University of Mysore

Department of Studies in Physics

Manasagangotri, MYSORE 570 006

Course Structure and Syllabus

for

B.Sc.(Hon.) and M.Sc. Physics

under

Choice Based Credit Scheme (CBCS)

2010

List of papers offered for B.Sc. (Hon.) and M.Sc. Physics under CBCS

Semester 1

PHY101 : Classical Mechanics
PHY102 : Mathematical Methods of Physics 1
PHY103 : Mathematical Methods of Physics 2
PHY104 : Classical Electrodynamics, Plasma Physics and Optics
PHY105 : Computer Lab CL-A
PHY106 : Optics Lab
PHY107 : Electronics Lab

Semester 2

PHY201 : Continuum Mechanics and Relativity
PHY202 : Thermal Physics
PHY203 : Quantum Mechanics 1
PHY204 : Spectroscopy and Fourier Optics
PHY205 : Computer Lab CL-B
PHY206 : Optics Lab
PHY207 : Electronics Lab
PHY208 : Electronics
PHY209 : Python Programming
PHY210 : Minor Project
PHY211 : Modern Physics
PHY212 : Energy Science

Semester 3

PHY301 : Quantum Mechanics 2
PHY302 : Condensed Matter Physics
PHY303 : Nuclear Physics and Particle Physics
PHY304 : Condensed Matter Physics 1
PHY305 : Nuclear Physics 1
PHY306 : Theoretical Physics 1
PHY307 : Accelerator Physics
PHY308 : Liquid Crystals
PHY309 : Atmospheric Physics
PHY313 : Condensed Matter Physics Lab
PHY314 : Nuclear Physics Lab
PHY315 : Condensed Matter Physics Lab 1
PHY316 : Nuclear Physics Lab 1
PHY317 : Theoretical Physics Lab 1

Semester 4

PHY401 : Condensed Matter Physics 2
PHY402 : Nuclear Physics 2
PHY403 : Theoretical Physics 2
PHY404 : Condensed Matter Physics 3
PHY405 : Nuclear Physics 3
PHY406 : Theoretical Physics 3
PHY407 : Nuclear Spectroscopy Methods
PHY408 : Numerical Methods
PHY409 : Modern Optics
PHY414 : Minor Project
PHY415 : Condensed Matter Physics Lab
PHY416 : Nuclear Physics Lab
PHY417 : Condensed Matter Physics Lab 2
PHY418 : Nuclear Physics Lab 2
PHY419 : Theoretical Physics Lab 2

Semester 1

Paper		Credits			
		Lecture	Tutorial	Practicals	Total
PHY101	Classical Mechanics	3.0	0.5	0.0	3.5
PHY102	Mathematical Methods of Physics 1	3.0	0.5	0.0	3.5
PHY103	Mathematical Methods of Physics 2	3.0	0.5	0.0	3.5
PHY104	Classical Electrodynamics, Plasma Physics and Optics	3.0	0.5	0.0	3.5
PHY105	Computer Lab CL-A	0.0	0.0	2.0	2.0
PHY106	Optics Lab*	0.0	0.0	4.0	4.0
PHY107	Electronics Lab*	0.0	0.0	4.0	4.0
	* A student can opt either for PHY106 or PHY107.				
	Total credits for Semester 1				20

Semester 2

Paper		Credits Lecture	Tutorial	Practicals	Total
PHY201	Continuum Mechanics and Relativity	3.0	0.5	0.0	3.5
PHY202	Thermal Physics	3.0	0.5	0.0	3.5
PHY203	Quantum Mechanics 1	3.0	0.5	0.0	3.5
PHY204	Spectroscopy and Fourier Optics	3.0	0.5	0.0	3.5
PHY205	Computer Lab CL-B	0.0	0.0	2.0	2.0
PHY206	Optics Lab*	0.0	0.0	4.0	4.0
PHY207	Electronics Lab**	0.0	0.0	4.0	4.0
	Trans-border/Cross-discipline				
	Students are permitted to register for any one of the following :				
PHY208	Electronics	3.0	0.5	0.5	4.0
PHY209	Python Programming	2.0	0.0	1.0	3.0
PHY210	Minor Project	3.0	0.5	0.5	4.0
	Following papers are only for students from other disciplines:				
PHY211	Modern Physics	3.0	0.5	0.5	4.0
PHY212	Energy Science	3.0	0.5	0.5	4.0

* For students who have completed PHY107.
** For students who have completed PHY106.

Total credits for Semester 2 — 23 or 24

Semester 3

Paper		Credits Lecture	Tutorial	Practicals	Total
PHY301	Quantum Mechanics 2	3.0	0.5	0.0	3.5
PHY302	Condensed Matter Physics	3.0	0.5	0.0	3.5
PHY303	Nuclear Physics and Particle Physics	3.0	0.5	0.0	3.5
	Students have to register for any one of the following :				
PHY304	Condensed Matter Physics 1	3.0	0.5	0.0	3.5
PHY305	Nuclear Physics 1	3.0	0.5	0.0	3.5
PHY306	Theoretical Physics 1	3.0	0.5	0.0	3.5
	Elective Papers				
	Students have to register for any one of the following :				
PHY307	Accelerator Physics	3.0	0.5	0.0	3.5
PHY308	Liquid Crystals	3.0	0.5	0.0	3.5
PHY309	Atmospheric Physics	3.0	0.5	0.0	3.5
PHY313	Condensed Matter Physics Lab‡	0.0	0.0	4.0	4.0
PHY314	Nuclear Physics Lab‡	0.0	0.0	4.0	4.0
PHY315	Condensed Matter Physics Lab 1*	0.0	0.0	2.0	2.0
PHY316	Nuclear Physics Lab 1**	0.0	0.0	2.0	2.0
PHY317	Theoretical Physics Lab 1†	0.0	0.0	2.0	2.0

‡ A student can opt either for PHY313 or PHY314.
* Compulsory for students who have opted for PHY304.
** Compulsory for students who have opted for PHY305.
† Compulsory for students who have opted for PHY306.

Total credits for Semester 3	23.5

Semester 4

	Paper	Credits			
		Lecture	Tutorial	Practicals	Total
	Students have to register for any two of the following :				
PHY401	Condensed Matter Physics 2*	3.0	0.5	0.0	3.5
PHY402	Nuclear Physics 2**	3.0	0.5	0.0	3.5
PHY403	Theoretical Physics 2†	3.0	0.5	0.0	3.5
PHY404	Condensed Matter Physics 3*	3.0	0.5	0.0	3.5
PHY405	Nuclear Physics 3**	3.0	0.5	0.0	3.5
PHY406	Theoretical Physics 3†	3.0	0.5	0.0	3.5
	* Compulsory for students who have completed PHY304.				
	** Compulsory for students who have completed PHY305.				
	† Compulsory for students who have completed PHY306.				
	Trans-border/Cross-discipline				
	Students are permitted to register for any one of the following :				
PHY407	Nuclear Spectroscopy Methods	3.0	0.5	0.0	3.5
PHY408	Numerical Methods	3.0	0.5	0.0	3.5
PHY409	Modern Optics	3.0	0.5	0.0	3.5
PHY414	Minor Project	0.0	0.0	4.0	4.0
PHY415	Condensed Matter Physics Lab*	0.0	0.0	4.0	4.0
PHY416	Nuclear Physics Lab**	0.0	0.0	4.0	4.0
	* For students who have completed PHY314.				
	** For students who have completed PHY313.				
PHY417	Condensed Matter Physics Lab 2*	0.0	0.0	2.0	2.0
PHY418	Nuclear Physics Lab 2**	0.0	0.0	2.0	2.0
PHY419	Theoretical Physics Lab 2†	0.0	0.0	2.0	2.0
	* Compulsory for students who have completed PHY315.				
	** Compulsory for students who have completed PHY316.				
	† Compulsory for students who have completed PHY317.				
	Total credits for Semester 4				20.5

Scheme of Examination under CBCS

Each student shall take an examination in each of the theory and practical papers prescribed for the semester at the end of the corresponding semester. The duration of the examination and maximum marks allotted for various papers shall be as follows.

Paper	Duration	Max marks
1. Theory examination	3 hours	80
2. Practical examination		
(Two practical papers per semester)		
a. Practical examination proper	4 hours	40
b. Practical record		10
c. Total marks per practical paper		50
d. Total marks for practicals per semester		100
3. Internal Assessment (IA) in Semesters 1–3		
a. Class room test for each paper	1.5 hours	15
b. Class room assignment for each paper		5
c. Total IA marks for each paper		20
4. Internal Assessment in Semester 4		
a. Class room test for each paper	1.5 hours	15
b. Seminar for each paper		5
c. Total IA marks for each paper		20
5. Project		
a. Project work and project report		80
b. Viva voce examination		20
c. Total marks for the project		100

PHY101 : Classical Mechanics

Mechanics of a system of particles: Center of mass. Conservation of linear and angular momenta in the absence of (net) external forces and torques. The energy equation and the total potential energy of a system of particles.

The Lagrangean method: Constraints and their classifications. Generalized coordinates. Virtual displacement, D'Alembert's principle and Lagrangean equations of the second kind. Examples of (I) single particle in (a) Cartesian coordinates, (b) spherical polar coordinates and (c) cylindrical polar coordinates, (II) Atwood's machine and (III) a bead sliding on a rotating wire in a force-free space. (IV) Simple pendulum. Derivation of Lagrange equation from Hamilton principle.

Motion of a particle in a central force field: Binet equation for central orbit (Lagrangean method), inverse square law force—Kepler's problem.

[16 hours]

Hamilton's equations: Generalized momenta. Hamilton's equations. Examples (i) the simple harmonic oscillator. (ii) Hamiltonian for a free particle in different coordinates. Cyclic coordinates. Physical significance of the Hamiltonian function. Derivation of Hamilton's equations from a variational principle.

Canonical transformations: Generating functions (Four basic types), examples of Canonical transformations, Poisson brackets; properties of Poisson brackets, angular momentum and Poisson bracket relations. Equation of motion in the Poisson bracket notation. The Hamilton-Jacobi equation; the example of the harmonic oscillator treated by the Hamilton-Jacobi method.

[16 hours]

Mechanics of rigid bodies: Degrees of freedom of a free rigid body, Angular momentum and kinetic energy of rigid body. Moment of inertia tensor, principal moments of inertia, products of inertia, the inertia tensor. Euler equations of motion for a rigid body. Torque free motion of a rigid body. Precession of earths axis of rotation, Euler angles, angular velocity of a rigid body.

Small oscillations of mechanical system: Introduction, types of equilibria, Quadratic forms of kinetic and potential energies of a system in a equilibrium, General theory of small oscillations, secular equation and Eigen value equation, small oscillations in normal coordinates and normal modes, examples of two coupled oscillators, vibrations of a linear triatomic molecule.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Goldstein H., Poole C. and Safko J., Classical mechanics, 3rd Edn., Pearson Education, New Delhi. 2002.
- Upadhaya J.C., Classical mechanics, Himalaya Publishing House, Mumbai. 2006.
- Srinivasa Rao K.N., Classical mechanics, Universities Press, Hyderabad. 2003.
- Takwale R.G. and Puranik S., Introduction to classical mechanics, Tata McGraw, New Delhi,1991.

- Landau L.D. and Lifshitz E.M., Classical mechanics, 4th Edn., Pergamon Press, 1985.

PHY102 : Mathematical Methods of Physics 1

Tensor analysis: Curvilinear coordinates, tensors and transformation theory: Tensors of rank r as a r-linear form in base vectors. Transformation rules for base vectors and tensor components. Invariance of tensors under transformation of coordinates. Sum, difference and outer products of te -nsors, Contraction. Curvilinear coordinates in the Euclidean 3-space. Covariant and contravariant basis vectors. Covariant and contravariant components of the metric tensor. Raising and lowering of indices. Differentials of base vector fields. Christoffel symbols. The invariant del operator. Covariant differentiation. The contracted Christoffel symbol. Grad, divergence, curl and Laplacian in arbitrary curvilinear coordinates.

[16 hours]

Special functions: Differential equations, Hermite and Lagaurre functions: Partial differential equations, Separation of variables- Helmholz equation in cylindrical and spherical polar coordinates. Differential equations: Regular and irregular singular points of a second order ordinary differential equation. Series solutions–Frobinius method. Linear independence of solutions-Wronskian. Hermite functions: Generating functions, Recurrence relations, Rodrigues representation, Orthogonality. Laguerre functions: Differential equation-Laguerre polynomials, Generating function, Recurrence relations, Rodrigues representation, Orthogonality, Associated Laguerre functions and its general properties. The gamma function and beta function; definition and simple properties .

[16 hours]

Linear vector space: Definition. Linear dependence and independence of vectors. Dimension. Basis. Change of basis. Subspace. Isomorphism of vector spaces. Linear operators. Matrix representative of a linear operator in a given basis. Effect of change of basis. Invariant subspace. Eigenvalues and eigenvectors. Characteristic equation. The Schur canonical form. Diagonalisation of a normal matrix. Schur's theorem.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Arfken G.B. and Weber H.J., Mathematical methods for physicists, 4th Edn., Academic Press, New York (Prism Books, Bangalore, India), 1995.
- Harris E.G., Introduction to modern theoretical physics, Vol. 1, John Wiley, New York, 1975.
- Srinivasa Rao K.N,, The rotation and Lorentz groups and their representations for physicists, Wiley Eastern, New Delhi, 2003.
- Shankar R., Principles of quantum mechanics, 2nd Edn., Plenum Press, New York, 1984.

PHY103 : Mathematical Methods of Physics 2

Rotation group: Rotation matrix in terms of axis and angle. Eigen values of a rotation matrix. Euler resolution of a rotation. Definition of a representation. Equivalence. Reducible and irreducible representations. Schur's lemma. The groups $O(3)$ and $SO(3)$.Construction of the $D^{1/2}$ and D^1 representation of $SO(3)$ by exponentiation. Mention of the D^j irreps $SO(3)$.

[16 hours]

Special functions: Sturm Liouville theory, Bessel functions, Legendre functions and Spherical harmonics: Sturm Liouville theory: Self adjoint ODE's, Hermitian operators, completeness of eigen functions, Green's function-eigen function expansion. Bessel functions: Bessel functions of the first kind J(x). Orthogonality. Legendre functions: Generating function. Recurrence relation, Rodrigues representation, Orthogonality. Associated Legendre functions: The differential equation, orthogonality relation. Spherical harmonics: Definition and Orthogonality.

[16 hours]

Fourier transforms and integral equations: Integral transforms, Development of the Fourier integral. Fourier transforms-inversion theorem. Fourier transform of derivatives. Convolution theorem. Momentum representation, Integral equations: Types of linear integral equations—definitions. Transformation of a differential equation into an integral equation. Abel's equation, Neumann series, separable kernels.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Srinivasa Rao K.N., The rotation and Lorentz groups and their representations for physicists, Wiley Eastern, New Delhi, 1988.
- Arfken G.B. and Weber H.J., Mathematical methods for physicists, 5th. Edn., Academic Press,New York, 2001.

PHY104 : Classical Electrodynamics, Plasma Physics and Optics

Electric multipole moments: The electric dipole and multipole moments of a system of charges. Multipole expansion of the scalar potential of an arbitrary charge distribution.

Potential formulation: Maxwell equations in terms of electromagnetic potentials. Gauge transformations. The Lorentz, Coulomb and radiation gauges.

Fields of moving charges and radiation: The retarded potentials. The Lienard- Wiechert potentials. Fields due to an arbitrarily moving point charge. The special case of a charge moving with constant velocity.

Radiating systems: Radiation from an oscillating dipole. Power radiated by a point charges—Larmor formula. Lienard's generalisation of Larmor formula. Energy loss in bremsstrahlung and linear accelerators. Radiation reaction—Abraham-Lorentz formula.

[16 hours]

Relativistic electrodynamics: Charge and fields as observed in different frames. Covariant formulation of electrodynamics-Electromagnetic field tensor-Transformation of fields - Field due to a point charge in uniform motion-Lagrangian formulation of the motion of charged particle in an electromagnetic field.

Plasma physics: Quasineutrality of a plasma-plasma behaviour in magnetic fields, Plasma as a conducting fluid, magnetohydrodynamics, magnetic confinement, Pinch effect, instabilities, Plasma waves.

[16 hours]

Electromagnetic waves: Monochromatic plane waves—velocity, phase and polarization. Propagation of plane electromagnetic waves in (a) conducting media and (b) ionized gases. Reflection and refraction of electromagnetic waves—Fresnel formulae for parallel and perpendicular components. Brewster law. Normal and anomalous dispersion—Clausius -Mossotti relation.

Interference: General theory of interference of two monochromatic waves. Multiple beam interference. Fabry-Perot etalon and its resolving power. Coherence—temporal and spatial. Partial coherence. Complex representation. Mutual coherence function and degree of coherence. Quasi-monochromatic sources.

Diffraction: Integral theorem of Helmholtz and Kirchoff. Fresnel- Kirchoff diffraction formula—conditions for Fraunhofer and Fresnel diffraction. Fraunhofer diffraction due to a circular aperture.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Griffiths D.J., Introduction to electrodynamics, 5th Edn., Prentice-Hall of India, New Delhi, 2006.
- Jackson J.D., Classical electrodynamics, 2nd Edn., Wiley-Eastern Ltd, India, 1998.
- Born M. and Wolf E., Principles of optics, 6th Edn., Pergamon Press, Oxford, 1980.
- Matveev A.N., Optics, Mir Publishers, Moscow, 1988.
- Laud B.B., Electromagnetics, Wiley Eastern Limited, India, 2000.

PHY105 : Computer Lab CL-A

- Linux operating system basics (4 sessions) :
  Login procedure; creating, deleting directories; copy, delete, renaming files; absolute and relative paths; Permissions—setting, changing; Using text editor.
- Scientific text processing with LaTeX.
  Typeset text using text effects, special symbols, lists, table, mathematics and including figures in documents.
- Using the plotting program GNUPLOT (2 sessions) :
  Plotting commands; To plot data from an experiment and applying least-squares fit to the data points. Including a plot in a LaTeX file.
- Using the mathematics package OCTAVE (2 sessions) To compute functions, matrices, eigenvalues, inverse, roots.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY106 : Optics Lab

Any ten of the following experiments:

- Verification of the Brewster law of polarisation.
- Verification of Fresnel laws of reflection from a plane dielectric surface.
- Determination of the inversion temperature of the copper-iron thermocouple.
- Birefringence of mica by using the Babinet compensator.
- Birefringence of mica by using the quarter-wave plate.
- Experiments with the Michelson interferometer.
- Determination of the refractive index of air by Jamin interferometer.

- Determination of the size of lycopodium spores by the method of diffraction haloes.
- Determination of wavelength by using the Fabry-Perot etalon.
- Dispersion of the birefringence of quartz.
- The Franck-Hertz experiment.
- Experiments with the laser.
- Determination of the Stokes vector of a partially polarised light beam
- Determination of the modes of vibration of a fixed-free bar.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

PHY107 : Electronics Lab

Any ten of the following experiments:

- Regulated power supply.
- Active filters : low pass (single pole).
- Active filters : high pass (double pole).
- Voltage follower.
- Colpitts' oscillator.
- Opamp as an integrator and differentiator.
- Opamp as a summing and log amplifier.
- Opamp as an inverting and non-inverting amplifier.
- Coder and encoder.
- Half adder and full adder.
- Boolean algebra-Logic gates.
- Opamp astable multivibrator.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

NOTE: Normally, students belonging to a semester are divided into 4 batches A1, A2, A3 and A4. Optics Lab for batches A1 and A2. Electronics Lab for batches A3 and A4.

PHY201 : Continuum Mechanics and Relativity

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

Fluid mechanics: 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 Poiseulle formula.

[16 hours]

Minkowski space time: Real coordinates in Minkowski space time. Definition of 4-tensors. The Minkowski scalar product and the Minkowski metric ij diag (1 - 1 - 1 - 1). Orthogonality of 4-vectors. Raising and lowering of 4-tensor indices. Time like, null, and space like vectors and world-lines. The light-cone at an event.

Relativistic mechanics of a material particle: The proper-time interval d along the world-line of a material particle. The instantaneous (inertial) rest-frame of a material particle and the components of 4-velocity, 4-acceleration and the 4-momentum vector in this frame. Statement of second law of Newton in this frame. Determination of the fourth component F4 of the 4-force along the world-line of the particle. Motion of a particle under the conservative 3-force field and the energy integral. The rest energy and the relativistic kinetic energy of a particle.

[16 hours]

Einstein's equations: The Principle of Equivalence and general covariance, inertial mass, gravitational mass, Etvs experiment, gravitation as space time curvature, Gravitational field equations of Einstein and its Newtonian limits.

The Schwarzschild metric: Heuristic derivation of the Schwarzschild line element. Motion of particles and light rays in the Schwarzschild field. Explanation of the (i) perihelion advance of planet Mercury, (ii) gravitational red shift and (iii)gravitational bending of light. A brief discussion of the Schwarzschild singularity and the Schwarzschild black hole.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Landau L.D. and Lifshitz E.M., Fluid mechanics, Pergamon Press, 1987.
- Landau L.D. and Lifshitz E.M., Theory of elasticity, Pergamon Press, 1987.
- Synge J.L., Relativity: The special theory, North-Holland, 1972.
- Landau L.D. and Lifshitz E.M., The classical theory of fields, 4th Edn., (Sections 1 to 6, 16 to 18, 23 to 25, 26 to 35), Pergamon Press, Oxford, 1985.
- Wald R.M., General relativity, The University of Chicago Press, Chicago, 1984.
- Schutz B.F., A first course in general relativity, Cambridge University Press, Cambridge, 1985.
- Bergman P., Introduction to theory of relativity, Prentice-Hall of India, 1969.
- Rindler R., Relativity: Special, general and cosmological, Oxford University Press, 2006.

PHY202 : Thermal Physics

Thermodynamics preliminaries: A brief overview of thermodynamics, Maxwell's relations, specific heats from thermodynamic relations, the third law of thermodynamics. Applications of thermodynamics: Thermodynamic description of phase transitions, Surface effects in condensation. Phase equilibria; Equilibrium conditions; Classification of phase transitions; phase diagrams; Clausius-Clapeyron equation, applications. Van der Wall's equation of state. Irreversible thermodynamics—Onsager's reciprocal relation, thermoelectric phenomenon, Peltier effect, Seebeck effect, Thompson effect, systems far from equilibrium.

[16 hours]

Classical statistical mechanics: The postulate of equal a priori probability; The Liouville theorem; the microcanonical ensemble, canonical ensemble, Grand canonical ensemble, mean value and fluctuations, Entropy and thermodynamic probability, Reduction of Gibbs distribution to Maxwell and Boltzmann distribution, Entropy of an ideal gas; Gibbs paradox; Law of the equipartition theorem; Sackur-Tetrode formula, Molecular partition function, translational and rotational and vibrational partition function and applications to solids. Chemical equilibrium.

[16 hours]

Quantum statistical mechanics: The postulates of quantum statistical mechanics. Symmetry of wave functions. The Liouville theorem in quantum statistical mechanics; condition for statistical equilibrium; Ensembles in quantum mechanics; The quantum distribution functions (BE and FD);

the Boltzmann limit of Boson and Fermion gases; the derivation of the corresponding distribution functions.

Applications of quantum statistics: Equation of state of an ideal Fermi gas (derivation not expected), application of Fermi-Dirac statistics to the theory of free electrons in metals, degeneracy and magnetic susceptibility. Application of Bose statistics to the photon gas, derivation of Planck's law, comments on the rest mass of photons, Thermodynamics of Black body radiation. Bose-Einstein condensation.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Agarwal B.K. and Eisner M., Statistical mechanics, New Age International Publishers, 2000.
- Roy S.K., Thermal physics and statistical mechanics, New Age International Pub., 2000.
- Huang K., Statistical mechanics, Wiley-Eastern, 1975.
- Laud B.B., Fundamentals of statistical mechanics, New Age International Pub.,2000.
- Schroeder D.V., An introduction to thermal physics, Pearson Education New Delhi, 2008.
- Salinas S.R.A., Introduction to statistical physics, Springer, 2004.

PHY203 : Quantum Mechanics 1

introduction: The wave function The Schroedinger Equation, The Statistical Interpretation, Probability, discrete and continuous variables, Normalisation, Momentum, The Uncertainty Principle.

The time-independent Schroedinger Equation: Stationary States, The Infinite Square Well, The Harmonic Oscillator, Algebraic and analytic methods, The Free Particle, The Delta-Function Potential, The Finite Square Well.

[16 hours]

Formalism: Hilbert space, Observables, Eigenfunctions of a Hermitian operator. The Generalized Statistical Interpretation, The Uncertainty Principle, Dirac notation. Quantum Mechanics in three dimensions, Schroedinger Equations in Spherical Co-ordinates, The Hydrogen Atom, Angular Momentum, Spin. Identical particles: two particle systems, atoms, solids.

[16 hours]

The time-independent perturbation Theory: Nondegenerate Perturbation Theory, first and second order perturbation, Degenerate Perturbation Theory, The Fine Structure of Hydrogen, The Zeeman Effect, Hyperfine Splitting. The Variation Principle: Theory, The Ground State of Helium, The Hydrogen Molecule Ion. The WKB Approximation: The Classical Region, Tunneling, The Connection Formulae.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Griffiths D.J., Introduction to quantum mechanics, Prentice-Hall, USA, 1994.
- Sakurai J.J. and Tuan S.F. (Editor), Modern quantum mechanics, Addison Wesley, India, 1999.
- Shankar R., Principles of quantum mechanics, 2nd Edn., Plenum Press, New York, 1984.

- Schiff L.I., Quantum mechanics, 3rd. Edn., McGraw-Hill, Kogakusha Ltd., New Delhi, 1968.

PHY204 : Spectroscopy and Fourier Optics

Atomic spectroscopy: Spectroscopic terms and their notations. Spin-orbit interaction, quantum mechanical relativity correction; Lamb shift. Zeeman effect, Normal and anomalous Zeeman effect, Paschen-Back effect. Stark effect, Weak field and strong field effects, quantum mechanical treatment of stark effect. Hyperfine structure of spectral lines: Nuclear spin and hyperfine splitting, intensity ratio and determination of nuclear spin. Breadth of spectral lines, natural breadth, Doppler effect and external effect.

[16 hours]

Nuclear magnetic resonance: Resonance condition. Chemical shift and spin-spin interaction. Example of ethyl alcohol. FTNMR. A brief account of NMR in medicine.

Microwave spectroscopy: The classification of molecules. The rotational spectra of rigid and non-rigid rotators. The example of HF. The microwave owen.

Infrared spectroscopy: The Born-Oppenheimer approximation. The diatomic vibrating rotator, example of the CO molecule. The vibrations of polyatomic molecules; skeletal and group frequencies. Experimental technique (FTIR).

Raman spectroscopy: The quantum theory of Raman effect. Pure rotational Raman spectra. Vibrational Raman spectra. Instrumentation–use of laser as a source. Structure determination from Raman and IR spectroscopy. Laser-Raman effects.

[16 hours]

Fourier optics: Spatial frequency filter–effect of a thin lens on an incident field distribution. Lens as a Fourier transforming element. Application to phase contrast microscopy.

Propagation of light in an anisotropic medium: Structure of a plane electromagnetic wave in an anisotropic medium. Wave surface, normal surface and ray surface. Dielectric tensor. Equation to the normal surface Fresnel equation of wave normals. Light propagation in uniaxial and biaxial crystals. Elements of non-linear optics: Optical rectification and second harmonic generation. Phase matching; third harmonic generation.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Tralli N. and Pomilla P.R., Atomic theory, McGraw-Hill, New York, 1999.
- Banwell C.N. and McCash E.M., Fundamentals of Molecular Spectroscopy, 4th Edn., Tata McGraw-Hill, New Delhi, 1995.
- Mahan B.H., University chemistry, 3rd Edn. (Chapters 3, 10, 11 and 12), Narosa, New Delhi, 1975.
- Hecht E., Optics, Addison-Wesley, 2002.
- Lipson S.G., Lipson H. and Tannhauser D.S., Optical physics, Cambridge University Press, USA, 1995.

PHY205 : Computer Lab CL-B

Programming in C

- Check whether given number is odd or even.
- Find the largest and smallest number in the input set.
- Compute the Fibonacci sequence.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Generate Pascal's triangle.
- To add two $m \times n$ matrices.
- To find the sum and average of a data stored in a file.
- Linear least-squares fitting to data in a file.
- To find the trajectory of a projectile shot with an initial velocity at an angle. Also, find the maximum height travelled and distance travelled. Write the trajectory data to a file specified and plot using Gnuplot.

Programming in Perl

- Searching for a pattern in a string.
- Counting the number of characters, words and lines in a given file.
- Sorting strings.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Linear least squares fitting to data in a file.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY206 : Optics Lab

For those who have completed PHY107

Any ten of the following experiments:

- Verification of the Brewster law of polarisation.
- Verification of Fresnel laws of reflection from a plane dielectric surface.
- Determination of the inversion temperature of the copper-iron thermocouple.
- Birefringence of mica by using the Babinet compensator.
- Birefringence of mica by using the quarter-wave plate.
- Experiments with the Michelson interferometer.
- Determination of the refractive index of air by Jamin interferometer.
- Determination of the size of lycopodium spores by the method of diffraction haloes.
- Determination of wavelength by using the Fabry-Perot etalon.
- Dispersion of the birefringence of quartz.
- The Franck-Hertz experiment.
- Experiments with the laser.
- Determination of the Stokes vector of a partially polarised light beam
- Determination of the modes of vibration of a fixed-free bar.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

PHY207 : Electronics Lab

For those who have completed PHY106

Any ten of the following experiments:

- Regulated power supply.
- Active filters : low pass (single pole).
- Active filters : high pass (double pole).
- Voltage follower.
- Colpitts' oscillator.
- Opamp as an integrator and differentiator.
- Opamp as a summing and log amplifier.
- Opamp as an inverting and non-inverting amplifier.
- Coder and encoder.
- Half adder and full adder.
- Boolean algebra-Logic gates.
- Opamp astable multivibrator.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

Elective Papers (Trans-border/Cross discipline)

PHY208 : Electronics

Transistor amplifiers: BJT transistor modelling, Hybrid equivalent model, Voltage divider bias, CE and Emitter follower configurations, Frequency response. Hybrid model equivalent circuit concept.

Feedback amplifier: Feedback concept, Feedback connections type, Practical feedback circuits.

Oscillators: Oscillator operation, Phase shift Oscillator, Wien-bridge Oscillator, Crystal Oscillator—BJT version.

FET amplifiers: FET small signal model, Biasing of FET, Common drain common gate configurations, MOSFETs, FET amplifier and its frequency response.

[16 hours]

Operational amplifiers: Concepts of differential amplifier, Ideal op-amp, op-amp parameters,ideal voltage transfer curve, open loop and closed op-amp configurations, inverting amplifier, noninverting amplifier, limitations of open loop op-amp configurations.

Operational amplifier applications: Summing, scaling and averaging amplifiers, voltage to current converter with grounded load, current to voltage converter, integrator, differentiator,. V to I and I to V converters, Log and antilog amplifiers, Wave form generators, phase shift oscillator, Wein bridge oscillator. Non-linear circuit applications: Crossing detectors, 555 timer as a mono-stable and astable multivibrators, Active Filters—First and second order Low pass and High pass filters, Butterworth filters.

[16 hours]

Digital electronics: Boolean Laws and Theorems, addition and subtraction based on 1's and 2's complements, Families of gates, RS and JK flip-flops, The Master-Slave JK Flip-Flop, D and T flipflops. Karnaugh maps for 3 and 4 variables, Decoders-BCD decoders, Encoders.

Combinational logic circuits: Shift registers-series, series in-series out and parallel in parallel out. Half and full adders, Registers, Counters - Binary Ripple Counters, Synchronous Binary counters, Counters based on Shift Registers, Synchronous counters, Synchronous Mod-6 Counter using clocked JK Flip-Flops. Synchronous Mod-6 Counter using clocked D, T, or SR Flip-Flops. Memory cells, memory registers

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Boylestad R.L. and Nashelsky L., Electronic devices and circuit theory, 4th Edn., Pearson Education, 2006.
- Bell D.A., Operational amplifiers and linear circuits, 2nd Edn., Pearson Education, 2004.
- Gaekwad R.A., Operational amplifiers and linear integrated circuits, Prentice-Hall of India, New Delhi, 1993.
- Malvino A.P. and Leach D.P., Digital principles and applications, 4th Edn., Tata McGraw Hill, 1988.
- Arivazhagan S. and Salivahananan S., Digital circuits and design, Vikash Publishing House Pvt. Ltd.New Delhi, 2001.

PHY209 : Python Programming

Introduction to programming: Problem solving by computers; Flowcharts; Algorithms; Elements of programming; Brief introduction to object-oriented programming.

Computer arithmetic: Integers; Floating point representation of numbers; Arithmetic operations with normalisation; Errors in representation; Commonly used number types and their limits like max. and min. integer, float, double precision, long, etc.

[16 hours]

Programming in python: Introduction; Types and operations : Numbers, strings, lists and dictionaries, tuples, files; Statements : Assignment, Control flow; Functions : scope and arguments; Modules.

[16 hours]

Python programming lab : 1 day per week × 2 hours × 16 weeks 32 hours

List of programs :

- Check whether given number is odd or even.
- Find the largest and smallest number in the input set.
- Compute the Fibonacci sequence.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Generate Pascal's triangle.
- Sum of two matrices.
- Product of two matrices.
- Linear, exponential and power least-squares fitting to data in a file.
- To find the trajectory of a projectile shot with an initial velocity at an angle. Also, find the maximum height travelled and distance travelled. Write the trajectory data to a file specified and plot using Gnuplot.

Total work load 64 hours

References

- Lutz M. and Ascher D., Learning python, Second edition, O'Reilly, USA, 2003.
- Python online documentation.
- Swaroop C.H., A byte of python, (free online book), http://www.swaroopch.com/notes/Python.

Note :

- This paper comprises both theory and labwork. The question paper will be a mixed one to be answered in a computer lab only.
- This paper is mostly for students who do not have any prior programming training/experience.

PHY210 : Minor Project

Total work load 64 hours

PHY211 : Modern Physics

Paper to be offered to Non-Physics Postgraduate students

Nuclear physics: A brief overview of nuclear physics. Nuclear reactions, a brief description of nuclear models. Interactions of X-rays and -rays with matter, slowing down and absorption of neutrons. Fundamental particles, classification of fundamental particles, fundamental forces, conservation laws in particle physics, a brief outline of the quark model.

Nuclear power: Nuclear fission, fission chain reaction, self sustaining reaction, uncontrolled reaction, nuclear bomb. Nuclear reactors, different types of reactors and reactors in India. Nuclear waste management. Nuclear fusion, fusion reactions in the atmosphere. Radiation effects—dosage calculation. Nuclear energy—applications and disadvantages.

[16 hours]

Condensed matter physics: Amorphous and crystalline state of matter. Crystal systems. Liquid crystals. X-ray diffraction—Bragg equation. Structure of NaCl. FTIR—Experiment analysis. NMR—Experiment and analysis. Electrical conductivity of metals and semiconductor. Magnetic materials—para,ferro, ferri and anti-magnetism. Dielectrics—para, ferro, pyro and piezo properties. Symmetry in physics.

[16 hours]

Quantum physics: Qualitative discussion. Molecules, atoms, nucleus, nucleons, quarks and gluons. Particle physics (qualitative). Stern-Gerlach experiment and consequences. Uncertainty relation. Hydrogen atom. Positron annihilation. Laser trapping and cooling. Ion traps. Electromagnetic, strong, weak and Gravitational forces. Big Bang theory, String theory. Linear Hadron Collider experiment, consequences. Higgs Boson.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Ghoshal S.N., Atomic and nuclear physics, Vol.2., S. Chand and Company, Delhi, 1994.
- Evans R.D., Atomic nucleus, Tata Mc Grow Hill, New Delhi, 1976.
- Penrose R., Road to Reality, Vintage Books, 2007.
- Ladd M.F.C. and Palmer R.A., Structure determination by X-ray crystallography, Plenum Press, USA, 2003.
- De Gennes P.G. and Prost J., The physics of liquid crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
- Myer R., Kennard E.H. and Lauritsern T., Introduction to modern physics, 5th Edn., McGraw-Hill, New York, 1955.
- Halliday D., Resnick R. and Merryl J., Fundamentals of physics, Extended 3rd Edn., John Wiley, New York, 1988.

PHY212 : Energy Science

Paper to be offered to Non-Physics Postgraduate Students

Renewable energy resources: Energy and Thermodynamics, Forms of Energy, Conservation of Energy, Entropy, Heat capacity, Thermodynamic cycles: Brayton, Carnot Diesel, Otto and Rankin cycle; Fossil fuels, time scale of fossil fuels and solar energy as an option. Solar Energy for Clean Environment Sun as the source of energy and its energy transport to the earth, Extraterrestrial and terrestrial solar radiations, solar spectral irradiance, Measurement techniques of solar radiations, Estimation of average solar radiation.

[16 hours]

Materials and solar cell technology : Single, poly and amorphous silicon, GaAs, CdS , fabrication of single and polycrystalline silicon solar cells, amorphous silicon solar cells, photovoltaic systems, and technical problems. Wind Energy Origin and classification of winds, Aerodynamics of windmill: Maximum power, and Forces on the Blades and thrust on turbines; Wind data collection and field estimation of wind energy, Site selection, Basic components of wind mill, Types of wind mill, Wind energy farm, Hybrid wind energy systems: The present Indian Scenario.

[16 hours]

Biomass energy and biogas technology: Nature of Biomass as a fuel, Biomass energy conversion processes, Direct combustion: heat of combustion, combustion with improved Chulha and cyclone furnace; Dry chemical conversion processes: pyrolysis, gasification, types of gasification Importance of biogas technology, anaerobic decomposition of biodegradable materials, Factors affecting Bio-digestion, Types of biogas plants, Applications of biogas.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Peter A., Advances in energy systems and technology, Academic Press, USA, 1986.
- Neville C.R., Solar energy conversion: The solar cell, Elsevier North-Holland, 1978.
- Dixon A.E. and Leslie J.D., Solar energy conversion, Pergamon Press, New York, 1979.
- Ravindranath N.H., Biomass, energy and environment, Oxford University Press, 1995.
- Cushion E., Whiteman A. and Dieterle G., World Bank Report, 2009.

PHY301 : Quantum Mechanics 2

Time-dependent perturbation theory: Two-Level Systems, Emission and Absorption of Radiation, Spontaneous Emission. Rabi Oscillations.

Adiabatic approximation: The Adiabatic Theorem, Berry's Phase, Sudden approximation.

Scattering: Introduction, Scattering cross section, Partial Wave Analysis,The Born Approximation, Rutherford scattering, The Lippmann- Schwinger equation.

[16 hours]

Relativistic kinematics: Relativistic kinematics of scattering and reactions. Elastic, Inelastic reactions, Decay of a particle $A \to B + C$, $A + B \to C$, $P + \bar{P} \to P + \bar{P} + P + \bar{P}$.

Relativistic quantum mechanics: Klein Gordon equation, plane-wave solutions, negative energy. Equation of continuity. The difficulties of the Klein-Gordon equation. The Dirac equation: The free-particle Dirac equation in the Hamiltonian form. The algebra of Dirac γ matrices, Plane wave solutions of the free-particle equation, the two-component form of the solution in the Dirac-Pauli representation, standard normalisation of the solutions. Non-relativistic reduction and g factor.

[16 hours]

Spin of the Dirac particle: Non-conservation of the angular momentum operator $\vec{L}$; the spin operator $\vec{S}$ and the conservation of $\vec{J} = \vec{L} + \vec{S}$. Helicity. A brief discussion of the hydrogen atom according to Dirac theory, energy spectrum of the hydrogen atom. Negative energy states and anti-particles. Dirac operators in the Heisenberg representation, velocity, zitterbewegung.

Field quantisation: The Lagrangian formalism for a Classical field; Euler-Lagrange equations. Quantisation of the electromagnetic field. Creation and annihilation operators. Number representation. Quantisation of the Dirac field.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Sakurai J.J. and Tuan S.F. (Editor), Modern quantum mechanics, Addison Wesley, India, 1999.
- Sakurai J.J., Advanced quantum mechanics, Addison-Wesley, Harlow, England, 1999.
- Griffiths D., Introduction to elementary particles, John Wiley and Sons, New York, 1987.
- Gasiorowicz S., Elementary particle physics, John-Wiley, New York, 1966.
- Muirhead H., The physics of elementary particles, Pergamon Press, London, 1965.

PHY302 : Condensed Matter Physics

X-ray crystallography: Crystalline state. Reference axes, equation of a plane, Miller indices. External symmetry of crystals; symmetry operations. Two and three dimensional point groups. Lattices; two dimensional lattices, choice of unit cell. Three-dimensional lattices; crystal systems and Bravais lattices. Screw and glide operations. Space groups; analysis of the space group symbol. Diffraction of Xrays by crystals: Laue equations. Reciprocal lattice. Bragg equations. Equivalence of Laue and Bragg equations. Atomic scattering factor (qualitative).

Experimental techniques: Brief introduction to Laue, Oscillation, Weissenberg, Powder and Counter methods. Using synchrotron radiation for structure studies.

Electron and neutron diffraction: Basic principles. Differences between them and X-ray diffraction. Applications (qualitative).

Crystal growth: Crystal growth from melt and zone refining techniques. Liquid crystals: Morphology. The smectic (A-H), nematic and cholesteric phases. Birefringence, texture and X-ray studies in these phases. Orientational order and its determination in the case of nematic liquid crystals.

[16 hours]

Crystal lattice dynamics: Vibration of an infinite one-dimensional monoatomic lattice, First Brillouin Zone. Group velocity. Finite lattice and boundary conditions. Vibrations of a linear diatomic lattice—optical and acoustical branches; relation.

Magnetic properties of solids: Diamagnetism and its origin. Expression for diamagnetic susceptibility. Paramagnetism. Quantum theory of paramagnetism. Brillouin function. Ferromagnetism. Curie-Weiss law. Spontaneous magnetisation and its variation with temperature. Ferromagnetic domains. Antiferromagnetism. Two sub-lattice model. Susceptibility below and above Neel's temperature.

[16 hours]

Superconductivity: Experimental facts. Type I and type II semiconductors. Phenomena logical theory. London equations. Meissner effect. High frequency behaviour. Thermodynamics of superconductors. Entropy and Specific heat in the superconducting state. Qualitative ideas of the theory of superconductivity.

Semiconductors: Intrinsic Semiconductors. Crystal structure and bonding. Expressions for carrier concentrations. Fermi energy, electrical conductivity and energy gap in the case of intrinsic semiconductors. Extrinsic Semiconductors; impurity states and ionization energy of donors. Carrier concentrations and their temperature variation. Qualitative explanation of the variation of Fermi energy with temperature and impurity concentration in the case of impurity semiconductors.

Semiconductor devices: Brief discussion of the characteristics and applications of, phototransistors, JFET, SCR and UJT.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Stout G.H. and Jensen L.H., X-ray structure determination, MacMillan, USA, 1989.
- Ladd M.F.C. and Palmer R.A., Structure determination by X-ray crystallography, Plenum Press, USA, 2003.
- Buerger M.J., Elementary crystallography, Academic Press, London.
- Dekker A.J., Solid state physics, Prentice Hall, 1985.
- Kittel C., Introduction to solid state physics, 7th Edn., John Wiley, New York, 1996.
- Mckelvey J.P., Solid state and semiconductor physics, 2nd Edn., Harper and Row, USA, 1966.
- Streetman B.G., Solid state electronic devices, 2nd Edn., Prentice-Hall of India, New Delhi, 1983.
- De Gennes P.G. and Prost J., The physics of liquid crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
- Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.
- Azaroff L.V., Introduction to solids, McGraw-Hill Inc, USA, 1960.
- Pillai S.O., Solid state physics, New Age International Publications, 2002.

PHY303 : Nuclear Physics and Particle Physics

Properties of the nucleus: Nuclear radius-determination by mirror nuclei, mesic X-rays and electron scattering methods. Nuclear moments—spin, magnetic dipole moment. Relation between J and μ on the basis of single particle model. Determination of nuclear magnetic moment by molecular beam experiment.

Nuclear models: Liquid drop model—Weissacker's formula and its application to (i) stability of isobars and (ii) fission process. Shell model—single particle potentials, spin-orbit coupling. Magic numbers. Fermi gas model—well depth, level density and nuclear evoparation.

Nuclear reactions: Q-values. Threshold energy. Reactions induced by proton, deutron and particles. Photodisintegration.

[16 hours]

Nuclear decay modes: Beta decay: Beta ray spectrum, neutrino hypothesis, mass of the neutrino from beta ray spectral shape, Fermi theory of beta decay, Kurie plot, ft- values and forbidden transitions. Methods of excitation of nuclei. Nuclear isomerism. Mossbauer effect. Auger effect.

Interaction of nuclear radiation with matter and detectors: Energy loss due to ionization for protonlike particles and electrons. Bethe-Bloch formula. Range-energy relations. Radiation loss of fast electrons (Bremsstrahlung - qualitative only). Interaction of gamma and X-rays with matter. Brief description of NaI (Tl) gamma ray spectrometer. Boron triflouride counter.

Nuclear reactors: Slowing down of neutrons, logarithmic decrement in energy, condition for controlled chain reactions, Homogeneous spherical reactor, Critical size. Effect of reflectors. Breeder reactor (Qualitative discussion).

[16 hours]

Nuclear forces and elementary particles: General features of nuclear forces: General features of nuclear forces; spin dependence, charge independence, exchange character etc. Meson theory of nuclear forces- Yukawa's theory. Properties of pi mesons, charge, isospin, mass, spin and parity, decay modes, meson resonances.

Particle interactions and families: Conservation laws—classification of fundamental forces and elementary particles. Associated particle production, Gellmann-Nishijima scheme, strange mesons and baryons. CP violations in Kaon decay. Symmetries—Eight-fold way symmetry, quarks and gluons. Elementary ideas of the standard model.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Krane K.S., Introductory nuclear physics, Wiley, New York, 1955.
- Wong S.S.M., Introductory nuclear physics, Prentice Hall of India, Delhi, 1998.
- Ghoshal S.N., Atomic and nuclear physics, Vol. 2., S.Chand and Company, Delhi, 1994.
- Khanna M.P., Introduction to particle physics, Prentice Hall of India, Delhi, 2008.
- Kapoor S.S. and Ramamoorthy V., Nuclear radiation detectors, Wiley Eastern, Bangalore, 2007.

PHY304 : Condensed Matter Physics 1

Dielectric properties of solids: Polarisation: Macroscopic electric field. Depolarisation field. Local electric field at an atom.Lorentz field. Field of dipoles inside cavity. Dielectric constant and polarizability, Clausius- Mossotti relation. Electronic, ionic and orientational polarizabilities. Polarisation catastrophe. Dipole orientation in solids. Debye relaxation time, relaxation times insolids, complex dielectric constants and loss angle. Classical theory of electronic polarization and optical absorption.

Ferroelectricity: Basic properties of ferroelectric materials. Classification of ferroelectric crystals. Theories of Barium titanate. Displacive transition, thermodynamics of ferroelectric phase transitions. Landau theory of the phase transition. Dielectric constant near the curie point. LST relation and its implication. Ferroelectric domains. Antiferroelectricity.

[16 hours]

Magnetic properties: Hund's rule, Van Vleck paramagnetism, Curie's law in solids, Pauli paramagnetism, Magnetization density and susceptibility. Calculation of the singlet-triplet splitting, Spin Hamiltonian and Heisenberg model, Direct exchange, Super exchange, Indirect exchange and Itinerant exchange, Kondo theory of resistance minimum.

Zero-temperature properties: Ground state of the Heisenberg ferromagnet, Zero-temperature properties: Ground state of the Heisenberg antiferromagnet, Low-temperature behaviour of the Heisenberg ferromagnet: Spin waves, High-temperature susceptibility, Analysis of the critical point, Mean field theory, Consequences of dipolar interactions in ferromagnets: Domains, Consequences of dipolar demagnetization factors.

Magnetic resonance: Elements of theory of NMR, Bloch's equations, solutions for the steady state case and that of the weak RF field, power absorption, change of inductance near resonance, saturation at high RF power. Dipolar line width in a rigid lattice. Ferromagnetic resonance; elements of the theory.

[16 hours]

Band theory of solids: Bloch theorem, Bloch functions, periodic potentials, reciprocal lattice, periodic boundary conditions, density of states, Brillouin zones, nearly free electron approximation, approximate solution near a zone boundary, tight-binding approximation, application to square and cubic lattices. Constant energy surfaces, Fermi surfaces. Brillouin zones in square lattice. Overlapping of bands.

Superconductivity: Elementary ideas of BCS theory. Cooper pairs, energy gap, Meissner effect, flux quantisation, Josephson tunnelling, Josephson junction. Elements of theory for dc and ac bias. Quantum interferometers. High T_c superconductors.

Elastic constants of crystals: Analysis of elastic strains and stresses. Elastic compliance and stiffness constants, applications to cubic crystals and isotropic solids. Elastic waves and experimental determination of elastic constants.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Dekker A.J., Solid state physics, Prentice Hall, 1985.
- Kittel C., Introduction to solid state physics, 7th Edn., John Wiley, New York, 1996.

- Ashcroft N.W. and Mermin N.D., Solid State Physics, Saunders College Publishing, 1996.
- Solid State Physics, Ibach H. and Luth H., Narosa, New Delhi, 1996.
- Pillai S.O., Solid state physics, New Age International Publications, 2002.
- Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.

PHY305 : Nuclear Physics 1

Nuclear detectors: Scintillation processes in inorganic crystals (NaI(Tl)). Semiconductor detectors—Diffused junction, Surface barrier and Lithium drifted detectors Relation between applied voltage and depletion layer thickness in junction detectors, Hyper pure germanium detectors, Cerenkov detectors.

Nuclear pulse techniques: Preamplifier circuits. Charge sensitive and voltage sensitive preamplifiers. Linear pulse amplifiers. Linearity,stability, pulse shaping, pulse stretching. operational amplifiers. Analog to digital converters. Scalars, Schmidt trigger as a pulse discriminator, Single channel analyser-Integral and differential discriminators. Multichannel Analysers, memory devices and On-line data processing.

[16 hours]

Shell model: Motion in a mean potential. Square well and simple harmonic oscillator potential well, spin-orbit interaction and Magic numbers. Extreme single particle model, Single particle model; Spin, magnetic and quadrupole moments. Nordhiem's Rules.

Collective model: Evidences for the collective motion. Nuclear rotational motion. Rotational energy spectrum and nuclear wave functions for even-even nuclei. Odd- A nuclei energy spectrum and wave function.

Nilsson model: Nilsson diagrams. Many body self-consistent models: Hartree-Fock model.

[16 hours]

Timing spectroscopy: Coincidence and anti-coincidence circuits Delay circuits. Time to amplitude conversion- Start-stop and overlap converters.

Gamma ray spectroscopy: Life time measurements. Gamma-gamma, beta-gamma angular correlation studies. Angular distribution of gamma rays from oriented nuclei. Polarization of gamma rays.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Mermier P. and Sheldon E., Physics of the nuclei and particles, Vol. 1 and 2, Academic Press, New York 1970.
- Segre E., Nuclei and particles, Benjamin Inc, New York, 1977.
- Arya A.P., Fundamentals of nuclear physics, Allyn and Bacon, USA, 1968.
- Blatt J.M. and Weisskopf V.F., Theoretical nuclear physics, Wiley and Sons, New York, 1991.
- Siegbahn K., The alpha, beta and gamma ray spectroscopy: Vol. 1 and 2, North Holland, Amsterdam, 1965.
- Price J.W., Nuclear radiation detectors, McGraw Hill, New York, 1965.
- Kapoor S.S. and Ramamoorthy V., Nuclear radiation detectors, Wiley Eastern, Bangalore, 1993.

- Kowalski E., Nuclear electronics, Springer Verlag, Berlin,1970.
- Leo W.R.,Techniques for nuclear and particle physics experiments, Springer Verlag, 1992.
- Roy R.R. and Nigam B.P., Nuclear physics, New Age International, New Delhi, 1986.
- Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers, 2001.

PHY306 : Theoretical Physics 1

General theory of relativity: Tensor Calculus and Riemannian geometry : Covariant Differentiation, Parallel Transport, Geodesies, The Curvature Tensor

Riemannian geometry: Riemannian space, The determinant of $g_{\mu\nu}$. Metrical Densities, The Connection of a Riemannian Space: Christoffel Symbols, Geodesies in a Riemannian Space, The Curvature of a Riemannian Space: The Riemann Tensor.

[16 hours]

Gravitational field: The Principle of Equivalence, The Field Equations of General Relativity, Metrics with Spherical Symmetry, The Schwarzschild Solution. Geodesies in the Schwarzschild Space, Advance of the Perihelion of a Planet, The Deflection of Light Rays, Red Shift of Spectral Lines, The Schwarzschild Sphere. Gravitational Collapse. Black Holes.

[16 hours]

Quantum field theory-1: Classical and quantum fields: Particles and fields, Discrete and continuous mechanical systems, Classical scalar fields, Maxwell fields Quantum Theory of Radiation: Creation, annihilation, and number operators, Quantized radiation field, Fock states, Emission and absorption of photons by atoms, Rayleigh scattering, Thomson scattering, and the Raman effect.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Papapetrov A., Lectures on general relativity, D. Reidel Publishing Company, USA, 1974.
- Dirac P.A.M., The general theory of relativity, John Wiley and Sons, New York, 1975.
- Adler R., Bazin M. and Schiffer M., Introduction to general relativity, McGraw-Hill Kogakusha, Ltd. New Delhi, 1965.
- Hartle J.B., Gravity: An introduction to Einstein's general relativity, Benjamin-Cummings Pub. Co., USA, 2002.
- Sakurai J.J., Advanced quantum mechanics, Addison-Wesley, Harlow, England, First ISE Reprint, 1999.
- Griffiths D., Introduction to elementary particles, John Wiley and Sons, New York, 1987.
- Gasiorowicz S., Elementary particle physics, John-Wiley, New York, 1966.
- Muirhead H., The physics of elementary particles, Pergamon Press, London, 1965.

Elective Papers

PHY307 : Accelerator Physics

Ion sources: Brief introduction to ion sources for positive and negative ions. Ion production. Semi classical treatment of ionization, Townsend theory-comparison of theory and experiment for ion production. The gas plasma characterization: Conductivity and stability of a plasma-extraction of beams from plasma: examples of ion sources-properties of ion sources. Insulation at high voltages-Spark voltage. Paschen's law for gas breakdown.

Ion optics and focussing: Focussing properties of linear fields. Electrostatic and magnetic lenses.

[16 hours]

Particle accelerators: Introduction, development of accelerators. Direct-voltage accelerators: Cockroft-Walton generator, Van de Graff generator, Tandem accelerators, Pelletron. Resonance accelerators: Cyclotron—fixed and variable energy, principles and longitudinal dynamics of the uniform field cyclotron. Linear accelerators.

[16 hours]

Electron accelerators: Betatron, Beam focusing and Betatron Oscillation, Microtron. Synchronous accelerators: Principle of phase stability, Mathematical theory for Principle of phase stability. Electron synchrotron. Proton synchrotron. Alternating gradient machines: Alternating gradient principle, AG proton synchrotron.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Townsend P.D., Kelly J.C. and Hartley N.E.W., Ion implantation, sputtering and their applications, Academic Press, London, 1976.
- Humphrey S. Jr., Principles of charged particle acceleration, John Wiley, 1986.
- Arya A.P., Fundamentals of nuclear physics, Allyn and Bacon, USA, 1968.
- Ghoshal S.N., Atomic and nuclear physics, Vol. 2, S.Chand and Company, Delhi, 1994.
- Varier K.M., Joseph A. and Pradyumnan P.P., Advanced experimental techniques in modern physics, Pragathi Prakashan, Meerut, 2006.

PHY308 : Liquid Crystals

Anisotropic fluids: Main Types and properties: Introduction. The building blocks. Small organic molecules. Long helical rods. Associated structures. Nematics and Cholesterics. Nematics proper. Static pretransitional effects above $T'_{N\text{-}I}$.The cholesterics. A distorted form of the nematic phase. Smectic. Smectic A. Smectic B. Smectic C. Other mesomorphic phases. Exotic smectics; long range order in a system of long rods. Lyotropic systems. Remarkable features of liquid crystals. Applications of liquid crystals.

[16 hours]

Long and short range order in nematics: Definition of an order parameter. Microscopic approach. Order parameter from optical method, from diamagnetic anisotropy. Mean field theory with S2 interaction (Maier-Saupe).

Static distortion in nematics: Long range distortions, distortion free energy. Magnetic field effects—Molecular diamagnetism, Magnetic coherence length.

Defects and textures in nematics: Observations. Black filaments. Schlieren structures. Types of defects (qualitative discussion only).

Smectics: Continuum description of smectics A and C, Mean field description of S_A-N transition.

[16 hours]

Dynamical properties of nematics: Experiments measuring the Leslie coefficients—Laminar flow under a strong orienting field, Attenuation of ultrasonic shear waves, Laminar flow in the absence of external fields. Convective instabilities under electric fields—Basic electrical parameters, Experimental observations at low frequencies, The Helfrich interpretation. Extension to higher frequencies (qualitative).

Cholesterics: Optical properties of an ideal helix—The planar texture, Bragg reflection, Transmission properties at arbitrary wavelengths (normal incidence), The Mauguin limit, Rotatory Power. Agents influencing the pitch—Physicochemical factors, External fields(qualitative). Textures in cholesterics.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- De Gennes P.G. and Prost J., The physics of liquid crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
- Chandrashekhar S., Liquid crystals, Cambridge University Press, 1977.
- Gray G.W., Molecular structure and the properties of liquid crystals, Academic Press, 1962.
- Maier G., Sackmann E. and Grabmanier I.G., Applications of liquid crystals, Springer Verlag, 1975.
- Gray G.W. and Goodby J.W., Smectic liquid crystals (Textures and structures), Leanard Hill, London, 1984.

PHY309 : Atmospheric Physics

Atmospheric composition: Energy in the atmosphere, heating of the atmosphere, motions in the atmosphere. Variations in atmospheric composition, Structure on the basis of composition. Thermal structure of the atmosphere.

Thermodynamics: Entropy of dry air, vertical motion of saturated air, tephigram, potential energy of an air column.

Dynamics: Escape of hydrogen, photodissociation of oxygen, photo chemical processes. Equations of motion, the geostrophic approximation, cyclostrophic motion.

[16 hours]

Terrestrial and extra terrestrial radiation: General features of direct, diffuse and global radiation-attenuation of direct solar radiation-Rayleigh and Mie scattering. Angstrom turbidity formula for all aerosols. Direct transmittance due to continuum attenuation, diffuse spectral irradiance due to Rayleigh and aerosol scattering. Atmospheric albedo.

Aerosols and clouds: Production and properties of aerosols. Aerosol optical depth, Beer's law—Instrumentation- Pyroheliometer, pyrenometer Sun Photometer and Multiwavelength radiometer. Optical filters. Measurement of albedo.

Clouds: Microphysics of clouds, Macrocharacterization of clouds. Radiative transfer in clouds and aerosols.

[16 hours]

Atmospheric radioactivity: Background Radiation, Radioactivity in Atmosphere, Radon, Properties of radon, Origin of radon, Radon entry into the atmosphere: Diffusion, Advection and Convection. Health Effects: Dose.

Atmospheric electricity: The generation of an ion, The mobility of ions, Ion size, Adsorption, diffusion and recombination of ions. Ions in an electric field, The current voltage characteristics in a Gas under conditions of volume ionization. Ionizing agencies, radioactivity.The conductivity of the atmosphere and its origin, Relationship between ions and conductivity. Measurement of conductivity of the atmosphere near the ground.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Salby M.L., Fundamentals of atmospheric physics, Academic Press, USA, 2006.
- Houghton J., The physics of the atmosphere, Cambridge University Press, 2002.
- Siddhartha K., Atmosphere, weather and climate, Kisalaya Publications, 2000.
- Lutgens F.K. and Tarbuk E.K., The atmosphere: An introduction to meteorology, Prentice Hall, USA, 1986.
- Holton, J.R., Dynamic meteorology, 3rd edition, Academic Press, USA, 1992.
- Keshvamurthy R.N. and Shankar Rao M., The physics of monsoons, Allied Publishers, 1992.
- Iqbal M., An introduction to solar radiation, Academic Press, USA, 1983.
- Wilkening M., Radon in the environment, Elsevier Science Publishers, The Netherlands, 1990.
- Israel H., Atmospheric electricity-Vol II, Israel Program for Scientific Translations, Jerusalem, 1973.

PHY313 : Condensed Matter Physics Lab

1. Determination of the paramagnetic susceptibility of the given salt by Quincke's method
2. Study of mercury spectrum by superimposing it on brass spectrum
3. Sodium spectrum analysis by using Edser-Butler fringes
4. Temperature coefficient of resistance of a thermister
5. Analysis of the powder X-ray photograph of a simple cubic crystal
6. Thermionic work function of a metal (Richardson-Dushmann formula)
7. Energy gap of a semiconductor
8. Determination of Stefan'sconstant
9. Frank Hertz experiment
10. Magnetic Hysterisis
11. Measurement of magneto resistance of semiconductors

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

PHY314 : Nuclear Physics Lab

Any eight of the following experiments

1. Half-life of Indium-116 measurement.
2. Energy Resolution of a NaI(Tl) scintillation spectrometer.
3. Compton scattering—determination of the rest energy of an electron.
4. Beta absorption coefficient measurement.
5. Dekatron as a counter of signals.
6. Gamma-ray absorption coefficient measurement.
7. End-point energy of Beta particles by half thickness measurement.
8. Common Source amplifier.
9. Astable multivibrator using timer IC 555.
10. Dead time of the G.M. counter.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

PHY315 : Condensed Matter Physics Lab 1

For those who have opted for PHY304

Any five of the following experiments

- Optical rotatory dispersion of an uniaxial crystal.
- Birefringence of quartz using spectrometer.
- Paramagnetic susceptibility by Gouy balance method.
- Fermi energy of copper.
- Cell parameter(s) from an X-ray powder diffractogram.
- Verification of Langmuir-Child's law.
- Thermoluminescence.
- Curie temperature of a ferroelectric material.
- Dielectric constant and its temperature variation.
- Determination of the polarisabilities of the molecules of an uniaxial crystal using spectrometer.
- Photoelasticity in crystalline solids.
- Thermal expansion coefficient in solids.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY316 : Nuclear Physics Lab 1

For those who have opted for PHY305

Any five of the following experiments:

1. Cockroft-Walton voltage multiplier.
2. Coincidence circuit.
3. Linear amplifier.
4. Transistorised binary circuit.
5. Pulse shaping circuits.
6. Linear Gate.
7. Randomocity of radioactive decay.

8. Nomogram method : Measurement of endpoint energy of beta rays.
9. Study of linearity of the NaI(Tl) gamma ray spectrometer.
10. Determination of the energy of an unknown gamma ray source.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY317 : Theoretical Physics Lab 1

For those who have opted for PHY306

Any five of the following experiments:

- Calculation of Christoffel symbols.
- Geodesics and curvature calculations.
- Exterior Schwarzschild metric calculations.
- Robertson-Walker metric calculations.
- Lagrangian and Hamiltonian, Euler Lagrange equations for Schroedinger field.
- Lagrangian for Maxwell's field and The field equations.
- Symmetries of the Lagrangian and Constants of motion.
- Operator algebra-BCH formula.
- Relativistic kinematics-1: Relations between center of momentum and laboratory frames.
- Relativistic kinematics-2: Non-relativistic limit of relativistic kinematics.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY401 : Condensed Matter Physics 2

X-ray diffraction by crystals: The reciprocal lattice. Ewald sphere and construction. Scattering by an electron and atom. Atomic scattering factor. Anomalous scattering. Fourier analysis and inversion of Fourier series. Physical significance. Geometrical structure factor of the unit cell. Absent reflections and space groups.

Experimental techniques: Weissenberg and precession methods. Cell parameter and space group determination. Molecular weight determination. Low angle scattering. Reduction of intensities to structure amplitudes. Various corrections. Absolute scale factor and temperature factor from statistical methods. Statistical method for finding the presence of center of symmetry.

[16 hours]

Structure analysis: Fourier analysis of electron density. Patterson synthesis. Harker sections and lines. Heavy atom methods. Direct methods for phase determination. The inequality relations. Difference Patterson synthesis and error Fourier synthesis. Figure of merit. Cyclic Fourier refinement, Difference Fourier synthesis Refinement of structures: The least squares method. Accuracy of the parameters. Bond lengths and angles

SAXS: Particle size. Study of fibre structures.

[16 hours]

Imperfections in solids: Different types of imperfections and their energy of formation. Diffusion in metals. Kirkendall effect. Ionic conductivity in pure and doped halides. Colour centres, excitons, photoconductivity, traps, space charge effects, crystal counter. Photographic process.

Dislocations: Shear strength of single crystals. Dislocations—Buerger's vector. Stress fields of dislocation, Low-angle grain boundaries. Dislocation and crystal growth. Whiskers.

Luminescence: General remarks, Excitation and Emission. Franck-Condon principle. Decay mechanisms-Temperature dependent and independent decays. Thermoluminescence and glow curve, electroluminescence. Gudden-Pohl effect, carrier injection luminescence.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Stout G.H. and Jensen L.H., X-ray structure determination, MacMillan, USA, 1989.
- Ladd M.F.C. and Palmer R.A., Structure determination by X-ray crystallography, Plenum Press, USA, 2003.
- Sherwood D., Crystals, X-rays and proteins, Longman, London, 1976.
- Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.
- Azaroff L.V., Introduction to solids, McGraw-Hill Inc, USA, 1960.
- Weertman J. and Weertmann J.R., Elementary dislocation theory, McMillan, USA, 1964.
- Pillai S.O., Solid state physics, New Age International Publications, 2002.

PHY402 : Nuclear Physics 2

Nuclear fission: Nuclear fission, Mass-energy distribution of fission fragments. Statistical model of fission.

Reactor theory-1: Neutron and its interaction with matter-collision kinematics,differential elastic scattering cross sections, isotropic scattering, The criticality condition for a reactor. Neutron transport equation using elementary diffusion theory. One group critical equation. The age diffusion method, Fermi age equation. The critical size.

[16 hours]

Reactor theory-2: Reactors of various shapes. Non-leakage probabilities. The effective multiplication factor. Reflector reactors: effects of reflector. One group method, reflector savings. Homogeneous reactor systems. Infinite multiplication, critical size and critical mass. Heterogeneous reactor systems: calculation of thermal utilization. Fast Breeder reactors, Evaluation of Buckling.

[16 hours]

Beta decay: Classification of beta interactions. Matrix elements. Fermi and Gamow-Teller selection rules for allowed beta decay. The non conservation of parity in beta decay. Experiments with Co-60. The universal Fermi interaction.

Gamma decay: Electromagnetic interactions with nuclei. Multipole transitions. Transition probabilities in nuclear matter. Weisskopf's estimates. Structure effects. Selection rules. Internal conversion Photo disintegration of deuteron and radiative capture of neutron by proton.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Glasstone S. and Edlund M.C., Elements of nuclear reactor theory, D. Van Nostrand Co., USA, 9th Print, 1963.

- Garg S., Ahmed F. and Kothari I.S., Physics of nuclear reactors, Tata McGraw-Hill, New Delhi, 1986.
- Roy R.R. and Nigam B.P., Nuclear physics, New Age International, New Delhi, 1986.
- Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers, 2001.

PHY403 : Theoretical Physics 2

Relativistic quantum mechanics: Probability conservation in relativistic quantum mechanics, The Dirac equation, Conserved current, Representation independence, large and small components, approximate Hamiltonian for an electrostatic problem, free particle solutions, Relativistic covariance, Space inversion, Bilinear covariants and their properties, Klein's paradox, Hole theory and charge conjugation.

[16 hours]

Quantization of the Dirac field: Second quantization, positron operators and positron spinors, Electromagnetic and Yukawa couplings. Weak interactions and parity nonconservation: Classification of interactions, parity and hyperon decay, Fermi theory of beta decay, the two-component neutrino. Pion decay and the CPT theorem.

[16 hours]

Covariant perturbation theory: Natural units and dimensions, S-matrix expansion in the Interaction representation. Unitarity, First order processes: Matrix element for electron scattering. Cross section for Mott scattering. Helicity change and spin projection operator. Pair annihilation, pair creation, hyperon decay. S -matrix for two photon annihilation, electron propagator, Matrix element for Compton scattering, Feynman rules. Cross section for two photon annihilation.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Sakurai J.J., Advanced quantum mechanics, Addison-Wesley, Harlow, England, First ISE Reprint, 1999.
- Griffiths D., Introduction to elementary particles, John Wiley and Sons, New York, 1987.
- Gasiorowicz S., Elementary particle physics, John-Wiley, New York, 1966.
- Muirhead H., The physics of elementary particles, Pergamon Press, London, 1965.

PHY404 : Condensed Matter Physics 3

Free electron theory of metals: Boltzmann transport equation, Sommerfeld's theory of electrical conductivity, mean free path in metals, temperature dependence of resistivity on temperature and impurities. Matthiessens rule. Electron-photon collisions. Thermal conductivity of insulators, Umklapp processes. Electrical conductivity of metals at high frequencies. Plasma frequency. Transparency of alkali metals to UV radiation. Anomalous skin effect. Plasmons. Field enhanced emission, Schottky effect. Hall effect and magnetoresistance in metals. Cyclotron frequency.

[16 hours]

Elemental and compound semiconductors: A brief discussion on elemental and compound semiconductors and their properties.

Impurity semiconductors: Carrier concentrations. Effect of temperature and impurity density. Electrical neutrality condition. Fermi energy. Variation of Fermi energy with temperature and impurity density, when the Boltzmann approximation is valid,. Effect of impurity density at very low temperatures. Mobility of current carriers. Effect of temperature and impurity. Electrical conductivity. Effect of temperature, impurity concentration and the energy band gap. Impurity band conductivity. Hall effect in semiconductors: Expression for Hall co-efficient in terms of mobility of current carriers and carrier densities. Hall mobility and Hall factor. Effect of temperature, impurity concentration and magnetic field. Magneto-resistance phenomenon (qualitative).

Cyclotron resonance: Cyclotron resonance in Si and Ge semiconductors. Effective mass tensor. Variation of cyclotron resonance frequency with orientation of the crystal in the magnetic field.

[16 hours]

Excess carriers in semiconductors: Generation and recombination rates. Excess carriers. Continuity equations for excess carriers; Einstein equations, Expression for the diffusion length of electrons and holes. High field transport in semiconductors—electron temperature. Gunn effect, Expression for drift velocity. Superlattice phenomenon.

Semiconductor devices: The pn junction diode. Formation of space charge region. Expressions for barrier potential, barrier thickness and contact field. Effect of the applied field on the above junction parameters. Transition capacitance associated with the space-charge region. Expressions for current densities using continuity equations for excess carriers. Transistors; dc current gain, α and β and cut-off frequencies.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Dekker A.J., Solid state physics, Prentice Hall, 1985.
- Mckelvey J.P., Solid state and semiconductor physics, 2nd Edn., Harper and Row, USA, 1966.
- Roy D.K., Physics of semiconductor devices, University Press, Hyderabad, 1992.
- Schur M., Physics of semiconductor devices, Prentice-Hall of India, New Delhi, 1999.
- Wilson J. and Hawkes J.F.B., Optoelectronics—An introduction, 2nd Edn., Prentice-Hall of India, New Delhi, 1996.
- Streetman B.G., Solid state electronic devices, 2nd Edn., Prentice-Hall of India, New Delhi, 1983.
- Omar M.A., Elementary solid state physics, Addison Wesley, New Delhi, 2000.
- Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.

PHY405 : Nuclear Physics 3

Two particle systems: Deuteron: Schrdinger equation for a two nucleon system. Theory of the ground state of the deuteron under central and non central forces. Excited states of the deuteron. Rarita-Schwinger relations. Deuteron magnetic and Quadrupole moments.

Nucleon-nucleon scattering processes: Theory of s-wave scattering of neutrons by free protons and experimental results. Wigner's formula for n-p scattering. Theory of scattering of slow neutrons by bound protons (Ortho and Para hydrogen) and experimental results. Effective range theory for n-p scattering. S-wave theory of proton-proton scattering. Mott's modification of Rutherford's formula. Pion-nucleon scattering experimental results, (3/2,3/2) resonance.

[16 hours]

Nuclear reactions-1: Plane wave theory of direct reactions. Born approximation-(Plane wave)-Butler's theory. Cross section for nuclear scattering and reactions. Shadow scattering, Breit-Wigner resonance formulae.

Nuclear reactions-2: Bohr's independence hypothesis. The compound nucleus (CN) reactions, decay rates of CN, Statistical theory of nuclear reactions. Evaporation probability and cross sections for specific reactions.

[16 hours]

Optical model: Giant resonances, Kapur-Pearls' dispersion formula for potential scattering. Direct reactions: Kinematics of stripping and pickup reactions. Theory of stripping and pickup reactions. Inverse reactions.

Heavy ion physics: Special features of heavy ion Physics. Remote heavy ion electromagnetic interactions. Coulomb excitations. Close encounters. Heavy ion scattering. Grazing interactions. Particle transfer. Direct and head on collisions, compound nucleus and quasi molecule formation.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Roy R.R. and Nigam B.P., Nuclear physics—Theory and experiment, New Age International Ltd, New Delhi, 1986.
- Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers 2001.
- Sachtler G.R., Nuclear reactions, Addison Wesley, New York, 1983.
- Mermier P. and Sheldon E., Physics of nuclei and particles, Vol. 2, Academic Press, USA, 1971.
- Jackson D.F., Nuclear reactions, Chapman and Hall, London, 1975.

PHY406 : Theoretical Physics 3

Angular momentum theory and applications: Angular momentum: Transformations under rotations. Coupling of three and four angular momenta. Racah coefficients, Wigner $9j$ symbols, applications. Wigner-Eckart theorem. Projection theorem. j-j and L-S coupling. Angular momentum in nuclear reactions, Spherical tensors. Evaluation of matrix elements between coupled angular momentum states. Vector spherical harmonics. Gradient theorem (without proof). Multipole radiation.

[16 hours]

Spin density matrix: Spin and helicity in a relativistic process. Effect of Lorentz and discrete transformations on helicity states. Wick and Wigner rotations, pure rotation, pure boost, parity, time reversal and charge conjugation. The spin density matrix (ρ), general properties, multipole parameters, combined systems, Diagonalization of ρ. Oriented and non-oriented systems, Polarized and aligned systems, Spherical tensor basis and $SU(N)$ basis.

[16 hours]

Relativistic density matrix: Helicity multipole parameters and their transformation laws. Helicity amplitudes for elastic reactions and their symmetry properties. Polarization in scattering of spin 1/2 particles, Final state density matrix. Observables of a reaction, reactions involving polarized beam and polarized targets.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Sakurai J.J. and Tuan S.F. (Editor), Modern quantum mechanics, Addison Wesley, India, 1999.
- Leader E., Spin in particle physics, Cambridge University Press, London, 2001.
- Rose M.E., Elementary theory of angular momentum, John Wiley and Sons, USA, 1957.
- Blum K., Density matrix theory and applications, Plenum Press, New York, 1981.

PHY407 : Nuclear Spectroscopy Methods

Ion implantation and backscattering spectroscopy: Ion implantation, Implantation technique, Ion beam diffusion, Thermal annealing and sputtering, Analysis techniques. Backscattering, Energy loss and straggling. Kinematics factor, differential scattering cross sections, depth scale, backscattering yield, instrumentation. Application to elemental and compound targets. Axial and planar half angles. Estimates of minimum yield. Lattice location of impurities, alignment procedures. Ion induced X-rays. Application of ion implantation.

[16 hours]

Compton scattering: Compton scattering from free electrons. Effects of external potential. Klein-Nishina cross sections for polarized and unpolarized radiation. Compton profiles, momentum distributions and impulse Compton profiles. Calculation of Compton profiles for electron models. Relativistic profile corrections: experimentation. Discussion of methodology including sources, detectors and geometry. Data accumulation, analysis and multiple scattering corrections. Discussion of experimental results for some simple metals, ionic and covalent crystals.

[16 hours]

Positron annihilation spectroscopy: The positron and its discovery, Positronium, its characteristics, formation. Spur model and Ore gap model of positronium formation. Quenching and enhancement. Theory of 2-gamma and 3-gamma annihilations. Positron and positronium states in solids: trapping of positrons. Two state trapping model.

Experimental methods of positron annihilation spectroscopy: Positron lifetime techniques (PLT), Angular Correlation of Annihilation Radiation (ACAR), Doppler broadening (DB) and Coincidence DB. Methods of data analysis: PLT and ACAR. Experimental results of some metals and defected materials. Interpretation of the experimental results. PAS in the study of polymers. Multiparameter techniques. A brief mention of slow positron beams.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Townsend P.D., Kelly J.C. and Hartley N.E.W., Ion implantation, sputtering and their applications, Academic Press, London, 1976.
- Chu W.K., Mayer J.W. and Nicholate Mar A.O., Backscattering spectroscopy, Academic Press, New York, 1978.
- Mayer J.W. and Rimini B. (Eds.), Ion beam handbook for material analysis, Academic Press, 1977.
- Williams B. (Ed.), Compton scattering, McGraw-Hill, New York, 1977.
- Hautojarvi P. (Ed.), Positrons in solids, Springer Verlag, New York, 1979.
- Fava R.A. (Ed.), Methods of experimental physics, Academic Press, New York, 1980.
- Schradev D.M. and Jean Y.C., Positron and positronium chemistry, Elsevier Science Publication, Amsterdam, 1988.
- Jayaram B., Mass spectrometry–Theory and applications, Plenum Press, New York, 1966.

PHY408 : Numerical Methods

Computer arithmetic: Integers; Floating point representation of numbers; Arithmetic operations with normalisation; Errors in representation; Commonly used number types and their limits like max. and min. integer, float, double precision, long, etc.

Iterative methods: Bisection method, Newton-Raphson method, Secant method, the method of successive approximations. Solution of a polynomial equation.

[16 hours]

Linear algebraic equations: The Gauss elimination method, LU decomposition method, Gauss-Jordon method, An introduction to the solution of simultaneous non-linear equations.

Interpolations: Introduction, Newton interpolation formulae, extrapolation, Lagrange interpolation. spline interpolation.

Least-squares approximation of functions: Introduction, linear regression, algorithm for linear regression. Polynomial regression, fitting exponential and trigonometric functions.

[16 hours]

Differentiation and integration: Formulae for numerical differentiation, numerical integration. Trapezoidal method, Simpson rule. Errors in integration formulae (Romberg method). Algorithms for integration of a tabulated function. Algorithms for integrating a known function. Gaussian quadrature formulae.

Numerical solution of differential equations: Euler method, Runge-Kutta methods, Runge-Kutta 4th order formulae, predictor-corrector method. Higher order differential equations, comparison of predictor-corrector and Runge- Kutta methods.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Atkinson K.E., An introduction to numerical analysis, John Wiley and Sons, USA, 1988.
- Press W.H., Flannery B.P., Teukolsky S.A. and Vetterling W.T., Numerical recipes in C, Cambridge University Press, UK, 1989.
- Krishnamurthy E.V. and Sen S.K, Numerical algorithms, Affiliated East West Press Pvt. Ltd., India, 1993.

• Rajaraman V., Computer oriented numerical methods, Prentice Hall of India Pvt. Ltd., India, 2001.

PHY409 : Modern Optics

Polarization of light: Pure states and mixed states. Density operator, properties and equation of motion. Polarization of light, states of polarized light, Jones matrices, Jones formalism, Stokes parameters, Poincaré sphere, Mueller matrices and Mueller formalism, Mueller matrices and their characterization, Few illustrative examples; comparison of Jones and Mueller formalisms. Pancharatnam phase, dynamical phase, cyclic evolution of polarization state on Poincaré sphere; Applications of the concept of Pancharatnam phase,

[16 hours]

Quantum features of radiation field: Planck's law of radiation and Einstein coefficients, Thermal equilibrium, Semi-classical theory of two level atoms, quantum theory of B coefficient, Optical resonance, damping, Theory of chaotic light, coherence, temporal, spatial, mutual coherence, line broadening, natural and Doppler width, collision broadening.

[16 hours]

Quantized radiation field: Quantization of radiation field, States of radiation field; Fock states and phase eigenstates; Interaction of radiation with matter, theory of spontaneous emission; Coherent states and their properties, BCH formula, P, Q and Wigner distribution functions, Squeezed states of light and their properties; applications. Correlation functions, Brown-Twiss correlations.

[16 hours]

Tutorial [16 hours]

Total work load 64 hours

References

- Loudon R., The quantum theory of light, Clarendon Press, Oxford, 1973.
- Mandel L. and Wolf E., Optical coherence and quantum optics, Cambridge University Press, 1995.
- Louisell W.H., Quantum statistical properties of radiation, John Wiley and Sons, New York, 1973.
- Blum K., Density matrix theory and applications, Plenum Press, New York, 1981.
- Pancharatnam S., Collected works, Oxford University Press, 1975.

PHY414 : Minor Project

Total work load 64 hours

PHY415 : Condensed Matter Physics Lab

For those who have completed PHY314

Any eight of the following experiments :

1. Determination of the paramagnetic susceptibility of the given salt by Quincke's method.
2. Study of mercury spectrum by superimposing it on brass spectrum.

3. Sodium spectrum analysis by using Edser-Butler fringes.
4. Temperature coefficient of resistance of a thermistor.
5. Analysis of the powder X-ray photograph of a simple cubic crystal.
6. Thermionic work function of a metal (Richardson-Dushmann formula).
7. Energy gap of semiconductor.
8. Determination of Stefan'constant.
9. Frank Hertz experiment
10. Magnetic hysterisis.
11. Measurement of magneto resistance of semiconductors.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

PHY416 : Nuclear Physics Lab

For those who have completed PHY313

Any eight of the following experiments

1. Half-life of Indium-116 measurement.
2. Energy Resolution of a NaI(TI) scintillation spectrometer.
3. Compton scattering determination of the rest energy of an electron.
4. Beta absorption coefficient measurement.
5. Dekatron as a counter of signals.
6. Gamma-ray absorption coefficient measurement.
7. End-point energy of beta particles by half thickness measurement.
8. Common source amplifier.
9. Astable multivibrator using timer IC 555.
10. Dead time of the G.M. counter.

Total work load : 2 day(s) per week × 4 hours × 16 weeks 128 hours

PHY417 : Condensed Matter Physics Lab 2

For those who have completed PHY315

Any five of the following experiments:

1. Photovoltaic cell.
2. Photoconductive cell.
3. Hall effect in semiconductors.
4. Determination of the energy gap of semiconductors by four-probe method.
5. Temperature variation of the junction voltage of a p-n diode.
6. Temperature variation of the reverse saturation current in a p-n diode.
7. Depletion capacitance of a junction diode.
8. Determination of material constant of an intrinsic semiconductor.
9. Schottky effect.
10. Ionic conductivity of an alkali halide crystal.
11. Dielectric constant and its temperature variation.
12. Ultrasonic velocity and elastic constants of a solid.
13. Determination of Curie temperature of a magnetic material.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY418 : Nuclear Physics Lab 2

For those who have completed PHY316

Any five of the following experiments:

1. Schmitt trigger.
2. Variable delay line.
3. Pulse recorder.
4. Display devices.
5. Feather analysis: End-point energy of beta rays measurement.
6. Z dependence of external Bremsstrahlung radiation.
7. Fermi-Kurie plot : Determination of the end-point energy of beta rays using a plastic scintillation detector.
8. Determination of the resolving time of a coincidence circuit.
9. Determination of source strength by gamma-gamma coincidence.
10. Determination of source strength by beta-gamma coincidence.
11. Multichannel analyser : Study of the variation of energy resolution as a function of gamma ray energies.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours

PHY419 : Theoretical Physics Lab 2

For those who have completed PHY317

Any five of the following experiments:

1. Density matrix description of polarization of light.
2. Double scattering of spin-1/2 particles on spin-zero targets.
3. Second order QED processes (Compton scattering).
4. Evolution of matrix elements between coupled angular momentum states.
5. Dirac matrix representations.
6. Algebra of Dirac matrices.
7. Electron-proton scattering, Rosenbluth formula.
8. Relativistic kinematics-3: Study of decay and production processes.
9. Feynman diagrams and calculations.
10. Energy matrix calculation.

Total work load : 1 day(s) per week × 4 hours × 16 weeks 64 hours