BSc Physics (Honours) Syllabus (CBCS)

Revision Cycle 1.0, May 2019

Physics Department, Gauhati University
Web : https://gauhati.ac.in
GUWeb : http://web.gauhati.ac.in/syllabus

BSc Physics (Honours) Syllabus (CBCS)
physics@gauhati.ac.in

May 2019

Legends : L - Lecture   P - Practical   H - Home Assignments   T - Tutorial

Course Structure for BSc in Physics (Honours) under CBCS

May 2019

Semester	Type	Core	AECC	SEC	DSE	GE
	Credits	**14 × 6 = 84**	**2 × 4 = 8**	**2 × 4 = 8**	**4 × 6 = 24**	**4 × 6 = 24**
I		PHY-HC-1016	ENG-AE-1014			PHY-HG-1016
		PHY-HC-1026				
II		PHY-HC-2016	ENV-AE-2014			PHY-HG-2016
		PHY-HC-2026				
III		PHY-HC-3016		PHY-SE-3XX4		PHY-HG-3016
		PHY-HC-3026				
		PHY-HC-3036				
IV		PHY-HC-4016		PHY-SE-4XX4		PHY-HG-4016
		PHY-HC-4026				
		PHY-HC-4036				
V		PHY-HC-5016			PHY-HE-5XX6	
		PHY-HC-5026			PHY-HE-5YY6	
VI		PHY-HC-6016			PHY-HE-6XX6	
		PHY-HC-6026			PHY-HE-6YY6	

Legends

HC : Core Papers

HE : Discipline Specific Elective Papers

SE : Skill Enhancement Papers

HG : Generic Elective Papers

Directives & Advisory

(a) *A student majoring (honours) in Physics MAY take GE papers from any available discipline in the college, except Physics.*

(b) *It is advisable that a student majoring (honours) in Physics take at least one GE paper from Mathematics*

List of Papers

Core Papers

1. PHY-HC-1016 : Mathematical Physics I
2. PHY-HC-1026 : Mechanics
3. PHY-HC-2016 : Electricity & Magnetism
4. PHY-HC-2026 : Waves & Optics
5. PHY-HC-3016 : Mathematical Physics II
6. PHY-HC-3026 : Thermal Physics
7. PHY-HC-3036 : Digital Systems & Applications
8. PHY-HC-4016 : Mathematical Physics III
9. PHY-HC-4026 : Elements of Modern Physics
10. PHY-HC-4036 : Analog Systems & Applications
11. PHY-HC-5016 : Quantum Mechanics & Applications
12. PHY-HC-5026 : Solid State Physics
13. PHY-HC-6016 : Electromagnetic Theory
14. PHY-HC-6026 : Statistical Mechanics

Discipline Specific Elective (DSE) Papers

1. PHY-HE-5016 : Experimental Techniques (PHY-RE-5016)
2. PHY-HE-5026 : Embedded Sys : Introduction to Microcontrollers (PHY-RE-5026)
3. PHY-HE-5036 : Advanced Mathematical Physics I (PHY-RE-5036)
4. PHY-HE-5046 : Physics of Devices and Instruments (PHY-RE-5046)
5. PHY-HE-6016 : Communication Electronics (PHY-RE-6016)
6. PHY-HE-6026 : Digital Signal Processing (PHY-RE-6026)
7. PHY-HE-6036 : Advanced Mathematical Physics II (PHY-RE-6036)
8. PHY-HE-6046 : Biophysics (PHY-RE-6046)
9. PHY-HE-6056 : Astrophysics (PHY-RE-6056)

Generic Elective (GE) Papers

1. PHY-HG-1016 : Mechanics (PHY-RC-1016)
2. PHY-HG-2016 : Electricity & Magnetism (PHY-RC-2016)
3. PHY-HG-3016 : Thermal Physics & Statistical Mechanics (PHY-RC-3016)
4. PHY-HG-4016 : Waves & Optics (PHY-RC-4016)

Skill Based (SEC) Papers

5. PHY-SE-3014 : Renewable Energy and Energy Harvesting (PHY-SE-3014)
6. PHY-SE-4014 : Basic Instrumental Skill (PHY-SE-4014)
7. PHY-SE-5XX4 :
8. PHY-SE-6XX4 :

Note : ***(a) The details of the DSE and SEC papers will be given later.***

(b) The courses given in Red colour are equivalent in content to the corresponding courses given alongside.

(c) In the Lab classes, wherever applicable, students and instructors can use either of C, C++, FORTRAN 90/95, Matlab, Scilab, or Python environment.

Contents

Part I

Core Papers

1

PHY-HC-1016
Mathematical Physics I

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

1.1 Theory

1.1.1 Unit I : *Vector Calculus* (Lectures 25)

Revision: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities.

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications (no rigorous proofs).

1.1.2 Unit II : *First and Second order Differential Equations* (Lectures 17)

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution.

Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration.

1.1.3 Unit III : *Orthogonal Curvilinear Coordinates* (Lectures 06)

Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

1.1.4 Unit IV : *Dirac Delta function and its Properties* (Lectures 02)

Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

1.1.5 Unit V : *Introduction to Probability* (Lectures 04)

Independent random variables: Probability distribution functions; binomial, Gaussian and Poisson, with examples. Mean and variance.

1.1.6 Unit VI : *Theory of Errors* (Lectures 06)

Systematic and Random Errors. Propagation of Errors. Normal Law of Errors. Standard and Probable Error. Least-squares fit.

1.2 Lab

1.2.1 Aim

The aim of this Lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- Highlights the use of computational methods to solve physical problems
- The course will consist of lectures (both theory and practical) in the Lab
- Evaluation done not on the programming but on the basis of formulating the problem
- Aim at teaching students to construct the computational problem to be solved
- Students can use any one operating system Linux or Microsoft Windows

Introduction and Overview Computer architecture and organization, memory and Input/output devices

Basics of scientific computing Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Se- lection and Repetition, single and double precision arithmetic, underflow & overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods

Review of C & C++ Programming fundamentals Introduction to Programming, constants, variables and data types, operators and Expressions I/O statements, scanf and printf, c in and c out, Manipulators for data formatting, Control statements (decision making and looping statements) (`if` statement. `if-else` Statement. Nested if Structure. `else-if` Statement. Ternary Operator. `goto` Statement. `switch` Statement. Unconditional and Conditional Looping. `while` Loop. `do-while` Loop. `for` Loop. `break` and `continue` Statements. Nested Loops), Arrays (1D & 2D) and strings, user defined functions, Structures and Unions, Idea of classes and objects.

Programs Sum & average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order, Binary search

Random number generation Area of circle, area of square, volume of sphere, value of pi (π)

Solution of Algebraic and Transcendental equations by Newton Raphson methods Solution of linear and quadratic equation, solving $\alpha = \tan\alpha, I = I_0(\sin\alpha/\alpha)^2$ in optics

Interpolation by Newton Gre- gory Forward and Backward difference formula Evaluation of trigonometric functions e.g. $\sin\theta, \cos\theta, \tan\theta$ etc.

Numerical Integration (Trapezoidal and Simpson rules), Monte Carlo method Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop

Solution of Ordinary Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods First order differential equation (a) Radioactive decay (b) Newton's law of cooling.

Reference Books

[1] Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, and F. E.. Harris, 2013, 7th Edn., Elsevier.

[2] An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI

[3] Learning Differential Equations, George F. Simmons, 2007, McGraw Hill.

[4] Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

[5] Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book

[6] Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning

[7] Mathematical Physics, Goswami, 1st edition, Cengage Learning

[8] Engineering Mathematics, S. Pal and S. C. Bhunia, 2015, Oxford University Press

[9] Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India

[10] Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge University Press

2

PHY-HC-1026
Mechanics

Total Lectures : 60 **Credits : 6 (Theory : 04, Lab : 02)**

2.1 Theory

2.1.1 Unit I : *Fundamentals of Dynamics* (Lectures 06)

Reference frames. Inertial frames; Review of Newton's Laws of Motion. Galilean transformations; Galilean invariance. Momentum of variable mass system: motion of rocket. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse.

2.1.2 Unit II : *Work and Energy* (Lectures 04)

Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.

2.1.3 Unit III : *Collisions* (Lectures 03)

Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.

2.1.4 Unit IV : *Rotational Dynamics* (Lectures 12)

Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.

2.1.5 Unit V : *Elasticity* (Lectures 03)

Relation between Elastic constants. Twisting torque on a Cylinder or Wire. Cantilever.

2.1.6 Unit VI : *Fluid Motion* (Lectures 02)

Kinematics of Moving Fluids: Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

2.1.7 Unit VII : *Gravitation and Central Force Motion* (Lectures 08)

Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere.

Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws.

2.1.8 Unit VIII : *Oscillations* (Lectures 08)

SHM: Simple Harmonic Oscillations. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, sharpness of resonance; power dissipation and Quality Factor. Compound Pendulum.

2.1.9 Unit IX : *Non-Inertial Systems* (Lectures 04)

Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications.

2.1.10 Unit X : *Special Theory of Relativity* (Lectures 10)

Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum.

2.2 Lab

A minimum of seven experiments to be done.

1. Measurements of length (or diameter) using vernier caliper, screw gauge, Spherometer and travelling microscope.
2. To study the Motion of Spring and calculate (a) Spring constant and (b) Rigidity modulus.
3. To determine the Moment of Inertia of a cylinder about two different axes of symmetry by torsional oscillation method.
4. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
5. To determine the Young's Modulus of the material of a wire by Searle's apparatus.
6. To determine the Modulus of Rigidity of a Wire Static method.
7. To determine the value of g using Bar Pendulum.
8. To determine the value of g using Kater's Pendulum.
9. To determine the height of a building using a Sextant.
10. To determine g and velocity for a freely falling body using Digital Timing Technique.

Reference Books

[1] An Introduction to Mechanics, D. Kleppner, R. J. Kolenkow, 1973, McGraw-Hill.

[2] Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et.al. 2007, Tata McGraw-Hill.

[3] Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.

[4] Analytical Mechanics, G. R. Fowles and G. L. Cassiday. 2005, Cengage Learning.

[5] Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education

[6] Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.

[7] University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

[8] Mechanics, D. S. Mathur, S. Chand and Company Limited, 2000

[9] University Physics, F. W. Sears, M. W. Zemansky, H.D Young 13/e, 1986, Addison Wesley

[10] Physics for Scientists and Engineers with Modern Phys., J. W. Jewett, R. A. Serway, 2010, Cengage Learning

[11] Theoretical Mechanics, M. R. Spiegel, 2006, Tata McGraw Hill.

3

PHY-HC-2016
Electricity & Magnetism

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

3.1 Theory

3.1.1 Unit I : *Electric Field and Electric Potential* (Lectures 26)

Electric field: Electric field lines. Electric flux. Gauss' Law with applications to charge distributions with spherical, cylindrical and planar symmetry.

Conservative nature of Electrostatic Field. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole.

Electrostatic energy of system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere.

3.1.2 Unit II : *Dielectric Properties of Matter* (Lectures 08)

Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector $\vec{D}$. Relations between $\vec{E}$, $\vec{P}$ and $\vec{D}$. Gauss' Law in dielectrics.

3.1.3 Unit III : *Magnetic Field* (Lectures 09)

Magnetic Force on a point charge, definition and properties of magnetic field $\vec{B}$. Curl and Divergence. Vector potential $\vec{A}$. Magnetic Force on (1) a current carrying wire (2) between current elements. Torque on a current loop in a uniform magnetic field. Biot-Savart's law and its simple application : straight wire and circular loop. Current loop as a magnetic dipole and its dipole moment (analogy with electric dipole) Ampere's circuital law and its application to (1) Solenoid (2) Torus.

3.1.4 Unit IV : *Magnetic Properties of Matter* (Lectures 04)

Magnetization vector ($\vec{M}$). Magnetic Intensity ($\vec{H}$). Magnetic Susceptibility and permeability. Relation between $\vec{B}, \vec{H}, \vec{M}$. Ferromagnetism. B-H curve and hysteresis.

3.1.5 Unit V : *Electromagnetic Induction* (Lectures 06)

Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge Conservation and Displacement current.

3.1.6 Unit VI : *Electrical Circuits* (Lectures 04)

AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) 13 Quality Factor, and (4) Band Width. Parallel LCR Circuit.

3.1.7 Unit VII : *Network Theorems*

Ideal Constant-voltage and Constant-current Sources. Network Theorems: Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits.

3.1.8 Unit VIII : *Ballistic Galvanometer* (Lectures 03)

Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR.

3.2 Lab

A minimum of seven experiments to be done.

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.
2. To study the characteristics of a series RC Circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De'Sauty's bridge.
6. Measurement of field strength $\vec{B}$ and its variation in a solenoid (determine dB/dx).
7. To verify the Thevenin and Norton theorems.
8. To verify the Superposition, and Maximum power transfer theorems.
9. To determine self inductance of a coil by Anderson's bridge.
10. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
11. To study the response curve of a parallel LCR circuit and determine its (a) Anti- resonant frequency and (b) Quality factor Q.
12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer.
13. Determine a high resistance by leakage method using Ballistic Galvanometer.

14. To determine self-inductance of a coil by Rayleigh's method.
15. To determine the mutual inductance of two coils by Absolute method.

Reference Books

[1] Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw

[2] Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education

[3] Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.

[4] Feynman Lectures Vol.2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education

[5] Elements of Electromagnetics, M. N. O. Sadiku, 2010, Oxford University Press.

[6] Electricity and Magnetism, J. H. Fewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press.

4

PHY-HC-2026 Waves & Optics

Total Lectures : 60   Credits : 6 (Theory : 04, Lab : 02)

4.1 Theory

4.1.1 Unit I : *Superposition of Collinear Harmonic Oscillations* (Lectures 05)

Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences.

4.1.2 Unit II : *Superposition of Two Perpendicular Harmonic Oscillations* (Lectures 02)

Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses.

4.1.3 Unit III : *Wave Motion* (Lectures 04)

Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves: Ripple and Gravity Waves.

4.1.4 Unit IV : *Velocity of Waves* (Lectures 06)

Velocity of Transverse Vibrations of Stretched Strings. Velocity of Longitudinal Waves in a Fluid in a Pipe. Newton's Formula for Velocity of Sound. Laplace's Correction.

4.1.5 Unit V : *Superposition of Two Harmonic Waves* (Lectures 07)

Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.

4.1.6 Unit VI : *Wave Optics* (Lectures 03)

Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence.

4.1.7 Unit VII : *Interference* (Lectures 09)

Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.

4.1.8 Unit VIII : *Interferometer* (Lectures 04)

Michelson Interferometer-(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index. 5. Visibility of fringes. Fabry-Perot interferometer.

4.1.9 Unit IX : *Diffraction* (Lectures 09)

Fresnel and Fraunhofer diffraction. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel diffraction pattern of a straight edge and at a circular aperture . Resolving Power of a telescope.

4.1.10 Unit X : *Fraunhofer Diffraction* (Lectures 08)

Single slit. Double slit . Multiple slits. Diffraction grating . Resolving power of grating. (8 Lectures)

4.1.11 Unit XI : *Holography* (Lectures 03)

Principle of Holography. Recording and Reconstruction Method. Theory of Holography as Interference between two Plane Waves. Point source holograms.

4.2 Lab

A minimum of seven experiments to be done.

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify $\lambda^2 - T$ law.
2. To study Lissajous Figures.
3. Familiarization with: Schuster's focusing, determination of angle of prism.
4. To determine refractive index of the Material of a prism using sodium source.
5. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
6. To determine wavelength of sodium light using Fresnel Biprism.
7. To determine wavelength of sodium light using Newton's Rings.
8. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
9. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
10. To determine dispersive power and resolving power of a plane diffraction grating.

Reference Books

[1] Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.

[2] Fundamentals of Optics, F. A. Jenkins and H.E. White, 1981, McGraw-Hill

[3] Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.

[4] Optics, Ajoy Ghatak, 2008, Tata McGraw Hill

[5] The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

[6] The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.

[7] Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.

5

PHY-HC-3016
Mathematical Physics II

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

5.1 Theory

5.1.1 Unit I : *Frobenius Method and Special Functions* (Lectures 18)

Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials.

5.1.2 Unit II : *Partial Differential Equations* (Lectures 14)

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation.

5.1.3 Unit III : *Some Special Integrals* (Lectures 04)

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions.

5.1.4 Unit IV : *Matrix* (Lectures 15)

Matrix algebra using index notation, Properties of matrices, Special matrix with their proper- ties: Transpose matrix, complex conjugate matrix, Hermitian matrix, Anti-Hermitian matrix, special square matrix, unit matrix, diagonal matrix, co-factor matrix, adjoint of a matrix, self- adjoint matrix, symmetric matrix, anti-symmetric matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse matrix. Determinant, Rank, Eigen value, Eigen vector and diagonalisation of matrix.

5.1.5 Unit V : *Fourier Series* (Lectures 09)

Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Application to square and triangular waves.

5.2 Lab

5.2.1 Aim

The aim of this Lab is to use the computational methods to solve physical problems. Course will consist of lectures (both theory and practical) in the Lab. Evaluation done not on the programming but on the basis of formulating the problem.

Introduction to Numerical computation softwares Introduction to Scilab/Mathematica/Matlab, Advantages and disadvantages, Scilab / Mathematica / Matlab environment, Command window, Figure window, Edit window, Variables and arrays, Initialising variables in Scilab / Mathematica / Matlab, Multidimensional arrays, Subarray, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab / Mathematica / Matlab functions, Introduction to plotting, 2D and 3D plotting.

Curve fitting, Least square fit, Goodness of fit, standard deviation Ohms law to calculate R, Hooke's law to calculate spring constant.

Solution of Linear system of equations Solution of Linear system of equations by Gauss elimination method and Gauss Seidal method. Diagonalisation of matrices, Inverse of a matrix, Eigen vectors, eigenvalues problems. Solution of mesh equations of electric circuits (3 meshes) Solution of coupled spring mass systems (3 masses).

Generation of Special functions Generation of Special functions using User defined functions in Scilab / Mathematica / Matlab. Generating and plotting Legendre Polynomials Generating and plotting Hermite function.

First order ODE Solution of first order Differential equation Euler, modified Euler and Runge-Kutta second order methods. First order differential equation (a) Current in RC, LC circuits with DC source (b) Classical equations of motion.

Second order ODE Second order differential equation. Fixed difference method. Second order Differential Equation (a) Harmonic oscillator (no friction) (b) Damped Harmonic oscillator (c) Over damped (d) Critical damped.

Partial Differential Equation (PDE) Solution of Partial Differential Equation: (a) Wave equation (b) Heat equation.

Reference Books

[1] Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, and F. E.. Harris, 2013, 7th Edn., Elsevier.

[2] An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI

[3] Learning Differential Equations, George F. Simmons, 2007, McGraw Hill.

[4] Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

[5] Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book

[6] Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning

[7] Mathematical Physics, Goswami, 1st edition, Cengage Learning

[8] Engineering Mathematics, S. Pal and S. C. Bhunia, 2015, Oxford University Press

[9] Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India

[10] Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge University Press

6

PHY-HC-3026
Thermal Physics

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

6.1 Theory

6.1.1 Introduction to Thermodynamics

6.1.2 Unit I : *Zeroth and First Law of Thermodynamics* (Lectures 08)

Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient.

6.1.3 Unit II : *Second Law of Thermodynamics* (Lectures 10)

Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

6.1.4 Unit III : *Entropy* (Lectures 07)

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.

6.1.5 Unit IV : *Thermodynamic Potentials* (Lectures 07)

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic

Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations.

6.1.6 Unit V : *Maxwell's Thermodynamic Relations* (Lectures 07)

Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process.

6.1.7 Kinetic Theory of Gases

6.1.8 Unit VI : *Distribution of Velocities* (Lectures 07)

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases.

6.1.9 Unit VII : *Molecular Collisions* (Lectures 04)

Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

6.1.10 Unit VIII : *Real Gases* (Lectures 10)

Behaviour of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule- Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule- Thomson Cooling.

6.2 Lab

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
6. To study the variation of Thermo-emf of a Thermocouple with Difference of Temperature of its Two Junctions.
7. To calibrate a thermocouple to measure temperature in a specified Range using (1) Null Method, (2) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

Reference Books

[1] Heat and Thermodynamics, M. W. Zemansky, Richard Dittman, 1981, McGraw-Hill.

[2] A Treatise on Heat, Meghnad Saha, and B. N.Srivastava, 1958, Indian Press

[3] Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill

[4] Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.

[5] Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.

[6] Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press

[7] Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

7

PHY-HC-3036
Digital Systems & Applications

Total Lectures : 60 **Credits : 6 (Theory : 04, Lab : 02)**

7.1 Theory

7.1.1 Unit I : *Introduction to CRO* (Lectures 03)

Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.

7.1.2 Unit II : *Integrated Circuits (qualitative treatment only)* (Lectures 03)

Active & Passive components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. Scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital lCs.

7.1.3 Unit III : *Digital Circuits* (Lectures 06)

Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates.

7.1.4 Unit IV : *Boolean Algebra* (Lectures 06)

De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

7.1.5 Unit V : *Data Processing Circuits (*Lectures 04)

Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders.

7.1.6 Unit VI : *Arithmetic Circuits* (Lectures 05)

Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor.

7.1.7 Unit VII : *Sequential Circuits* (Lectures 06)

SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK Flip-Flop.

7.1.8 Unit VIII : *Timers: IC 555* (Lectures 03)

block diagram and applications: Astable multivibrator and Monostable multivibrator.

7.1.9 Unit IX : *Shift Registers* (Lectures 02)

Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits).

7.1.10 Unit X : *Counters (4 bits)* (Lectures 04)

Ring Counter, Asynchronous counters, Decade Counter. Synchronous Counter.

7.1.11 Unit XI : *Computer Organization* (Lectures 06)

Input/Output Devices. Data storage (idea of RAM and ROM). Computer memory. Memory organization & addressing.

7.1.12 Unit XII : *Intel 8085 Microprocessor Architecture* (Lectures 08)

Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing & Control circuitry.

7.1.13 Unit XIII : *Introduction to Assembly Language* (Lectures 04)

1 byte, 2 byte, & 3 byte instructions.

7.2 Lab

A minimum of eight experiments to be done.

1. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO.
2. To test a Diode and Transistor using a Multimeter.
3. To design a switch (NOT gate) using a transistor.
4. To verify and design AND, OR, NOT and XOR gates using NAND gates.
5. To design a combinational logic system for a specified Truth Table.
6. To convert a Boolean expression into logic circuit and design it using logic gate ICs.

7. Half Adder, Full Adder and 4-bit binary Adder.
8. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder IC.
9. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
10. To build JK Master-slave flip-flop using Flip-Flop ICs .
11. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
12. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
13. To design an astable multivibrator of given specifications using 555 Timer.
14. To design a monostable multivibrator of given specifications using 555 Timer.
15. Write the following programs using 8085 Microprocessor
    (a) Addition and subtraction of numbers using direct addressingmode
    (b) Addition and subtraction of numbers using indirect addressin gmode
    (c) Multiplication by repeated addition
    (d) Division by repeated subtraction
    (e) Handling of 16-bit Numbers
    (f) Use of CALL and RETURN Instruction
    (g) Block data handling

Reference Books

[1] Digital Principles and Applications, A. P. Malvino, D. P. Leach and Saha, 7th Ed., 2011, Tata McGraw

[2] Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.

[3] Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.

[4] Digital Electronics G. K. Kharate ,2010, Oxford University Press

[5] Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning

[6] Logic circuit design, Shimon P. Vingron, 2012, Springer.

[7] Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.

[8] Digital Electronics, S. K. Mandal, 2010, 1st edition, McGraw Hill

[9] Microprocessor Architecture Programming & applications with 8085, 2002, R. S. Goankar, Prentice Hall.

8

PHY-HC-4016
Mathematical Physics III

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

8.1 Theory

8.1.1 Unit I : *Complex Analysis* (Lectures 10)

Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity.

8.1.2 Unit II : *Complex Integration* (Lectures 10)

Integration of a function of a complex variable. Cauchys Integral formula. Simply and mul- tiply connected region. Laurent and Taylors expansion. Residues and Residue Theorem with numerical application.

8.1.3 Unit III : *Fourier Transforms* (Lectures 15)

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier trans- form of trigonometric, Gaussian functions Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem (Statement only). Properties of Fourier transforms (translation, change of scale, complex conjugation).

8.1.4 Unit IV : *Laplace Transforms* (Lectures 15)

Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem (Statement only). Inverse LT. Application of Laplace Transforms to 2nd order Differential Equations: Damped Harmonic Oscillator.

8.1.5 Unit V : *Tensor Algebra* (Lectures 10)

Introduction to tensor, Transformation of co-ordinates, Einsteins summation convention. contravariant and co-variant tensor, tensorial character of physical quantities, symmetric and antisymmetric tensors, kronecker delta, Levi-Civita tensor. Quotient law of tensors, Raising and lowering of indices Rules for combination of tensors-addition, subtraction, outer multiplication, contraction and inner multiplications.

8.2 Lab

1. Solve differential equations

$$\frac{dy}{dx} = e^{-x}\,\text{with}\,y = 0\,\text{for}\,\text{x} = 0 \tag{8.1}$$

$$\frac{dy}{dx} + e^{-x}y = x^2 \tag{8.2}$$

$$\frac{d^2y}{dt^2} + 2\frac{dy}{dt} = -y \tag{8.3}$$

$$\frac{d^2y}{dt^2} + e^{-t}\frac{dy}{dt} = -y \tag{8.4}$$

2. Dirac Delta Function
Evaluate the integral I

$$I = \frac{1}{\sqrt{2\pi\sigma^2}} \int \exp\left[-\frac{(x-2)^2}{2\sigma^2}\right](x+3)\,dx, \quad \text{for}\,\sigma = 1, 0.1, 0.01$$

and show the $I \to 5$.

3. Fourier Series
Make a program to evaluate

$$\sum_{n=1}^{\infty}(0.2)^n.$$

Evaluate the Fourier coefficients of a given periodic function (square wave)

4. Frobenius method and Special functions
Evaluate

$$\int_{-1}^{1} P_n(\mu)P_m(\mu)\,d\mu = \delta_{n,m}.$$

Plot $P_n(x), j_\nu(x)$ and show the recursion relation.

5. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two).

6. Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.

7. Evaluation of trigonometric functions e.g. $\sin\theta$, given Bessel's function at N points find its value at an intermediate point.

8. Integrate

$$\frac{1}{(x^2+2)}$$

numerically in a given interval.

9. Compute the nth roots of unity for $n = 2, 3, \text{and}\, 4$.

10. Find the two square roots of $5 + 12j$.

11. Integral transform
Evaluate FFT of e^{-x^2}.

12. Solve Kirchoff's Current law for any node of an arbitrary circuit using Laplace's trans- form.

Reference Books

[1] Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, and F. E.. Harris, 2013, 7th Edn., Elsevier.

[2] An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI

[3] Learning Differential Equations, George F. Simmons, 2007, McGraw Hill.

[4] Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

[5] Mathematical Methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book

[6] Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning

[7] Mathematical Physics, Goswami, 1st edition, Cengage Learning

[8] Engineering Mathematics, S. Pal and S. C. Bhunia, 2015, Oxford University Press

[9] Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India

[10] Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge University Press

9

PHY-HC-4026 Elements of Modern Physics

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

9.1 Theory

9.1.1 Unit I : *Quantum Theory and Blackbody Radiation* (Lecture 14)

Quantum theory of light; photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. group and phase velocities and relation between them. Two-slit experiment with electrons. Probability. wave amplitude and wave functions.

9.1.2 Unit II : *Uncertainty and Wave-Particle Duality* (Lecture 05)

Position measurement : gamma ray microscope thought experiment; wave-particle duality, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Derivation from wave packets, impossibility of a particle following a trajectory; estimating minimum energy of a confined particle using uncertainty principle; energy-time uncertainty principle- application to virtual particles and range of an interaction.

9.1.3 Unit III : *Schrödinger Equation* (Lecture 10)

Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Schrödinger equation for non- relativistic particles; momentum and energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; probability and probability current densities in one dimension.

9.1.4 Unit IV : *One-dimensional Box and Step Barrier* (Lecture 10)

One dimensional infinitely rigid box- energy eigenvalues and eigenfunctions, normalization; quantum dot as example; quantum mechanical scattering and tunnelling in one dimension-across a step potential and rectangular potential barrier.

9.1.5 Unit V : *Structure of the Atomic Nucleus* (Lecture 06)

Size and structure of atomic nucleus and its relation with atomic weight; impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. nature of nuclear force, $N - Z$ graph, liquid drop model: semi-empirical mass formula and binding energy, nuclear shell model (qualitative discussions) and magic numbers.

9.1.6 Unit VI : *Radioactivity* (Lecture 08)

Alpha decay. Beta decay energy released, spectrum and Pauli's prediction of neutrino. Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus.

9.1.7 Unit VII : *Fission and Fusion* (Lecture 03)

mass deficit, Einstein's mass-energy equivalence principle and generation of nuclear energy. Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235. Fusion and thermonuclear reactions driving stellar energy (brief qualitative discussions).

9.1.8 Unit VIII : *Lasers* (Lecture 04)

Einstein's A and B coefficients. Metastable states. Spontaneous and Stimulated emissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Ruby Laser and He-Ne Laser. Basic lasing.

9.2 Lab

A minimum of six experiments to be done.

1. Measurement of Planck's constant using black body radiation and photo-detector.
2. Photo-electric effect
   Photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
3. To determine work function of material of filament of directly heated vacuum diode.
4. To determine the Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of $H - \alpha$ emission line of hydrogen atom.
6. To determine the ionization potential of mercury.
7. To determine the absorption lines in the rotational spectrum of iodine vapour.
8. To determine the value of e/m by (a) magnetic focusing or (b) bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunneling effect in tunnel diode using $I - V$ characteristics.
11. To determine the wavelength of laser source using diffraction of single slit.
12. To determine the wavelength of laser source using diffraction of double slits.
13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating.

Reference Books

[1] Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.

[2] Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill

[3] Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

[4] Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.

[5] Modern Physics, G. Kaur and G. R. Pickrell, 2014, McGraw Hill

[6] Quantum Mechanics: Theory & Applications, A. K. Ghatak & S. Lokanathan, 2004, Macmillan

10

PHY-HC-4036
Analog Systems & Applications

Total Lectures : 60   Credits : 6 (Theory : 04, Lab : 02)

10.1 Theory

10.1.1 Unit I : *Semiconductor Diodes* (Lectures 10)

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current flow mechanism in Forward and Reverse Biased Diode.

10.1.2 Unit II : *Two-terminal Devices and their Applications* (Lectures 06)

(1) Rectifier Diode: Half- wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter (2) Zener Diode and Voltage Regulation. Principle and structure of (1) LEDs, (2) Photodiode and (3) Solar Cell.

10.1.3 Unit III : *Bipolar Junction Transistors* (Lectures 06)

n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff and Saturation Regions.

10.1.4 Unit IV : *Amplifiers* (Lectures 10)

Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers.

10.1.5 Unit V : *Coupled Amplifier* (Lectures 04)

Two stage RC-coupled amplifier and its frequency response.

10.1.6 Unit VI : *Feedback in Amplifiers* (Lectures 04)

Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

10.1.7 Unit VII : *Sinusoidal Oscillators* (Lectures 04)

Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

10.1.8 Unit VIII : *Operational Amplifiers (Black Box approach)* (Lectures 04)

Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground.

10.1.9 Unit IX : *Applications of Op-Amps* (Lectures 03)

(1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector (8) Wein bridge oscillator. (9 Lectures) Conversion: Resistive network (Weighted and $R-2R$ Ladder). Accuracy and Resolution. A/D Conversion (successive approximation).

10.2 Lab

A minimum of eight experiments to be done.

1. To study $V-I$ characteristics of PN junction diode, and Light emitting diode.
2. To study the $V-I$ characteristics of a Zener diode and its use as voltage regulator.
3. Study of $V-I$ & power curves of solar cells, and find maximum power point & efficiency.
4. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
5. To study the various biasing configurations of BJT for normal class A operation.
6. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
7. To study the frequency response of voltage gain of a RC-coupled transistor amplifier.
8. To design a Wien bridge oscillator for given frequency using an op-amp.
9. To design a phase shift oscillator of given specifications using BJT.
10. To study the Colpitt's oscillator.
11. To design a digital to analog converter (DAC) of given specifications.
12. To study the analog to digital convertor (ADC) IC.
13. To design an inverting amplifier using Op-amp (741/351) for dc voltage of given gain .
14. To design inverting amplifier using Op-amp (741/351) and study its frequency response.
15. To design non-inverting amplifier using Op-amp (741/351) & study its frequency response.
16. To study the zero-crossing detector and comparator.
17. To add two dc voltages using Op-amp in inverting and non-inverting mode.
18. To design a precision Differential amplifier of given I/O specification using Op-amp.
19. To investigate the use of an op-amp as an Integrator.

20. To investigate the use of an op-amp as a Differentiator.

Reference Books

[1] Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-Graw Hill.

[2] Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall.

[3] Solid State Electronic Devices, B. G. Streetman & S. K. Banerjee, 6th Edn.,2009, PHI Learning

[4] Electronic Devices & circuits, S. Salivahanan & N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill

[5] OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall

[6] Microelectronic circuits, A. S. Sedra, K.C. Smith, A. N. Chandorkar, 2014, 6th Edn., Oxford University Press.

[7] Electronic circuits: Handbook of design & applications, U. Tietze, C. Schenk,2008, Springer

[8] Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd Ed., 2002, Wiley India

[9] Microelectronic Circuits, M. H. Rashid, 2nd Edition, Cengage Learning

[10] Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

11

PHY-HC-5016
Quantum Mechanics & Applications

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

11.1 Theory

11.1.1 Unit I : *Time Dependent Schrödinger Equation* (Lectures 06)

Time dependent Schrödinger equation and dynamical evolution of a quantum state, properties of wave function. Interpretation of wave function. Probability and probability current densities in three dimensions. Conditions for physical acceptability of wave functions. Normalization. Linearity and Superposition Principles. Eigenvalues and eigenfunctions. Position, momentum and energy operators; commutator of position and momentum operators. Expectation values of position and momentum. wave function of a free particle.

11.1.2 Unit II : *Time Independent Schrödinger Equation* (Lectures 10)

Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wave function as a linear combination of energy eigenfunctions; General solution of the time dependent Schrödinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wave function; Position-momentum uncertainty principle.

11.1.3 Unit III : *Bound States* (Lectures 12)

continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle.

11.1.4 Unit IV : *Hydrogen-like Atoms* (Lectures 10)

time independent Schrödinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wave functions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m; $s, p, d, \ldots$ shells.

11.1.5 Unit V : *Atoms in Electric & Magnetic Fields* (Lectures 12)

Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Zeeman Effect: Normal and Anomalous Zeeman Effect. Paschen-Back Effect and Stark Effect (Qualitative Discussion only).

11.1.6 Unit VI : *Many Electron Atoms* (Lectures 10)

Pauli's Exclusion Principle. Symmetric & Antisymmetric W ave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms: $L-S$ and $J-J$ couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc.).

11.2 Lab

Use C/C++/Scilab/ FORTRAN/Mathematica for solving the following problems based on Quantum Mechanics.

1. Solve the s-wave Schrödinger equation for the ground state and the first excited state of the hydrogen atom

$$\frac{d^2y}{dr^2} = A(r)\,u(r), \quad A(r) = \frac{2m}{\hbar^2}[V(r)-E] \text{ where } V(r) = -\frac{e^2}{r},$$

were, m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wave functions. Remember that the ground state energy of the hydrogen atom is $\approx -13.6\,\text{eV}$. Take $e = 3.795\,(\text{eVÅ})$, $\hbar c = 1973\,(\text{eVÅ})$ and $m = 0.511 \times 10^6\,\text{eV/c}^2$.

2. Solve the s-wave radial Schrödinger equation for an atom

$$\frac{d^2y}{dr^2} = A(r)\,u(r), \quad A(r) = \frac{2m}{\hbar^2}[V(r)-E]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened Coulomb potential

$$V(r) = -\frac{e^2}{r}e^{-r/a}.$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wave function. Take $e = 3.795\,(\text{eVÅ})$, and $a = 3$ Å, 5 Å, and 7 Åin the units of $\hbar c = 1973\,(\text{eVÅ})$. $m = 0.511 \times 10^6\,\text{eV/c}^2$. The ground state energy is expected to be above $-12\,\text{eV}$ in all three cases.

3. Solve the s-wave radial Schrödinger equation for a particle of mass m

$$\frac{d^2y}{dr^2} = A(r)\,u(r), \quad A(r) = \frac{2m}{\hbar^2}[V(r)-E]$$

The anharmonic potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose $m = 940\,\text{MeV/c}^2$, $k = 100\,\text{MeV fm}^{-2}$, $b = 0, 10, 30\,\text{MeV fm}^{-3}$. In these units, $c\hbar = 197.3\,\text{MeV fm}$. The ground state energy I is expected to lie in between 90 and 110 MeV for all three cases.

4. Solve the s-wave radial Schrödinger equation for the vibration of hydrogen molecule

$$\frac{d^2y}{dr^2} = A(r)\,u(r), \quad A(r) = \frac{2\mu}{\hbar^2}[V(r)-E]$$

where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D\left(e^{-2\alpha r'} - e^{-\alpha r'}\right),\; r' = \frac{r - r_0}{r}.$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of thee significant digits. Also plot the corresponding wave function. Take $m = 940 \times 10^6\,\mathrm{eV/c^2}$, $D = 0.755501\,\mathrm{eV}$, $\alpha = 1.44$, and $r_0 = 0.131349\,\text{Å}$.

Laboratory based experiments (Optional)

5. Study of electron spin resonance – determine magnetic field as a function of the resonance frequency.
6. Study of Zeeman effect – with external magnetic field; hyperfine splitting.
7. To show the tunneling effect in tunnel diode using $I - V$ characteristics.
8. Quantum efficiency of CCDs.

Reference Books

[1] A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill

[2] Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.

[3] Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.

[4] Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.

[5] Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.

[6] Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993, Springer

[7] Quantum Mechanics for Scientists & Engineers, D. A. B. Miller, 2008, Cambridge University Press

12

PHY-HC-5026
Solid State Physics

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

12.1 Theory

12.1.1 Unit I : *Crystal Structure* (Lectures 10)

Amorphous and Crystalline Materials. Lattice Translation Vectors. Symmetry operations, Lattice with a Basis - Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor.

12.1.2 Unit II : *Elementary Lattice Dynamics* (Lectures 10)

Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law.

12.1.3 Unit III : *Magnetic Properties of Matter* (Lectures 08)

Dia, Para, Ferri, and Ferromagnetic Materials. Classical Langevin Theory of Dia and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of $B - H$ Curve. Hysteresis and Energy Loss.

12.1.4 Unit IV : *Dielectric Properties of Materials* (Lectures 08)

Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeir relations. Langevin-Debye equation. Complex Dielectric Constant. Optical Phenomena. Application: Plasma Oscillations, Plasma Frequency, Plasmons, T_0 modes.

12.1.5 Unit V : *Ferroelectric Properties of Materials* (Lectures 06)

Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

12.1.6 Unit VI : *Free Electron Theory of Metals* (Lectures 12)

electrical and thermal conductivity of metals, Wiedemann-Franz law. Elementary band theory: Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (4-probe method) & Hall coefficient.

12.1.7 Unit VII : *Superconductivity* (Lectures 06)

Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation).

12.2 Lab

A minimum of five experiments to be done.

1. Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency.
5. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR).
6. To determine the refractive index of a dielectric layer using SPR.
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
9. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 °C) and to determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.

Reference Books

[1] Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.

[2] Elements of Solid State Physics, J. P. Srivastava, 4th Edition, 2015, Prentice-Hall of India

[3] Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill

[4] Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning

[5] Solid-state Physics, H. Ibach and H. Luth, 2009, Springer

[6] Solid State Physics, Rita John, 2014, McGraw Hill

[7] Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India

[8] Solid State Physics, M. A. Wahab, 2011, Narosa Publications

13

PHY-HC-6016
Electromagnetic Theory

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

13.1 Theory

13.1.1 Unit I : *Maxwell Equations* (Lecture 12)

Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density.

13.1.2 Unit II : *EM Wave Propagation in Unbounded Media* (Lecture 10)

Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth, application to propagation through ionosphere.

13.1.3 Unit III : *EM Wave in Bounded Media* (Lecture 10)

Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence).

13.1.4 Unit IV : *Polarization of Electromagnetic Waves* (Lecture 12)

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light.

13.1.5 Unit V : *Rotatory Polarization* (Lecture 08)

Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter. (5 Lectures) Wave Guides: Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission.

13.1.6 Unit VI : *Optical Fibres* (Lecture 03)

Numerical Aperture. Step and Graded Indices (Definitions Only). Single and Multiple Mode Fibres (Concept and Definition Only).

13.2 Lab

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection, refraction of microwaves.
7. To study Polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
11. To verify the Stefan's law of radiation and to determine Stefan's constant.
12. To determine the Boltzmann constant using $V - I$ characteristics of PN junction diode.

Reference Books

[1] Introduction to Electrodynamics, D. J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.

[2] Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.

[3] Introduction to Electromagnetic Theory, T. L. Chow, 2006, Jones & Bartlett Learning

[4] Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill

[5] Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning

[6] Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.

[7] Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer

14

PHY-HC-6026 Statistical Mechanics

Total Lectures : 60   Credits : 6 (Theory : 04, Lab : 02)

14.1 Theory

14.1.1 Unit I : *Classical Statistics* (Lectures 18)

Macrostate & Microstate, Elementary Concept of Ensemble, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Energy Levels System, Negative Temperature.

14.1.2 Unit II : *Classical Theory of Radiation* (Lectures 09)

Properties of Thermal Radiation. Blackbody Radiation. Pure temperature dependence. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Saha's Ionization Formula. Rayleigh-Jean's Law. Ultraviolet Catastrophe.

14.1.3 Unit III : *Quantum Theory of Radiation* (Lectures 05)

Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.

14.1.4 Unit IV : *Bose-Einstein Statistics* (Lectures 13)

B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law.

14.1.5 Unit V : *Fermi-Dirac Statistics* (Lectures 15)

Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

14.2 Lab

Use C/C++/Scilab/other numerical simulations for solving the problems based on Statistical Mechanics.

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:
   (a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations.
   (b) Study of transient behaviour of the system (approach to equilibrium).
   (c) Relationship of large N and the arrow of time.
   (d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution.
   (e) Computation and study of mean molecular speed and its dependence on particle mass.
   (f) Computation of fraction of molecules in an ideal gas having speed near the most probable speed
2. Computation of the partition function $Z(\beta)$ for examples of systems with a finite number of single particle levels (e.g., 2 level, 3 level, etc.) and a finite number of non-interacting particles N under Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein statistics:
   (a) Study of how $Z(\beta)$, average energy $\langle E \rangle$, energy fluctuation ΔE, specific heat at constant volume C_v, depend upon the temperature, total number of particles N and the spectrum of single particle states.
   (b) Ratios of occupation numbers of various states for the systems considered above.
   (c) Computation of physical quantities at large and small temperature T and comparison of various statistics at large and small temperature T.
3. Plot Planck's law for Black Body radiation and compare it with Raleigh-Jeans Law at high temperature and low temperature.
4. Plot Specific Heat of Solids (a) Dulong-Petit law, (b) Einstein distribution function, (c) Debye distribution function for high temperature and low temperature and compare them for these two cases.
5. Plot the following functions with energy at different temperatures
   (a) Maxwell-Boltzmann distribution
   (b) Fermi-Dirac distribution
   (c) Bose-Einstein distribution

Reference Books

[1] Statistical Mechanics, R. K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.

[2] Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill

[3] Statistical and Thermal Physics, S. Lokanathan and R. S. Gambhir. 1991, Prentice Hall

[4] Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.

[5] Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer

[6] An Introduction to Statistical Mechanics & Thermodynamics, R. H. Swendsen, 2012, Oxford Univ. Press

Part II

General Elective Papers

15

PHY-HG-1016 (PHY-RC-1016) Mechanics

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

15.1 Theory

15.1.1 Unit I : *Vectors* (Lectures 06)

Vector algebra. Scalar and vector products. Derivatives of a vector with respect to a parameter. (4 Lectures) Ordinary Differential Equations: 1st order homogeneous differential equations. 2nd order homogeneous differential equations with constant coefficients.

15.1.2 Unit II : *Laws of Motion* (Lectures 10)

Frames of reference. Newton's Laws of motion. Dynamics of a system of particles. Centre of Mass.

15.1.3 Unit III : *Momentum and Energy* (Lectures 06)

Conservation of momentum. Work and energy. Conservation of energy. Motion of rockets.

15.1.4 Unit IV : *Rotational Motion* (Lectures 05)

Angular velocity and angular momentum. Torque. Conservation of angular momentum.

15.1.5 Unit V : *Gravitation* (Lectures 07)

Newton's Law of Gravitation. Motion of a particle in a central force field (motion is in a plane, angular momentum is conserved, areal velocity is constant). Kepler's Laws (statement only).

15.1.6 Unit VI : *Oscillations* (Lectures 07)

Simple harmonic motion. Differential equation of SHM and its solutions. Kinetic and Potential Energy, Total Energy and their time averages. Damped oscillations. Compound pendulum.

15.1.7 Unit VII : *Elasticity* (Lectures 08)

Hooke's law - Stress-strain diagram – Elastic moduli-Relation between elastic constants - Poisson's Ratio-Expression for Poisson's ratio in terms of elastic constants – Work done in stretching and work done in twisting a wire – Twisting couple on a cylinder – Determination of Rigidity modulus by static torsion - Torsional pendulum-Determination of Rigidity modulus and moment of inertia – q, η and σ by Searles method.

15.1.8 Unit VII : *Special Theory of Relativity* (Lectures 07)

Constancy of speed of light. Postulates of Special Theory of Relativity. Length contraction. Time dilation. Relativistic addition of velocities.

15.2 Lab

A minimum of five experiments to be done.

1. Measurements of length (or diameter) using vernier caliper, screw gauge and Spherometer.
2. To determine the Moment of Inertia of a Symmetrical body about an axis by torsional oscillation method.
3. To determine the Young's Modulus of the material of a wire by Searle's apparatus.
4. To determine the Modulus of Rigidity of a Wire Static method.
5. To determine the elastic Constants of a wire by Searle's method.
6. To determine the value of g using Bar Pendulum.
7. To determine the value of g using Kater's Pendulum.
8. To study the Motion of Spring and calculate (a) Spring constant and (b) value of g.

Reference Books

[1] An Introduction to Mechanics, D. Kleppner, R. J. Kolenkow, 1973, McGraw-Hill.

[2] Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et.al. 2007, Tata McGraw-Hill.

[3] Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.

[4] Analytical Mechanics, G. R. Fowles and G. L. Cassiday. 2005, Cengage Learning.

[5] Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education

[6] Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.

[7] University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

[8] Mechanics, D. S. Mathur, S. Chand and Company Limited, 2000

[9] University Physics, F. W. Sears, M. W. Zemansky, H.D Young 13/e, 1986, Addison Wesley

[10] Physics for Scientists and Engineers with Modern Phys., J. W. Jewett, R. A. Serway, 2010, Cengage Learning

[11] Theoretical Mechanics, M. R. Spiegel, 2006, Tata McGraw Hill.

16

PHY-HG-2016 (PHY-RC-2016) Electricity & Magnetism

Total Lectures : 60   Credits : 6 (Theory : 04, Lab : 02)

16.1 Theory

16.1.1 Unit I : *Vector Analysis* (Lectures 12)

Review of vector algebra (Scalar and Vector product), gradient, divergence, Curl and their significance, Vector Integration, Line, surface and volume integrals of Vector fields, Gauss-divergence theorem and Stoke's theorem of vectors (statement only).

16.1.2 Unit II : *Electrostatics* (Lectures 22)

Electrostatic Field, electric flux, Gauss's theorem of electrostatics. Applications of Gauss theorem – Electric field due to point charge, infinite line of charge, uniformly charged spherical shell and solid sphere, plane charged sheet, charged conductor. Electric potential as line integral of electric field, potential due to a point charge, electric dipole, uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. Capacitance of an isolated spherical conductor. Parallel plate, spherical and cylindrical condenser. Energy per unit volume in electrostatic field. Dielectric medium, Polarisation, Displacement vector. Gauss's theorem in dielectrics. Parallel plate capacitor completely filled with dielectric.

16.1.3 Unit III : *Magnetism* (Lectures 10)

Magnetostatics: Biot-Savart's law & its applications – straight conductor, circular coil, solenoid carrying current. Divergence and curl of magnetic field. Magnetic vector potential. Ampere's circuital law. Magnetic properties of materials: Magnetic intensity, magnetic induction, permeability, magnetic susceptibility. Brief introduction of dia, para, and ferro-magnetic materials.

16.1.4 Unit IV : *Electromagnetic Induction* (Lectures 06)

Faraday's laws of electromagnetic induction, Lenz's law, self and mutual inductance, L of single coil, M of two coils. Energy stored in magnetic field.

16.1.5 Unit V : *Maxwell's Equations and EM Wave* (Lectures 10)

Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization.

16.2 Lab

1. To use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, and (d) checking electrical fuses.
2. Ballistic Galvanometer
   (a) Measurement of charge and current sensitivity
   (b) Measurement of CDR
   (c) Determine a high resistance by Leakage Method
   (d) To determine Self Inductance of a Coil by Rayleigh's Method.
3. To compare capacitances using De'Sauty's bridge.
4. Measurement of field strength B and its variation in a Solenoid (Determine dB/dx).
5. To study the Characteristics of a Series RC Circuit.
6. To study the a series LCR circuit and determine its (a) Resonant Frequency, (b) Quality Factor
7. To study a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q .
8. To determine a Low Resistance by Carey Foster's Bridge.
9. To verify the Thevenin and Norton theorem.
10. To verify the Superposition, and Maximum Power Transfer Theorem.

Reference Books

[1] Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw

[2] Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education

[3] Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.

[4] Feynman Lectures Vol.2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education

[5] Elements of Electromagnetics, M. N. O. Sadiku, 2010, Oxford University Press.

[6] Electricity and Magnetism, J. H. Fewkes & J. Yarwood. Vol. I, 1991, Oxford Univ. Press.

17

PHY-HG-3016 (PHY-RC-3016)
Thermal Physics & Statistical Mechanics

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

17.1 Theory

17.1.1 Unit I : *Laws of Thermodynamics* (Lectures 22)

Thermodynamic Description of system: Zeroth Law of thermodynamics and temperature. First law and internal energy, conversion of heat into work, Various Thermodynamical Processes, Applications of First Law: General Relation between CP & CV, Work Done during Isothermal and Adiabatic Processes, Compressibility & Expansion Coefficient, Reversible & irreversible processes, Second law & Entropy, Carnot's cycle & theorem, Entropy changes in reversible & irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, Unattainability of absolute zero.

17.1.2 Unit II : *Thermodynamic Potentials* (Lectures 10)

Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations & applications - Joule-Thompson Effect, Clausius- Clapeyron Equation, Expression for $(CP - CV)$, CP/CV, TdS equations.

17.1.3 Unit III : *Kinetic Theory of Gases* (Lectures 10)

Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (Zeroth Order), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case), Law of equipartition of energy (no derivation) and its applications to specific heat of gases; mono-atomic and diatomic gases.

17.1.4 Unit IV : *Theory of Radiation* (Lectures 06)

Blackbody radiation, Spectral distribution, Concept of Energy Density, Derivation of Planck's law, Deduction of Wien's distribution law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

17.1.5 Unit V : *Statistical Mechanics* (Lectures 12)

Phase space, Macrostate and Microstate, Entropy and Thermodynamic probability, Maxwell-Boltzmann law - distribution of velocity – Quantum statistics – Fermi-Dirac distribution law – electron gas – Bose-Einstein distribution law – photon gas – comparison of three statistics.

17.2 Lab

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2. Measurement of Planck's constant using black body radiation.
3. To determine Stefan's Constant.
4. To determine the coefficient of thermal conductivity of copper by Searle's Apparatus.
5. To determine the Coefficient of Thermal Conductivity of Cu by Angstrom's Method.
6. To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method.
7. To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
8. To study the variation of thermo emf across two junctions of a thermocouple with temperature.
9. To record and analyze the cooling temperature of an hot object as a function of time using a thermocouple and suitable data acquisition system.
10. To calibrate Resistance Temperature Device (RTD) using Null Method/Off-Balance Bridge.

Reference Books

[1] Heat and Thermodynamics, M. W. Zemansky, Richard Dittman, 1981, McGraw-Hill.

[2] A Treatise on Heat, Meghnad Saha, and B. N.Srivastava, 1958, Indian Press

[3] Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill

[4] Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer.

[5] Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.

[6] Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, Oxford University Press

[7] Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

[8] Statistical Mechanics, R. K. Pathria, Butterworth Heinemann: 2nd Ed., 1996, Oxford University Press.

[9] Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill

[10] Statistical and Thermal Physics, S. Lokanathan and R. S. Gambhir. 1991, Prentice Hall

18

PHY-HG-4016 (PHY-RC-4016) Waves & Optics

Total Lectures : 60 Credits : 6 (Theory : 04, Lab : 02)

18.1 Theory

18.1.1 Unit I : *Superposition of Two Collinear Harmonic Oscillations* (Lectures 04)

Linearity & Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats).

18.1.2 Unit II : *Superposition of Two Perpendicular Harmonic Oscillations* (Lectures 02)

Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses.

18.1.3 Unit III : *Waves Motion* (Lectures 07)

General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity.

18.1.4 Unit IV : *Fluids* (Lectures 06)

Surface Tension: Synclastic and anticlastic surface – Excess of pressure – Application to spherical and cylindrical drops and bubbles – variation of surface tension with temperature – Jaegar's method. Viscosity – Rate flow of liquid in a capillary tube – Poiseuille's formula – Determination of coefficient of viscosity of a liquid – Variations of viscosity of liquid with temperature – lubrication.

18.1.5 Unit V : *Sound* (Lectures 06)

Simple harmonic motion - forced vibrations and resonance - Fourier's Theorem - Application to saw tooth wave and square wave - Intensity and loudness of sound - Decibels - Intensity levels - musical notes - musical scale. Acoustics of buildings: Reverberation and time of reverberation - Absorption coefficient - Sabine's formula - measurement of reverberation time - Acoustic aspects of halls and auditoria.

18.1.6 Unit VI : *Wave Optics* (Lectures 03)

Electromagnetic nature of light. Definition and Properties of wave front. Huygens Principle.

18.1.7 Unit VII : *Interference* (Lectures 10)

Division of amplitude and division of wavefront. Young's Double Slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination and Fringes of equal thickness . Newton's Rings: measurement of wavelength . Michelson's Interferometer: Idea of form of fringes (no theory needed), Determination of wavelength, Wavelength difference, Refractive index Visibility of fringes.

18.1.8 Unit VIII : *Michelson Interferometer* (Lectures 03)

(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Refractive Index. (4) Visibility of fringes. (3 Lectures)

18.1.9 Unit IX : *Diffraction* (Lectures 14)

Fresnel and Fraunhofer diffraction . Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel diffraction pattern of a straight edge and at a circular aperture . Resolving Power of a telescope. Fraunhofer diffraction due to a Single slit , Diffraction grating . Resolving power of grating.

18.1.10 Unit X : *Polarization* (Lectures 05)

Transverse nature of light waves. Double Refraction, Plane, circular and elliptically polarized light , Production and analysis of polarized light. Retarding plates.

18.2 Lab

A minimum of five experiments to be done.

1. To study the variation in liquid column height with diameter of capillary tube and determine the surface tension of the liquid.
2. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify $\lambda^2 - T$ Law.
3. To determine the coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method)
4. To determine the focal length of a convex mirror with the help of convex lens .
5. To determine the refractive index of a liquid by using plane mirror and convex lens.
6. To determine the focal length of two lenses and their combination by displacement method .
7. Familiarization with Schuster's focussing; determination of angle of prism.
8. To determine the Refractive Index of the Material of a Prism using Sodium Light.
9. To determine wavelength of sodium light using Newton's Rings.

Reference Books

[1] Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.

[2] Fundamentals of Optics, F. A. Jenkins and H.E. White, 1981, McGraw-Hill

[3] Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.

[4] Optics, Ajoy Ghatak, 2008, Tata McGraw Hill

[5] The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

[6] The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.

[7] Fundamental of Optics, A. Kumar, H. R. Gulati and D. R. Khanna, 2011, R. Chand Publications.