of dislocations in crystal growth.

(13 hours)

Unit-II

Lattice vibrations and phonons: Elastic vibrations of continuous media, Group velocity of harmonic wave trains, Wave motion of one dimensional atomic lattice, lattice with two atoms with primitive cell, Some facts about diatomic lattice, number of possible normal modes of vibrations in a band, phonons, momentum of phonons,

Thermal properties: Classical calculations of lattice specific heat, Einstein theory of specific heats, Debye's model of lattice specific heat, Debye approximation, An-harmonic crystal interactions, thermal expansion, lattice thermal conductivity of solids- Umklapp process.

(13 hours)

Unit-III

Inter-atomic forces and bonding in solids: Forces between atoms-binding energy-cohesion of atoms and cohesive energy-calculation of cohesive energy-bond energy of Nacl molecule-calculation of lattice energy of ionic crystals-calculation of Madelung constant of ionic crystals-calculation of repulsive exponent from compressibility data-The Born-Haber cycle.

Diffusion in solids: Fick's law of diffusion, Determination of diffusion coefficients, diffusion couple, applications based on second law of diffusion, atomic model of diffusion-electrical conductivity of ionic crystals.

(13 hours)

Unit-IV

Optical properties: Absorption process, photoconductivity, photoelectric effect, photovoltaic effect, photoluminescence, color centers, types of color centers, generation of color centers-properties-models and applications.

Elastic constants: Stress components. Analysis of elastic strains, elastic compliance and stiffness constants, elastic energy density, stiffness constants of cubic crystals, elastic waves in cubic crystals, waves in [100] direction, [110] direction, experimental determinations of elastic constants.

(13 hours)

References

1. Solid State Physics- A. J. Dekker, Macmillan India Ltd., Bangalore, 1981.
2. Solid State Physics- C. Kittel, V Ed., Wiley Eastern Ltd. 1976.
3. Elementary Solid state physics,- M.A. Omar, Addisson Wesley, New Delhi, 2000.
4. Solid state Physics- S.O. Pillai. New Age International Publication. – 2002.
5. Solid state Physics- M.A. Wahab, Narosa Publishing House, New Delhi. 1999

6. Introduction to Solids – L. Azoroff.
7. Solid State Physics- H.C. Gupta- Vikas Publishing House, New Delhi. 2002

P403-E9: Nuclear Reactions and Particle Physics (4 credits, 4 lectures per week)

Unit- I

Low energy nucleon-nucleon interaction

n-p scattering: partial wave analysis, expression for total scattering cross section, n-p incoherent scattering using square well potential, singlet and triplet potentials, scattering length and its significance, coherent scattering by ortho and para hydrogen, spin dependence of nuclear forces, effective range theory for n-p scattering.

P-P scattering: Qualitative features, effect of Coulomb and nuclear scattering, charge symmetry and charge independence of nuclear forces, isospin formalism, generalized Pauli principle.

(13 hours)

Unit -II

Nuclear Reactions

Part I: Partial wave approach

Partial wave analysis of nuclear reactions, expressions for scattering and reaction cross sections and their interpretation, shadow scattering, resonance theory of scattering and absorption, overlapping and isolated resonances, Briet Wigner formula for scattering and reactions, shape of cross section curve near resonance.

Nucleon-Nucleon Interaction at High Energy:

Experimental results of p-p and n-p scattering at high energies, repulsion at very small distances, exchange forces, role of saturation, Polarization due to scattering, spin-orbit dependence of nuclear forces.

(13 hours)

Unit- III

Part II: Perturbation Approach

Density of energy states, Nuclear reaction cross-section-Derivation through the method of transition probability, its behavior near threshold, Principle of detailed balance, optical model-mean free path, optical potential and its parameters for elastic scattering, Transfer reactions-stripping and pickup, Plane Wave Born approximation (PWBA), its predictions of angular distribution, modifications introduced in the Distorted Wave Born Approximation (DWBA), spectroscopic factors, Transfer reactions and the shell model.

(13 hours)

Unit -IV

Elementary Particle Physics

SU(3) symmetry and eight fold way, Gell-Mann Okubo mass formula, mass formula for baryon octet; equal spacing rule for baryon decuplet, fundamental representation of SU(3) and quarks

Weak interaction: Weak decays, lifetimes and cross-sections, Feynman diagrams, leptonic, semi-leptonic and non-leptonic processes, quark flavour changing interactions with examples,

muon decay – Fermi's four particle coupling and modern perspective with a mediating vector boson, W and Z bosons; their masses and range of weak interactions.
Charged weak interactions of quarks: Cabibbo factor, GIM-mechanism (Glashow-Iliopoulos-Miani mechanism)
Neutral kaons: CP as a symmetry, CP violation in neutral kaon decay (Fitch-Cronin experiment), CPT theorem (qualitative), evolution of a neutral kaon beam with time, regeneration experiments.

(13 hours)

References

1. Nucleon-Nucleon Interaction, *G.E. Brown and A.D. Jackson:* North-Holland, Amsterdam,
2. 1976.
3. Nuclear Interaction, *S. de Bendetti:* John Wiley, New York, 1964.
4. Physics of Nuclei and Particles, *P. Marmier and E. Sheldon:* Vol. I and II, Academic
5. Press, 1969.
6. Nuclear Physics- *R. R. Roy and B. P. Nigam:* Theory and Experiments, John Wiley, 1967.
7. Introduction to Nuclear Reactions, *G. R. Satchler*: Macmillan Press, 1980.
8. Introduction to High Energy Physics, *D. H. Perkins:* Addison Wesley, London, 4th edition, 2000.
9. Quantum Collision Theory, *Jochain*: North Holland, 1975.
10. 8. Semi Classical Methods for Nucleus-Nucleus Scattering, *D. M. Brink*: Cambridge University Press, 1985.
11. Structure of the Nucleus, *M. A. Preston and R. K. Bhaduri*: Addn. Wesley, 1975.
12. Atomic and Nuclear Physics, *S. N. Ghoshal*: Vol. II., 2000.
13. Introduction to Elementary Particles, *D. Griffiths:* John Wiley, 1987.
14. Quarks and Leptons, *F. Halzen and A.D. Martin:*John Wiley and sons, New York, 1984.
15. Unitary Symmetry and Elementary Particles, *D. B. Lichtenberg:* 2nd edition, Academic Press, 1978.
16. Elementary Particles, *J. M. Longo:* II edition, Mc Graw-Hill, New York, 1973.

P403-E10: Observational Astronomy and Cosmology (4 credits, 4 lectures per week)

Unit I

Radio Astronomy: Radio Window, Rayleigh – Jeans law, Optical thickness, brightness temperature, radio telescopes, resolution, sensitivity, noise temperature, synthesis of telescopes, Interferometer, Radio sources and their spectra, Thermal and non thermal mechanisms, 21cm line, studies of other molecules lines.

(13 hours)

Unit II

Space Astronomy : Transparency of the earth's atmosphere, X- Ray Astronomy, X-ray telescopes, X-ray emission mechanisms, X- ray detection techniques, X- ray detectors, Scintillation and proportional counters, Infra-red sources and detectors, Ultraviolet Astronomy, Gamma ray telescopes, Gamma ray production mechanisms, Cerenkov radiation detection, Hubble Space Telescope and other space missions.

(13 hours)

Unit III

Milky Way and External Galaxies: Historical Models of Milky way, Morphology of Milky way, Rotation curve, Galactic nuclei, Galaxies and their classification, External Galaxies-Hubbles Classification, Distances and mass estimations, Clusters of Galaxies, Active Galaxies and their classification, Properties, Black hole paradigm, Super massive Black hole, Physical processes, Unification of AGNs

Unit-IV: Cosmology: Hubble's law, Uniform expansion, distance measures, Cepheid's, Type I supernova, Hubble's constant, the cosmological principle-Isotropy, Homogeneity, Dynamical Evolution and Cosmological solutions, Age of the universe, Dark Matter, Dark energy, CMBR, Matter content, Curvature of Space, Cosmological constant.

Visit to Observatories: IUCAA, VBO, Hanley, Gouribidanur Radio Telescope Centre, Ooty Radio Telescope Centre, Solar Observatories at Kodaikanal and other State Observatories.

References

1.Ostlie and Carroll: Introduction to Modern Astrophysics, Addison Wesley (II Edition), 1997
2.Kristian Rohlf : Tools of Radio Astronomy, Springer
3.John D. Krauss : Radio Astronomy, II Edition, Signet,
4.F. Shu : The Physical Universe, University So Press, 1987.
5.M. Schwarzschild : Structure and Evolution of Stars, Dover.
6.M. S. Longair : High Energy Astrophysics, CUP.
7.Kitchin C R : Stars, Nebulae and the Interstellar Medium, Taylor and Francis Group, 1987.

Elective-4 (One course to be opted from a group of 5)

P404-E11: Astro and Space Physics (4 credits, 4 lectures per week)

Unit I

Orbital Motion and Space Dynamics: Coordinate and time systems, Elements of orbits in space, motion, Elements of reduction of observational data, Review of two body problem: Kepler's law of orbital motion, Newton's laws of motion and gravitation, Solution to two body problem: Elliptical, parabolic and hyperbolic orbits, Orbits in space: f and g series, Many body problem: Equations of motion, Lagrange's solutions, Lagrange's planetary equations (Qualitatively), Artificial satellites, Types of orbits-geostationary and geosynchronous orbits, sun synchronous orbits and satellites, escape velocity, weightlessness and artificial gravity. Forces acting on artificial satellites, Atmospheric drag. Rocket Motion: Motion of a rocket in a gravitational field and in atmosphere, step rockets, Principle of staging, Transfer between orbits (qualitatively).

(13 hours)

Unit II

Solar atmosphere and active regions: Overview of Sun, Location of Sun, Sun's spectrum, Solar interior structure - Energy Generation, Radiative zone, Convection Zone, Observing the Sun, Solar Telescopes, Satellite Missions, Solar Polarimetry, Solar Radio Astronomy.

Solar Atmosphere – Photosphere - active Regions, Sunspots – solar cycle, active and quiet Sun, Granulation, Faculae, Chromosphere -Diagnostics, Radiative Transfer, Heating, Supergranulation, Solar Flares - Properties, Classification, Occurrence, Prominences, Corona - Basic Facts, Observational Features, CME, Radio bursts, Solar Wind and Interplanetary Magnetic field.

(13 hours)

Unit III

MHD and Space weather: MHD and the Solar Dynamo, Solar Magneto-hydrodynamics, Basic Equations, Important MHD Effects, Magnetic Reconnection, Fluid Equations, Equation of State, Structured Magnetic Fields, Potential Fields, 3D Reconstruction of Active Regions, Charged Particles in Magnetic Fields, MHD Waves, Magnetic Fields and Convection, The Solar Dynamo, Observational Features, $\alpha - \omega$ Dynamo, Solar Activity Prediction.

Space Weather and Climate - Atmosphere's Response to Solar Irradiation, UV Radiation, Energetic particles, Thermosphere and Exosphere, Mesosphere and Stratosphere, Troposphere, Solar Variability, Total Solar Irradiance Measurements, Long Term Solar Variations, Solar Protons, Cosmic Rays, Origination of Cosmic Rays, Heliosphere.

(13 hours)

Unit IV

Electromagnetic Processes in Space: Coulomb's Law and Dielectric Displacement, Cosmic Magnetic Fields, Ohm's Law and Dissipation, Magnetic Acceleration of Particles, Ampere's Law and the Relation Between Cosmic Currents and Magnetic Fields, Magnetic Mirrors, Magnetic Bottles, and Cosmic-Ray Particles, Maxwell's Equations, Wave Equation, Phase and Group Velocity, Energy Density, Pressure, and the Poynting Vector, Propagation of Waves Through a Tenuous Ionized Medium, Faraday Rotation, Light Emission by Slowly Moving Charges, Gravitational Radiation, Light Scattering by Unbound Charges, Scattering by Bound Charges, Extinction by Interstellar Grains, Absorption and Emission of Radiation by a Plasma, Radiation from Thermal Radio Sources, Synchrotron Radiation, Synchrotron Radiation Spectrum, Compton Effect and Inverse Compton Effect, Sunyaev–Zel'dovich Effect, Cherenkov Effect.

(13 hours)

References

1. Orbital Motion: A.E. Roy, Adam Hinglar Ltd. 2002.
2. Astrophysical concepts, Martin Harwit, 4th Edition, Springer, 2006.
3. The Sun and Space Weather, Arnold Hanslmeier, 2nd Edition, 2007.
4. R. Kippenhahn and Weigert A.: Stellar Structure and Evolution, Spinger Verlag, 1990.
5. C.J. Hansen and Kawaler S.D.: Stellar Interiors: Physical Principles, Structure and Evolution, Spinger Verlag, 1994.

P404-E12: Advance Electronics (4 credits, 4 lectures per week)

Unit-I

Second order filters: (Sallen key) – low pass and high pass – multiple feedback bandpass filter – state variable filter. The 555 timer – working and applications. Monostable multivibrator using 555, astable multivibrator using 555. Voltage controlled oscillators, 565 Phase Locked Loop-capture range – lock range. Applications of PLL.

(13 hours)

Unit-II

Microsensors: General principles-types of sensors; optical sensors, thermal sensors, pressure sensors, magnetic field measurements.

Measurement and control: Signal conditioning and recovery. Impedance matching, Op-amp based, instrumentation amp. Positive and negative feedback, filtering and noise reduction, shielding and grounding. Lock-in detector-principle – example of PSD, box-car integrator-principle – block diagram.

(13 hours)

Unit-III

Amplitude modulation: Sinusoidal AM, modulation index-frequency spectrum-average power-effective voltage and current. Non-sinusoidal modulation - modulation index. Generation of AM waves-BJT collector modulator-modulator using FETs. Block diagram of AM Transmitter.

Frequency modulation - Sinusoidal FM-frequency spectrum-average power-measurement of modulation index. Non-sinusoidal modulation-deviation ratio.

(13 hours)

Unit- IV

Microwave Devices: Tunnel diode, transfer Electron devices -Gunn diode. Avalanche Transit time devices -Read, Impatt diodes.

Digital communications: Sampling Theorem-low pass signals, PAM, channel bandwidth for a PAM signal, natural sampling, flat top sampling-signal recovery through holding. PCM-quantization of signals. Differential PCM, delta modulation, adaptive delta modulation. Time division multiplexing.

(13 hours)

References

1. Operational Amplifier and Linear Integrated Circuits 3rd Ed., R. A. Gayakwad, Prentice Hall India (1999).
2. Linear Integrated Circuits, D. Roy Choudhury and Shail Jain, New Age International (1991).
3. Microwave Active Devices, M.L.Sisodia, New Age International Publishers (2003).
4. Electronic Communications 4th Ed., D. Roddy and J.Coolen, Prentice Hall India (2000)
5. Electronic Communication Systems 4th Ed., G.Kennedy and B.Davis, Tata Mc-Graw Hill Publ. Co. Ltd, New Delhi (1999).
6. Communication Systems 3rd Ed., Simon Haykin, John Wiley and Sons Inc. (1994).
7. Modulation by F.R.Connor – 2nd edition (Edward Arrow publication) 1983 London NY

P404-E13: Physics of Nanomaterials (4 credits, 4 lectures per week)

Unit-I

Introduction to nanomaterials: Definition, reason for interest in nanomaterials, classification of nanostructures – 1D, 2D and 3D confinement.

Gas reactive applications of nanostructured materials: Catalysis, electrocatalysis processes, impact of nanostructure, **Gas Sensors**: physical principles of semiconductor sensors and nanostructure design,

Hydrogen storage: properties of hydrogen storage compounds and nanostructure design.

Nanomagnetic materials and applications: Domain and domain walls – bulk and nanostructures, magnetization processes in particulate nanomagnets and layered nanomagnets, applications.

(13 hours)

Unit –II

Overview of semiconductors: Electronic band structure, concept of the effective mass, optical processes, direct and indirect band gap semiconductors, exciton formation, superlattice- heterostructure.

Quantum size effect: Quantum confinement in one dimension: quantum wells, Electron confinement in infinitely deep square well square, square well of finite depth, optical absorption in quantum well in the case of heterostructure consisting of thin layer of GaAs sandwiched between thick layers of AlGaAs.

Quantum confinement in 2 dimensions: quantum wires, Quantum confinement in 3 dimensions: quantum dots.

Tunnelling transport: T-matrices for potential step and square barrier, current and conductance. Resonant tunnelling.

(13 hours)

Unit -III

Methods for preparation of Nano-materials:

Bottom Up: Nano Particles (metal and semiconductor) – nucleation – growth – chemical bath deposition – capping techniques.

Nano Structures**:** quantum dots, quantum well structures- Thin film deposition techniques. – molecular beam epitaxy methods of growth –MOVPE – MOCVD. Physical vapour deposition for nanoparticles.

Top Down: Ball milling**:** details, size and time of milling, shaker mills**,** planetary mills, attrition mills. Electron Beam, Lithography – resists- use of positive and negative resists – lift of process**.** Ion-beam lithography-main chemical reaction – use**.**

Self assembled molecular materials**:** principles of self assembly – micellar and vesicular polymerization – self organizing inorganic nanoparticles. Langmuir Blodgett techniques.

(13 hours)

Unit -IV

Characterization of nanomaterials:

Diffraction techniques: X-ray Diffraction (XRD) – Crystallinity, particle/crystallite size determination and structural analysis

Microscopic techniques: Scanning Electron Microscopy (SEM) – Morphology, grain size and EDX; Transmission Electron Microscopy (TEM) – Morphology, particle size and electron diffraction.

Scanning probe techniques: Scanning Tunnelling Microscopy (STM) – surface imaging and roughness ; Atomic Force Microscopy (AFM) - surface imaging and roughness; other scanning probe techniques.

Spectroscopy techniques: Photoluminescence – Emission (PL) and Excitation (PLE) spectroscopy; Infrared (IR) and Raman spectroscopy; X-ray Absorption (XAS).

(13 hours)

References

1. Introduction to Solid State Physics, Charles Kittel, VII edition, 1996.
2. Nanostructured Materials-Processing, Properties and Applications, Edited by Carl. C. Koch, William Andrew Publishing, Norwich, New York, USA, 2004.
3. Nanoscale Science and Technology, Edited by Robert W Kersall, Ian W Hamley and Mark Geoghegan, John Wiley and Sons, UK, 2005.
4. Physics of Semiconductor Nanostructures, K P Jain, Narosa, 1997.
5. Nanotechnology: Molecular Speculations on global abundance, B C Crandall, MIT Press, 1996.
6. Physics of low dimensional semiconductor nanostructures, John H Davies, Cambridge University Press, 1997.
7. Nano Materials: Synthesis, Properties and Applications, Edited by A S Edelsteins, R C Cammarata, Institute of Physics Publishing, Bristol and Philadelphia, 1996.
8. Nano particles and nano structured films: Preparation, characterization and applications, Ed. J H Fendler, John Wiley and Sons, 1998.
9. Quantum dot heterostructures, D Bimerg, M Grundmann and N N Ledentsoy, John Wiley and Sons.

P404-E14 : Crystal and Semiconductor Physics (4 credits, 4 lectures per week)

Unit-I

Crystal Physics

Introduction-symmetry elements of crystals-concept of point groups-derivation of equivalent point position-experimental determination of space groups-powder diffraction interpretation-expression for structure factor-analytical indexing-Weisenberg and rotating crystal method. Determination of relative structures-amplitudes from measured intensities-Multiplicity factor-Lorentz polarization factor. Reciprocal lattices-concept of reciprocal lattice-geometrical construction-relation between reciprocal lattice vector and inter-planar spacing-properties of reciprocal lattice.

(13 hours)

Unit-II

Energy bands in solids: Nearly free electron approximation-Tight binding method of energy bands (applications to cubic system)-orthogonalised plane wave method (OPW)-Wigner-Seitz method--pseudo-potential method. Fermi surface studies and Brillouin zones characteristics of Fermi-surfaces-effect of electric and magnetic field on Fermi surface-anomalous skin effect-cyclotron resonance-De Hass-van Alphen effect

(13 hours)

Unit-III

Semiconductors :Fermi level in intrinsic and extrinsic semiconductors-temperature dependence-carrier concentration-Charge neutrality equation-mobility-diffusion-Nernst-Einstein equation-Donor states-Acceptor states-Thermal ionization of donors and acceptors. Conductivity in semiconductors.

Devices-p-n-junction-fabrication-contact potential- equilibrium fermi levels-space charge at a junction-depletion width-I-V characteristics-generation-recombination-continuity equation-rectification-saturation-Zener break down. Negative conductive device-tunnel diode-Transistors (bipolar)-energy band diagram.

(13 hours)

Unit-IV

Films and surfaces:

Preparation-TVD, CVD-laser ablation-MBE -Study of surface topography by multiple beam interferometry, conditions for accurate determination of step height and film thickness (Fizeau fringes).Electrical conductivity of thin films, difference of behavior of thin films from bulk material, Boltzmann transport equation for a thin film (for diffuse scattering), expression for electrical conductivity for thin film. Enhancement of magnetic anisotropy due to surface pinning.

(13 hours)

References

1. A.R.Verma and O.N. Srivastava: Crystallography Applied to Solid State Physics, 2nd edition, New age International publishers, 2001
2. Solid State Physics- A. J. Dekker, Macmillan India Ltd., Bangalore, 1981.
3. Solid State Physics- C. Kittel, V Ed., Wiley Eastern Ltd., 2013.
4. Elementary Solid state physics,- M.A. Omar, Addissonwesley, New Delhi,2000.
5. Solid state Physics- S.O. Pillai. New age international publication. – 2002.
6. Solid state Physics- M.A. Wahab, Narosa publishing house, New Delhi.- 1999.
7. Modern theory of Solids- Seitz.
8. Semiconductors Devices-Physics and Technology- S.M. Sze.
9. Introduction to Solids – L. Azoroff.
10. Solid State Physics- H.C. Gupta- Vikas publishing house, New Delhi.-2002.

P404-E15: Nuclear Models and Reactor Theory (4 credits, 4 lectures per week)

Unit I
Nuclear Fission

Fission cross section, spontaneous fission, mass energy distribution of fission fragments, Liquid drop model applied to fission, Bohr-Wheeler theory, saddle point, barrier penetration, comparison with experiment .
Shell correction to the liquid drop model, Strutinsky's smoothing procedure, induced fission below the fission barrier, evidence for the existence of second well in fission isomers, photo fission.

(13 hours)

Unit II

Reactor theory

Slowing down of neutrons by elastic collisions, logarithmic decrement in energy, number of collisions for thermalisation, elementary theory of diffusion of neutron flux (i) in an infinite slab with a plan source at one end (ii) in an infinite medium point source at the center, reflections of neutrons, albedo .

Slowing down density, Fermi age equation, correction for absorption, resonance escape probability, the pile equation, bukling, critical size for a spherical and rectangular piles, condition for chain reaction, the four factor formula, classification of reactors, thermal neutron and fast breeder reactors.

(13 hours)

Unit III

Independent Particle Model

Empirical evidences for magic numbers and shell structure in nuclei, energy levels according to the 3-d isotropic oscillator potential .

Effect of spin orbit interaction, prediction of ground state spin-partity of odd-A nuclei, magnetic moments of nuclei (quantum treatment), Nordheim's rules for odd-odd nuclei: strong and weak rules, Schmidt lines.

Shell model for one nucleon outside the core, configurations for excited states, model for two nucleons outside the core, Oxygen-18 spectrum (qualitative only) for two particles in d-5/2 orbit and in the s-1/2, d-3/2 orbits, configuration mixing.

(13 hours)

Unit IV

Collective Model

Inadequacies of shell model, nuclear deformation: properties of deformation parameters, spheroidal and ellipsoidal deformations .

Vibrational Model: Hamiltonian for a charged liquid drop, phonons, vibrational energy levels of even-even nuclei .

Rotational Model: Principal axes co-ordinate system, Rotational model Hamiltonian, Rotational levels in even-even nuclei, semi-empirical formula for rotational levels, Rotational spectrum of odd-A nuclei, rotational particle coupling (RPC).

Nilsson Model: Nilsson Hamiltonian, calculation of energy levels, prediction of ground state spins.

(13 hours)

References

1. Structure of the Nucleus, *M. A. Preston and R. K. Bhaduri:* Addn. Wesley, 1975.
2. Theoretical Nuclear Physics, *M. Blatt and V. F. Weisskopf:* John Wiley, 1952.
3. Nuclear Physics- Theory and Experiments, *R. R. Roy and B. P. Nigam:* John Wiley, 1967.
4. Introduction to Nuclear Reactor Theory, *J. R. Lamarsh:* Addison Wesley, 1966.
5. The Elements of Nuclear Reactor Theory, *S. Glasstone and M. C. Edlund:* Van Nortrand Co. 1953.
6. Elementary Pile Theory, *S. Glasstone and M. C. Edlund:* John Wiley, 1950.
7. Atomic and Nuclear Physics, *S. N. Ghoshal:* Vol. II., 2000.
8. Physics of Nuclei and Particles, *P. Marmier and E. Sheldon:* Vol. I and II, Academic Press, 1969.

9. Theory of Nuclear Structure, *M. K. Pal*, Affiliated East West, Madras, 1982.
10. Nuclear Structure, *A. Bohr and B. R. Mottelson:*Vol. I and II, Benjamine, Reading. 1969.
11. Nuclear Models, *J. M. Eisenberg and W. Greiner*, North Holland, 1970.
12. Theoretical Nuclear Physics, *A. de Shalit and H. Feshbach:* Vol. I, John Wiley, 1974.

Laboratory courses

A general list of experiments is given below under different topics taught in the theory paper.
Optics experiments

Part A

1. Determination of the size of the lycopodium particles by diffraction method using
    a. Spectrometer b) Young's method.
2. Diffraction of laser light by single slit and diffraction grating – (a) determination of wavelength of laser (b) Determination of distance between two slits using interference of laser light through double slit
    a. Determination of refractive index of glass and perspex using total internal reflection.
    b. Determination of refractive index of liquids using shift in the diffraction pattern.
3. Determination of wavelength of iron arc spectral lines using constant deviation
    a. spectrometer.
4. Determination of Rydberg constant
5. Hartmann's method of spectral calibration using mercury spectrum and characterization of electronic absorption band of $KMnO_4$ based on Hartmann's formula.
6. Determination of elastic constants of glass (and perspex) by Cornu's interference method.

Part B

1. Determination of wavelength of sodium light by Michelson's interferometer.
2. Determination of wavelength of sodium light using Fabry Perot etalon.
3. Verification of Malus' law
4. Study of intensity distribution of elliptically polarized light
5. Study of elliptically polarized light using Babinet compensator.
6. Determination of thickness of mica sheet using Edser Butler Fringes
7. Optical rotatory Dispersion
8. Determination of velocity of ultrasonic waves in liquids using the method of diffraction and comparison with the mechanical method.
9. Verification of Beer-Lambert law

Part C

1. Determination of difference in wavelengths of D lines of Na using Michelson's interferometer.
2. Spatial and temporal coherence of He-Ne laser.
3. Experiments with lasers and fibre optics kit.
4. Experiments with lasers and reflection grating.
5. To photograph the spectra of Fe (standard) and Cu arc using CDS spectrograph and to determine the wavelengths of Cu spectrum using Hartman formula

Mechanics experiments

1. Young's modulus of steel by flexural vibrations of a bar
2. Torsional vibrations and determination of rigidity modulus

Heat and Temperature experiments

Part A

1. Thermal Conductivity of a material of a rod by Forbe's method
2. Thermal Diffusivity of a material (Angstrom's method)
3. Verification of Stefan's Law by electrical method.
4. Relaxation (thermal) time of a serial light bulb
5. Determination of Stefan's constant
6. Variation of surface tension with temperature.
7. Thermal and electrical conductivities of copper to determine the Lorentz number; Temperature coefficient of resistance of copper

Part B

1. Calibration of silicon diode and copper constantan thermocouple as temperature sensors.
2. Thermal conductivity of a poor conductor
3. Energy band gap of silicon
4. Verification of Curie-Weiss law for a ferroelectric material – temperature dependence of a ceramic capacitor
5. Thermal expansion -- Determination of coefficients of thermal expansion of some materials (Al, Cu, Brass, NaCl, KCl)

Electronics experiments

Part A

1. Active low pass filter using op-amp
2. Active high pass filter using op-amp
3. RC phase shift oscillator
4. Astable multivibrator using 555 timer
5. Sine wave and square wave generators
6. Summing, scaling and averaging amplifier using op-amp.
7. Half adder and full adder
8. Differentiator and integrator using op-amp.
9. Twin T-notch filter using op-amp
10. Boolean expression implementation
11. Measurement of offset voltage and offset current

Part B

1. Monostable multivibrator using 74121
2. 555 timer as a monostable multivibrator
3. Butterworth low pass filter using Sallen Key circuit
4. Voltage controlled oscillator using IC741 and 555
5. Phase locked loop using 565

Part C

1. Calibration of the lock-in amplifier
2. Mutual inductance with the lock-in amplifier
3. Measurement of low resistance with the lock-in amplifier
4. Measurement of high resistance by leakage
5. First order band pass filter using Op-amp

Computational Physics: C programming
Part A: Basics of C-programming – some simple programs

1. Printing Large Block letters
2. Program to check vowel or consonant
3. Computing powers of 2
4. Program to find the largest among three numbers
5. Program to check whether a number is positive, negative or zero
6. Program to find sum of natural numbers
7. Adding two integers
8. Adding n integers
9. Adding a sequence of positive integers
10. Swapping two numbers
11. Computing the factorial of a number
12. Program to display Fibonacci series
13. Programs to find HCF and LCM of two numbers
14. Computing area of a circle
15. Fahrenheit to Celsius conversion (°F to °C)
16. Program to (i) add and (ii) multiply two matrices and (iii) find transpose of a matrix

Part B: Numerical analysis with C- programs

1. Finding roots of a function using bisection method
2. Finding roots of a function using Newton-Raphson method
3. Solving algebraic equations using Gauss elimination method
4. Fitting the data to a straight line -- Least square fit method
5. Integration using Trapezoidal rule
6. Integration using Simpson's $1/3^{rd}$ rule
7. Integration using Simpson's $1/8^{th}$ rule
8. Differentiation of a function using Euler's method
9. Differentiation using Runge-Kutta 2^{nd} order method
10. Differentiation using Runge-Kutta 4^{th} order method

Atomic and Molecular Physics experiments

1. Determination of g-factor for standard ESR sample using portable ESR spectrometer
2. Ion trap (q/m determination) quadrupole AC trap
3. CCD spectrometer to record absorption bands of Iodine molecule
4. CCD spectrometer to record band spectrum of AlO
5. Analysis of band spectrum of PN molecule
6. Analysis of Rotational Raman spectrum of a molecule
7. Twyman-Green interferometer

8. Fabry-Perot interferometer experiments
9. Zeeman effect
10. Millikan's oil drop experiment

Condensed Matter Physics experiments

1. Analysis of X-ray powder Diffractogram (NaCl, KCl, Cu)
2. Analysis of single crystal rotation photograph.
3. Calibration of electromagnet and magnetic susceptibility determination of magnetic salts ($MnSO_4$, $MnCl_2$) by Quincke's method
4. Experiments with pn-junction (a) determination of n, E_g and dV/dt of *pn* -junction material (b) determination of junction capacitance C_D
5. Determination of Curie temp for a ferromagnetic material (Ni-Fe alloy)
6. Ionic conductivity of NaCl: Study of the temperature variation of σ and estimation of activation energy
7. B-H curve of a Ferromagnetic material (both hard and soft)
8. Electrical resistivity of thin films
9. Magnetic susceptibility of Ferrous ammonium sulphate by Gouy's balance method
10. Temperature variation of dielectric constant and determination of Curie point of a Ferro electric solid PZT (Lead Zirconium Titanate)
11. Thermostimulated luminescence of F-centre in Alkali halide.

Nuclear Physics experiments

Part A: Experiments with GM Counter

1. Study of beta absorption and determination of end point energy.
2. End point energy of beta particles – Feather analysis
3. Dead time of GM counter using two source method
4. Studying beta efficiency of GM counting system
5. Statistics of counting
6. Z-dependence of beta absorption coefficient
7. Determination of half-life of Indium-116m state

Part B: Experiments using Gamma Ray Spectrometer

1. Gamma ray spectrometer (Single channel analyser)
2. Determining rest mass energy of electrons using Gamma ray spectrometer
3. Study of absorption of gamma rays
4. Gamma ray spectrum using multichannel analyser
5. Z-dependence of external Bremsstrahlung radiation

Part C: Nuclear Electronics

1. Schmitt-Trigger as a discriminator
2. Transistor delay coincidence circuit
3. Linear Pulse amplifier
4. Preamplifier circuit

Astrophysics experiments

1. Determining solar rotation period from given data of sunspot motion
2. Spectral classification of stars using CLEA data
3. Equivalent width of a spectral line
4. Moon's distance by parallax method
5. Estimation of surface temperature of a star
6. Polarization of day/Moon light
7. Estimation of mass of Jupiter from its moon's periods
8. Determination of solar constant
9. Bending of light due to Sun
10. Determination of Galactic Centre distance (in Kpc) from sun using positional data of globular clusters
11. Estimation of gravitational bending of light
12. Determination of Hubble constant H_o using CLEA program data base
13. Determination of pulsar distance using CLEA data
14. Determination of distance of Pleaedes using CLEA software

Atmospheric and Space sciences experiments

1. Measurement of temperature by wet and dry bulb thermometers and estimation of humidity of the atmosphere
2. Measurement and analysis of atmospheric pressure and isobars
3. Study and plotting of temperature, pressure and humidity contours using the given experimental data
4. Estimation of saturation vapour pressure, dew point temperature, relative humidity and mixing ratio by measuring temperature and humidity
5. Measurement and analysis of solar radiation as a function of time using sunshine recorder
6. Estimation of abundance of sodium in solar atmosphere using Fraunhofer absorption lines in solar spectrum
7. Determination of extinction coefficient of earth's atmosphere using Beer's law with the help of given data
8. Measurement and analysis of wind speed by anemometer and wind direction by wind wane
9. Measurement of absorption spectrum of the earth's atmosphere for O_2, O_3, H_2O, CO_2
10. Measurement of relative humidity of the atmosphere using whirling hygrometer and comparison with theoretical values

Semester

P106: General Physics Lab-1
A minimum of **TEN** experiments to be performed. Experiments to be chosen from
(i) Optics: Part A
(ii) Mechanics
(iii) Heat and Temperature: Part A

P107: Electronics Lab
A minimum of **TEN** experiments to be performed. Experiments to be chosen from

Electronics Part A
II Semester
P206: General Physics Lab-2
A minimum of **TEN** experiments to be performed. Experiments to be chosen from
(i) Optics: Part B
(ii) Heat and Temperature Part B

P207: Optics Lab:
A minimum of **TEN** experiments to be performed. Experiments to be chosen from
(i) Optics Part C and
(ii) from Part A, B **(other than those already done in General Lab-I and II)**

III Semester
P306: Advanced Physics Lab-1
A minimum of **TEN** experiments to be performed. Experiments to be chosen from
(a) Atomic and Molecular Physics
(b) Condensed Matter Physics
(c) Nuclear Physics
(d) Electronics Part B
(e) Astrophysics and
(f) Atmospheric and Space Sciences

IV Semester
P405: Advanced Physics Lab-2
A minimum of **TEN** experiments tm be performed. Experiments to be chosen from
(a) Atomic and Molecular Physics
(b) Condensed Matter Physics
(c) Nuclear Physics
(d) Electronics Part C
(e) Astrophysics and
(f) Atmospheric and Space Sciences
Note: Experiments done in Advanced Physics Lab-I should not be included in Advanced Physics Lab-II

P406: Computer Lab (Computer Exercises: Numerical methods using C)
ALL of the experiments from Computational Physics: C-Programming

Question paper pattern for CBCS scheme

THEORY QUESTION PAPER PATTERN

Each hard core, soft core and open elective theory paper examination is for 70 marks.

Question paper pattern for hard core 70 marks theory paper:
Each hard core theory paper syllabus is divided into 4 units. The semester ending examination will be aimed at testing the student's proficiency and understanding in every unit of the syllabus. The blue print for the question paper pattern is as follows:
Each question paper will consists of 3 sections: A B and C.
Part A:Six questions of 5 marks each out of which **four** to be answered (4 x 5 =20 marks). Short answer conceptual/reasoning questions shall be asked in this section to test conceptual understanding of the student.
Part B: **Six** questions of 10 marks each, out of which **four** to be answered (4 x 10 = 40 marks). Descriptive/derivation questions shall be asked in this section.
Part C:Three problems (or questions on conceptual extensions) of 5 marks each, out of which **two** to be answered. (2 x 5 = 10 marks)

Question paper pattern for soft core 70 marks theory paper:
Each soft core theory paper is divided into 3 units. Each question paper will consists of two sections **Part A** and **Part B.**
Part A: Consists of 9 questions (three questions being drawn from each unit). Each question carries 5 marks. The candidate is required to answer any 6 questions. (5 x 6 = 30 marks).
Short answer conceptual/reasoning questions shall be asked in this section to test conceptual understanding of the student.

Part B : Consists of 6 questions (2 questions each being drawn from each unit). Each question carries 10 marks. The candidate is required to answer any 4 questions. (10 x 4 = 40 marks). Descriptive/derivation questions shall be asked in this section.
Total: 30+40 = 70 marks

Question paper pattern for open elective 70 marks theory paper:
Open elective theory paper syllabus is divided into 2 units. Question paper consists of 2 parts: Part A and Part B.
Part A: Consists of 4 questions (2 questions being drawn from each unit). Each question carries 15 marks. The candidate is required to answer any 2 questions. (15 x 2 = 30 marks).
The 15 marks question may be broken into 2 or 3 parts. The maximum marks for each part will be 10 and minimum will be 5 marks.

Part B : Consists of 4 questions (2 questions each being drawn from each unit). Each question carries 20 marks. The candidate is required to answer any 2 questions. (20 x 2 = 40 marks). The 20 marks question may be broken into 2 or 3 parts. The maximum marks for each part will be 10 and minimum will be 5 marks.
Total : 30 + 40 = 70 marks.

INTERNAL ASSESSMENT

There is NO internal assessment for soft core and open elective papers.

Internal Assessment for each hard core theory paper is for 30 marks. One internal test shall be conducted for 25 marks in each paper. 5 marks are reserved for attendance.

Allotment of marks for attendance:

Attendance greater than 95 % - 5 marks
Attendance between 95 – 90 % - 4 marks
Attendance between 90 – 85 % - 3 marks
Attendance between 85 – 80 % - 2 marks
Attendance between 80 – 75 % - 1 marks
Attendance less than 75% - ineligible to appear for examination.

PRACTICAL EXAMINATION

Semester end practical examination for each practical course is for 100 marks. Internal assessment for each practical course is for 30 marks. Marks for internal assessment shall be awarded on the basis of the performance of the student throughout the practical course. Internal test is **NOT** mandatory for this.