BSc PHYSICS SYLLABUS

COURSE STRUCTURE AND BROAD OUTLINE

Course Code	Course Title	Contact Hours	Weightage
Semester 1			
PHY101 (P&H)	Mechanics, Properties of Matter, Relativity and Electricity	60	4 Credits
PHY102 (P&H)	Practicals	45	1 Credit
PHY103 (H)	Mathematical Physics I	45	3 Credits
Semester 2			
PHY201 (P&H)	Thermal Physics and Oscillations	60	4 Credits
PHY202 (P&H)	Practicals	45	1 Credit
PHY203 (H)	Mathematical Physics II	30	2 Credits
PHY204 (H)	Computational Physics (Practicals)	45	1 Credit
Semester 3			
PHY301 (P&H)	Electrodynamics I and Quantum Mechanics I	60	4 Credits
PHY302 (P&H)	Practicals	45	1 Credit
PHY303 (H)	Thermodynamics and Statistical Physics	45	3 Credits
Semester 4			
PHY401 (P&H)	Electronics I and Optics	60	4 Credits
PHY402 (P&H)	Practicals	45	1 Credit
PHY403 (H)	Mathematical Physics III and Quantum Mechanics II	45	3 Credits
Semester 5			
PHY501 (P&H)	Nuclear Physics I and Solid State Physics I	60	4 Credits
PHY502 (P&H)	Practicals	45	1 Credit
PHY503 (H)	Electrodynamics II and Electronics II	45	3 Credits
Semester 6			
PHY601 (P&H)	Atomic Physics, Particle Physics & Cosmic Rays	60	4 Credits
PHY602 (P&H)	Practicals	45	1 Credit
PHY603 (H)	Astrophysics, Cosmology and Classical Mechanics	30	2 Credits
PHY604 (H)	Solid State Physics II	30	2 Credits
PHY605 (H)	Nuclear Physics II	30	2 Credits
PHY606 (H)	Practicals	45	1 Credit
PHY607 (H)	Project Work		2 Credits

Note: The student will select **only one paper** out of PHY603, PHY604, PHY605

Semester 1 - Physics (Pass & Honours) Theory Paper

PHY101

Mechanics, Properties of Matter, Relativity & Electricity

(4 credits - 60 hours)

Course Overview:

This paper provides a framework on which all other fields of physics are based. **Mechanics** deals with the study of forces that keep bodies in equilibrium or causes it to move. The hidden symmetry and invariance underlying Newton's laws, the relation between energy, momentum and their conservation laws which is at the heart of the motion of everything, will be studied. **Properties of Matter** will deal with the study of elastic properties of solids and fluids in motion. **Relativity** will introduce the student to the fascinating inter-relationship between space, time and mass and the equivalence between mass and energy. **Electricity** will explore the behaviour of alternating currents in various circuits, upon which electronics is based.

At the end of the study, the student will have learnt the fundamental principles governing the physical universe, have conceptual and mathematical understanding of the principles of physics and have developed problem solving skills.

Unit I: Mechanics (1) (12 lectures/hours)

Newton's laws of motion: absolute time and absolute space, superposition principle. Fundamental forces of nature: gravitational, electromagnetic, strong nuclear and weak nuclear forces, frictional forces.
Energy method to analyse mechanical systems: simple harmonic oscillator, pendulum.
Phase space description of mechanical systems: simple harmonic oscillator.
Symmetry properties of Newton's equations: invariance under shift of coordinate system, invariance under rotation of coordinate axes, invariance under time translation, invariance under time reversal, invariance under mirror reflection, invariance under Galilean transformation.
Central force problem: two-dimensional motion of a projectile in Cartesian coordinate system with and without air drag.
Motion of two-dimensional projectile in radial polar coordinate system.
Kepler's problem of planetary motion and its solution, classification of Kepler orbits, orbits of artificial satellites, Virial theorem.
Motion in non-inertial reference frames: accelerating reference frame along a straight line, reference frame rotating with constant angular velocity, earth as reference frame, apparent gravitational acceleration, Coriolis force, Focault pendulum.

Unit II: Mechanics (2) (12 lectures/hours)

Work-Energy theorem, vector field and scalar fields, conservative force fields, non-conservative force fields, conservation of momentum, system of particles and centre of mass, Sun-Earth system (Kepler's problem), kinetic and potential energy of a system of particles.

Translational symmetry and conservation of linear momentum, angular momentum of a single particle, angular momentum of a system of particles, rotational symmetry and conservation of angular momentum, angular momentum of rigid bodies.

Rigid Body Dynamics: kinetic energy of a rigid body and moment of inertia, equation of motion of a rigid body, examples of rotation about a single axis, rotation with constraints, rotation about more than one principal axis, gyroscope, gyroscopic motion, gyrostatic pendulum, precession of a top.

Unit III: Properties of Matter (12 lectures/hours)

(a) Elasticity

Hooke's law, work done in strain, elongation strain, volume strain, shearing strain, Young's modulus, Bulk modulus and rigidity modulus and their inter-relationship, Poisson's ratio, torsion in a cylinder, twisting couple, variation of strain along its length.

Bending of beams and cantilevers in different cases: loaded at free end, loaded uniformly, bending moments.

(b) Viscosity

Equation of continuity, Energy of a liquid in flow, Bernoulli's theorem, critical velocity, Reynold's number, Poiseuille's equation, motion in a viscous medium: Stoke's law, streamline and turbulent flow.

(c) Hydrodynamics

Vorticity, equation of continuity, Euler's equation of motion, stream function in two dimensions, gravity waves and surface ripples.

Unit IV: Relativity (12 lectures/hours)

Frames of reference, non-existence of absolute frame of reference, postulates of special relativity, Galilean and Lorentz transformations, inverse Lorentz transformations, length contraction, simultaneity, time dilation, proper time.

Doppler effect for light, expanding universe and Hubble's law, twin paradox, relation between electricity and magnetism.

Relativistic velocity addition, relativistic momentum, proper mass, relativistic mass, relativistic second law of motion, mass-energy equivalence, kinetic energy for slow speeds, energy and momentum relation in relativity, massless particles.

Minkowski's space time diagrams, Lorentz invariance, space time intervals.

General Relativity (without tensors - introduction only): Principle of equivalence, bending of starlight, perihelion of Mercury, gravitational waves.

Unit V: Electricity (12 lectures/hours)

Network Calculations: Y and Delta networks, conversion between them, superposition.

Thevenin's theorem, Norton's theorem, series-parallel circuits, Wheatstone's bridge circuit, maximum power transfer.

Inductance: inductive reactance, inductors in series and parallel, circuit containing inductance only, RL series circuit, RL parallel circuit, Q of a coil, power in RL circuits.

Capacitance: capacitive reactance, circuit containing capacitance only, RC series circuit, power in RC circuits.
Single Phase Circuits: RLC series circuit, RLC parallel circuit, Q factor and power factor.
Transformers: ideal transformer characteristics, voltage ratio, current ratio, efficiency, impedance ratio, transformer losses and efficiency.
Three Phase Systems: Characteristics, three phase transformer connections, power in balanced three phase loads, unbalanced three phase loads.
Waveforms and Time Constant: RL series circuit waveforms, RL time constant, RC series circuit waveforms, RC time constant.

Reading List for PHY101

Mechanics

Books:

1. *Introduction to Mechanics,* Mahendra K. Verma, (Universities Press)
2. *Mechanics and General Properties of Matter,* P. K. Chakrabarti (New Central Book Agency)
3. *Introduction to Classical Mechanics*, R.G. Takwale, P. S. Puranik, (Tata-McGraw Hill India)
4. *Classical Mechanics*, K. S. Rao, (Universities Press)
5. *Mechanics*, D. S. Mathur, (S. Chand & Company)

References:

1. *Classical Mechanics: Analytical Dynamics*, Tiwari & Thakur, (Prentice Hall of India)
2. *Classical Mechanics*, Herbert Goldstein, Charles P. Poole, John Safko (Pearson Education)
3. *Feynman lectures on Physics Vol 1*, R. P. Feynman, R. B. Leighton, M. Sands, (Narosa Publishing House)
4. *Physics*, Robert Resnick, David Halliday & Kenneth Krane, (Wiley India)

Properties of Matter

Books:

1. *Mechanics and General Properties of Matter,* P. K. Chakrabati, (New Central Book Agency)
2. *Elements of Properties of Matter,* D. S. Mathur, (S. Chand & Company)

References:

1. *General Properties of Matter,* C. J. Smith, (Radha Publishing House)
2. *Feynman lectures on Physics - Vol II,* R. P. Feynman, R. B. Leighton, M. Sands, (Narosa Publishing House)

Relativity

Books:

1. *Concepts of Modern Physics*, Arthur Beiser, (Tata McGraw-Hill)
2. *Modern Physics*, K. S. Krane, (Wiley India Pvt Ltd)
3. *Modern Physics,* Murugeshan & Sivaprasath, (S. Chand & Company Ltd)
4. *Introduction to Mechanics,* Mahendra K. Verma, (Universities Press)

References:

1. *Introduction to Special Relativity,* R. Resnick, (Wiley India Pvt Ltd)
2. *Elements of Properties of Matter,* D. S. Mathur, (S. Chand & Company)
3. *General Theory of Relativity,* P. A. M. Dirac, (Prentice-Hall of India)

Electricity

Books:

1. *Basic Electricity,* Milton Gussow, (Schaum's Outlines, Tata McGraw Hill)
2. *Electricity and Magnetism,* D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)

References:

1. *Introductory Circuit Analysis*, Robert Boylestad, (Prentice Hall)

Semester 1 – Physics (Pass & Honours) Practicals

PHY102

Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of Kater's pendulum
2. Study of elastic constant by Konig's method
3. Study of elastic constant using Barton's apparatus
4. Study of moment of inertia using torsional pendulum
5. Study of viscosity and terminal velocity using Stokes method
6. Study of resistance of a galvanometer using P.O. Box
7. Study of impedance of an AC circuit containing RLC elements
8. Study of figure of merit of a ballistic galvanometer

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

Semester 1 - Physics (Honours) Theory Paper

PHY103

Mathematical Physics I

(3 credits - 45 hours)

Course Overview

Mathematical Physics I focuses on mathematical tools from the physicist's point of view. **Vector Analysis** used extensively in almost all areas of physics; **Matrices** which finds applications in optics, quantum mechanics, solution of linear equations; **Fourier Series** which provides a simple analysis of complex oscillatory phenomena; these are all covered in this course.

At the end of the study, the student will have learned how to use these tools to apply them to various areas of physics and solve problems.

Unit I: Vectors (1) (9 lectures/hours)

Cartesian system of base vectors: orthogonal basis, position vector.
Cauchy's inequality, Vector differentiation: derivative of a vector, del operator, Gradient and its concept, Divergence, Curl and Laplacian operators
Integration of Vectors: line integral, conservative forces, Gauss' divergence theorem, applications to electrostatics, heat conduction.

Unit II: Vectors (2) (9 lectures/hours)

Green's theorem, Applications of Green's theorem, Stokes theorem, Applications of Stokes theorem.
Vector identities: Standard vector identities involving operator with their proofs.
Generalised curvilinear coordinates: orthogonal curvilinear coordinates, scale factors and unit vectors, expressions for gradient, divergence, curl and Laplacian, expressions in plane polar coordinates, cylindrical coordinates, spherical polar coordinates.

Unit III: Matrices (1) (9 lectures/hours)

Column matrix, row matrix, null matrix, matrix operations: addition, multiplication, inner product, direct product.
Derivative of a matrix, integral of a matrix.
Partitioned matrices, sub-matrices.
Transpose, complex conjugate, hermitian conjugate.
Special matrices: unit matrix, diagonal matrix, singular matrix, cofactor matrix, adjoint of a matrix, self-adjoint matrix, symmetric matrix, skew-symmetric matrix.

Unit IV: Matrices (2) **(9 lectures/hours)**

Hermitian matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse of a matrix. Solution of a system of linear equations, eigenvalue value problem.
Coordinate transformations: rotation in two dimensions, rotation in three dimensions.

Unit V: Fourier Series **(9 lectures/hours)**

Fourier Cosine and Sine series, change of interval, Fourier integral, Fourier's Theorem, Dirichlet's condition.
Complex form of Fourier series, examples $f(x) = x^2$ $(-\pi,\pi)$, sawtooth wave, square wave and others, full wave rectifier, heat conduction equation.
Generalised Fourier series and Dirac delta function, Gibbs' phenomena.

Books:

1. *Introduction to Mathematical Physics,* Charlie Harper (Prentice-Hall India)
2. *Mathematical Methods in the Physical Sciences,* Mary L. Boas (Wiley India Pvt Ltd)
3. *Mathematical Physics,* H. K. Dass, (S. Chand)

References:

1. *Mathematical Methods for Physicists,* Arfken and Weber (Academic Press)
2. *Mathematical Physics,* B. D. Gupta (Vikas Publication House Pvt Ltd)
3. *Mathematical Physics,* B. S. Rajput. (Pragati Prakashan)
4. *Vector Analysis (Schaum's Outline),* Murray Spiegel (Tata McGraw-Hill)
5. *Matrices and Tensors in Physics,* A. W. Joshi (New Age International)

Semester 2 – Physics (Pass & Honours) Theory Paper

PHY201

Thermal Physics & Oscillations

(4 credits – 60 hours)

Course Overview

Thermal Physics studies the relation between heat and work, the motion at the molecular and atomic level and its relation to the quantity we call heat and temperature on the large scale platform. This paper also deals with the kinetic theory, thermodynamics and thermal properties at ultra cold temperatures and the phenomenon of superconductivity. **Oscillations** starts from a study of simple repetitive motion of particles and then on to more complex motions which is at the heart of much of physics: mechanical oscillations such as sound, water waves to electrical oscillations and waves to quantum phenomenon. It ends with application of sound in real life; hall acoustics, music etc.

At the end of the study, the student will have learned the fundamental principles governing the behaviour of matter at the molecular level and its large-scale aspects of heat and temperature, have conceptual and mathematical understanding of the principles of oscillation physics and develop problem solving skills in these areas.

Unit I : Thermal Physics (12 lectures/hours)

(a) Kinetic Theory of Gases

Maxwell's velocity distribution, average speed, rms speed, most probable speed, energy distribution of molecules, temperature dependence, degrees of freedom and equipartition of energy, mean free path, collision probability.

Transport phenomena: viscosity, diffusion, transport coefficients and size of molecules, relationship between transport coefficients, Brownian motion, vertical distribution of Brownian particles, Einstein's Theory of Brownian motion.

Behavior of Real Gases, isotherms and deviations from perfect gas equation, virial coefficients, van der Waals' equation of state, van der Waals' constants, critical constants.

(b) Radiation

Radiation: black body, Kirchoff's law, energy density and pressure of diffuse radiation, Stefan-Boltzmann law and Newton's law of cooling, Wein's law, Rayleigh-Jeans law, UV catastrophe, Planck's law.

Unit II: Thermodynamics (12 lectures/hours)

Thermodynamics system, thermodynamics equilibrium, thermodynamic processes, first law of thermodynamics, difference between specific heats (Mayer's relation), elasticities of perfect gas, work done in different processes.

Second law of thermodynamics, Carnot cycle, heat engines, thermal efficiency, refrigerator, different statements of the second law, Carnot's theorem, reversible and irreversible processes, entropy, entropy change in reversible processes, principle of increase of entropy, Joule expansion, entropy change of an ideal gas and van der Waals' gas, entropy and disorder, heat death.

Heat Engines: Rankine cycle, Otto cycle, Diesel cycle.

Low Temperature Physics: Joule-Thomson effect for a real gas, Joule-Thomson effect for a van der Waals' gas, regenerative cooling, adiabatic demagnetization, third law of thermodynamics and its consequences.

Unit III: Oscillations & Waves (12 lectures/hours)

(a) Simple Harmonic Oscillations

Differential Equation of simple harmonic motion and its solution, displacement, velocity and acceleration, energy of oscillations, elasticity and simple harmonic vibrations, study of oscillations: gas in a cylinder, mass suspended by a spring, superposition of rectangular simple harmonic oscillations, Lissajous figures.

Damped simple harmonic vibration, motion of a dissipative system, energy of damped vibrations, effect of damping on frequency.

Forced vibration and resonance, amplitude resonance, power dissipation and sharpness of resonance, Q factor, mechanical impedance and resonance.

(b) Progressive Waves

Transverse and longitudinal waves, condensation and pressure curve, velocity curve, equation of a progressive wave, particle velocity and acceleration, wave velocity and particle velocity, differential equation of wave motion, energy of progressive wave.

Unit IV: Vibrations & Sound Waves (12 lectures/hours)

(a) Vibration of Strings:

Equation of motion of a vibrating string, velocity of waves along a string, frequency and period of vibration of a string, harmonics and overtones.

(b) Propagation and Velocity of Sound Waves

Velocity of a wave in a fluid, Laplace's correction, factors affecting velocity, velocity of sound in solids, velocity of torsional waves in a rod.

(c) Interference of Sound Waves

Interference of parallel wave trains, interference of spherical waves, zones of silence, beats, combination tones.

(d) Stationary Waves

Reflection of waves in strings from free and fixed ends, stationary waves, nodes and anti-nodes, pressure and density changes at nodes and anti-nodes, distribution of energy in a stationary wave.

(e) Reflection, Refraction and Diffraction

Reflection of sound waves, Huygen's Principle, acoustical image, echo, reflection from curved surfaces, Applications of reflection.

Refraction of sound waves, Huygen's Principle, effect of wind on refraction of sound, effect of temperature.

Diffraction of sound waves, sound shadow, diffraction bands, sound filter,megaphone.

(f) Attenuation of Sound Waves

Causes of dissipation of sound energy, effect of viscosity, attenuation constant, effect of heat conduction, absorption of high frequency waves in gases, sound absorption in narrow tubes and cavities, transmission of power by plane waves, radiation resistance.

Unit V: Oscillations & Waves: Applications (12 lectures/hours)

(a) Vibration of Rods and Surfaces

Longitudinal vibrations of rods, velocity of a longitudinal wave in a rod, stationary longitudinal waves in rods, transverse vibration of rods, tuning fork, vibration of plates, Chladni's figures, vibration of bells, vibration of stretched membranes and diaphragms, (non-mathematical treatment).

(b) Vibration of Air Columns

Flue pipes and reed pipes, vibrations of air columns in closed and open organ pipe, overtones, resonance in air columns, end corrections, effect of temperature on pitch.

(c) Musical Sounds

Noise and musical sounds, loudness, intensity level, decibel and phon, intensity of a sound, pitch, quality of sound.

(d) Musical Scales and Consonance

Diatonic musical scale, musical intervals, consonant intervals, Helmholtz's theory, consonance of important musical intervals, beats caused by difference tones and its effect on music, equal tone temperament..

(e) Technical Applications of Acoustical Principles

Sound ranging, geophone, hydrophone, echo sounding, seismograph, ultrasonics, piezoelectric effect, resonant vibration of crystal slices, piezoelectric generator, magnetostriction.

Architectural Acoustics: reverberation, absorption coefficient, Sabine's law, good acoustical designs of rooms, noise, measurement, noise reduction and sound insulation.

Reading List for PHY201

Thermal Physics

Books:

1. *Heat & Thermodynamics,* A. B. Gupta & H. P. Roy (New Central Book Agency)
2. *Theory and Experiment on Thermal Physics,* P. K. Chakrabarti (New Central Book Agency)
3. *Thermodynamics: A Core Course,* Saha Jain Srivastava, Abhay K. Jain (Prentice Hall of India)
4. *Thermodynamics,* S. C. Gupta (Pearson Education)
5. *Thermal Physics, S.* Garg, R. Bansal, C. Ghosh (Tata-McGraw Hill)
6. *A Text Book of Heat and Thermodynamics,* J. B. Rajam and C. L. Arora (S. Chand & Company)

References:

1. *A Treatise on Heat,* M. N. Saha and B. N. Srivastava, (Indian Press)
2. *Text Book of Thermodynamics,* D.K. Jha (Discovery House Publishers)

Oscillations

Books:

1. *A Text Book of Sound,* D. R. Khanna and R. S. Bedi, (Atma Ram & Sons)
2. *Vibrations, Waves and Acoustics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Sound,* M. Ghosh, (S. Chand & Company)

References:

1. *Fundamentals of Acoustic,* Lawrence Kinsler and Austin Frey, (Wiley Eastern)
2. *Introduction to Mechanics,* Mahendra K. Verma, (Universities Press)

Semester 2 – Physics (Pass & Honours) Practicals

PHY202

Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of mechanical equivalent of heat by Joule's electrical calorimeter
2. Study of linear expansion of a solid by Pullinger's apparatus
3. Study of oscillations by Melde's apparatus
4. Study of Lissajous' figures with CRO
5. Study of specific heat by the method of cooling
6. Study of pressure coefficient and volume coefficients by Joly's constant volume and constant pressure thermometer
7. Study of resonance in series LCR circuits
8. Study of resonance in parallel LCR circuits

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

Semester 2 - Physics (Honours) Theory Paper

PHY203

Mathematical Physics - II

(2 credits - 30 hours)

Course Overview

This paper dwells on the mathematical tools for the physicist. **Differential Equations** provides a simple description of natural phenomena involving rate at which things happen and has wide application in modeling (situations where simple equations and solutions are not available). Not only in physics but other areas of science and economics makes extensive use of differential equations. The harmonic functions such as Legendre polynomials, Hermite functions, Bessel functions etc will be studied in this paper. **Beta and Gamma Functions** which are essential to the solution of many integrals in applied physics, are covered in this paper.

At the end of the study, the student will have learned how to use these tools to apply them to various areas of physics and solve problems.

Unit I: Differential Equations (1) (6 lectures/hours)

Ordinary differential equations: first order homogeneous/non-homogeneous equations with variable coefficients, separable equations, exact differentials.
General first order linear differential equation, integrating factor, Jacob Bernoulli equation.
Second order homogeneous equations with constant coefficients, examples: classical linear harmonic oscillator.

Unit II: Differential Equations (2) (6 lectures/hours)

Second order non-homogeneous equations with constant coefficients, examples.
Second order non-homogeneous equations with variable coefficients, examples.
Second order homogeneous equations with variable coefficients, examples.

Unit III: Differential Equations (3) (6 lectures/hours)

Partial Differential Equations: introduction and some examples - wave equation in 1-dimension, Poisson's and Laplace's equations, diffusion equation, Schrödinger wave equation, Helmholtz's equation, method of separation of variables.
Special Functions: One dimensional linear harmonic equation as Hermite's equation, series solution of Hermite's equation, generating function, Rodrigue's formula, Weber-Hermite functions, energy quantization, zero point energy.
Laplace's equation in spherical coordinates, spherical harmonics, separation of variables, solution to the azimuthal equation (Legendre differential equation).

Unit IV: Differential Equations (4) (6 lectures/hours)

Associated Legendre polynomials, angular momentum quantum number.

Radial equation and the Laguerre equation, solutions of the Laguerre equation, associated Laguerre polynomials.

Helmholtz's equation in cylindrical coordinates and Bessel's equation, solution of Bessel's equation, Bessel functions of the 1st kind, Bessel functions for integral, half-integral orders, Neumann functions.

Unit V: Differential Equations (5) (6 lectures/hours)

Hankel functions, modified Bessel function, spherical Bessel function, characteristics of various Bessel functions.

Gamma function, recursion formula, beta functions, their different forms, relation between beta and gamma functions, evaluation of integrals using gamma-beta functions

Books:

1. *Introduction to Mathematical Physics,* Charlie Harper (Prentice-Hall of India)
2. *Mathematical Methods in the Physical Sciences,* Mary L. Boas (Wiley India Pvt Ltd)
3. *Mathematical Physics,* H. K. Dass, (S. Chand)

References:

1. *Mathematical Methods for Physicists,* Arfken and Weber (Academic Press)
2. *Mathematical Physics,* B. D. Gupta (Vikas Publication House Pvt Ltd)
3. *Mathematical Physics,* B. S. Rajput (Pragati Prakashan)

PHY204

Computational Physics Practicals

(1 credit)

Course Overview

This course introduces computational approach to solve physics problems. After introducing the nuances of numerical programming, four different problems are addressed. Although each problem may have various approaches with their advantages and disadvantages, only one approach is selected. This is to ensure that the student gets enough time to focus on the problem and learn this new discipline.

At the end of the course, the student will have learnt to do numerical computations and be able to apply it to real-life problems of physics.

LIST OF NUMERICAL PROGRAMS TO DEVELOP

1. Numbers and their accuracy: exact and approximate numbers, significant digits and rounding off, errors and their computation, inherent errors and truncation errors
2. Displaying text: source code of a program, its structure, compiling a program, executing the compiled program, example of *Hello World*
3. Programming language characteristics: (taking Fortran as example, corresponding equivalents may be used for C or C++) character set, constants, variables, arithmetic expressions and statements, basic library functions
4. Introductory Program 1: *How to define variables and evaluate arithmetic expressions*
   (With two numbers, to add, subtract, multiply, divide, exponentiation)
5. Introductory Program 2: *How to handle large/small numbers, define constants and use format command to display the results*
   (To calculate up to nine significant figures, the gravitational force and the coulomb force between two electrons separated 1 mm apart and to find their ratio etc)
6. Introductory Program 3: *How to use control statements*
   (To identify maximum, minimum and range of a set of numbers)
7. Introductory Program 4: *How to use loops to sum a series*
   (ex: To find the value of e^x for a given x)
8. Program 5: *Finding the roots of a program by Newton-Raphson method*
   (a) Theory
   (b) Demo with different examples
   (c) Typing/developing of code by student
   (d) Compilation, execution and troubleshooting

(e) Running code for at least three different variable examples – calculating the error in the result
(f) Summary and submission of report by student

9. Program 6: *Interpolating a function by Lagrange's method* (with same six steps as above)
10. Program 7: *Numerical integration by Simpson's ⅓ rule* (with same six steps as above) (Background of trapezoid integration given first in theory)
11. Program 8: *Numerical solution of a differential equation by Runge-Kutta method* (with same six steps as above)
12. Program 9: *Least Squares approximation of a function by linear regression* (with the same six steps as above)

Books:

1. *Computer Oriented Numerical Methods,* V. Rajaraman, (Prentice Hall of India)
2. *Introductory Methods of Numerical Analysis,* S. S. Sastry (Prentice-Hall India)
3. *Fortran 77 and Numerical Methods,* C. Xavier (New Age International Publishers)

References:

1. *Numerical Recipes in Fortran*, William Press, Saul Teukolsky, William Vetterling, Brian Flannery (Cambridge University Press)
2. *Numerical Recipes in C*, William Press, Saul Teukolsky, William Vetterling, Brian Flannery (Cambridge University Press)
3. *Numerical Recipes: The Art of Scientific Computing*, William Press, Saul Teukolsky, William Vetterling, Brian Flannery (Cambridge University Press)
4. *Numerical Mathematical Analysis,* J. B. Scarborough (Oxford and IBH Publishing Co)

NOTE:

1. Computational Physics is only for Honours students. However, pass course students may be given the chance to attend this course if they so desire, as a non-credit course. It is expected that having learnt the essentials of programming, students will use this skill to gain better understanding of Physics as they go on to higher semesters.
2. Programming languages such as FORTRAN, C, C++ may be used. However, use of sophisticated software such as Maxima, Mathematica, Maple, Mathcad, Matlab etc (where the programming details are hidden from the user) may not be used. Other skills such as reading and writing to a file, using dimensioned variables, defining functions, plotting graphs etc may be developed gradually.
3. The choice of operating systems such as Linux/Open Source products is highly recommended as most distributions come complete with editors, graph plotting programs and compilers with support for the above mentioned programming language. Additional software can also be freely downloaded from the internet.

Semester 3 - Physics (Pass & Honours) Theory Paper

PHY301

Electrodynamics I and Quantum Mechanics I

(4 credits - 60 hours)

Course Overview

Electrodynamics I expounds on the fundamental inter-relation between magnetism and electricity. It starts off from Coulomb's law and ends up in electro-magnetic induction which relates mechanical energy to electric and magnetic energies. **Quantum Mechanics** studies the properties of matter and energy at sub-atomic levels and takes a different look at reality with non-intuitive conclusions. The student will learn how starting from simple assumptions, one can calculate the energy levels and states of atoms, lifetime of states etc.

At the end of the study, the student will have learnt the fundamental principles governing the relationship between electric and magnetic fields, have conceptual and mathematical understanding of the close inter-relation between electricity and magnetism as well as quantum mechanical concepts and develop problem solving skills.

Unit I: Electrostatics **(12 lectures/hours)**

Coulomb's law, electric field, continuous charge distributions, electric field lines, electric flux, Gauss' law, differential and integral form, applications of Gauss' law, curl of **E,** electric potential, Poisson's and Laplace's equation, potential of localised charge distributions, electrostatic boundary conditions.

Work done to move a charge, energy of a point charge and continuous charge distributions.

Basic properties of conductors, induced charges, surface charge and force on a conductor.

Capacitors and energy in a charged capacitor, electric dipoles (without multipole expansion), potential, field (polar and vector forms).

Unit II: Electric Fields **(12 lectures/hours)**

Force in a non uniform field, torque and energy in an uniform field.

Method of images: point charge in front an infinite grounded plane, induced surface charge, force and energy, point charge near a grounded conducting sphere

Electric Fields in Matter

Dielectrics, induced dipoles, atomic polarizability, alignment of polar dipoles, electric polarization, electric field of a uniformly polarized sphere, bound charges and their interpretation, electric field inside a dielectric, electric displacement, Gauss' law for dielectrics, boundary conditions.

Linear dielectrics: susceptibility, absolute and relative permittivity, dielectric constant, parallel plate capacitor with a dielectric, energy in a dielectric system, forces on a dielectric, Clausius-Mossotti equation.

Unit III: Magnetic Fields (12 lectures/hours)

Lorentz force law, cyclotron motion, cycloid motion.

Currents: line, surface and volume currents, continuity equation.

Biot-Savart's law, magnetic flux, Ampere's law: integral and differential form, application of Ampere's law: straight line current, uniform surface current, application of Ampere's law: solenoid, toroid.

Magnetic vector potential (without problems): magnetostatic boundary conditions, magnetic dipoles (without multipole expansion): torque and energy in an uniform field.

Magnetic Field in Matter

Effect of magnetic field on atomic orbits.

Magnetization, vector potential of a magnetised object, magnetic field of a uniformly magnetised sphere, bound currents, Ampere's law in magnetised materials, boundary conditions, magnetic susceptibility, absolute and relative permeability.

Electrodynamics

Ohm's law; emf, Faraday's and Lenz's laws, inductance and Neumann formula, energy in a magnetic field.

Maxwell's equations: displacement current, charging capacitor, Maxwell's equations in vacuum, Maxwell's equations in matter.

Unit IV: Quantum Mechanics (1) (12 lectures/hours)

Particle Properties of Waves

Photoelectric effect, Einstein's photoelectric equation, Compton effect, pair production, gravitational red shift.

Wave Properties of Particles

Dual nature of light, wave-particle duality, de-Broglie waves, probability density, characteristics of waves (amplitude, frequency, angular frequency, time period, wave number, phase), wave packet, phase velocity, group velocity.

Davisson and Germer's experiment, G. P. Thomson's experiment, energy levels for a particle in a box.

Uncertainty principle

Gamma ray microscope, electron diffraction, uncertainty principle in atomic emissions, non-existence of nuclear electrons, proof using one-dimensional wave packet.

Unit V: Quantum Mechanics (2) (12 lectures/hours)

Wave Mechanics

Wave function, normalisation, well-behaved wave functions, time-dependent wave equation, superposition of wave functions, expectation values, operators: energy and momentum operators.

Time-independent Schrödinger equation, eigenvalues, eigenfunctions, Hamiltonian operator.

Applications of the Wave Equation

Particle in a rigid box: energy levels, eigenfunctions, momentum.

Approximation to particle in a non-rigid box, step potential: reflectance and transmittance, probability current and its conservation, tunnel effect: transmission coefficient, applications of tunnel effect (without derivations): Scanning Electron Microscope, Atomic Force Microscope, α-decay.

Harmonic oscillator: energy levels, zero-point energy, wave functions of harmonic oscillator (without derivation) for first four, tenth quantum states.

Postulates of Quantum Mechanics

Five basic postulates of quantum mechanics with explanations.

Reading List for PHY301

Electrodynamics

Books:

1. *Introduction to Electrodynamics,* D. J. Griffiths, (Prentice-Hall of India)
2. *Electricity and Magnetism*, A. S. Mahajan and A. A. Rangwala, (Tata McGraw-Hill)
3. *Electricity and Magnetism*, Prantosh Chakraborty, (New Age International)
4. *Electricity and Magnetism,* D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
5. *Electricity and Magnetism,* K. K. Tewari, (S. Chand)
6. *Electricity and Magnetism,* R. Murugeshan, (S. Chand)
7. *Electricity and Magnetism,* Navina Wadhwani, (Prentice-Hall India)

Reference:

1. *Feynman Lectures in Physics - Volume II,* R. P. Feynman, R. B. Leighton and M. Sands, (Narosa Publishing House)
2. *Electricity and Magnetism,* Edward M. Purcell, (Tata McGraw-Hill)

Quantum Mechanics

Books:

1. *Concepts of Modern Physics,* Arthur Beiser, (Tata McGraw-Hill)
2. *Modern Physics, R.* Murugeshan and K. Sivaprasath, (S. Chand & Company Ltd)

References:

1. *Modern Physics,* K. S. Krane, (Wiley India Pvt Ltd)
2. *Introduction to Quantum Mechanics,* D. J. Griffiths, (Pearson Education)
3. *Quantum Mechanics,* G. Aruldhas, (Prentice Hall India)
4. *Quantum Mechanics,* John L. Powell and Bernd Crasemann, (Oxford & IBH Publishing Co)

PHY302

Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of magnetic moments using magnetometer
2. Study of variation of magnetic field with current and distance
3. Study of thermocouples
4. Study of photo electric effect and Planck's constant
5. Study of O ray and E ray by spectrometer using calcite/quartz prism
6. Study of electrolytic conductivity by Kohlrausch's method
7. Study of reduction factor of tangent galvanometer
8. To measure resistance of a wire using Carey Foster bridge

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Text Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

Semester 3: Physics (Honours) Theory Paper

PHY303

Thermodynamics & Statistical Physics

(3 credits - 45 hours)

Course Overview

This course is an advanced treatment of **Thermodynamics**. Starting from Maxwell's equations, it relates the measurable properties such as pressure and temperature to more abstract quantities such as entropy as well as phase transitions. **Statistical Physics** studies the motion of matter at the atomic level and relates the microscopic quantities such as molecular velocities to the macroscopic quantities such as pressure, heat etc and connects order/disorder to entropy. The statistics of classical particles and quantum particles are also discussed.

At the end of the study, the student will have learned the fundamental principles of heat at the macroscopic and microscopic levels, have conceptual and mathematical understanding of the principles involved and develop problem solving skills.

Unit I: Thermodynamic Relationships (9 lectures/hours)

Maxwell's Relations, applications: specific heat equation, Joule-Thomson cooling, Clausius-Clayperon equation, thermodynamic relations with heat capacities, T-dS equations, free energy equations, heat of reaction (Gibbs-Helmholtz equation).

Free Energies, Equilibria & Phase Transitions

Helmholtz free energy, Gibbs free energy, enthalpy, thermodynamic potentials, thermodynamic equilibrium.

Unit II: Thermodynamics (Phase Transitions) (9 lectures/hours)

Equilibrium between phases, phase transition, first order phase transitions, saturated vapour pressure, Young and Kirchoff's equation.

Clausius equation (second latent equation), second order phase transitions, Ehrenfest's equations, triple point, thermodynamics of triple point.

Behavior of thermodynamic potential during phase transition, Gibbs' phase rule.

Unit III: Statistical Physics (1) (9 lectures/hours)

Statistical Basis of Thermodynamics

Energy states and energy levels, degeneracy, macroscopic and microscopic states, thermodynamic probability and mathematical probability, connection between statistics and thermodynamics, physical significance of Ω, Boltzmann's theorem and entropy, classical ideal gas.

Statistical Description of Systems of Particles

Statistical description of states, statistical ensemble, number of states accessible to a macroscopic system, constraints, equilibrium and irreversibility, quantum state and phase space.

Ensembles

Microcanonical ensemble, canonical ensemble, grand canonical ensemble, partition function, statistical analogue of entropy, electronic partition function.

Unit IV: Statistical Physics (2) (9 lectures/hours)

Classical Statistics

Maxwell-Boltzmann distribution formula, Gibb's paradox, law of equipartition of energy, Maxwell-Boltzmann distribution of molecular velocities, partition function and thermodynamic quantities.

Quantum statistical mechanics

Difficulties with classical statistics, Bose-Einstein statistics, chemical potential, Boltzmann limit, Ideal Bose systems: Planck's radiation law, Bose-Einstein condensation.

Unit V: Statistical Physics (3) (9 lectures/hours)

Fermi Dirac statistics, Fermi energy, Boltzmann limit for the fermion system, Richardson-Dushmann equation for thermionic emission.

Applications of statistical mechanics: equation of state for an ideal gas, equilibrium of sedimentation, classical para-magnetism, Liouville's theorem.

Reading List for PHY303

Thermodynamics

Books:

1. *Heat and Thermodynamics,* A. B. Gupta and H. P. Roy (New Central Book Agency)
2. *Heat, Thermodynamics and Statistical Physics,* Brij Lal, N. Subrahmanyam, P. S. Hemne (S. Chand & Co)

References:

1. *A Treatise on Heat,* Saha & Srivastava, (Universities Press)

Statistical Physics

Books:

1. *Fundamentals of Statistical Mechanics,* A. K. Dasgupta (New Central Book Agency)
2. *Heat and Thermodynamics,* A. B. Gupta and H. P. Roy (New Central Book Agency)
3. *Heat, Thermodynamics and Statistical Physics,* Brij Lal, N. Subrahmanyam, P. S. Hemne (S. Chand & Co)

References:

1. *Fundamentals of Statistical and Thermal Physics,* Frederick Reif, (McGraw-Hill)

PHY401

Electronics I & Optics

(4 credits - 60 lectures)

Course Overview

Electronics is at the heart of the amazing technology at our disposal. The students will learn about the building blocks of electronics technology (diodes and transistors) and their roles and properties in different circuits. In **optics**, the student will study the principles of image formation from geometrical considerations and the oscillatory nature of light is brought out by the phenomenon of interference, diffraction and its relation to electrodynamics through the phenomenon of polarization and lasers.

At the end of the study, the student will have learned the fundamental principles governing the operation of electronic devices and circuits and optics, have developed conceptual and mathematical understanding of the principles involved and develop problem solving skills.

Unit I: Electronics (Diodes) (12 lectures/hours)

p-n junction diode: forward and reverse biasing of *p-n* junction diode with their respective *V-I* characteristics, avalanche breakdown and dynamic resistance, load line and Q-point.
Junction diode as a half wave rectifier with mathematical analysis for DC current and power output, RMS output current, AC power input, rectifier efficiency, ripple factor, peak inverse voltage, voltage regulation.
Full wave rectifier (for centre tapped transformer) with mathematical analysis for DC output current (average and RMS), power supplied and power output to a load, efficiency, ripple factor, PIV, bridge rectifier, average value of output voltage, output frequency.
Filter circuits with ripple factor calculations for shunt capacitance, series inductance, L – section filter, π – section filter.
Zener diode: *V-I* characteristics, voltage regulation.

Unit II: Electronics (Transistors) (12 lectures/hours)

Construction (*pnp* and *npn*) of transistors and principles of operation, CE *V-I* input-output characteristics and current gain, CB circuit, current amplification factor, relation between α and β, active region, cut-off region, saturation region, dynamic output resistance, current gain, CB characteristics: input and output characteristics, CC circuit, input and output characteristics.
Transistor Biasing
Base bias, collector bias, emitter bias, thermal runaway, voltage divider circuit and its AC equivalent circuit.

Transistor amplifiers

CE amplifier; DC current gain, AC current gain, voltage and power gain, input-output phase relationship, DC load line, AC load line and Q-point.

Frequency response of (capacitor coupled and bypass capacitor) CE single stage amplifier.

Field Effect Transistors

Construction (*n*-channel, *p*-channel) and principle, *n*-channel characteristics, drain curves, transconductance curves, drain resistance, transconductance, amplification factor, their relations.

Unit III: Optics (Geometrical Optics & Interference) (12 lectures/hours)

Geometrical Optics

Aberrations: chromatic aberrations, achromatic doublet, removal of chromatic aberration of a separated doublet, monochromatic aberrations: spherical aberrations, coma, astigmatism, distortion.

Interference

Interference from two point sources by division of wavefront, intensity distribution, Fresnel's bi-prism, phase change on reflection.

Interference by division of amplitude, colours of thin films, Newton's rings, Michelson's interferometer, coherence, line width, spatial coherence.

Unit IV: Optics (Diffraction) (12 lectures/hours)

Fraunhofer diffraction from single slit, limit of resolution and resolving power, two-slit Fraunhofer diffraction pattern, N-slit diffraction pattern, diffraction grating and resolving power.

Fresnel diffraction, half period zones, zone plate, diffraction at a straight edge.

Unit V:Optics (Polarization & Lasers) (12 lectures/hours)

Polarization

Production of polarized light, polarization by reflection, polarization by double refraction, Malus law, superposition of two disturbances, double refraction, interference of polarized light, optical activity.

Lasers

Einstein coefficients, population inversion, ruby laser, He-Ne laser, line shape function, threshold power calculation for ruby laser, optical resonators, stability conditions

Reading List for PHY 401

Electronics I

Books:

1. *Modern Physics,* R. Murugeshan and S. Sivaprasath, (S. Chand & Company Ltd)
2. *Handbook of Electronics,* S. L. Gupta, V. K. Kumar, (Pragati Prakashan)
3. *Basic Electronics (Solid State),* B. L. Theraja, (S. Chand & Company Ltd)

References:

1. *Electronic Principles,* A. P. Malvino, (Tata McGraw-Hill)
2. *Electronic Devices and Circuits,* Theodore F. Bogart, (Prentice Hall)
3. *Basic Electronics for Scientists,* James Brophy, (McGraw-Hill)
4. *Electronic Fundamentals and Applications,* John Ryder, (Prentice Hall)

Optics

Books:

1. *Optics,* Ajoy Ghatak, (Tata McGraw-Hill Publishing Company Ltd)
2. *Geometrical and Physical Optics,* P. K. Chakrabarti, (New Central Book Agency)
3. *Lasers and Non-Linear Optics,* B. B. Laud, (New Age International)
4. *A Text Book of Optics,* N. Subrahmanyam & Brij Lal, (S. Chand & Company)

References:

1. *Optics*, Miles V. Klien & Thomas E. Furtak, (John Wiley & Sons)
2. *Fundamentals of Optics*, Francis A. Jenkins & Harvey E. White, (McGraw-Hill)
3. *Lasers*, K. R. Nambiar, (New Age International)
4. *Optics*, Hecht (Pearson Education)

PHY402

Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of rectifiers
2. Study of voltage regulation
3. Study of transistors characteristics and h parameters
4. Study of diode characteristics
5. Study of interference using Fresnel's bi-prism
6. Study of interference using diffraction grating
7. Study of optical activity using polarimeter
8. Study of refractive index of a prism using spectrometer

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

Semester 4 - Physics (Honours) Theory Paper

PHY403

Mathematical Physics III & Quantum Mechanics II

(3 credits - 45 hours)

Course Overview

The algebra and calculus of complex number and complex functions is developed in **Mathematical Physics III** and the student will appreciate how complex integrations can greatly simplify a problem. Tensors which takes mathematics to a higher level of understanding and is the language of general relativity, fluid mechanics, elasticity, electrodynamics is studied in this paper. **Quantum Mechanics II** focuses of the matrix mechanics approach to the study of the field and develops the operator mechanism for solution of problems.

At the end of the study, the student will have learnt the fundamental principles governing the physical properties of matter at sub-microscopic levels, have developed conceptual and mathematical understanding of the principles involved and develop problem solving skills using these and the mathematical tools developed.

Unit I: Mathematical Physics (Complex Analysis) (9 lectures/hours)

Complex Functions

Derivative of *f(z)* and analyticity, Cauchy-Riemann conditions, Harmonic functions.
Contour integrals, Cauchy integral theorem, Cauchy's integral formula, Taylor series, Maclaurin series, Laurent expansion, analytical and principal parts.

Calculus of Residues

Zeros, singular points, poles, evaluation of residues: *n*th order pole, simple pole, Cauchy residue theorem, Cauchy principal value, evaluation of definite integrals .
Dispersion relations, Hilbert transform, conformal mapping.

Unit II: Mathematical Physics (Tensors) (9 lectures/hours)

Notation, Rank and number of components of a tensor.
Transformation of co-ordinates in linear space, Einstein summation convention, Jacobian, Tensors of 1st rank, Kronecker delta, scalars and their invariance, higher rank tensors.
Symmetric and anti-symmetric tensors, polar and axial vectors.
Tensor addition, multiplication, contraction and inner products, quotient law.

Unit III: Quantum Mechanics (Operator Formalism) (9 lectures/hours)

Linear Vector Space, orthogonal functions.
Operators, linear operators, product of two operators, commuting and non-commuting operators, commutator algebra and some relations; $[x,p_x]$, $[H, p_x]$,
Eigen values and eigen functions, Hermitian operators, properties and theorems.

Postulates of Quantum Mechanics - 1 (wave function, operators, expectation values).
Postulates of Quantum Mechanics - 2, (eigen values, eigen functions).
Time evolution of a quantum system, simultaneous measurability of observables, general uncertainty relation.

Unit IV: Quantum Mechanics (Operator Approach) (9 lectures/hours)

Operator approach to Linear Harmonic Oscillator

Simple harmonic oscillator, creation and annihilation operators, commutator relations, eigen values, ground state, excited state, eigen functions and probability functions, orthogonality of the wave functions.

Angular Momentum

Cartesian operators for angular momentum and their commutation relations, ladder operators, L_z operator and their commutation relations, general orbital angular momentum operators in spherical coordinates. and their commutations, eigen values of L_2 and L_z operators, eigen functions of the angular momentum operators.

Unit V: Quantum Mechanics (Spin & Theory of Hydrogen Atom)
(9 lectures/hours)

Spin

Stern-Gerlach experiment, Uhlenbeck and Goudsmit's hypothesis for spin, spin angular momentum, spin 1/2 systems, spin magnetic moment of the electron, Pauli spin matrices and their properties, spin vectors.

Quantum theory of Hydrogen Atom

Schrödinger equation for the Hydrogen atom, and separation of the variables, solutions and the quantum numbers, space quantization, effect of spin.

Reading List for PHY403

Mathematical Physics III

Books:

1. *Introduction to Mathematical Physics,* Charlie Harper (Prentice-Hall India).
2. *Mathematical Methods in the Physical Sciences,* Mary L. Boas (Wiley India Pvt Ltd)
3. *Mathematical Physics ,* H. K. Dass, (S. Chand)

References:

1. *Mathematical Methods for Physicists,* Arfken and Weber (Academic Press)
2. *Mathematical Physics,* B. D. Gupta (Vikas Publication House Pvt Ltd)
3. *Mathematical Physics,* B. S. Rajput. (Pragati Prakashan)

Quantum Mechanics II

Books:

1. *Quantum Mechanics,* G. Aruldhas (Prentice-Hall India)
2. *Introduction to Quantum Mechanics,* D. J. Griffiths (Pearson Education)
3. *Quantum Mechanics,* Ajoy Ghatak and S. Lokanathan (Macmillan India Ltd)
4. *Modern Physics,* R. Murugeshan and S. Sivaprasath; (S. Chand & Company Ltd.)

References:

1. *Feynman Lectures in Physics,* Feynman, Mathew, Sands (Narosa Publishing House)
2. *The Principles of Quantum Mechanics,* P. A. M. Dirac (Oxford University Press)

Semester 5 - Physics (Pass & Honours) Theory Paper

PHY501

Nuclear Physics I & Solid State Physics I

(4 credits - 60 hours)

Course Overview

Nuclear Physics I focuses on the sub-atomic world of the nucleus and its constituents. The shape of the nucleus and its properties, the lifetime of excited states and the extraction of energy through the process of fusion and fission will be studied. **Solid State Physics I** studies the inter-relations between the atoms to form the structures that we are more familiar with. From thermal properties and electrical properties of matter to the shape of the atomic crystals - the reach of this subject is vast.

At the end of the study, the student will have learnt the fundamental principles governing the behaviour of the nucleus and the complex relations between atoms to form structures through bonds, have conceptual and mathematical understanding of the principles of physics involved and develop problem solving skills.

Unit I: Nuclear Physics (Nuclear Structure & Radioactivity) (12 lectures/hours)

Nuclear Structure

Nuclear constituents, nuclear sizes and shapes, nuclear radii, nuclear masses, binding energy, binding energy per nucleon, packing fraction, nuclear forces, exchange forces (meson theory).

Radioactivity

Nuclear stability and decay, radioactivity, activity, radioactive decay laws, half life, mean life, Curie, conservation laws, Q value, α decay, Gamow's theory, properties of α particles (charge/mass, charge, velocity range, spectra), β decay, β decay spectra.

Unit II: Nuclear Physics (Radioactivity & Nuclear Reactions) (12 lectures/hours)

Radioactivity

Fermi's theory of β decay, *K* electron capture, γ decay, theory/origin of γ decay, nuclear isomerism, natural radioactivity, radio carbon dating, biological effects, Mossbauer effect.

Nuclear Reactions

Nuclear reactions and cross section, barns, centre of mass coordinate systems, compound nucleus, radio isotope production, low energy reactions, *Q* value, threshold kinetic energy.
Fission, delayed neutrons, neutron moderators, nuclear fission reactors, different types (in brief).
Fusion reaction, *p-p* cycle, *CNO* cycle, confinement of fusion reactions: magnetic confinement (tokamak), inertial confinement (laser squeezing), applications in brief: Medical radiation physics, neutron activation analysis, synthetic elements.

Unit III: Nuclear Physics (Detectors & Accelerators) (12 lectures/hours)

Particle Detectors

Ionization chamber, solid state detectors, Geiger-Muller counter, Wilson cloud chamber, spark chamber, nuclear emulsions, scintillation counter, Cerenkov counter.

Particle Accelerators

Cockcroft-Walton tension multiplier, Van de Graaf generator, linear accelerator, cyclotron electron synchrotron, proton synchrotron, betatron.

Unit IV: Solid State Physics (1) (12 lectures/hours)

Properties of Crystals

Crystalline and Amorphous solids: long-range and short-range order, crystal defects, point defect, ductility, edge dislocation, screw dislocation.

Crystal lattice: lattice translation vectors, unit cell, symmetry operations: translation, rotation, reflection, inversion, types of lattices: lattice directions and planes, Miller indices, inter-planar spacing.

Simple crystal structures: hexagonal closed-packed structure, face-centered cubic structure, body-centered cubic structure, simple cubic structure, packing fractions of different crystal structures.

X-ray diffraction: Bragg's law

Crystal Binding

Bonding in Solids: ionic crystals: electron affinity, cohesive energy, binding energy, Madelung constant, covalent crystals: properties, examples, van der Waals bond: polar molecules, polarizability of molecules, hydrogen bond: dipole, Metallic bond: energy band, Ohm's law, resistivity, collision time, drift velocity, Weidemann-Franz Law.

Unit V: Solid State Physics (2) (12 lectures/hours)

Band Theory

Band theory of solids: conductors, insulators, semiconductors, doped semiconductors, drift velocity, mobility and conductivity of intrinsic semiconductors, variation with temperature, carrier concentration and Fermi level for intrinsic semiconductors, law of mass action, carrier concentration, Fermi level and conductivity for extrinsic semiconductor, energy bands, free electron, Brillouin zones, origin of forbidden bands, effective mass.

Magnetic effects on charge carriers: Hall effect.

Superconductivity

Magnetic effects, Meissner effect, critical field and critical temperature, type I and type II superconductors, thermodynamic and optical properties: entropy, specific heat, energy gap, isotope effect, flux quantization, Josephson effect, Josephson junction.

BCS theory, bound electron pairs, Cooper pairs, High temperature superconductors.

Reading List for PHY501

Nuclear Physics I

Books:

1. *Nuclear Physics*, S. B. Patel, (New Age International)
2. *Modern Physics*, Kenneth Krane, (Wiley India)
3. *Concepts of Nuclear Physics*, Bernard L. Cohen, (McGraw-Hill)
4. *Modern Physics,* R. Murugeshan and S. Sivaprasath (S. Chand & Company Ltd)

References:

1. *Introductory Nuclear Physics,* K. S. Krane (Wiley India Pvt Ltd)
2. *Nuclear Physics,* S. N. Goshal (S. Chand)
3. *Introductory Nuclear Physics,* Samuel Wong (Prentice-Hall India)

Solid State Physics I

Recommended Books:

1. *Solid State Physics,* R. K. Puri and V. K. Babbar, (S. Chand & Company Ltd)
2. *Concepts of Modern Physics,* Arthur Beiser, (Tata McGraw-Hill)
3. *Modern Physics,* K. S. Krane, (Wiley India Pvt Ltd)
4. *Solid State Physics,* S. O. Pillai, (New Age International Publishers)
5. *Modern Physics,* R. Murugeshan and S. Sivaprasath, (S. Chand & Company Ltd)

Reference Books:

1. *Introduction to Solid State Physics,* C. Kittel, (Wiley Eastern Limited)

PHY502

Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of band gap of a semiconductor
2. Study of Hall effect
3. Study of dispersive power of a prism
4. Study of interference using Michelson interferometer
5. Study of oscillators
6. Study of frequency response of amplifiers
7. Study of integrating and differentiating circuits
8. Study of focal length of a combination of lenses

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

Semester 5 - Physics (Honours) Theory Paper

PHY503

Electrodynamics II and Electronics II

(3 credits - 45 hours)

Course Overview

Electrodynamics II provides more in-depth exposition of the subject, from Maxwell's equations to electromagnetic waves in media. **Electronics II** also gives a more detailed study of electronics including multistage amplifiers and oscillators and ends with digital electronics.

At the end of the study, the student will have learnt the fundamental principles of electromagnetism and electronics, have conceptual and mathematical understanding of the principles of physics involved and develop problem solving skills.

Unit I: Electrodynamics (1) (9 lectures/hours)

Special techniques in calculating potentials

Laplace's equation and 1st and 2nd uniqueness theorems, solution of Laplace's equation in spherical coordinates.

Potential inside and outside an equipotential hollow sphere, uncharged metal sphere in a uniform electric field.

Multipole expansion: monopole and dipole terms and their fields, electric quadrapole and octopole moments (no field calculations), homogeneous linear dielectric sphere in an uniform electric field.

Multipole expansion of the magnetic vector potential, monopole, dipole and quadrupole terms.

Maxwell's equations

Review of Maxwell's equations, boundary conditions for electrodynamics, continuity equation, electrodynamic energy density, Poynting's theorem, conservation of momentum in electrodynamics.

Unit II: Electrodynamics (Electromagnetic Waves) (9 lectures/hours)

Electromagnetic waves in vacuum, plane monochromatic electromagnetic waves, energy and momentum in electromagnetic waves, electromagnetic waves waves in linear media.

Reflection and transmission of electromagnetic waves under normal incidence, reflection and transmission of electromagnetic waves under oblique incidence, electromagnetic waves in conductors, skin depth, reflection at a conducting surface.

Dispersion, complex susceptibility, complex permittivity, complex dielectric constant, absorption coefficient, anomalous dispersion, Cauchy's formula.

Unit III: Electronics (Amplifier Circuits) (9 lectures/hours)

Analysis of Amplifiers

Two - port analysis of a network, *Y* and *Z* parameters, *h*-parameters, conversion formula, hybrid equivalent circuits, gain and impedance parameters, transistor *h*-parameters, BJT amplifier analysis using *h*-parameters, CE amplifier, CE *h*-parameter approximations.

Frequency Response of Amplifiers

Bandwidth, half-power frequencies, amplitude and phase distortion, decibels and log/semi-log plots, series capacitance and low frequency response, normalized gain and phase plots, Bode plots, shunt capacitance and high frequency response, transient response and high frequency response, low frequency response of CE amplifiers, high frequency response of CE amplifiers.

Unit IV: Electronics (Multi-Stage Amplifiers) (9 lectures/hours)

Multistage amplifiers

Gain relation in multistage amplifiers, frequency response of cascaded stages, RC-coupled amplifier.

Operational Amplifiers

Differential amplifier, difference voltage, ideal op-amp, common mode parameters, CMRR, practical differential amplifiers, bias methods in integrating circuits, ideal op-amp, inverting amplifier, non-inverting amplifier, feedback in non-inverting and inverting amplifiers, frequency response, stability, gain-bandwidth product, slew-rate, input offset currents and voltage, output offset voltage, simple application of op-amps: voltage summation and subtraction, integrating and differentiating circuits.

Oscillators

Negative feedback, Barkhausen criterion, Hartley oscillator, Colpitts oscillator, Wein-bridge oscillator, phase-shift oscillator.

Unit V: Electronics (Digital Electronics) (9 lectures/hours)

Binary systems and Boolean algebra: addition,subtraction, multiplication, division, commutative, associate and distributive law, De-Morgan’s theorem.

OR, AND, NOT, NOR, NAND and XOR logic gates, equivalence of NAND and NOR gates and realization of De Morgans law.

Logic gate realization with TTL circuits, RS, JK and Master-Slave, half-adder and full-adder.

Reading List for PHY503

Electrodynamics II

Books:

1. *Introduction to Electrodynamics,* D. J. Griffiths, (Prentice-Hall of India)
2. *Electricity and Magnetism*, Mahajan and Rangwala, (Tata McGraw-Hill)
3. *Electricity and Magnetism,* D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)

References:

1. *Feynman Lectures in Physics - Volume II,* Feynman, Leighton and Sands, (Narosa Publishing House)
2. *Electricity and Magnetism,* Edward M. Purcell, (Tata McGraw-Hill)

Electronics II

Books:

1. *Modern Physics,* R. Murugeshan and S. Sivaprasath, (S. Chand & Company Ltd)
2. *Handbook of Electronics,* S. L. Gupta, V. K. Kumar, (Pragati Prakashan)
3. *Basic Electronics (Solid State),* B. L. Theraja, (S. Chand & Company Ltd)

References:

1. *Electronic Principles,* A. P. Malvino, (Tata McGraw Hill)
2. *Electronic Devices and Circuits,* Theodore F. Bogart, (Prentice Hall)
3. *Basic Electronics for Scientists,* James Brophy, (McGraw Hill)
4. *Electronic Fundamentals and Applications,* John Ryder, (Prentice Hall)

Semester 6 - Physics (Pass & Honours) Theory Paper

PHY601

Atomic Physics, Particle Physics & Cosmic Rays

(4 credits - 60 hours)

Course Overview

Atomic Physics studies the behavior of atoms and molecules and the manifestations of its properties through emission of light, X rays and so on. The esoteric world of sub-nuclear particles at ultra high energies will be dealt with in **particle physics and cosmic rays**.

At the end of the study, the student will have learnt the fundamental principles governing the structure of the atom and the interactions of particles at ultra high energies, have developed conceptual and mathematical understanding of the principles of physics and problem solving skills.

Unit I: Atomic & Molecular Physics (Atom Models) (12 lectures/hours)

Rutherford scattering experiment and the nuclear model of the atom, size of the nucleus, atomic spectra and spectral series.

Bohr model of the atom: energy levels and spectral series, line spectra, $m_e : m_H$ H, He^+ spectra, discovery of deuterium, correspondence principle, nuclear (reduced) mass and its effect of the atomic spectra: discovery of deuterium, positronium and muonic atom energy levels compared to hydrogen energy levels, critical potentials, atomic excitation, Franck-Hertz experiments.

Sommerfeld relativistic model and fine structure of hydrogen.

Quantum (Vector) model of the hydrogen atom (no derivation) and quantum numbers, principal quantum number, orbital quantum number, magnetic quantum number, probabilistic electronic orbits (radial and angular), radiative transitions, selection rules.

Unit II: Atomic & Molecular Physics (Effect of Magnetic Fields and Many Electron Atoms) (12 lectures/hours)

Normal Zeeman effect, gyro-magnetic ratio, Bohr magneton, spin of the electron, spin angular momentum, magnetic dipole moments due to orbital motion and spin of the electron, exclusion principle, Stern-Gerlach experiment.

Symmetric and anti-symmetric wave functions, bosons and fermions, atomic shells, sub-shells and periodic table

Spin-orbit coupling, anomalous Zeeman effect, Paschen-Back effect, Stark effect, total angular momentum, *LS* coupling, *j-j* coupling, singlet, doublet, triplet, term symbols.

Atomic spectra of hydrogen, sodium.

Atomic spectra of helium and mercury.

Unit III: Atomic & Molecular Physics (X-Ray and Molecular Physics)
(12 lectures/hours)

X-Ray Spectra

X-rays: production, Laue's experiment, Bragg's law, X-ray spectra: continuous and characteristic spectra, Mosley's law and X-ray series, Auger effect, X-ray absorption spectra, absorption edges

Molecular Physics

Molecular bond, covalent bond, H2+ molecular ion, Hydrogen molecule, complex molecules, hybrid orbitals: ethylene, benzene .

Rotational energy levels and rotational spectra, vibrational energy levels and spectra, vibration-rotation spectra, electronic spectra: fluorescence, phosphorescence.

Raman effect: stokes and anti-stokes lines, selection rules

Unit IV: Particle Physics & Cosmic Rays (Elementary Particles)

(12 lectures/hours)

Particles and fields, strong, electromagnetic and weak interactions, leptons, mesons and baryons, antiparticle, examples.

Conservation laws, lepton number, families of particles, leptons, mesons, strangeness, baryon, baryon number.

Particle interaction and decays, resonance particles, Q-value of particle reactions, reaction threshold kinetic energy.

Quark model

Unit V: Particle Physics & Cosmic Rays (Cosmic Rays) (12 lectures/hours)

Discovery of cosmic rays, latitude effect, east-west effect, altitude effect.

Primary cosmic rays, secondary cosmic rays, cosmic ray showers, discovery of positron and mesons, effect of earth’s magnetic field, Van Allen belts.

Origin of cosmic rays.

Reading List for PHY601

Atomic Physics

Books:

1. *Concepts of Modern Physics,* Arthur Beiser, (Tata McGraw-Hill)
2. *Modern Physics, R.* Murugeshan and S. Sivaprasath, (S. Chand & Company Ltd)
3. *Modern Physics,* K. S. Krane, (Wiley India Pvt Ltd)

References:

1. *Introduction to Atomic Spectra,* H. E. White, (McGraw-Hill)
2. *Atomic Physics,* S. N. Goshal, (S. Chand & Company)
3. *Atomic Physics,* J. B. Rajam, (S. Chand & Company)
4. *Elements of Spectroscopy,* Gupta, Kumar, Sharma, (Prakati Prakashan)

Particle Physics & Cosmic Rays

Books:

1. *Modern Physics,* K. S. Krane (Wiley India Pvt Ltd)
2. *Concepts of Modern Physics,* Arthur Beiser (Tata McGraw-Hill)
3. *Modern Physics,* R. Murugeshan and S. Sivaprasath (S. Chand & Company Ltd)

References:

1. I*ntroduction to Elementary Particles,* D. J. Griffiths (Wiley India Pvt Ltd)
2. *Atomic Physics*, J. B. Rajam, (S. Chand)

PHY602

Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of Rydberg constant using hydrogen spectrum
2. Study of thermal conductivity by Searle's apparatus
3. Study of surface tension by Jaeger's method
4. Study of interference using Newton's rings
5. Study of power supply and filter circuits
6. Study of resistance of a galvanometer with post office box
7. Study of angle of minimum deviation of a prism with spectrometer
8. Study of Planck's constant and work function

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

Semester 6 - Physics (Honours) Theory

Note: The student will select only one paper from among PHY603, PHY604 and PHY605

PHY603

Astrophysics, Cosmology and Classical Mechanics

(2 credits - 30 hours)

Course Overview

Astrophysics deals with the physics of the Universe, including the physical properties of celestial objects, their interactions and behaviour. **Cosmology** deals with the origin, structure and space-time relationships of the universe. Stellar evolution, black holes, the Big Bang and the future of the universe are some of the topics to be studied in this paper. **Classical Mechanics** studies the fundamental nature of the forces governing motion, by reformulating Newton's laws of motion to address a huge range of problems ranging from molecular dynamics to the motion of celestial bodies. The student will study constrained motion, principle of virtual work, d'Alembert Principle to Lagrange's equation of motion.

At the end of the study, the student will have learnt the fundamental principles governing the structure and growth of celestial bodies in the universe and the complex relations between them. They will have developed conceptual and mathematical understanding of the principles of motion and develop problem solving skills.

(**Note**: Tensors are not to be used and depth should be at the level of the recommended texts)

Unit I: Astrophysics **(6 lectures/hours)**

Classification of Stars - Harvard Classification Scheme, Hertzsprung - Russel Diagram, luminosity of a star, stellar evolution and the HR diagram, Chandrashekar Limit, photon diffusion time in a star.

Gravitational potential energy of a star, internal temperature of a star, internal pressure of a star.

Space and time, curved space and Gauss' law.

Unit II: General Relativity **(6 lectures/hours)**

Gravity and curved space-time, equivalence principle, inertial and gravitational mass, general theory of relativity, Schwarzschild solution, Hubble's constant and deceleration parameter.

Tests of general relativity: gravitational spectral shift, deflection of starlight, delay of radar echoes, precession of perihelion of mercury, Schwarzschild radius, black holes.

Unit III: Stellar Evolution and Cosmology **(6 lectures/hours)**

Stellar evolution, p-p cycle, nucleo-synthesis, s-process, r-process, white dwarf stars, their radius, neutron stars, their radius, pulsars, black holes.

Cosmology

Expansion of the universe, Hubble's law, cosmic background radiation, total number of blackbody photons.

Big Bang cosmology, neutrino decoupling, deuterium formation, helium abundance, photon decoupling, Big Bang features: neutrino background, gravity waves, helium abundance, antimatter, mini black holes.

Quasars: cosmological red shift, Doppler red shift, gravitational red shift.

Critical density of the universe and its future, evidence of dark matter and dark energy.

Unit IV: Classical Mechanics (d'Alembert's Principle and Virtual Work)

(6 lectures/hours)

Constraints and their classification, examples of constraints, degrees of freedom and generalized coordinates, virtual displacement and principle of virtual work.

Lagrange's equation of motion of first kind, system of N particles with k constraints, d'Alembert's principle, applications of d'Alembert's principle: simple pendulum, inclined plane.

Unit V: Classical Mechanics (Lagrangian Formulation) **(6 lectures/hours)**

Lagrange's equation of motion of the second kind, application of Euler-Lagrange's motion to simple pendulum, application of Euler-Lagrange's motion to central force, application of Euler-Lagrange's motion to linear harmonic oscillator.

Reading List for PHY603

Astrophysics and Cosmology

Recommended Books:

1. *Modern Physics,* K. S. Krane (Wiley India Pvt Ltd)
2. *Concepts of Modern Physics,* Arthur Beiser (Tata McGraw-Hill)
3. *Modern Physics,* R. Murugeshan and S. Sivaprasath (S. Chand & Company Ltd)
4. *An Introduction to Astrophysics*, H. L Duorah and K. Duorah

Reference Books:

1. *An Introduction to the Study of Stellar Structure,* S. Chandrasekhar (Dover Publications)
2. *An Introduction to Cosmology,* J. V. Narlikar (Cambridge University Press)
3. *Astrophysics For Physicists,* Choudhuri (Cambridge University Press)
4. *An Introduction To Astrophysics,* B. Basu, T. Chattopadhyay and S. N. Biswas (Prentice-Hall of India)
5. *Astronomy*, Dinah L. Moche (John Wiley & Sons)

Classical Mechanics

Recommended Books:

1. *Classical Mechanics,* N. C. Rana and P. S. Joag (Tata McGraw-Hill India)
2. *Classical Mechanics*, S.N. Biswas (Books and Allied Ltd)
3. *Introduction to Classical Mechanics*, Takwale and Puranik (Tata McGraw-Hill).

Reference Books:

1. *Classical Mechanics,* H. Goldstein (Narosa Publishing House)
2. *Classical Mechanics,* Mondal (Prentice-Hall India)
3. *Classical Mechanics: A Modern Perspective*, Barger & Olsson (McGraw Hill International)

Semester 6 – Physics (Honours) Theory

Note: The student will select only one paper from among PHY603, PHY604 and PHY605

PHY604

Solid State Physics II

(2 Credits – 30 hours)

Course Overview

Solid State Physics II continuous on with the study of crystals and X rays diffraction, heat, electrical and magnetic properties.

At the end of the study, the student will have developed deeper insight into solid state physics and the have developed problem solving skills.

Unit I: Crystal Physics **(6 lectures/hours)**

Crystal systems: cubic, tetragonal, orthorhombic, monoclinic, triclinic, trigonal, hexagonal, symmetry elements in crystals: combination of symmetry elements, translational symmetry elements.

Point groups and space groups: Bravais lattices, types of lattices.

Reciprocal lattice, reciprocal lattice to SC lattice, reciprocal lattice to BCC lattice, reciprocal lattice to FCC lattice.

Unit II: X Ray Diffraction **(6 lectures/hours)**

Laue's equations, Bragg's law of X ray diffraction in reciprocal lattice, Ewald construction, Brillouin zones of simple lattices, atomic scattering factor, geometrical scattering factor.

Unit III: Lattice Vibration and Specific Heat **(6 lectures/hours)**

Vibrations of one-dimensional monatomic lattice, dispersion relation, phase velocity, group velocity.

Phonons: momentum of phonons, inelastic scattering of photons by phonons.

Specific Heat: classical theory of lattice heat capacity, Einstein's theory of lattice heat capacity, Debye's model of lattice heat capacity, density of modes, Debye approximation.

Unit IV: Free Electron Theory and Band Theory of Solids **(6 lectures/hours)**

Drude-Lorentz classical theory, Sommerfeld's quantum theory: free electron gas in one-dimensional box, free electron gas in three dimensions, fermi function, density of available states, Fermi energy, average kinetic energy, electronic specific heat.

Band theory of solids: Bloch theorem, Kronig-Penney model, effective mass of electron.

Unit V: Magnetic and Di-electric Properties **(6 lectures/hours)**

Types of magnetism, diamagnetism, Langevin's classical theory, quantum theory of diamagnetism, para-magnetism: Langevin's classical theory, quantum theory of para-magnetism, ferromagnetism: Weiss theory. nature and origin of Weiss molecular field, exchange interaction, domains, hysteresis, antiferromagnetism, ferrimagnetism.

Books:

1. *Solid State Physics,* R. K. Puri and V. K. Babbar, (S. Chand & Company Ltd)
2. *Solid State Physics,* S. O. Pillai, (New Age International Publishers)
3. *Concepts of Modern Physics,* Arthur Beiser, (Tata McGraw-Hill)
4. *Modern Physics,* K. S. Krane, (Wiley India Pvt Ltd)
5. *Fundamentals of Solid State Physics,* B. S. Saxena, R. C. Gupta, P. N. Saxena, (Pragati Prakashan)
6. *Modern Physics,* Murugeshan & Sivaprasath, (S. Chand & Company Ltd)

References:

1. *Introduction to Solid State Physics,* C. Kittel, (Wiley Eastern Limited)

Semester 6 – Physics (Honours) Theory

Note: The student will select only one paper from among PHY603, PHY604 and PHY605

PHY605

Nuclear Physics II

(2 units – 30 hours)

Course Overview

Nuclear Physics II studies α, β and γ ray spectroscopy, the liquid drop and shell models of the nucleus and the still not well-understood nature of nuclear forces.

At the end of the study, the student will have learnt the fundamental principles of nuclear physics and develop problem solving skills.

Unit I: β Ray Spectroscopy (6 lectures/hours)

Continuous β ray spectrum, Pauli's neutrino hypothesis, Fermi's theory of β decay, life times of β decay and strength of interaction matrix element, selection rules for β decay, parity non-conservation in β decay.

Unit II: α and γ Ray Spectroscopy (6 lectures/hours)

Range of α particles, Geiger-Nuttal law, α spectrum and fine structure, long range α particles, disintegration energy of spontaneous α decay, α decay paradox, barrier penetration.

γ Ray Spectroscopy

γ ray emission, selection rules, multipolarity in γ transitions, internal conversion.

Unit III: Liquid Drop Model (6 lectures/hours)

Binding energies of nuclei, variation with mass number, Weizsacher's semi-empirical mass formula: volume term, surface energy term, coulomb term, asymmetry term, pairing term mass parabolas, stability limits against spontaneous fission, potential barrier for fusion, barrier penetration decay probabilities for spontaneous fission, nucleon emission

Unit IV: Shell Model of the Nucleus (6 lectures/hours)

Experimental evidence, main assumptions of single particle shell model, spin-orbit coupling of electron bound in atom, spin-orbit coupling in nuclei, single particle shell model with parabolic potential, single particle shell model with square well potential, predictions of shell model.

Unit V: Nuclear Force (6 lectures/hours)

Ground state of the deuteron, magnetic dipole and electric quadrupole moments of the deuteron, square well solution for the deuteron, central and non-central forces: tensor force, exchange theory: meson force, types of exchange forces: space exchange, spin exchange, space-spin exchange.

Books:

1. *Nuclear Physics*, S. B. Patel, (New Age International)
2. *Concepts of Nuclear Physics*, Bernard L. Cohen, (McGraw-Hill)

References:

1. *Nuclear Physics Theory and Experiment*, R. R. Roy and B. P. Nigam (Wiley Eastern)
2. *Nuclear Physics Experimental and Theoretical*, H. S. Hans (New Age International)
3. *The Atomic Nucleus*, Robley D. Evans (Tata McGraw-Hill)

PHY606

Physics (Honours) Practicals

(1 credit)

Course Overview

This course introduces students to the methods of experimental physics. Emphasis will be given on laboratory techniques such as accuracy of measurements and data analysis. The concepts that are learnt in the lecture sessions will be translated to the laboratory sessions thus providing a hands-on learning experience.

LIST OF EXPERIMENTS

1. Study of viscosity using capillary flow
2. Study of mechanical equivalent of heat by Callendar and Barnes' method
3. Study of thermal conductivity of bad conductors by Lee's method
4. Study of diffraction caused by a thin wire
5. Study of DAC
6. Study of triode valves

Phoenix Experiments

Additional experiments can be done using the phoenix kit. Some of the experiments that can be done with phoenix are

1. Analysis of AC mains pickup
2. Capacitor charging/discharging
3. Electro magnetic induction
4. Mutual induction
5. Dielectric constant of glass
6. Oscillation of pendulum
7. Pendulum with light barrier
8. Value of g
9. Cooling curve
10. Velocity of sound
11. Radiation counter using GM tube
12. Energy spectrum of radiation
13. High resolution ADC/DAC

Reference: www.iuac.res.in/~elab/phoenix/docs/phm_book.pdf

Note:

1. A student should try to perform/complete all the experiments in each practical paper. Most of the experiments are open-ended experiments; hence the instructor can modify the experiment to suit local conditions/constraints.

2. For assessment of each experiment, the marks/scores may be awarded as follows.
   (a) Theory, presentation/scope of the technique, limitations of the technique etc - 20 %
   (b) Accuracy of observations, precautions observed rigorously – 50 %
   (c) Presentation of data in tables, graphs, error estimation etc – 30 %

3. Marks/Weightage allotted to the different experiments may be proportional to the level of complexity of the experiment.

Books:

1. *BSc Practical Physics*, C. L. Arora, (S. Chand)
2. *An Advanced Course in Practical Physics*, D. Chattopadhyay and P. C. Rakshit, (New Central Book Agency)
3. *A Text Book of Advanced Practical Physics*, S. Ghosh, (New Central Book Agency)

PHY607

Project Work

(2 credits)

Course Overview

This course will introduce students to simple research work appropriate to their level where they will use their knowledge to apply it to some simple problem/application. This will lead them learn by themselves and develop a better understanding of Physics and may inspire them to take up research at a higher level.