Bangalore University
Department of Physics

Jnanabharathi Campus
Bengaluru – 560 056

Syllabus
for
M.Sc. in Physics

CBCS - 2018

With effect from the academic year 2018-19

Department of Physics, Bangalore University, Bengaluru - 560056					
Paper Code, Title and marks along with credits offered for MSc in Physics					
Paper Code	**Paper Title**	**Theory Marks**	**Internal Marks**	**Total Marks**	**Total Credits**
First Semester					
P101	Classical Mechanics	70	30	100	4
P102	Electronic Circuits and Devices	70	30	100	4
P103	Quantum Mechanics- I	70	30	100	4
P104	Mathematical Methods of Physics and C- programming	70	30	100	4
P105	Soft Core: Atmospheric and Astro Physics	70	30	100	2
P106a	GeneralPhysics Lab-I	35	15	50	2
P106b	General Physics Lab-II	35	15	50	2
P107a	Electronics Lab-I	35	15	50	2
P107b	Electronics Lab-II	35	15	50	2
	Total	**490**	**210**	**700**	**26**
Second Semester					
P201	Statistical Mechanics	70	30	100	4
P202	Electrodynamics	70	30	100	4
P203	Quantum Mechanics-II	70	30	100	4
P204	Mathematical Methods of Physics and Numerical Techniques	70	30	100	4
P205	Soft Core: Experimental techniques in Physics	70	30	100	2
P206a	General Physics Lab-III	35	15	50	2
P206b	General Physics Lab-IV	35	15	50	2
P207a	Computer Lab-I	35	15	50	2
P207b	Computer Lab-II	35	15	50	2
	Total	**490**	**210**	**700**	**26**
Third Semester					
P301	Atomic and Molecular Physics (General)	70	30	100	4
P302	Nuclear and Particle Physics (General)	70	30	100	4
P303	Condensed Matter Physics (General)	70	30	100	4
Elective-1 (One course to be opted from P304 group)		70	30	100	4
P304a	Atomic and Molecular Physics – I (Elective)				
P304b	Nuclear and Particle Physics (Elective)				
P304c	Condensed Matter Physics-I (Elective)				
P304d	Atmospheric and Space physics (Elective)				
P304e	Astrophysics-I (Elective)				
P304f	Physics of Nanomaterials (Elective)				
P305	Open elective: Physics for all	70	30	100	4
P306a	Advanced Physics lab-I	35	15	50	2
P306b	Advanced Physics lab-II	35	15	50	2
	Total	**420**	**180**	**600**	**24**

Fourth Semester					
P401	Computational Physics (General)	70	30	100	4
P402	Continuum mechanics and special theory of relativity (General)	70	30	100	4
Elective-2 (One course to be opted from P403 group)		70	30	100	4
P403a	Soft and Living Matter (Elective)				
P403b	Applications of Theoretical Concepts in Physics (Elective)				
P403c	Laser and Optics (Elective)				
P403d	Materials Science (Elective)				
Elective-3 (One course to be opted from P404 group)		70	30	100	4
P404a	Atomic and Molecular Spectroscopy – II (Elective)				
P404b	Reactor theory and nuclear models (Elective)				
P404c	Condensed Matter Physics-II (Elective)				
P404d	Planetary physics (Elective)				
P404e	Astrophysics-II (Elective)				
P405a	Advanced Physics lab-III	35	15	50	2
P405b	Advanced Physics lab-IV	35	15	50	2
P406	Project work* (8 hours per week)	70	30	100	4
	Total	**420**	**180**	**120**	**24**
	Grand total for all semester	**1820**	**780**	**2600**	**100**
Note: Additional experiments can be introduced with prior approval of BOS					

**Note: P406 Project work: 70 marks for report evaluation and 30 marks for presentation & viva-voce*

I Semester

P101: Classical Mechanics

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 and b) plane polar coordinates 2) Atwood's machine 3) bead sliding on a uniformly rotating wire in a force free space 4) Motion of a 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 coordinate 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, 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 coordinates 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 (anti-symmetry, 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 Goldstein, C Poole, J Safco, III Edition, Pearson Education Inc.2018.
2. Classical mechanics, KN Srinivasa Rao, University Press, 2003.
3. Classical mechanics, NC Rana and PS Joag, Tata McGraw-Hill, 1991.
4. Classical dynamics of particles and systems, JB Marian, Academic Press, 1970.
5. Introduction to classical mechanics, Takwale and Puranik, Tata McGraw-Hill, 2006.
6. Classical mechanics, LD Landau and EM Lifshitz, 4th edition, Pergamon press, 1985.
7. Classical Mechanics, BA Kagali and T Shivalingaswamy, Himalaya publications, 2018.

P102: Electronic Circuits and Devices

Unit- I

Physics of devices: Calculation of carrier concentration in intrinsic semiconductors; Calculation of carrier concentration in extrinsic semiconductors; Fermi energy level; electrical conductivity; p-n junction; abrupt junction; band structure; Calculation of junction voltage; variation of electric field across the junction; expression for width of the depletion region; expression for junction capacitance; diffusion and drift currents; equilibrium current calculation; forward and reverse bias of the diode; current relations under non equilibrium; Derivation of diode equation; V-I characteristics of diode; Junction field effect transistor; band structure; construction and working principle; current – voltage characteristics; Metal semiconductor contacts - Schottky and ohmic contacts with band structure; Depletion and Enhancement mode MOSFET: Principle and working; calculation of threshold voltage; V-I characteristics.

(13 hours)

Unit -II

Operational amplifiers: Operational amplifier as 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 – I: Simplification using Karnaugh Map technique (6 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 / asynchronous counters truth table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counter.

(13 hours)

Unit- IV

Digital circuits - II: Digital to Analog converters, ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter. Read Only Memory (ROM) and applications(Embedded microprocessor program memory, data tables, function generator) Random Access Memory (RAM), DRAM basics. Microprocessors and Microcontrollers basics – evolution of microprocessors, registers in 8085, data and address bus multiplexing in 8085, RISC and CISC instruction sets, concept of pipelining.

(13 hours)

References

1. Semiconductor Devices Physics and Technology, SM Sze, 3rd Edition, John Wiley and Sons Inc. Asia, 2006.
2. Solid State Electronic Devices, Ben G Streetman, Sanjay Bannerjee, 7th edition, Pearson, Asia, 2014.
3. The art of electronics, Paul Horowitz and Winfield Hill, Second Edition, Foundation Books, Delhi, 2008.
4. Electronic Principles, AP Malvino and J Bates, Eighth Edition, Tata McGraw Hill, Delhi, 2016.
5. Op-Amps and Linear Integrated Circuits, RA Gayakwad, 4th Edition, Eastern Economy Edition, 2004.
6. Operational Amplifiers with Linear Integrated Circuits, William Stanley, 4th Edition, CBS Publishers, 2002.
7. Linear Integrated Circuits, D Roy Choudhury and Shail Jain, 4th Edition, New Age International Ltd, 2010.
8. Digital principles and applications, DP Leach and AP Malvino, 5th Edition, Tata McGraw Hill, 2002.
9. Digital systems, Principles and applications, RJ Tocci and NS Widmer, 10th Ed, Pearson Education, 2007.
10. Introduction to electronic devices, MichealShur, PHI, 1996.

P103: Quantum Mechanics – I

Unit-I

Introductory concepts: Wave-particle duality, interpretation of the wave function, wave function for particles having a definite momentum, Schrodinger equation, Gaussian wave Packets and their time evolution, Fourier transform and momentum space wave function, Heisenberg uncertainty principle for position and momentum, conservation of probability, operators and expectation values, Ehrenfest theorem, time-independent Schrodinger equation, stationary states and their properties, energy quantization, properties of energy Eigen functions, general solution of the time dependent Schrodinger equation for a time independent potential.

(13 hours)

Unit-II

One-dimensional problems: Free-particle, box normalization, Eigen values and Eigen functions of particle in a) infinitely deep potential b) finite square well potential, and c) simple harmonic oscillator potential, potential barrier - transmission and reflection coefficients.

Extension to three dimensional problems: Separation of the Schrodinger equation in Cartesian coordinates, particle in a three dimensional box.

(13 hours)

Unit-III

General formalism of quantum theory: operator methods: Hilbert space, linear operators, observables, Dirac notation, Eigen functions of Hermitian operators, degeneracy, commutation of operators and compatibility, generalized uncertainty principle for two non-commuting observables, Unitary transformations, time-dependence of observables: Schrodinger and Heisenberg 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 for the case$j_1 = j_2$=1/2.

(13 hours)

References

1. Introduction to Quantum Mechanics, David J Griffiths, 2ndEdition, Pearson Prentice Hall, 2005.
2. Quantum Mechanics, BH Bransden and CJ Joachain, 2ndEdition, Pearson Education, 2007.
3. Quantum Mechanics, VK Thankappan, 2ndEdition, Wiley Eastern Limited, 1993.
4. Quantum Mechanics Vol I & II, C CohenTannoudji, B Diu and F Laloe, 2ndEdition, Wiley Interscience Publication, 1977.
5. Quantum Mechanics, LI Schiff, 3rdEdition, McGraw Hill Book Company, 1955.
6. Modern Quantum Mechanics, JJ Sakurai, Revised Edition, Addison-Wesley, 1995.
7. Principles of Quantum Mechanics, R Shankar, 2ndEdition, Springer, 1994.
8. Quantum Mechanics, E Merzbacher, John Wiley and Sons, 1998.
9. Quantum Physics, S Gasiorowicz, John Wiley and Sons 2014.
10. Introduction to vectors, axial vectors, tensors and spinors, GRamachandran, MS Vidya and Venkataraya, Vijayalakshmi Prakashana, Mysuru, 2017.

P104: Mathematical Methods of Physics and C programming

Unit-I

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

(13 hours)

Unit-II

Complex analysis: Functions of a complex variable, Analytic functions, Cauchy-Riemann relations – Cartesian and polar coordinates, 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.

(13 hours)

Unit-III

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)

Unit-IV

CProgramming-I: Compiler and interpreter, constants and variables, arithmetic expressions, data types, input and output statements, control statements, switch statements,loop statements, format specifications, arrays, algorithms, flowcharts, functions, simple C programs like i) area of a triangle ii) to check the entered letter is an vowel or consonant using switch iii) computing the sum and average of ten numbers using one dimensional arrays iv) to calculate Fibonacci series using while loop v) sorting numbers in ascending and descending order vi) computing the factorial of a number using for loop vii) addition of two matrices using arrays.

(13 hours)

References

1. Mathematical Methods of Physics, J Mathews and RL Walker, 2ndEdition, Addison-Wesley, 1971.
2. Mathematical Methods for Physicists, GB Arfken and H Weber, 7thEdition, Academic Press, 2012
3. Complex variables, MR Spiegel, Schaum Series, Metric edition, 1981, McGraw Hill.
4. Theory of functions - Part I, K Knopp, Dover Publications New York, 1947.
5. Vector Analysis – an introduction to tensor analysis, Murray R Spiegel, Schaum outlines Series.
6. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series, 4th Edition, 2009.
7. Matrices and Tensors in Physics - AW Joshi, Wiley Eastern Ltd, 3rd edition, 1995.
8. Vector Analysis - MR Spiegel, Schaum Series, Indian Edition, 17th reprint, 2015.
9. Mathematical Methods in the Physical Sciences, Mary L Boas, 3rdEdition, Wiley, New York, 2006.
10. Mathematical Physics with Applications, Problems and Solution, V Balakrishnan, Ane Books, 2017.
11. Programming in ANSI – C, E Balaguruswamy, 2ndEdition, Tata McGraw Hill, 1992
12. Lecture notes at http://www.cplusplus.com/doc/tutorial/
13. Computational Physics Course at http://www.phys.unsw.edu.au/~mcba/phys2020/#numint
14. Introduction to vectors, axial vectors, tensors and spinors, G Ramachandran, MS Vidya and Venkataraya, Vijayalakshmi Prakashana, Mysuru, 2017.
15. Let us C, Yashavant Kanetkar, Infinity Science Press, 2002.

P105: Atmospheric and Astro Physics (Soft core paper)

Duration: 39 hours **Credits: 2** **No. of hours per week: 3**

Unit – I

Atmospheric physics: Origin and composition of the atmosphere, distribution of atmospheric mass and gaseous constituents, temperature distribution, winds, clouds and precipitation; Atmospheric thermodynamics – gas laws, hydrostatic equation and its applications, laws of thermodynamics, latent heats and adiabatic processes,Aerosols andits properties, Atmospheric dynamics, coordinate system, forces in a rotating coordinate system, real forces, horizontal and vertical equations of motion, thermodynamic energy equation, continuity equation, primitive equations.

(13 hours)

Unit-II

Astrophysics: Concepts of astronomy, coordinate system, time system-solar and sidereal times, apparent and absolute magnitudes, trigonometric parallax, atmospheric extinction, optical telescopes – types and characteristics, modern optical telescopes, astronomical Instruments –photometer, photographic plates, spectrographs, Charge Coupled Detector, AstroSat.

(13 hours)

Unit-III

Stellar Physics: Stellar spectral features, classification of stars-Harward scheme, luminosity classes and H-R diagram, Saha ionization Equation, Wilson-Bappu effect, binary stars, variable stars-types and characteristics, Cepheids-Period-luminosity relation, mass-luminosity relation, white dwarfs-discovery and properties, Chandrashekar limit, pulsating stars, properties of neutron stars and supernova, black hole and properties.

(13 hours)

Reference

1. Atmospheric Science-An Introductory Survey, John M Wallace and Peter V Hobbs, Academic Press, 2006.
2. Basics of Atmospheric Science, Chandrasekhar A, PHI Learning Private Limited, 2010.
3. An Introduction to Dynamic Meteorology, James Holton and Gregory J Hakim, 2012.
4. Introduction to Modern Astrophysics, Ostlie and Carroll, Addison Wesley, 1997.
5. The Physical Universe – an introduction to astronomy, Frank Shu, University Science Books, 1981.
6. An introduction to Modern Cosmology, Andrew Liddle, Wiley pubs, 2015.
7. Fundamental Astronomy, Karttunen H, Kroger P, Oja H, Poutanen M,3rd edition, Springer, 1997.
8. Stellar Astrophysics, Huang RQ and Yu KN, Springer, 1996
9. Introduction to Modern Astrophysics, Bradley W Carroll and DA Ostlie, Pearson- Addison Wesley, 2007.

P106(a) and (b): General Physics Lab-I and II

List of experiments

1. Evaluation of errors, least square fit (compulsory)
2. Determination of elastic constants of glass (and Perspex) by Cornu's interference method.
3. Laser experiments: (a) Determination of distance between two slits using interference of laser light through double slit. (b) Determination of refractive index of glass and Perspex using total internal reflection. (c) Determination of refractive index of liquids using shift in the diffraction pattern.
4. Determination of the size of the lycopodium particles by diffraction method using a) Spectrometer method and b) Young's method.
5. Statistics of counting of background radiation (using GM counter)
6. Study of intensity distribution of elliptically polarized light
7. Fabry-Perot etalon spacing.
8. Diffraction of laser light by single slit and diffraction grating – determination of wavelength of laser.
9. Babinet's compensator
10. Determination of thickness of mica sheet using Edser-Butler Fringes.
11. Variation of surface tension with temperature.
12. Determining solar rotation period from given data of sunspot motion.
13. Young's modulus of steel by flexural vibrations of a bar.
14. Torsional vibrations and determination of rigidity modulus.
15. Millikan's oil drop experiment.
16. Simulations of physics concepts based on online virtual lab (using MHRD web resource).

P107(a) and (b): Electronics Lab-I and II

List of experiments

1. Determination of practical op amp parameters: Input impedance, output impedance, Bandwidth of the open loop configuration.
2. Determination of difference mode gain, common mode gain and slew rate of an op amp.
3. Inverting op amp: Study of frequency response curve (for two different gains), determination of input and output impedance.
4. Non-Inverting op amp: Study of frequency response curve (for two different gains), determination of input and output impedance.
5. Study of frequency response and phase response of a first order op-amp based low pass filter.
6. Study of frequency response and phase response of a first order op-amp based high pass filter.
7. Study of the frequency response of a Band pass and band reject filter. Determination od quality factor.
8. Op amp with more than one input – Inverting and non-inverting configurations.
9. Study of op amp based integrator and differentiator.
10. Phase shift oscillator to determine the input impedance of the circuit.
11. JFET based amplifier.
12. RS and JK flip flop.
13. Implementing a Boolean expression and its simplified form using digital gates.
14. Timer 555 experiments.

P201: Statistical Mechanics

Unit-I

Classical statistical description of system of particles: Specification of the state of a classical system, Phase space, Statistical ensemble, Basic postulates, Probability calculations, Behaviour of density of states, Statistical Equilibrium, Liouville theorem, Irreversibility and conditions of equilibrium, Reversible and irreversible processes, Thermal interaction between macroscopic systems, Microcanonical, canonical, grand canonical ensembles.

(13 hours)

Unit-II

Application of classical statistical mechanics: System in contact with a heat reservoir (Maxwell Boltzmann distribution), Simple applications of the canonical distribution – Paramagnetism, Molecule of an ideal gas in the presence of gravity, Calculation of mean values in the presence of gravity, Connection with thermodynamics, Partition function of ideal gas and their properties, Calculation of thermodynamic quantities of ideal monoatomic gas, Gibbs' paradox, Equipartition theorem.

(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 of Ideal Bose gas, 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 Onsager relations.

(13 hours)

References

1. Fundamentals of Statistical and Thermal Physics, F Reif, First Indian Edition, Levant Books, 2010.
2. Statistical Mechanics, K Huang, Wiley Eastern Limited, New Delhi, 1963.
8. Statistical Mechanics, RK Pathria and PD Beale,3rd Edition, Academic Press (Oxford), 2011.
9. Introduction to Statistical Physics, Silvio R A Salinas, Springer, 2001.
10. Fundamentals of Statistical Mechanics, BB Laud, 5th Edition, New Age International Publication, 2015.
11. An introduction to statistical thermodynamics, Terrel Hill, Courier corporation, 1986.
12. Principles of statistical Mechanics, Richard Tollman Claredon Press, 1979.
13. An introduction to Thermodynamics and Statistical Mechanics, 2dnd Edition, Cambridge Uni Press, 2013.
14. Statistical mechanics, McQuarrie, Donald A, New York: Harper & Row, 2nd edition, 2000.

P202: Electrodynamics

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.

Magnetostatics: Biot-Savart Law, Divergence and Curl of B, Ampere's law and applications of Ampere's law, Magnetic vector potential, Multipole expansion of the vector potential.

(13 hours)

Unit-II

Electrodynamics: Faraday's law, Energy in magnetic fields, Maxwell's equations, Maxwell's displacement current, Maxwell's equations and magnetic charge, Maxwell's equations inside matter, boundary conditions.

Scalar and vector potentials, Gauge transformations, Coulomb and Lorentz Gauge; Lorentz force law in potential form, Energy and momentum in electrodynamics, Poynting's theorem Maxwell's stress tensor, Conservation of momentum.

(13 hours)

Unit –III

Electromagnetic waves: Electromagnetic waves in non-conducting media: Monochromatic plane waves in vacuum, propagation through linear media, 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, TE waves in a rectangular wave guide.

(13 hours)

Unit-IV

Electromagnetic radiation: Retarded potentials, Electric dipole radiation, magnetic dipole radiation, 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.

(13 hours)

References

1. Introduction to Electrodynamics, David J Griffiths, 2ndEdition, Prentice Hall India, 1989.
2. Classical Electrodynamics, JD Jackson, 4thEdition, John Wiley & Sons, 2005.
3. Classical Electromagnetic Radiation, MA Heald and JB Marion, Saunders, 1983.
4. Electrodynamics, Gupta,Kumar, Singh, Pragathiprakashan,18th edition, 2010.

P203: Quantum Mechanics – II

Unit-I

Approximation Methods for stationary problems: Time independent perturbation theory: Time independent perturbation theory for i) non-degenerate and ii) degenerate energy levels, applications: 1) one dimensional harmonic oscillator subjected to a perturbing potential in x and x^2, 2) the fine structure of the hydrogen atom and 3) Zeeman effect.

Variational Method: Bound states (Ritz Method), Expectation value of the energy, Applications: 1) Ground state of harmonic oscillator, 2) ground state of Helium.
WKB approximation: the 'classical region', connection formulae, alpha decay and tunneling.

(13 hours)

Unit –II

Approximation Methods for time dependent problems: Time dependent perturbation theory: Approximate solution of the Schrodinger equation with time dependent Hamiltonian, constant perturbation, harmonic perturbation, transition to a continuum, transition probability and Fermi golden rule.

Quantum Collision Theory: The scattering experiment, relationship of the scattering cross section to the wave function, scattering amplitude and scattering cross-section, Integral equation of potential scattering, Born approximation, scattering by a spherically symmetric potential, cross-section for scattering in a screened coulomb potential.

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

(13hours)

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.

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

Three dimensional problems: Spin 1/2 particles in a box – The Fermi gas.

(13 hours)

Unit-IV

Relativistic quantum mechanics: Klein-Gordon equation for a free relativistic particle, Plane wave solutions, probability density and probability current density.

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.

(13 hours)

References

1. Introduction to Quantum Mechanics, David J Griffiths, 2ndEdition, Pearson Prentice Hall, 2005.
2. Quantum Mechanics, VK Thankappan, 2ndEdition, Wiley Eastern Limited, 1993.
3. Quantum Mechanics Vol I & II, C CohenTannoudji, B Diu and F Laloe, 2ndEdition, Wiley Interscience Publication, 1977.
4. Quantum Mechanics, LI Schiff, 3rdEdition, Mc Graw Hill Book Company, 1955
5. Quantum Mechanics, BH Bransden and CJ Joachain, 2ndEdition, Pearson Education, 2007.
6. Modern Quantum Mechanics, JJ Sakurai, Revised Edition, Addison-Wesley, 1995.
7. Principles of Quantum Mechanics, R Shankar, 2ndEdition, Springer, 1994.
8. Quantum Mechanics, E Merzbacher, John Wiley and Sons, 1998.
9. Quantum Physics, S Gasiorowicz, John Wiley and Sons, 2014.
10. Introduction to vectors, axial vectors, tensors and spinors, G Ramachandran, MS Vidya and Venkataraya, Vijayalakshmi Prakashana, Mysuru, 2017.

P204: Mathematical Methods of Physics and Numerical Techniques

Unit-I

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

Tensors: 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 tensors.

(13 hours)

Unit-II

Properties of Fourier series, Fourier integral, Fourier transform, inverse transform, Fourier transform of the derivative, Convolution theorem, Parseval's theorem, Laplace transform and its properties, convolution theorem, inverse Laplace transforms, solution of differential equations using Laplace transforms, Fourier and Laplace transform of Dirac Delta function.

(13 hours)

Unit-III

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)

Unit-IV

C programming-II:C program for (i) finding roots using (a) Newton-Raphson method and (b) bisection method, (ii)solving a system of linear equations (Gauss elimination method)(iii) evaluating integrals using Simpson's and trapezoidal rules, (iv) solving ordinary differential equations based on Euler and Runge-Kutta methods, Fitting data using (i) least square fitting (ii) Lagrange's interpolation

(13 hours)

References

1. Mathematical methods of physics, J Mathews and RL Walker,2ndEdition, Addison-Wesley, 2003.
2. Mathematical methods for Physicists, GB Arfken and H Weber, 7thEdition, Academic Press, 2012.
3. Introduction to vectors, axial vectors, tensors and spinors, G Ramachandran, MS Vidya and Venkataraya, Vijayalakshmi Prakashana, Mysuru, 2017.
4. Mathematical Physics with Applications, Problems and Solution, V. Balakrishnan, Ane Books, 2017.
5. Mathematical Physics, PK Chattopadhyay, Wiley Eastern Ltd.1990.
6. Mathematical Methods in the physical sciences, AW Joshi, New Age International Publishers, 2018.
7. Mathematical Methods in the Physical Sciences, Mary L Boas, Wiley, New York, 1983.
8. Programming in ANSIC, E Balaguruswamy, 2ndEdition, Tata McGraw Hill, 1992
9. Lecture notes athttp://www.cplusplus.com/doc/tutorial/
10. Computational Physics Course athttp://www.phys.unsw.edu.au/~mcba/phys2020/#numi

P205:Experimental Techniques in Physics (Soft core paper)

Duration: 39 hours **Credits: 2** **No. of hours per week: 3**

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. Cosmic microwave background radiation (CMBR) detection
4. Josephson tunnelling
5. Laser cooling of atoms
6. Bose-Einstein Condensation

(13 hours)

Reference

1. Measurement, Instrumentation and Experimental design 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.
6. Introduction to Modern Astrophysics, Bradley W Carroll and DA Ostlie, Pearson- Addison Wesley, 2007.

P206(a) and (b): General Physics Lab-III and IV

1. Evaluation of errors, least square fit (compulsory)
2. Inverse square dependence of counts (using GM counter)
3. Analysis of binary star system
4. Solar cell characteristic curve and efficiency of solar cell.
5. Thermal conductivity of a material of a rod by Forbe's method
6. Verification of Stefan's Law by electrical method.
7. Determination of Stefan's constant
8. Determination of velocity of ultrasonic waves in liquids
9. Analysis of X-ray diffraction pattern
10. Energy gap of a thermistor.
11. Thermal diffusivity of a material (Angstrom's method)
12. Thermal conductivity of a poor conductor
13. Determination of velocity of ultrasonic waves in liquids using the method of diffraction and comparison with the mechanical method.
14. Thermal and electrical conductivities of copper to determine the Lorentz number
15. Relaxation (thermal) time of a serial light bulb
16. Verification of Curie-Weiss law for a ferroelectric material – T dependence of a ceramic capacitor
17. Thermal expansion - Determination of coefficients of thermal expansion of some materials (Al, Cu, Brass, NaCl, KCl)
18. Zeeman effect
19. Simulations of physics concepts based on online virtual lab (using MHRD web resource).
20. Determination of wavelength of iron arc spectral lines using constant deviation spectrometer.
21. Hartmann's method of spectral calibration using mercury spectrum and characterization of electronic absorption band of $KMnO_4$ based on Hartmann's formula.
22. Determination of wavelength of sodium light by Michelson's interferometer.
23. Determination of wavelength of sodium light and laser light using Fabry-Perot interferometer.
24. Verification of Brewster's law
25. Verification of Fresnel's laws.
26. Verification of Malus' law.
27. Experiments with lasers and reflection grating.
28. Verification of Beer-Lambert law
29. Determination of birefringence of Mica.
30. Optical rotatory dispersion (verification of Biot's law).
31. Rydberg constant using Hydrogen emission lines.
32. Rydberg constant using Hydrogen absorption lines.
33. Analysis of vibrational spectra of PN molecule.
34. Analysis of rotational Raman spectrum.
35. Simulations of physics concepts based on online virtual lab (using MHRD web resource).

P207(a) and (b): Computer Lab – I and II

Lab-I: Examples to illustrate the fundamental concepts of C-programming (minimum of 20 programs)

Lab-II: C-programs

1. Finding roots using (a) Bisection method and (b) Newton-Raphson method
2. Solving a system of linear equations (Gauss elimination method)
3. Evaluating integrals using Trapezoidal rule and Simpson's rule
4. Solving ordinary differential equations based on Euler and Runge-Kutta methods
5. Fitting data using least square fitting

P301: Atomic and Molecular Physics (General)

Unit – I

Atomic Physics – A: Brief review of early atomic models of Bohr and Sommerfeld: One electron atom; Atomic orbitals, spectrum of Hydrogen atom: Energy levels and selection rules, Rydberg atoms, relativistic correction to the kinetic energy, spin – orbit interaction and fine structure in alkali spectra, Lamb shift. Magnetic dipole hyperfine structure, energy shift, hyperfine transition on Hydrogen, Isotope shifts.

(13 hours)

Unit - II

Atomic Physics – B: Interaction with external fields: (Quantum mechanical treatment) Zeeman effect and Anomalous Zeeman effect – magnetic interaction energy, selection rules, splitting of levels in Hydrogen atom. Linear stark effect order correction to energy and Eigen states: Paschen-Back effect, Two electron atom: ortho & para states, role of Pauli exclusion principle, level schemes of two electron atoms. Many electron atoms: LS and JJ coupling scheme, Lande interval rule.

(13 hours)

Unit – III

Molecular Physics-A: Born-Oppenheimer approximation (qualitative).Classification of molecules: Rotational spectra of diatomic molecules as a rigid rotator, centrifugal distortion and non-rigid rotator, intensity of rotational lines, Rotational spectra of symmetric rotors, Experimental technique of microwave spectroscopy. Raman scattering and polarizability, Rotational Raman spectrum of diatomic and linear polyatomic molecules. Experimental technique. Applications of Raman spectroscopy: Determination of nuclear spin.

(13 hours)

Unit -IV

Molecular Physics-B: Vibrational energy of diatomic molecule, diatomic molecules as simple harmonic oscillator, anharmonicity, effect of anharmonicity on vibrational terms, energy levels and spectrum, Morse potential energy curve, Vibrational Raman effect, Rovibronic spectrum of a diatomic molecule with example. Diatomic molecules in excited vibrational states. Mutual exclusion principle, Correlation between Raman and IR spectroscopy, Experimental technique of IR spectroscopy: IR spectrometer, Applications of IR spectroscopy: Material characterization and structural elucidation.

(13 hours)

Reference

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, JM Hollas, John Wiley, 1998.
4. Molecular Spectroscopy, Jeanne L McHale, Pearson Education, 2008.
5. Molecular Quantum Mechanics, PW Atkins and RS Friedman, 3rd Edition, Oxford Press, 2004.
6. Molecular Structure and Spectroscopy, G Aruldhas, Prentice Hall of India, New Delhi, 2001.
7. Introduction to Molecular Physics, Gordon M Barrow, International Student Edition, McGraw Hill, 1961.

P302: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 Detectors and Nuclear Electronics: Nuclear Detectors: Scintillation Detectors-NaI(Tl) detector, Scintillation spectrometer, Semiconductor detectors: Surface barrier detector, Li ion drifted detector, 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) and integral discriminators, Analog to Digital Converter (ADC), Multi Channel Analyzer (MCA) - functional block diagram, working and its use in data processing.

(13 hours)

Unit -III

Nuclear Models and Nuclear Decay

Nuclear Models: Liquid drop model - Semiempirical mass formula, stability of nuclei against beta decay, mass parabola; Fermi gas model - density of states, Fermi momentum and Fermi energy, depth of nuclear potential, evaluation of average kinetic energy per nucleon; Shell model - Evidence for magic numbers, spin-orbit interaction, Energy levels in spectroscopic notation, prediction of ground state spin & parity of nuclei, Magnetic moment (Schmidt lines).

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

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

(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, SN Ghoshal, Vol. II,2000.
2. The Atomic Nucleus, Evans RD, Tata McGraw Hill, 1955.
3. Nuclear Physics, RR Roy and BP Nigam, Wiley-Eastern Ltd, 1983.
4. Nuclear Physics- an Introduction, SBPatel,New Age international (P) Limited, 1991.
5. Radiation Detection and Measurements, GF Knoll, 3rd edition, John Wiley and Sons, 2000.
6. Nuclear Radiation Detectors, SS Kapoor and VSRamamurthy, Wiley-Eastern, New Delhi, 1986.
7. Nuclear Interaction, S de Benedetti, John Wiley, New York, 1964.
8. Nuclear Radiation Detection, WJPrice, McGraw Hill, New York, 1964.
9. Introduction to Elementary particles, D Griffiths, John Wiley, 1987.
10. Elementary Particles, JM Longo, 2nd edition, McGraw-Hill, New York, 1973.
11. Introduction to Nuclear Physics, Wong, 2nd edition, PHI, 2007.

P303: Condensed Matter Physics (General)

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 3d Bravais 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, the energy distribution of the emitted electrons, field enhanced electron emission from metals, changes of work function due to absorbed atoms, the contact potential between two metals, Hall effect.

(13 hours)

Unit-III

Semiconductors: Introduction to semiconductors, band structure of semiconductors, 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-Isotope effect-BCS theory (qualitative)-Josephson tunnelling-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 Mossotti equation relation- expressions for electronic, ionic and dipolar polarizability, Ferroelectricity and piezo 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. Crystallography Applied to Solid State Physics, ARVerma and ON Srivastava, 2^{nd} edition, New Age International Publishers, 2001.
2. Solid State Physics, AJ Dekker, Macmillan India Ltd., Bangalore, 1981.
3. Solid State Physics, C Kittel, V Ed., Wiley Eastern Ltd., 1976.
4. Elementary Solid state physics, MA Omar, Addison Wesley, New Delhi, 2000.
5. Solid state Physics, SO Pillai. New Age International Publication, 2002.
6. Solid state Physics, MA Wahab, Narosa Publishing House, New Delhi, 1999.
7. Introduction to Solid state physics, L Azoroff, Tata McGraw Hill publications, 1993.
8. Solid State Physics, HC Gupta, Vikas Publishing House, New Delhi, 2002.

P304a: Atomic and Molecular Physics – I (Elective)

Unit – I

Interaction of Matter with radiation: Interaction of electromagnetic radiation with matter, Einstein coefficients (2 level system interacting with radiation) Beer's law- attenuation and amplification of light. Width and shape of spectral lines: natural broadening-derivation of line shape, Doppler broadening-estimation of half width, Voigt profiles, transit time broadening, power broadening, pressure broadening.

(13 hours)

Unit - II

Molecular symmetry: Review of definition and properties of a Group. Molecular symmetry elements and symmetry operations: Notations, symmetry classifications of molecular point groups: C_{2v} and C_{3v} point groups. Matrix representation of symmetry operations, geometric transformations. Reducible and Irreducible representation for simple molecules such as NH_3 and H_2O. Great Orthogonality Theorem, character table for C_{2v} and C_{3v} point groups.

(13 hours)

Unit-III

Spin resonance spectroscopy-A: Basic principles of 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-IV

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 sets of nuclei, experimental technique and ESR spectrometer (Block diagram level). Basic principles of NQR, nuclear quadrupole interaction, fundamental requirements of NQR. Electron Nuclear Double Resonance (ENDOR)-General treatment of an ENDOR experiment in a system with s = ½ and I = ½. Advantages of ENDOR over ESR.

(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, JM Hollas, John Wiley, 1998.
4. Molecular Quantum Mechanics, PW Atkins and RS Friedman, 3rd Edition, Oxford Press, 2004.
5. Spectra of Atoms and Molecules, P Bernath, Oxford Press, 1999.
6. Molecular Spectroscopy, JL McHale, Pearson Education, 1999.
7. Atomic Physics, CJ Foot, Oxford University Press, 2008.
8. Introduction to Magnetic Resonance Spectroscopy: ESR, NMER, NQR, 2ndEdition, DN Sathyanarayana, IK International Publishing House Ltd, 2014.
9. Basic Principles of Spectroscopy, Raymond Chang, McGraw-Hill Kogakusha Ltd, 1971.
10. Chemical Applications of Group Theory, F Albert Cotton, 3rdEdition, John Wiley and Sons, 1990.

P304b: Nuclear and Particle Physics (Elective)

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: 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, Breit-Wigner formula for scattering and reactions, shape of cross section curve near resonance.

Electron scattering on nuclei: Rutherford scattering cross-section-Scattering from a point-like source, Mott scattering, Scattering from an extended charge distribution, the form factor, determination of nuclear size and charge distribution.

(13 hours)

Unit-III

Electromagnetic interaction of nuclei: Gamma decay of nucleus - selection rules; transverse electric and transverse magnetic multipole solutions of Maxwell field outside the source region; multipolarity and parity of the solutions; extension of the theory to discuss radiative transitions in nuclei; transition probability, electric and magnetic multipole moments; absence of $0\rightarrow 0$ radiative transitions in nuclei, Weisskopf estimates, gamma-gamma angular correlation experiments, theory of internal conversion, derivation of K-conversion coefficient, $0\rightarrow 0$transition under internal conversion.

(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, 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, GE Brown and AD Jackson, North-Holland, Amsterdam,1976.
2. Nuclear Interaction, S de Bendetti, John Wiley, New York, 1964.
3. Physics of Nuclei and Particles, P Marmier and E Sheldon, Vol. I and II, Academic Press, 1969.
4. Atomic and Nuclear Physics, SNGhoshal, Vol. II,2000.
5. The Atomic Nucleus, Evans RD, Tata McGraw Hill, 1955.
6. Nuclear Physics, RR Roy and BP Nigam, Wiley-Eastern Ltd. 1983.
7. Theoretical Nuclear Physics, Blatt and Weisskopf, Dover, 2003.
8. Theory of Nuclear Structure, MK Pal, Affiliated East West, Madras, 1982.
9. Introduction to High Energy Physics, DH Perkins, Addison Wesley, London, 4thedition, 2000.
10. Quantum Collision Theory, Jochain, North Holland, 1975.
11. Structure of the Nucleus, MA Preston and RK Bhaduri, Addn. Wesley, 1975.
12. Atomic and Nuclear Physics, SN Ghoshal, Vol. II., 2000.
13. Introduction to Elementary Particles, D Griffiths, John Wiley, 1987.
14. Quarks and Leptons, F Halzen and AD Martin, John Wiley and sons, New York, 1984.
15. Unitary Symmetry and Elementary Particles, DB Lichtenberg, 2nd edition, Academic Press, 1978.
16. Elementary Particles, JM Longo, 2ndedition, McGraw-Hill, New York, 1973.

P304c: Condensed Matter Physics-I (Elective)

Unit-I

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, 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-II

Imperfections in crystals: Classification of imperfections, crystallographic imperfections, point defects, concentrations of Schottky and Frenkel defects, line defects, edge dislocations, screw dislocation, Burgers vector, 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-III

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-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, AJDekker, MacmillanIndia Ltd, Bangalore, 1981.
2. Solid State Physics, C Kittel, V Ed, Wiley Eastern Ltd, 1976.
3. Elementary Solid state physics,MA Omar, AddisonWesley, New Delhi, 2000.
4. Solid State Physics, SO Pillai,New Age International Publication, 2002.
5. Solid State Physics, MA Wahab, Narosa Publishing House, New Delhi. 1999
6. Introduction to Solids, L Azoroff, Tata McGraw Hill publications, 1993.
7. Solid State Physics,HC Gupta,Vikas Publishing House, New Delhi. 2002

P304d: Atmospheric and Space physics (Elective)

Unit – I

Atmospheric dynamics

Basics of atmosphere: Scope of meteorology, composition of the atmosphere, temperature, pressure and density variations in atmosphere.

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, primitive equations - pressure as a vertical coordinate, hydrostatic balance, thermodynamic energy equation, solution of the primitive equations, atmospheric general circulation.

Monsoon dynamics: 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 troposphere during pre, post and mid-monsoon seasons; Intra-seasonal and Inter-annual variability of monsoon precipitation – anomalous over India and Asia, El Nino Southern Oscillation.

(13 hours)

Unit – II

Satellite meteorology

Space based atmospheric studies: Orbits and navigation, orbit perturbations, meteorological satellite orbits, satellite positioning, tracking and navigation, space-time sampling, launch vehicles and profiles.

Radiative transfer: Basic Quantities, Blackbody Radiation, Radiative transfer equation, gaseous absorption, scattering, surface reflection, solar radiation.

Satellite instrumentation: Operational polar-orbiting satellites, operational geostationary satellites, other satellite instruments viz., radiometer, altimeters, scatterometer, multi-wavelength imageries, satellite data archives.

Image processing and interpretation: Satellite imageries, thematic mapping, spectral properties, Image enhancement techniques, geolocation and calibration, atmospheric and surface phenomena, mass spectrometry.

(13 hours)

Unit- III

Space Physics: Photodissociation and ionization in the upper atmosphere, effect of terrestrial and solar radiation on earth’s upper atmosphere, photochemical processes, formation of ionospheric layers, D-, E- and F-layers of ionosphere, electron density and ion composition of ionosphere, conductivity and currents in ionosphere, measuring techniques.

Earth’s magnetic field: 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, radiation belts, space weather.

(13 hours)

Unit-IV

Instrumentation: Ground based, air borne and space borne techniques, meteorological instruments, magnetometer, Ionosonde and Langmuir probe, GPS for navigation, upper air observation-sensors for meteorological observations, ozone sonde, radiosonde and rocket sonde, satellite observation techniques, aerosol and cloud measurements, atmospheric electricity.

References

1. Atmospheric Science-An Introductory Survey, John M Wallace and Peter V Hobbs, Academic Press, 2006.
2. Basics of Atmospheric Science, Chandrasekhar A, PHI Learning Private Limited, 2010
3. The Sun and Space Weather, Arnold Hanslmeier, 2nd Edition, Springer, 2007.
4. An introduction to Atmospheric physics, David G Andrews, 2ndEdition, Cambridge Univ press, 2010.
5. Fundamentals of Atmospheric physics, Murry L Salby, Academic Press, 1996.
6. The atmosphere, Frederick K Lutgens and Edward J Tarbuck, Pearson Prentice Hall, 2007.
7. An introduction to Dynamic Meteorology, Holton JR, Academic Press NY 2006.
5. A course in Dynamic meteorology, Naval Pandarinath, BS Publications, 2006.
8. The Physics of Monsoons, RN Keshvamurthy and M Shankar Rao, Allied Publishers, 1992.
9. Ionospheres:Physics, Plasma Physics and Chemistry, RW Schunk& AF Nagy, Cambridge Uni Press, 2000
10. Basic Space Plasma Physics: W Baumjohann and RA Treumann, Imperial College Press, 1997.

P304e: Astrophysics-I (Elective)

Unit-I

Radio Astronomy: Radio Window, Early experiments of Karl Jansky, Radio astronomy fundamentals, Blackbody radiation and Planck's radiation law, Rayleigh – Jeans law, brightness temperature, Optical thickness, radio telescopes, resolution, sensitivity, noise temperature, GMRT, Interferometer, Radio sources and their spectra, Thermal and non-thermal mechanisms, 21cm line, studies of radio molecular lines.

(13 hours)

Unit-II

Solar System: General characteristics of planets, Titius-Bode rule, Asteroid belt, comets, Kuiper Belt objects, Tidal force, Roche limit, Temperatures of planets, Loss of atmospheric constituents, circulation patterns, Terrestrial planets - Mercury, Venus, Earth, Earth's atmosphere, Earth's interior, properties of moons, Radioactive dating, properties of Mars.

(13 hours)

Unit-III

Star formation and evolution: Formation of proto stars - Jeans criterion, Homologous collapse, Fragmentation of collapsing clouds, Pre-main sequence evolution - Hayashi track, Zero - Age Main Sequence, Initial mass function, Main sequence evolution -timescales, Schonberg - Chandrasekhar limit, Late stages of stellar evolution - subgiant and red giant branch, Helium core flash, Evolution of massive stars - Neutron stars, Supernova and black holes.

(13 hours)

Unit-IV

Milky Way Galaxy: Historical models, star count analysis, Morphological components - thick and thin disks, age-metallicity relation, Mass to light ratio, spiral structure, interstellar dust and gas, galactic bulge, stellar halo and globular clusters, open clusters, galactic coordinate system, Solar motion, Differential rotation and Oort's constants, flat rotation curve and dark matter, distances of clusters, Galactic center, Supermassive black hole.

(13 Hours)

Note: Students who opt for this paper willll be taken to any one of the Indian observatories for observational training as part of the curriculum.

References

1. Introduction to Modern Astrophysics, Bradley W Carroll and DA Ostlie, Pearson- Addison Wesley, 2007.
2. Tools of Radio Astronomy, TL Wilson, K Rohlf, S Huttemeister, Springer, 2009.
3. Radio Astronomy, John D, Krauss, 2ndEdition, McGraw-Hill,1966.
4. The Invisible Universe – the story of radio astronomy, GL Verschuur, 2nd Edition, Springer, 2007.
5. The Physical Universe, Frank Shu, University Science Book, 1981.
6. Structure and Evolution of Stars, M Schwarzschild, Princeton University Press, 2016.
7. High Energy Astrophysics, MS Longair, Cambridge University Press, 3rd Edition, 2011.
8. Kitchin CR: Stars, Nebulae and the Interstellar Medium, Taylor and Francis group, 1987.
9. Fundamental Astronomy, Karttunen H, Kroger P, Oja H, Poutanen M (Eds), Springer, 1997.
10. Stellar Astrophysics, Huang RQ and Yu KN, Springer, 1996.

P304f: Physics of Nanomaterials (Elective)

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

Quantum confinement in semiconductors:

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

(13 hours)

Unit -III

Preparation of Nano-materials

Bottom Up methods: 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.
Self assembled molecular materials: principles of self assembly – micellar and vesicular polymerization – self organizing inorganic nanoparticles. Langmuir Blodgett techniques.
Top Down methods: 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.

(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, Selected Area Electron Diffraction (SAED).
Scanning probe techniques: Scanning Tunneling Microscopy (STM) – surface imaging and roughness; Atomic Force Microscopy (AFM) - surface imaging and roughness; other scanning probe techniques.
Spectroscopic 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, 7thedition, 1996.
2. Nanostructured Materials-Processing, Properties and Applications, 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 Univ 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 NN Ledentsoy, John Wiley and Sons, 1999.
10. Nanostructures and Nanomaterials, Guozhong Cao, Imperial College Press, 2004.

P305: Physics for all
(Open Elective)

Unit I

Energy and Power: Explosions and energy; Energy, heat and its units; Energy table and discussions; Discussion of cost of energy; Measuring energy; Power; Different power sources; Kinetic energy.

(13 hours)

Unit II

Gravity, Force and Space: The force of Gravity; Newton's third law; Weightlessness; Low earth orbit; Geosynchronous satellites; Spy satellites; Medium Earth Orbit satellite; Circular Acceleration; momentum; Rockets; Airplanes, helicopters and fans; Hot air and helium balloons; angular momentum and torque.

(13 hours)

Unit III

Nuclei and radioactivity: Radioactivity; Elements and isotopes; Radiation and rays; Seeing radiation; The REM – The radiation poisoning; Radiation and cancer; The linear hypothesis; Different types of radiation; The half-life rule; Smoke detectors; measuring age from radioactivity; Environmental radioactivity; Glow of radioactivity; Nuclear fusion.

(13 hours)

Unit IV

Climate change: Global warming; IPCC; A brief history of climate; carbon dioxide; The greenhouse effect; Enhancing the Greenhouse effect; Hurricane and tornadoes; Antarctica; Fluctuations; Paleoclimate; Global warming vs Human caused global warming; Can we stop global warming?, Fossil Fuel Resources; Energy security; Energy efficiency and conservation; Biofuels; Nuclear, Wind and Solar power.

(13 hours)

References

This course is extracted from the book titled "Physics and Technology for Future Presidents: An Introduction to the Essential Physics Every World Leader Needs to Know" by Richard A Muller, WW Norton and Company, 2007. (Unit-1 to 4 are from chapters 1, 3, 4 and 10, respectively).

P401: Computational physics (General)

Unit I

Probability and Statistics: Random variables, basic probability laws, permutations and combinations, discrete and continuous probability distributions, mean and standard deviations, Binomial distribution, Poisson distribution, Normal distribution, statistics of counting.

Errors in computation: Types of errors: random errors, approximation errors, roundoff errors, model for roundoff error accumulation, minimizing the error.

(13 hours)

Unit II

Experimental measurements and errors: Types and sources of experimental errors, significant digits in measurements, evaluation of errors in derived quantities with more than one variable, propagation of errors, mean and standard deviation, estimation of error, reporting experimental results with error bars.

Data fitting: Lagrange interpolation and least squares fit methods, specific example of fitting experimental data on exponential decay, goodness of fit.

Error analysis: Estimation of errors in the numerical integration and differentiation in the specific example of exponential decay.

(13 hours)

Unit-III

Numerical methods: From analytical methods to numerical approach, numerical differentiation: Euler's method, Runge-Kutta second and fourth order methods, Solution of a system of linear algebraic equations using Gauss elimination method without pivoting, Numerical integration: Trapezoidal and Simpson's rules, Finding roots, bisection method, Newton-Raphson method.

(13 hours)

Unit-IV

Computational approach in physics: Application of numerical differentiation, Newton's law of cooling and Euler and Runge-Kutta methods, numerical solution of freely falling body, effect of air-resistance.

Approximating an integral: Gauss-Legendre method; computing Legendre polynomials of order n using recursion relations.

Quantum states in a square-well: finding energy eigen values based on trial and error search for roots - bisection and Newton-Raphson methods.

(13 hours)

References

1. Lecture notes on computational physics, Morten Hjorth-Jensen, Univ of Oslo, 2014.
2. Computational physics, problem solving with computers, Rubin H Landau, Manuel J Paez, and Cristian C Bordeianu, Wiley, 2007.
3. Computational physics Lecture notes by Adrain E Feiguin, Web link: https://web.northeastern.edu/afeiguin/p4840/
4. Experimental errors and uncertainty, Rochester University notes, Web link: http://www2.ece.rochester.edu/courses/ECE111/error_uncertainty.pdf
5. Introduction to experimental errors, Susan Cartwright, University of Sheffield, weblink:https://www.sheffield.ac.uk/polopoly_fs/1.14221!/file/IntroToExperimentalErrors_y2.pdf

P402: Continuum mechanics and special theory of relativity (General)

Unit I

Continuum mechanics of solid media: Review of Cartesian tensors and derivatives of tensors, Small deformations of an elastic solid; the strain tensor and the stress tensor, principal strain, Equations of equilibrium and the symmetry of the stress tensor, The generalized Hooke law for a homogeneous elastic medium; the elastic modulus tensor, Navier equations of motion for a homogeneous isotropic medium.

(13 hours)

Unit-II

Fluid mechanics: Newtonian Fluids, Viscous Compressible Flow, Equation of continuity, Flow of a viscous fluid - Navier-Stokes equation and its solution for the case of a flow through a cylindrical pipe, The Poiseuille formula, Ideal and Rotational Flows, Fundamentals of Non-Newtonian Fluids.

(13 hours)

Unit-III

Special Relativity: Minkowski space time, Real coordinates in Minkowski space time, Definition of 4-tensors. The Minkowski scalar product and the Minkowski metric G_{ij}=diag (1 - 1 - 1 - 1), Orthogonality of 4-vectors, space-like, time-like and light-like four vectors,Lorentz group, Orthochronous subgroup SO(3,1), Lorentz boost and rotations.

(13 hours)

Unit-IV

Relativistic mechanics of a point particle: Proper-time interval, components of 4-velocity, 4-acceleration and the 4-momentum vector, Covariant formulation of Newton's second law, Determination of the fourth component of the four-force, Rest energy and the relativistic kinetic energy of a particle.

Electromagnetic interactions of a relativistic charged particle: Lagrangian description of relativistic charged particle in an external electric and magnetic field and the corresponding Lorentz force equation, solutions of equations of motion for a relativistic charged particle moving in orthogonal electric & magnetic fields when (i)magnitude of electric field is larger than that of the magnetic field (ii) magnitude of electric field is equal to that of the magnetic field (iii) magnitude of electric field is smaller than that of the magnetic field.

(13 hours)

References

1. Fluid mechanics, Landau LD and Lifshitz EM, Pergamon Press, 1987.
2. Theory of elasticity, Landau LD and Lifshitz EM, Pergamon Press, 1987.
3. Relativity: the special theory, Synge JL, North-Holland, 1972.
4. The classical theory of fields, Landau LD and Lifshitz EM, Pergamon Press, Oxford, 1985.
5. The Rotation and Lorentz Groups and their Representations for Physicists, Srinivasa Rao KN, New Age International Pvt Ltd, 2016
6. Classical electrodynamics, Jackson JD, John Wiley & Sons, 1998.
7. Introduction to vectors, axial vectors, tensors and spinors, G Ramachandran, MS Vidya and Venkataraya, Vijayalakshmi Prakashana, Mysuru, 2017.

P403a: Soft and Living Matter (Elective)

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 viscoelasticbehaviour - 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, glasstransition - 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 repitation 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, stretching single macromolecules, Protein folding.

(13 hours)

Unit IV

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

Enzymes and molecular machines: Molecular devices found in cells, purely mechanical machines, molecular implementation of mechanical principles, kinetics of real enzymes and machines.

Biological membranes: Electrosmotic effects, ion pumping, mitochondria as factories, powering flagellar motors.

(13 hours)

References

1) Soft Condensed Matter, Richard AL Jones, Oxford University press, 2002.
2) Biological Physics, Energy, Information, Life, Philip Nelson, 2002.
3) Principles of Condensed Matter Physics, PM Chaikin and TC Lubensky, Cambridge University press, 1995.
4) Biophysics - An Introduction, Rodney Cotterill, John Wiley, 2003.

P403b: Applications of Theoretical Concepts in Physics (Elective)

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 included with the syllabus.

Unit-I
Mathematical Methods

Vector algebra and vector calculus: Evaluating volume, surface and line integrals of vector fields; Applying vector algebra to find the vector representing the refracted ray in optics; integral of $\oint[r\times(d\theta)]$over a contour in a plane and its connection with finding the magnetic moment of a current distribution.

Matrices, Minimal polynomial of a matrix and diagonalizability; Canonical forms (Diagonal form, Jordan form, Triangular form); nature of the eigenvalues of special kinds of matrices (real and odd dimensional, triangular, antisymmetric, normal) without solving the eigenvalue equations; matrix exponentials.

Using residue theorem and analytic extension to evaluate integrals, Using recurrence relations and orthogonality relations of special functions to evaluate some special integrals.

Fourier and Laplace transforms: Finding the Fourier transform of exp(-|x|) and its connection with the wave-function of a particle bound in delta function potential; Fourier transform of Gaussian function.

Group theory: SU(2) and SO(3) groups and their connection with rotations in three dimensional space, Importance of SU(3), SL(2,R), SL(2,C) and SO(3,1) groups in physics.

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; Lorentz invariants of electromagnetic field.

(13 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$y(x) = d\cos kx$.

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

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$V(x) = \frac{1}{2}kx^2 + \frac{\lambda}{4}x^4$.

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, Canonical transformations, Poisson brackets, Symplectic transformations.

(13 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; Tunneling 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 initially in a Gaussian wave function.

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 external electric and magnetic fields.

(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^γ= 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.

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 for 8085-registers, simple programs.

(13hours)

References

1. Mathematical Methods of Physics, J Mathews and RL Walker, 2nd Edition, Addison-Wesley, 2007.
2. Mathematical Methods for Physicists, GB Arfken and H Weber, 7th Edition, Academic Press, 2012.
3. Matrices and Tensors in Physics, MR Spiegel, Schaum Series
4. Linear Algebra, Seymour Lipschutz, Schaum Outlines Series
5. Vector Analysis, MR Spiegel, Schaum Series.
6. Complex functions, MR Spiegel, Schaum Series.
7. Mathematical Physics with Applications, Problems and Solution, V Balakrishnan, Ane Books, 2017.

8. Classical mechanics, H Goldstein, C Poole, J Safco, 3rd edition, Pearson Education Inc. 2002.
9. Introduction to Quantum Mechanics, David J Griffiths, 2ndEdition, Pearson Prentice Hall, 2005.
10. Quantum Mechanics Vol I & II, C CohenTannoudji, B Diu and F Laloe, 2ndEdition, Wiley Interscience Publication, 1977.
11. Modern Quantum Mechanics, JJ Sakurai, Revised Edition, Addison-Wesley, 1995.
12. Principles of Quantum Mechanics, R Shankar, 2ndEdition, Springer, 1994.
13. Quantum Mechanics, EMerzbacher, John Wiley and Sons, 1998.
14. Quantum Physics, S Gasiorowicz, John Wiley and Sons, 2014.
15. The Mathematics of Classical and Quantum Physics, FW Byron Jr. and RW Fuller, Dover Books on Physics, 1992.
16. Fundamentals of Statistical and Thermal Physics, F Reif, McGraw Hill, Singapore 1985.
17. Introduction to Statistical Physics, Silvio RA Salinas, Springer, 2001
18. Introduction to Electrodynamics, David J Griffiths, 2ndEdition, Prentice Hall India, 1989.
19. Electronic Principles, AP Malvino, 6thEdition,Tata McGraw Hill, New Delhi, 1999
20. Operational Amplifiers with Linear Integrated Circuits, William Stanley, CBS Publishers, 1988.
21. Op-Amps and Linear Integrated Circuits, RA Gayakwad, 3rdEdition, Eastern Economy Edition, 2004.
22. Digital principles and applications, Donald P Leach and AP Malvino, 5thEdition,Tata McGraw Hill, 2002.
23. Princeton problems in Physics with solutions, Nathan Newbury, M Newmen.
24. Schaum's 3000 solved problems in Physics, Alvin Halpern.
25. Problems and solutions series, Yung-Kuo Lim (series), World Scientific, 1990.
26. Physics by example, WG Rees, Reprinted in 1996, Cambridge University Press.
27. 10 free physics solving books, e-material, 2014.

Sample Exercises

1) Find the equation of the path joining the origin to the point P(1, 1) in the XY plane that makes the integral $\int_0^P (y'^2 + yy' + y^2)\, dx$ 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)

P403c: Laser and Optics (Elective)

Unit-I

Lasers: Review of fundamentals of laser action in a medium, Einstein coefficients, population inversion and stimulated light amplification, pumping techniques and types. Characteristics of laser beams – Gaussian beam and its properties. Expression for cavity modes. Threshold conditions for laser action. Laser rate equations for 2, 3 and 4 level laser systems. Mode selection, mode locking and Q-switching in lasers. Some laser systems: Nd:YAG, Dye laser, Semiconductor laser.

(13 hours)

Unit-II

Propagation of light in optical media: Dispersion in dilute and dense gases, Group velocity and signal velocities. Anisotropic media: Fresnels' equation, uniaxial and biaxial crystals, double refraction, polarizing prisms. Jone vectors and Jone matrices, linear, circular, elliptic states of polarization, Malus' law and linear optical devices, phase retarders, quarter and half wave plates.

(13 hours)

Unit-III

Interference and Diffraction: Two beam interference, Michelson interferometer. Multi-beam interference: Fabry-Perot interferometer, distribution of intensity in Fabry-Perot fringes.

Diffraction: Classification of diffraction, The Fresnel diffraction at straight edge and circular aperture, Fraunhofer diffraction at a single slit and circular aperture.

(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-focusing of light, parametric generation of light.

(13 hours)

References

1. Optical Electronics, AK Ghatak and K Thyagarajan, Cambridge University Press, 2004
2. Lasers – theory and applications, K Thyagarajan and AK Ghatak, McMilan India Ltd, 1995.
3. Optics – Principles and Applications, KK Sharma, Academic Press, 2004.
4. Optics, E Hecht, 4th Edition, Addison-Wesley, NY, 2001.
5. Introduction to Modern Optics, GR Eowles, 2nd Edition, Dover, 1975.
6. Principles of Optics,Max Born and E Wolf, 2013.
7. Schaum's Outline of Theory and Problems of Optics, E. Hecht, McGraw-Hill.
8. Laser Fundamentals, Silfvast Cambridge Press, 1998.
9. Lasers and Nonlinear Optics, BB Laud, 2/c, New Age International (P) Publishers, 2002.

P403d: Materials Science (Elective)

Unit-I

Formation and structure of materials: Introduction to Materials Science; classification of engineering materials; structure - property relationship in materials; Chemical bonding-Bond energy, Bond type and Bond length. Ionic bonding; Covalent bonding; Metallic bonding; secondary bonding.

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 imperfections, Schottky and Frenkel defects-Equilibrium concentrations; edge and screw dislocations; surface imperfections.

(13 hours)

Unit -II

Elastic and plastic behavior of materials: Atomic model of elastic behavior-rubber like Elasticity; anelastic behavior; viscoelastic behavior; spring-dashpot model; Maxwell element; Voigt-Kelvin element; fracture of materials-Ductile and brittle fracture; Griffith energy balance criteria; Ductile brittle transition; protection against fracture

Plastic deformation by slip; shear strength of perfect and real crystals; Critical resolved shear stress (CRSS) ratio; maximum stress to move dislocation - Peierls and Nabarro model; Frank-Read source; Methods of strengthening crystalline materials against plastic deformation; strain hardening; grain refinement; solid solution strengthening; precipitation strengthening.

(13 hours)

Unit- III

Composite materials: Introduction and importance of composite materials; Classification of composite materials based on matrix phase and reinforcements; popular matrix materials-polymers, metals and ceramics; popular reinforcing materials-fibers, particles; particle reinforced composites, concrete (Portland and reinforced) structure, composition, properties and applications; polymer-concrete composites- fabrication, structure, applications; polymer matrix composites; metal matrix composites; ceramic matrix composites; carbon-carbon composites; rule of mixtures; fiber reinforced composites-influence of fiber length, orientation and concentration.

(13 hours)

Unit -IV

Elements of polymer science: Definition-Monomers, Polymers; classification of polymers with examples; synthesis of polymers-chain polymerization, step polymerization; Industrial polymerization methods -bulk, solution and suspension polymerization; degree of polymerization; Average molecular weight- weight and number averaged; Microstructure of polymers- chemical, geometric, random, alternating and block polymers; polymer crystallinity; Phase transition-Polymer melting and glass transition; stereo isomerism; Process of plastic materials: Compression moulding, Injection moulding, Blow moulding; extrusion; spinning.

(13 hours)

References

1. Elements of Materials Science and Engineering, Lawrence H Van Vleck, Addison Wesley, 1975.
2. Callister's Materials Science and Engineering, WD Callister, DG Rethwisch, Adopted by R Balasubramaniam, Wiley, 2014.
3. Introduction to Ceramics, WD Kingery, HK Bowen and DR Uhlmann, John Wiley, (1960)
4. Foundations of Materials Science and Engineering, WilliamF Smith, McGraw Hills International Edition, 1986.
5. Materials Science and Engineering, V Raghavan, Prentice Hall, 1993.
6. Structure & Properties of materials, vol I-IV, Rose, Shepard and Wulff, 1987.
7. Polymer Science,VR Gowariker, NV Vishwanathan, JoydevShreedhar, Wiley Eastern, 1987.
8. Text of Polymer Science, Fred W Billmeyer, John Wiley and Sons, Inc. 1984.

P404a: Atomic and Molecular Spectroscopy – II (Elective)

Unit-I

Absorption spectroscopy: Basic principles, Beer - Lambert law, Molar extinction coefficient, Intensity of electronic transitions. Types of electronic transitions. Franck - Condon principle, Ground and excited electronic states of diatomic molecules. Electronic spectra of polyatomic molecules, Electronic spectra of conjugated molecules - dissociation and pre-dissociation spectra, UV-Visible spectrophotometer - Principles and Instrumentation, Applications.

(13 hours)

Unit-II

Fluorescence spectroscopy: Jablonski diagram; characteristics of fluorescence emission - Stokes shift, mirror image rule; solvent and environmental effects on fluorescence; lifetimes and quantum yields; Fluorescence quenching: mechanism and dynamics; Fluorescence anisotropy; Spectrofluorimeter - Principles and Instrumentation, Applications.

(13 hours)

Unit-III

Laser Raman spectroscopy: Review of Raman scattering and Raman spectrum of diatomic and linear polyatomic molecules, molecular polarizability, Polarization of Raman lines, Depolarization ratio and its determination, Resonance Raman scattering. Application of Raman spectroscopy to study phase transitions and proton conduction in solids. Non- linear effects of Raman scattering: General principles. Hyper Raman effect, Inverse Raman effect, stimulated Raman scattering, Principle and experimental technique.

(13 hours)

Unit-IV

Mossbauer spectroscopy: Mossbauer effect, recoilless absorption and emission of gamma rays, basic principles of gamma ray fluorescence spectroscopy, hyperfine interaction, chemical isomer shift, magnetic hyperfine and quadruple interaction and interpretation of spectra. Mossbauer isotopes, applications to study magnetic materials.

(13 hours)

References

1. Fundamental of Photochemistry, KK Rohatgi-Mukherjee, New Age International Ltd, New Delhi, 1986.
2. Principles of Fluorescence Spectroscopy, 3rd Ed, JR Lakowicz, Springer, New York, 2006.
3. Fundamentals of Molecular Spectroscopy, Banwell and McCash, Tata McGraw Hill, 1998.
4. Modern Spectroscopy, JM Hollas, John Wiley, 1998.
5. Molecular Quantum Mechanics, PW Atkins and RS Friedman, 3rd Edition, Oxford Press, 2004.
6. Spectra of Atoms and Molecules, P Bernath, Oxford Press, 1999.
7. Molecular Spectroscopy, JL McHale, Pearson Education, 1999.
8. Mossbauer effect, Principles and application, GK Wathaim, Academic Press, New York, 1964.
9. Mossbauer effect and its applications, VG Bhide, Tata McGraw Hill publications, 1973.

P404b: Reactor theory and nuclear models (Elective)

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 thermalization, 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, buckling, 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-parity 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, MA Preston and RK Bhaduri, Addn. Wesley, 1975.
2. Theoretical Nuclear Physics, M Blatt and VF Weisskopf, John Wiley, 1952.
3. Nuclear Physics- Theory and Experiments, RR Roy and BP Nigam, John Wiley, 1967.
4. Introduction to Nuclear Reactor Theory, JR Lamarsh, Addison Wesley, 1966.
5. The Elements of Nuclear Reactor Theory, S Glasstone and MC Edlund, Van NortrandCo. 1953.
6. Elementary Pile Theory, S Glasstone and MC Edlund, John Wiley, 1950.
7. Atomic and Nuclear Physics, SN 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, MK Pal, Affiliated East West, Madras, 1982.
10. Nuclear Structure, A Bohr and BR Mottelson, vol. I and II, Benjamine, Reading. 1969.
11. Nuclear Models, JM Eisenberg and W Greiner, North Holland, 1970.
12. Theoretical Nuclear Physics, A de Shalit and H Feshbach, Vol. I, John Wiley, 1974.
13. Introductory nuclear physics, YR Waghmare, Oxford, 1981.

P404c: Condensed Matter Physics-II (Elective)

Unit-I

Crystal Physics: Introduction, symmetry elements of crystals, concept of point groups, derivation of equivalent point position, experimental determination of space groups, expression for structure factor, analytical indexing, Weissenberg 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: 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.

Nearly free electron approximation, Tight binding method of energy bands-applications to cubic system, orthogonalized plane wave method, Wigner-Seitz method, pseudo, potential method. Fermi surface studies and Brillouin zones characteristics of Fermi surfaces.

(13 hours)

Unit-III

Ferroelectrics: General properties of ferroelectric materials, Classification and properties of representative ferroelectrics, The dipole theory of ferroelectricity, objections against the dipole theory, ionic displacements and behaviour of $BaTiO_3$ above the Currie temperature, The theory of spontaneous polarization of $BaTiO_3$, Thermodynamics of ferroelectric transitions, ferroelectric domains.

(13 hours)

Unit-IV

Films and surfaces: Preparation - Thermal Vapour Deposition, Chemical Vapour Deposition, laser ablation, Molecular Beam Epitaxy, 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 behaviour of thin films from bulk material, expression for electrical conductivity for thin film.

(13 hours)

References

1. Crystallography Applied to Solid State Physics, AR Verma and ON Srivastava 2nd edition, New age International publishers, 2001.
2. Solid State Physics, AJDekker, MacmillanIndia Ltd, Bangalore, 1981.
3. Solid State Physics, C Kittel, V Ed, Wiley Eastern Ltd, 2013.
4. Elementary Solid state physics, MA Omar, Adison Wesley, New Delhi,2000.
5. Solid state Physics, SO Pillai. New age international publication, 2002.
6. Solid state Physics, MA Wahab, Narosa publishing house, New Delhi., 1999.
7. Introduction to Solid state physics, L Azoroff, Tata McGraw Hill publications,1993.
8. Solid State Physics, H.C. Gupta, Vikas publishing house, New Delhi,2002.

P404d: Planetary physics (Elective)

Unit – I

Orbital motion: Gravitation and central-force motion, central forces, two-body problem, solution for the two-body problem, effective potential energy-radial motions, Bertrand's theorem, shape of central-force orbits, central spring-force orbits, shape of gravitational orbits, orbital geometry.

Orbital dynamics: Kepler's law, Newton's law of motion, Universal law of gravitation, elliptical motion, orbital elements, the orbit in space, elliptical, parabolic and hyperbolic orbits, Halley's comet, minimum-energy transfer orbits, Hohmann transfer orbit, application HTO – trip to Mars, relativistic gravitation.

(13 hours)

Unit – II

Planets of the solar system : The sun and planets of the solar system, Titius – Bode rule, orbital velocities, surface temperature and bulk densities; Orbital velocity of Ceres, radius and volume of the rocky core of Pluto.

Planetary evolution – origin, growth from planetesimals, internal differentiation, atmosphere, internal structure of the earth, interior of the earth – temperature, melting of Peridotite, mantle plumes, plate tectonics, magnetic field, interactions with solar wind; meteorites and impact craters, classification and mineralogy of meteorites, carbonaceous Chondrites, Tektites.

(13 hours)

Unit – III

Terrestrial planets: Mercury and Venus – general properties and characteristics.

Earth-moon system: land forms of the lunar surface – highlands, Maria, impact craters, regolith, water on moon,Lunar missions of ISRO,isotopic dating, geology, lunar meteorites, internal structure, origin of the moon,spin-orbit coupling of moon, lunar orbit, ocean tides, expression for tidal force.

Mars: origin, physical and chemical properties of mars, evolution of the Martian atmosphere, orbit of mars, surface features – Tharsis plateau, Olympus mons, young lava flows, Valles marineris, Utopia Planitia,volcanoes on the southern hemisphere, stream valleys, Martian meteorites, water on Mars – hydrological cycle, phase diagram of water and carbon dioxide, polar ice caps, satellites of mars; possible microbial life on mars, features of extra terrestrial planets.

(13 hours)

Unit-IV

Planetary exploration: Inventory of solar system - giant, terrestrial, minor planets, comets, satellite and ring systems, heliosphere, planetary properties, planning missions – Viking 1, Viking 2 and other missions.

Planetary atmosphere: Thermal structure – sources and transport of energy, thermal profiles, atmospheric composition, clouds, meteorology – Coriolis effect, winds forced by solar heating, atmospheric escape – Jeans, non-thermal, hydrodynamic escapes, impact erosion.

Planetary surfaces and interiors, mineralogy and petrology, planetary interiors, surface morphology, impact cratering, giant planets - atmosphere, interior structure, magnetic fields, Observations of exo-planets.

(13 hours)

References

1. Orbital Motion, AE Roy, 4th Edition, CRC Press, 2004.
2. Fundamental Planetary science, Jack J Lissauer, Imke de Pater, Cambridge University Press, 2013.
3. Introduction to planetary science, Gunter Faure and Teresa M Mensing, Springer, 2007.
4. Introduction to earth and planetary system science, NaotatsuShikazono, Springer, 2012.
5. Lunar and Planetary Rovers, AH Young, Springer, 2007.
6. Mars – an introduction to its interiors, surface and atmosphere, Nadine Barlow, Cambridge Uni Press, 2008.
7. Solar Planetary systems, AB Bhattacharya, JM Lichtman, Taylor and Francis group, 2017.

P404e: Astrophysics-II (Elective)

Unit-I

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

(13 hours)

Unit-II

Nature of Galaxies: Messier Catalog, Shapley–Curtis debate, Hubble's classification scheme, Characteristic properties of galaxies, Surface brightness of galaxies, Tully-Fisher relation, Mass to light ratios and colours, Supermassive black holes, spiral structure - density wave theory, Elliptical galaxies- types and characteristics, Faber-Jackson relation, Interactions of galaxies, Formation of galaxies.

(13 hours)

Unit-III

Active galaxies: Active galaxies, characteristic properties, Observational classification-Seyfert galaxies, LINERS, BL-Lacertae, Radio galaxies - Jets and lobes, Star Burst galaxies, Quasars, Spectroscopic study of active galaxies, Photoionization models, variability of active galaxies, Continuum radiation emission processes, Black hole paradigm, Masses of active galaxies, super massive black hole, Eddington limit, AGN paradigm, Unification models.

(13 hours)

Unit-IV

Large Scale Structure of Universe and Cosmology: Extragalactic distance scale, Cepheid distance scale, supernova as distance indicators, Hubble's law of expansion, Hubble's constant, D-σ relation, Other distance indicators, Expansion of the Universe - Hubble's law, Big bang and age of the Universe, Olbers's Paradox, Newtonian Cosmology- Pressurelessdust model, evolution, Critical density, Look back time, Simple model of the Universe with pressure, Deceleration Parameter, Cosmic Microwave Background radiation prediction and its detection.

(13 Hours)

Note: Students who opt for this paper will be taken to any one of the Indian observatories for observational training as part of the curriculum.

References

1. X-Ray Astronomy, R Giacconi, H Gursky, Singer, 1974.
2. Handbook of X-ray Astronomy,Arnaud K, Randall Smith, Aneta S, Cambridge University Press, 2011
3. Gamma-ray Astronomy,PV Ramana Murthy, AW Wolfendale, 2nd Edition, Cambridge UnivPress, 1993.
4. Very High Energy Gamma-Ray Astronomy, TC Weekes, CRC Press, 2003.
5. Handbook of Infrared Astronomy,IS Glass, Cambridge University Press, 1999.
6. Introduction to Modern Astrophysics, Bradley W Carroll and Dale A Ostlie, Pearson-Addison Wesley (II Edition), 2007.
7. The Physical Universe, Frank Shu, University Science Book, 1981.
8. High Energy Astrophysics, MS Longair, Cambridge University, Press, 1992
9. Stars, Nebulae and the Interstellar Medium, Kitchin CR, Taylor and Francis Group, 1987.
10. Fundamental Astronomy, Karttunen H, Kroger P, Oja H, Poutanen M (Eds) Springer, 3rd edition, 1997.
11. An Introduction to Active Galactic Nuclei, Peterson, 1997.
12. Active Galactic Nuclei, Ian Robso, John Wiley & Sons, 1996.
13. Quasars and Active Galactic Nuclei- An Introduction, Ajit K Kembhavi and Jayant Narlikar, Cambridge University Press, 1999.

P306(a) and (b): Advanced Physics Lab – I and II
P405(a) and (b): Advanced Physics Lab – III and IV

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 experiment
10. Numerical aperture and bending loss of optical fiber.
11. Wavelength of laser by diffraction method (Transmission grating).
12. Wavelength of laser by diffraction method (Reflection grating).
13. Wavelength of laser by interference method.
14. Determination of spin coupling constant from NMR spectrum of a molecule
15. Determination of hyper fine coupling constant from ESR spectrum of a molecule
16. Michelson Interferometer:
17. Experiment with CCD: Analysis of the spectrum of aluminium oxide (AlO)
18. Analysis of Mossbauer spectrum
19. Visual mapping of some important sources: Hg, Na, Fe, Cu arc, Brass arc and laser
20. Refractive index of liquid using Hallow prism
21. Experiment and analysis the spectrum of iron and Brass arc using Photograph method
22. Spatial and temporal coherence of He-Ne laser.
23. Experiments with lasers and fibre optics kit.
24. Experiments with lasers and reflection grating.
25. To photograph the spectra of Fe (standard) and Cu arc using CDS spectrograph and to determine the wavelengths of Cu spectrum using Hartman formula
26. Verification of Beer-Lambert law
27. Iodine absorption spectra using CDS

Nuclear and Particle Physics experiments

Experiments using alpha ray spectrometer

1. Energy loss of alpha particles.
2. Scattering of alpha particles.

Experiments using GM counting system

3. Randomocity of nuclear counts (using a weak source).
4. Dead time of GM counting system using two source method.
5. Study of beta absorption and determination of end point energy.
6. End point energy of beta particles by half thickness measurement
7. End point energy of beta particles by nomogram method
8. Feather analysis – End point energy of beta particles
9. End point energy of beta particles using Fermi Kurie plot
10. Studying beta efficiency of GM counting system.
11. Z-dependence of beta absorption coefficient.
12. Determination of half-life of Indium-116m state.

Experiments using Gamma Ray Spectrometer

13. Study of gamma ray spectrum using Single Channel Analyser (SCA)
14. Determining the rest mass energy of electrons using Gamma ray spectrometer
15. Study of absorption of gamma rays
16. Gamma ray spectrum using Multi Channel Analyser (MCA)
17. Z-dependence of external Bremsstrahlung radiation using SCA.
18. Determination of half-life of Indium-116m state.
19. Internal conversion using MCA
20. Resolving time of a coincidence module

Nuclear Electronics Experiments

21. Two stage amplifier.
22. Transistor coincidence circuit
23. SchmittTrigger as a discriminator
24. Preamplifier circuit
25. Linear Pulse amplifier

Numerical analysis of experimental data

26. Numerical fitting of binding energy curve using semi-empirical mass formula and identifying stable isobar for a given mass number.
27. Evaluation of masses of baryons and mesons using Gell-Mann & Okubo mass formula
28. Multipole analysis of gamma using data.
29. Study of range-energy relations using experimental data.

Condensed Matter Physics experiments

1. Analysis of X-ray powder photographs (NaCl, KCl, Cu)
2. Analysis of single crystal rotation photograph(NaCl)
3. Analysis of a backscattering of powder photograph of copper
4. Estimation of R-factor using X-ray diffractogram.
5. Calibration of electromagnet and magnetic susceptibility determination of magnetic salts ($MnSO_4$, $MnCl_2$) by Quincke's method
6. Experiments with pn-junction (a) determination of n, E_g and dV/dt of *pn* -junction material (b) determination of junction capacitance C_D
7. Determination of Curie temp for a ferromagnetic material (Ni-Fe alloy)
8. Study of the temperature variation of conductivity (σ) and estimation of activation energy of ionic solid.
9. Study of B-H curve of a Ferromagnetic material (both hard and soft).
10. Electrical resistivity of semiconducting Ge sample using four probe method.
11. Magnetic susceptibility of Ferrous ammonium sulphate by Gouy's balance method
12. Temperature variation of dielectric constant and determination of Curie point of a Ferro electric solid PZT (Lead Zirconium Titanate)
13. Thermo-stimulated luminescence of F-centre in Alkali halide.
14. Hall effect experiment in semiconductors.
15. Determination of Fermi energy of copper.
16. Determination of Plank's constant using LED's
17. Determination of energy gap of a semiconductor using diode.
18. Determination of Solar cell characteristics
19. Energy band gap of a thermistor
20. Determination of lattice parameter using Bernal Chart

Astrophysics Experiments

1. Characteristics of Telescopes
2. Atmospheric Extinction Coefficient using CLEA software and photometric data
3. Spectral Classification of Stars using CLEA software
4. Distance of Pleaedes Cluster by Main Sequence Fitting and using CLEA software
5. Estimation of Surface Temperature of Stars
6. Mass of Globular Cluster
7. Proper Motion of Stars
8. Distance of Cepheid Variable
9. Solar Rotation period using Sun's images from CLEA Software.
10. Efficiency of Solar cell
11. Determination of Sun's temperature and Luminosity using Sun's flux data
12. Mass of globular cluster NGC 362
13. Determination of the declination of the Sun using Equatorial Sun-dial model
14. Estimation of the Hubble's constant using CLEA
15. Large scale structure of the Universe
16. Estimation of the Solar constant using Suryamapi

17. Estimation of the distance galactic center using given data
18. Spectral study of Seyfert-1 galaxies using IUE data
19. Estimation of the distance of Hyades cluster using given data (Convergent point method)
20. Distances of Pulsars using CLEA software
21. Gravitational Bending of star light using vector-representation data

Atmospheric and Space Science Experiments

1. Estimation of Relative Humidity of the Atmosphere
2. Simulation of altitude from pressure and also writing code in c-program
3. Estimation of atmospheric pressure using height, temperature and humidity from GPS-RS data
4. Computation of potential temperature for various heights with GPS-RS data
5. Estimation of horizontal wind speed and direction from radiosonde observations
6. Study of the variations of temperature, pressure and humidity and plotting their contours by making use of given experimental data
7. Estimation of dew point temperature
8. Measurement and analysis of wind speed by anemometer and wind direction by wind wane
9. Zeroth order Climate Model
10. Study of atmospheric parameters and their variations
11. Analysis of incoming solar radiation and outgoing long wave radiation
12. Determination of extinction coefficient of earth's atmosphere using Beer's law using satellite data
13. Determination of extinction coefficient of earth's atmosphere using Beer's law from multi wavelength radiometer using observed values of aerosol optical depth
14. Analysis of Satellite cloud imageries- OLR and cyclone genesis and movement
15. Measurement of magnetic field of earth using magnetometers
16. Total Electron Content measurement using GPS receiver
17. Study of atmospheric features from satellite images and obtaining derived parameters
18. Ionograms for reducing real-height profiles of ionospheric layers and electron densities
19. Study of the variation of sunspot numbers and its cycle
20. Analysis of the trend of solar cycle and activity of Sun
21. Study of orbital motion of inner and outer planets
22. Estimation of orbital parameters of inner planets
23. Write a c-program for the estimation of orbital parameters of planets
24. Architecture of Hohmann orbit for planetary probes
25. Verification of Kepler's law for planetary system
26. Write a c-program for estimating the periodicity of outer planets
27. Computation of orbital parameters of planetary satellites
28. Computation of velocities of multi-stage rockets
29. Verification of Titius Bode rule
30. Study of temperature, densities and atmosphere of inner planets
31. Study of temperature, densities and atmosphere of outer planets
32. Estimation of solar radiation flux incident on different planets
33. Write a c-program for the estimation of solar radiation flux incident on different planets
34. Sketch diagrams to depict solar/lunar total and partial eclipses
35. Tracing of trajectory of Haley's comet and estimation of its periodicity
36. Statistical variability of meteoric showers
37. Estimation of energy of impact craters
38. Estimation of lunar tidal forces
39. Comparison of internal magnetic field of different planets
40. Write a c-program for the estimation of orbital parameters of planets

Question paper pattern

THEORY QUESTION PAPERPATTERN

- Each hard core theory paper (4 credit course) examination is for 70 marks.
- Each soft core (2 credit course) theory paper examination is for 70 marks.
- Open elective (4 credit course) theory paper examination is for 70 marks.

Question paper pattern for hard core (70 marks)

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 consist 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:Four** 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)

Each soft core theory paper syllabus is divided into 3 units.

- Each question paper will consist of 2 sections: A & B.
- **Part A**: **Nine** questions of 5 marks each, out of which **six** to be answered(6 x 5 = 30 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.

Question paper pattern for open elective (70 marks)

Each question paper will consist of 3 sections: A, B and C.

- **Part A:Ten** questions of 2 marks each. All questions are compulsory (2 x 10 =20 marks).
- **Part B**: **Six** questions of 5 marks each, out of which **four** to be answered (4 x 5 = 20 marks).
- **Part C: Five** questions of 10 marks each, out of which **three** to be answered (3 x 10 = 30 marks)

INTERNAL ASSESSMENT

- Internal Assessment for each theory / practical paper is 30 marks.
- Internal tests shall be conducted for 30 marks in each paper.

  - 5 marks is reserved for attendance.
    Allotment of marks for attendance:
    Attendance greater than95% - 5 marks
    Attendance between 95 – 91% - 4 marks
    Attendance between 90 – 86 % - 3 marks
    Attendance between 85 – 81 % - 2 marks
    Attendance between 80 – 76 % - 1 marks

Attendance less than 75% - ineligible to appear for examination.

PRACTICAL EXAMINATION

Semester end practical examination for each practical course is for 70 marks. Internal assessment for each practical course is for 30 marks based on conduct of internal tests.