Major Subject Syllabus
(Credits: Theory-03, Practical/Tutorial-01)

Semester I

UPHYMAJ-1 (Theory): Mathematical Physics-I

45 Lectures	3 Credits

Vector Algebra

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 Calculus

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. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of vector fields. Flux of a vector field. Gauss's divergence theorem, Green's and Stokes Theorems and their applications.

Orthogonal Curvilinear Coordinates and Expansion in Series

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

Differential Equations

First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for initial value problems.

Reference Books:

- Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. E. Harris, 2013, Elsevier.
- An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI learning.
- Differential Equations, George F. Simmons, 2007, McGraw Hill.
- Vector Analysis, M. R. Spiegel, Schaum Series
- Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
- Mathematical methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book.
- Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, Jones and Bartlett Learning.
- Mathematical Physics, Goswami, 1st edition, Cengage Learning.
- Engineering Mathematics, S. Pal and S. C. Bhunia, 2015, Oxford University Press.
- Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
- Essential Mathematical Methods, K. F. Riley & M. P. Hobson, 2011, Cambridge Univ. Press.
- Mathematical methods in the Physical Sciences, M. L. Boas, 2005, Wiley.

UPHYMAJ-1 (Practical): Mathematical Physics-I Lab

30 Lectures	1 Credit

Errors and Error Analysis in scientific computing:

Floating point numbers, single and double precision arithmetic, underflow & overflow. Truncation and round-off errors, Absolute and relative errors.

Introduction to programming in Python:

Introduction to programming: constants, variables and data types, dynamical typing, operators and expressions, modules, I/O statements, iterables, compound statements, indentation in python, the if-elif-else block, for and while loops, nested compound statements, lists, tuples, dictionaries and strings, basic file handling, basic ideas of object oriented programming.

Basic Programs in Python along with algorithms: (Without using any library function)

- Input a list of numbers and obtain their sum & average
- Finding odd/even from a list of numbers
- Find the largest / smallest number of the list and its location in the list
- Sorting a list of numbers in ascending and descending order
- Finding sum and product of a series (e.g. $\Sigma_n\, n^2$, $\Sigma_i\, x^i$, $\Pi_n\, x^n$ etc.)
- Simple problems in matrix: Addition, subtraction, multiplication, equality, etc.
- Dot product, cross product, triple product of vectors
- Verify vector identities
- Print the Fibonacci sequence, Factorial of Number
- Find the frequency of each element in an array, etc.
- Sort words in alphabetical order, Remove punctuation from a string, Reverse a string
- Convert list to string, Concatenate two strings

File handling tools may also be used for the above programs

Reference Books:

- Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
- Learning with Python-how to think like a computer scientist, J. Elkner, C. Meyer, and A. Downey, 2015, Dreamtech Press.
- Introduction to computation and programming using Python, J. Guttag, 2013, Prentice Hall India.
- Effective Computation in Physics- Field guide to research with Python, A. Scopatz and K. D. Huff, 2015, O'Rielly.
- A first course in Numerical Methods, U. M. Ascher & C. Greif, 2012, PHI Learning.
- Elementary Numerical Analysis, K. E. Atkinson, 3 rd Edn., 2007, Wiley India Edition.
- Numerical Methods for Scientists & Engineers, R. W. Hamming, 1973, Courier Dover Pub.
- An Introduction to Computational Physics, T. Pang, 2nd Edn., 2006,Cambridge Univ. Press.
- Computational Physics, Darren Walker, 1st Edn., 2015, Scientific International Pvt. Ltd.

UPHYMAJ-2 (Theory): Mechanics

45 Lectures	3 Credits

Fundamentals of Dynamics

Reference frames. Inertial frames – Review of Newton's laws of motion. Galilean transformations; Galilean invariance. Momentum of variable-mass system: motion of rocket. Dynamics of a system of particles – conservation of linear momentum, Centre of mass. Conservative and non-conservative forces. Potential energy. Stable and unstable equilibrium. Force as gradient of potential energy. Law of conservation of energy.

Rotational dynamics

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

Elasticity

Hooke's law, Stress-strain diagram, Elastic moduli – relation between elastic constants, Poisson's ratio – expression of Poisson's ratio in terms of elastic constants. Work done in stretching and twisting a wire.

Gravitation and Central Force Motion

Law of gravitation. Gravitational potential energy, self-energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere. Motion of a particle under the central force field. Two-body problem, its reduction to one-body problem and its solution. Effective potential of a particle in gravitational field, Trajectory of a particle in inverse-square force potential. Kepler's laws. Escape velocity, satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness.

Non-Inertial Systems

Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems.

Reference Books:

- An introduction to mechanics, D. Kleppner, R. J. Kolenkow, 1973, McGraw-Hill.
- Mechanics, Berkeley Physics, Vol.1, C. Kittel, W. Knight, et.al. 2007, Tata McGraw-Hill.
- Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
- Analytical Mechanics, G. R. Fowles and G. L. Cassiday. 2005, Cengage Learning.
- Feynman Lectures, Vol. I, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
- Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
- University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
- Mechanics, D. S. Mathur, S. Chand and Company Limited, 2000
- University Physics. F. W Sears, M. W Zemansky, H. D. Young 13/e, 1986, Addison Wesley
- Physics for scientists and Engineers with Modern Phys., J. W. Jewett, R. A. Serway, 2010, Cengage Learning
- Theoretical Mechanics, M. R. Spiegel, 2006, Tata McGraw Hill.

UPHYMAJ-2 (Practical): Mechanics-I Lab

30 Lectures	1 Credit

List of Experiments

1. Measurements of volume of a hollow cylinder using Vernier calipers, Screw gauge and
2. Traveling microscope.
3. To determine the height of a building using a Sextant.
4. To study the motion of a spring and calculate (a) Spring Constant (b) Value of g.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine g and velocity for a freely falling body using Digital Timing Technique.
7. To determine the moment of inertia of a) cylindrical, b) rectangular bar about an axis passing through its centre of mass
8. To determine the value of g by Bar Pendulum.
9. To determine the value of g by Kater's Pendulum.
10. Determination of rigidity modulus of the material of a wire by static method.
11. Determination of rigidity modulus of the material of a wire by dynamic method.
12. To determine the modulus of rigidity of a wire by Maxwell's needle.
13. To determine the Young's Modulus of a wire by Optical Lever method.
14. To determine the elastic constants of a wire by Searle's method.

Reference Books:

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.
- Engineering Practical Physics, S. Panigrahi & B. Mallick,2015, Cengage Learning India Pvt. Ltd.
- A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
- Physics through experiments, B. Saraf, Vikas Publications, 2013
- A lab manual of Physics for undergraduate classes, 1st Edition, Vikas Publications.
- B.Sc. Practical Physics Revised Ed, C. L. Arora, S. Chand & Co. 2007

Semester II

UPHYMAJ-3 (Theory): Electricity and Magnetism

45 Lectures	3 Credits

Electric Field and Electric Potential

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. Potential and Electric Field of a dipole. Force and Torque on a dipole.

Electrostatic energy of a system of charges. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Parallel-plate capacitor. Capacitance of an isolated conductor. Uniqueness theorem (statement). Method of Images and its application to: A point charge placed in front of: (1) a plane infinite sheet and (2) a Sphere.

Dielectric Properties of Matter

Electric Field in matter. Polarization, Polarization Charges. Electric susceptibility and dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector *D*. Relations between *E*, *P* and *D*. Gauss's Law in dielectrics.

Magnetic Field

Magnetic force between current elements and definition of Magnetic Field B. Biot-Savart's Law and its applications: 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) infinite straight wire, (2) infinite planar surface current, and (3) solenoid.

Properties of B: curl and divergence. Vector Potential. Magnetic Force on (1) a point charge (2) a current carrying wire (3) between current elements. Torque on a current loop in a uniform magnetic field.

Magnetic Properties of Matter

Magnetization vector (M). Magnetic Intensity (H). Magnetic susceptibility and permeability. Relation between B, H, M.

Electromagnetic Induction

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.

Electrical Circuits

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

Network theorems

Ideal constant-voltage and constant-current sources. Network theorems: Thevenin theorem, Norton theorem, Superposition theorem, Maximum Power Transfer theorem. Applications to DC circuits.

Reference Books

- Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw Hill Education.
- Electricity and Magnetism, E. M. Purcell, 1986, McGraw-Hill Education
- Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
- Feynman Lectures, Vol.2, R. P. Feynman, and R. B. Leighton, and M. Sands, 2008, Pearson Education.
- Elements of Electromagnetics, M. N. O. Sadiku, 2010, Oxford University Press.
- Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol.I, 1991, Oxford Univ. Press.

UPHYMAJ-3 (Practical): Electricity and Magnetism Lab

30 Lectures	1 Credits

General topic

Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses.

List of Experiments

1. To study the charging and discharging characteristics of a capacitor using series DC C-R Circuit.
2. To determine an unknown Low Resistance using Potentiometer.
3. To determine an unknown Low Resistance using Carey Foster's Bridge.
4. To determine the resistance of a galvanometer using Thomson's method.
5. Measurement of field strength B and its variation in a solenoid (determine dB/dx)
6. To verify the Thevenin and Norton theorems.
7. To verify the Superposition, and Maximum power transfer theorems.
8. To study the AC L-R circuit, to draw the phase diagrams, to study the current voltage relationship across L and to study the variation of reactance of L with frequency and hence to find the inductance.
9. To study the AC C-R circuit, to draw the phase diagrams, to study the current voltage relationship across L and to study the variation of reactance of C with frequency and hence to find its loss factor.
10. To study the response curve of a series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor 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.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- A Text Book of Practical Physics, I. Prakash and Ramakrishna,11th Ed.,2011, Kitab Mahal.
- Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th Edition, Heinemann Educational Publishers.
- Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning.
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.

UPHYMAJ-4 (Theory): Waves and Optics

45 Lectures	3 Credits

Oscillations

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.

Superposition of Collinear Harmonic oscillations

Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats).

Superposition of two perpendicular Harmonic Oscillations

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

Wave Motion

Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave velocities. Differential equation of a wave. Pressure of a longitudinal wave. Energy transport. Intensity of a wave.

Superposition of Two Harmonic Waves

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.

Wave Optics

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

Interference

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.

Interferometer

Michelson Interferometer : (1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes.

Diffraction

Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating.

Fresnel Diffraction: Fresnel's assumptions. 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's Integral, Fresnel diffraction pattern of a straight edge, a slit, and a wire.

Reference Books

- Waves: Berkeley Physics Course, vol.3, F. Crawford, 2007, TataMcGraw-Hill.
- Fundamentals of Optics, F. A. Jenkins and H. E. White, 1981, McGraw Hill.
- Principles of Optics, M. Born and E. Wolf, 7th edition, 1999, Pergamon Press.
- Optics, A. Ghatak, 2008, Tata McGraw Hill.
- The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
- The Physics of Waves and Oscillations, N. K. Bajaj, 1998, Tata McGraw Hill.
- Fundamental of Optics, A. Kumar, H. R. Gulati, and D. R. Khanna, 2011, R.Chand Publications.

UPHYMAJ-4 (Practical): Waves and Optics Lab

30 Lectures	1 Credit

List of Experiments

1. To determine the frequency of an electric tuning fork by Meld's experiment and verify λ^2 -T law.
2. To investigate the motion of coupled oscillators.
3. To study Lissajous Figures.
4. Adjustment of a spectrometer by Schuster's method and to calibrate the spectrometer (D-λ curve) and hence determination of an unknown wavelength.
5. To determine the angle of a prism and hence to find out the refractive index of the material of a prism using sodium source.
6. To draw the μ-λ curve of the material of a prism using Hg/He/Ar source and determine the dispersive power and Cauchy constants.
7. To determine the wavelength of sodium source using Michelson's interferometer.
8. To determine wavelength of sodium light using Fresnel Biprism.
9. To determine wavelength of sodium light using Newton's Rings.
10. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
11. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
12. To determine dispersive power and resolving power of a plane diffraction grating.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971,Asia Publishing House
- A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition., 2011, Kitab Mahal
- Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers.
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.

Semester III

UPHYMAJ-5 (Theory): Mathematical Physics-II

45 Lectures	3 Credits

Fourier Series

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. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

Frobenius Method and Special Functions

Frobenius Method: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Series solution to Legendre, Bessel, Hermite, Laguerre differential equations.

Special Functions: Properties of Legendre polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations, spherical harmonics, Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions ($J_0(x)$ and $J_1(x)$) and Orthogonality.

Special Integrals

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

Partial Differential Equations

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.

Reference Books

- Mathematical Methods for Physicists: G. B. Arfken, H. J. Weber, and F. E. Harris, 2005, Elsevier.
- Fourier Analysis by M. R. Spiegel, 2004, Tata McGraw Hill.
- Mathematics for Physicists, S. M. Lea, 2004, Thomson Brooks/Cole.
- Differential Equations, G. F. Simmons, 2006, Tata McGraw Hill.
- Partial Differential Equations for Scientists and Engineers, S.J. Farlow, 1993, Dover Pub.
- Engineering Mathematics, S. Pal and S.C.Bhunia,2015, Oxford University Press
- Mathematical methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Books.
- Mathematical Physics, P. K. Chattopadhyay, 2014, New Academic Science.

UPHYMAJ-5 (Practical): Mathematical Physics II Lab	
30 Lectures	**1 Credits**
Introduction to Numerical computation using numpy and scipy	
Introduction to the python numpy module. Arrays in numpy, array operations, array item selection, slicing, shaping arrays. Basic linear algebra using the linalg submodule. Introduction to plotting using matplotlib. Introduction to the scipy module. Uses in optimization and solution of differential equations.	
Curve fitting, Least square fit, Goodness of fit, standard deviation (using numpy and scipy)	
Ohm's law to calculate Resistance, Hooke's law to calculate spring constant	
Solution of Linear system of equations, Diagonalization of matrices, Inverse of a matrix, Eigen vectors, Eigenvalue problems (using numpy and scipy)	
Solution of mesh equations of electric circuits having 3 meshes. Solution of coupled spring mass systems with 3 masses.	
Generation of Special functions by user defined functions	
Generating and plotting Legendre Polynomials; Generating and plotting Bessel function	
Solution of First order and second order ordinary Differential equation using numpy and scipy	

First order differential equation

1. Radioactive decay
2. Current in RC, LC circuits with DC source
3. Newton's law of cooling
4. Classical equations of motion, Second order Differential Equation
5. Harmonic oscillator (no friction)
6. Damped Harmonic oscillator, Overdamped and Critically damped cases.
7. Forced Harmonic oscillator
8. Transient and Steady state solution
9. Apply above to LCR circuits also
10. Solve

$$x^2\frac{d^2y}{d^2x} - 4x(1+x)\frac{dy}{dx} + 2(1+x)y = x^3$$

with the boundary conditions: at $x = 1$, $y = 0.5e^2$, $\frac{dy}{dx} = -1.5e^2 - 0.5$, in the range $1 \leq x \leq 3$. Plot y and $\frac{dy}{dx}$ against x in the given range in the same graph.

Reference Books

- Mathematical Methods for Physics and Engineers, K. F. Riley, M. P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Complex Variables, A. S. Fokas and M. J. Ablowitz, 8th edition, 2011, Cambridge Univ. Press
- Numpy beginner's guide, I. Alba, 2015, Packt Publishing
- Computational Physics, D.Walker, 1st edition, 2015, Scientific International Pvt. Ltd.
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. V. Wouwer, P. Saucez, and C. V. Fernandez, 2014, Springer

UPHYMAJ-6 (Theory): Thermal Physics

45 Lectures	3 Credits

Kinetic Theory of Gases

Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas (No proof required). Mean RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases.

Molecular Collisions: Mean Free Path. Collision Probability. Estimates of Mean Free Path.

Real Gases: Behaviour of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waals 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.

Introduction to Thermodynamics

Zeroth and First Law of Thermodynamics: Extensive and intensive thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of thermodynamics and concept of Temperature, Concept of Work and Heat, State Functions, First Law of thermodynamics and its differential form, Internal Energy, First Law and various processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes.

2^{nd} Law of Thermodynamics: Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine and efficiency. Refrigerator and coefficient of performance, 2^{nd} Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their equivalence.

Entropy: 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. Temperature–Entropy diagrams for a given Cycle. Third Law of Thermodynamics. Unattainability of absolute Zero.

Thermodynamic Potentials

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties and Applications. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations

Maxwell's Thermodynamic Relations

Derivations and applications of Maxwell's Relations, Maxwell's Relations:

(1) Clausius-Clapeyron equation, (2) Expression of $C_p - C_v$, (3) *TdS* Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process.

Reference Books

- Heat and Thermodynamics, M. W. Zemansky and R. Dittman, 1981, McGraw Hill.
- Thermal Physics, S. Garg, R. Bansal, and Ghosh, 2nd edition, 1993, Tata McGraw Hill
- Modern Thermodynamics with Statistical Mechanics, C. S. Helrich, 2009, Springer.
- Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Sears and Salinger, 1988, Narosa.
- Concepts in Thermal Physics, S. J. Blundell and K. M. Blundell, 2nd edition., 2012, Oxford University Press
- Thermodynamics and an introduction to thermostatistics, H. B. Callen, 1985, Wiley.
- Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.

UPHYMAJ-6 (Practical): Thermal Physics Lab

30 Lectures	1 Credit

List of Experiments

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 using Searle's apparatus.
3. To determine the coefficient of thermal conductivity of Cu using Angstrom's Method.
4. To determine the coefficient of thermal conductivity of a bad conductor using Lee and Charlton's disc method.
5. Determination of the thermal conductivity of glass in the form of a tube.
6. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
7. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
8. 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
9. To measure the coefficient of thermal linear expansibility of a rod using optical lever.
10. To determine the temperature coefficient of resistance of copper using metre bridge.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House
- A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal
- Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers
- A Laboratory Manual of Physics for undergraduate classes, D. P. Khandelwal, 1985, Vani Pub.

Semester IV

UPHYMAJ-7 (Theory): Quantum Mechanics

45 Lectures	3 Credits

Introduction to Quantum Mechanics

Blackbody Radiation: Rayleigh- Jeans law (statement only), Wein's distribution law (Statement only) and Planck's radiation law; 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. Wave amplitude and wave functions.

Uncertainty principle, introduction to operator physics and Schrödinger equation

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.

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

Simple applications of Schrödinger equation

One dimensional infinitely rigid box-energy eigenvalues and eigenfunctions, normalisation; Quantum dot as example; Quantum mechanical scattering and tunnelling in one dimension – across a step potential, rectangular potential barrier, and square well. Linear harmonic oscillator; Zero point energy and uncertainty principle.

Reference Books

- Concepts of Modern Physics, A. Beiser, 2002, McGraw Hill.
- Introduction to Modern Physics, F. K. Richtmyer, E. H. Kennard, and J. N. Cooper, 2002, Tata McGraw Hill
- Introduction to Quantum Mechanics, D. J. Griffith, 2005, Pearson Education.
- Physics for scientists and Engineers with ModernPhysics, Jewett and Serway, 2010, Cengage Learning.
- Modern Physics, G. Kaur and G. R. Pickrell, 2014, McGraw Hill
- Quantum Mechanics: Theory and Applications, A.K.Ghatak and
- S.Lokanathan, 2004, Macmillan
- Modern Physics, J. R. Taylor, C. D. Zafiratos, and M. A. Dubson, 2004, PHI Learning.
- Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd edition, Tata McGraw Hill Publishing Co. Ltd.
- Quantum Physics, Berkeley Physics, Vol.4. E. H. Wichman, 1971, TataMcGraw Hill Co.
- Basic ideas and concepts in Nuclear Physics, K. Heyde, 3rd edition, Institute of Physics Pub.
- Six Ideas that Shaped Physics: Unit-Q, Particles Behave like Waves, T.A.Moore, 2003, McGraw Hill

UPHYMAJ-7 (Practical): Quantum Mechanics Lab

30 Lectures	1 Credit

List of Experiments

1. Measurement of Planck's constant using blackbody radiation and photo-detector
2. Photo-electriceffect: photocurrent versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
3. To determine the 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 the H-alpha emission line of Hydrogen atom.
6. To determine the ionisation 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 set up the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunnelling effect in a tunnel diode using I-V characteristics.
11. To determine the wavelength of a laser source using diffraction from a single slit.
12. To determine the wavelength of a laser source using diffraction from double slits.
13. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating

Reference Books

- Advanced Practical Physics for students, B.L. Flint and H. T. Worsnop, 1971, Asia Publishing House
- Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers
- A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal

UPHYMAJ-8 (Theory + Tutorial): Classical Mechanics –I

45 Lectures (Theory) **15 Lectures (Tutorial)**	**Theory: 3 Credits** **Tutorial: 1 Credit**

Classical Mechanics

Work, Energy and Collisions: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Qualitative study of one dimensional motion from potential energy curves. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work and potential energy. Work done by non-conservative forces. Law of Conservation of Energy. Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.

Constraints: Degrees of freedom, constraints, holonomic and nonholonomic constraints with examples, generalized coordinates.

Principle of Virtual Work: Virtual displacement and virtual work, principle of virtual work, D'Alembert's principle, simple applications, generalized force and generalized moments.

Lagrangian Formalism: Lagrange's equations of motion from D'Alembert's principle, application to simple systems, canonically conjugate momenta, cyclic coordinates.

Variational Principle: Functionals. Basic ideas of functionals. Extremization of action as a basic principle in mechanics, variational calculus, Lagrange's equations from the variational principle, Applications to simple systems.

Hamiltonian Formalism: The Hamiltonian and its physical significance, Hamilton's equations of motion and application to simple systems. Applications to simple systems.

Special Theory of Relativity

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.

Reference Books

- Classical Mechanics, H. Goldstein, C. P. Poole, and J. L. Safko, 3rd edition. 2002, Pearson Education.
- Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
- The Feynman Lectures on Physics, R. P. Feynman, Vol. 1 (2nd ed.), 2005, Addison-Wesley.
- Classical Mechanics: Systems of Particles and Hamiltonian Dynamics, W. Greiner, 2009, Springer
- An Introduction to Mechanics, D. Kleppner and R. Kolenkow, 1973, McGraw Hill

Semester V

UPHYMAJ-9 (Theory): Analog Electronics

45 Lectures	3 Credits

Semiconductor Diodes

P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. Barrier Formation in p-n junction diodes. 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.

Two-terminal Devices and their Applications

Zener diode and Voltage regulation. Principle and structure of (1) LEDs, (2) Photo diode, and (3) Solar Cell.

Bipolar Junction transistors

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.

Field Effect transistors

Basic principle of operations only (JFET & MOSFET).

Amplifiers

Amplifiers: 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. Frequency response of a CE amplifier.

Coupled Amplifier: Two-stage RC-coupled amplifier.

Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise. Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley and Colpitts oscillators.

Operational Amplifiers (Black Box approach): 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.

Applications of Op-Amps: Linear - (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. Nonlinear – (1) inverting and non-inverting comparators, (2) Schmidt triggers.

Conversion: Resistive network (Weighted and R-2R Ladder). Accuracy and Resolution. A/D Conversion (successive approximation)

Reference Books

- Integrated Electronics, J. Millman and C. C. Halkias, 1991, Tata Mc-GrawHill.
- Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall.
- Solid State Electronic Devices, B. G. Streetman and S. K. Banerjee, 6th edition, 2009, PHI Learning
- Electronic Devices and circuits, S. Salivahanan and N. S. Kumar, 3rd edition, 2012, Tata Mc-GrawHill
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
- Microelectronic circuits, A. S. Sedra, K. C. Smith, and A. N. Chandorkar, 2014, 6th edition, Oxford University Press.
- Electronic circuits: Handbook of design and applications, U. Tietze, and C. Schenk, 2008, Springer
- Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd edition, 2002, Wiley India
- Microelectronic Circuits, M. H. Rashid, 2nd edition, Cengage Learning
- Electronic Devices, T. L. Floyd, 7th edition, 2008, Pearson India

UPHYMAJ-9 (Practical): Analog Electronics Lab

30 Lectures	1 Credit

List of Experiments

1. To study V-I characteristics of p-n junction diodes, and Light emitting diodes.
2. To study the V-Icharacteristics of a Zener diode and its use as voltage regulator.
3. Study of V-I and power curves of solar cells, and find maximum power point and 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 a 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) and 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.
21. To design a circuit to simulate the solution of a 1st/2nd order differential equation.

Reference Books

- Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, and M. A. Miller, 1994, Mc-GrawHill.
- OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall.
- Electronic Principle, A. Malvino, 2008, Tata Mc-GrawHill.
- Electronic Devices and circuit Theory, R. L. Boylestad and L. D. Nashelsky, 2009, Pearson

UPHYMAJ-10 (Theory): Mathematical Physics III

45 Lecture	3 Credits

Dirac Delta function

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

Fourier Transforms

Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train and other functions. Representation of Dirac delta functions as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations.

Matrices

Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar and Unit Matrices. Upper-Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew-Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Trace of a Matrix. Inner Product Eigen-values and Eigenvectors, Cayley- Hamilton Theorem. Diagonalization of Matrices. Solutions of Coupled Linear Ordinary Differential Equations. Functions of a Matrix.

Probability Theory

Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance. Fundamental Probability Theorems. Conditional Probability, Bayes' Theorem, hypothesis testing , Repeated Trials, Binomial and Multinomial expansions. Random Variables and probability distributions, Expectation and Variance, Special Probability distributions: The binomial distribution, The Poisson distribution, Continuous distribution: The Gaussian (or normal) distribution, The principle of least squares.

Reference Books

- Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd edition, 2006, Cambridge University Press
- Mathematics for Physicists, P. Dennery and A. Krzywicki, 1967, Dover Publications
- Mathematical Methods for Physicists: G. B. Arfken, H. J. Weber, and F. E. Harris, 2005, Elsevier.
- Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw Hill.
- Mathematics for Physicists, S. M. Lea, 2004, Thomson Brooks/Cole.
- Differential Equations, G.F. Simmons, 2006, Tata McGraw Hill.
- Partial Differential Equations for Scientists and Engineers, S.J. Farlow, 1993, Dover Pub.
- Engineering Mathematics, S. Pal and S.C.Bhunia,2015, Oxford University Press
- Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Books.
- Mathematical Physics, P. K. Chattopadhyay, 2014, New Academic Science.

UPHYMAJ-10 (Practical): Mathematical Physics III Lab

30 Lecture	1 Credit

Practicals: Using Numpy/ Scipy. Plotting should be done wherever possible.

1. To compute forward and inverse Fourier transform of a given signal using FFT. Determination of frequencies in the signal by plotting power spectral density.

2. To evaluate Fourier coefficients of given functions.

3. Dirac Delta Function: Evaluate

$$\frac{1}{\sqrt{2\pi\sigma^2}}\int e^{\frac{-(x-2)^2}{2\sigma^2}}(x+3)\,\mathrm{d}x\,,$$

for σ=1, 0.1, and 0.01. and find the limiting value of the integral as σ → 0. Verify using Dirac Delta function.

4. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two). Perform a least square fitting of the data without giving weightage to error.

5. Evaluation and plotting of $P_n(x)$ and $J_n(x)$ for integer values of n, verification of orthogonality properties of Legendre function and Bessel function of the first kind.

6. Solve the differential equations of the following type and plot the solutions.

$$dy/dx = e^{-x} \text{ with } y = 0 \text{ at } x = 0.$$

$$dy/dx + e^{-x}y = x^2 \text{ with } y = 0 \text{ at } x = 0.$$

$$d^2y/dt^2 + 2dy/dt = -y \text{ with } y = 0 \text{ and } y' = 1 \text{ at } t = 0.$$

$$d^2y/dt^2 + e^{-t}dy/dt = -y \text{ with } y = 0 \text{ and } y' = 1 \text{ at } t = 0.$$

Reference Books

- Mathematical Methods for Physics and Engineers, K. F. Riley, M. P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
- Complex Variables, A. S. Fokas and M. J. Ablowitz, 8th edition, 2011, Cambridge Univ. Press
- Numpy beginner's guide, I. Alba, 2015, Packt Publishing
- Computational Physics, D.Walker, 1st edition, 2015, Scientific International Pvt. Ltd.
- Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. V. Wouwer, P. Saucez, and C. V. Fernandez, 2014, Springer

UPHYMAJ-11 (Theory+Tutorial): Atomic Physics

45 Lectures (Theory) 15 Lectures (Tutorial)	Theory: 3 Credits Tutorial: 1 Credit

Angular Momentum

Angular momentum operator in Cartesian coordinates and its representation in spherical polar coordinates; Angular momentum operator related commutation relations; Eigenvalues and eigenfunctions of L^2.

Quantum theory of hydrogen-like atoms

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

Atoms in Electric and Magnetic Fields

Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton.

Atoms in External Magnetic Fields

Normal and Anomalous Zeeman Effect. Paschen-Back and Stark Effect (Qualitative Discussion only).

Many electron atoms

Pauli's Exclusion Principle. Symmetric and Antisymmetric Wave 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.).

Lasers

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.

Reference Books

- A Textbook of Quantum Mechanics, P. M. Mathews and K. Venkatesan, 2nd edition, 2010, McGraw Hill
- Quantum Mechanics, R. Eisberg and R. Resnick, 2nd edition, 2002, Wiley.
- Quantum Mechanics, L. I. Schiff, 3rd edition, 2010, Tata McGraw Hill.
- Quantum Mechanics, G. Aruldhas, 2nd edition, 2002, PHI Learning of India.
- Quantum Mechanics, B. C. Reed, 2008, Jones and Bartlett Learning.
- Quantum Mechanics: Foundations and Applications, A. Bohm, 3rd edition, 1993, Springer
- Quantum Mechanics for Scientists and Engineers, D. A. B. Miller, 2008, Cambridge University Press
- Quantum Mechanics, E. Merzbacher, 2004, John Wiley and Sons Inc.
- Introduction to Quantum Mechanics, D. J. Griffith, 2nd edition, 2005, Pearson Education
- QuantumMechanics, W. Greiner, 4th edition, 2001, Springer

UPHYMAJ-12 (Theory): Solid State Physics

45 Lectures	3 Credits

Crystal Structure

Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. 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.

Elementary Lattice Dynamics

Lattice Vibrations and Phonons: Linear Monatomic 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

Magnetic Properties of Matter

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.

Dielectric Properties of Materials

Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius-Mossotti Equation. Classical Theory of Electric Polarizability. Normal and Anomalous Dispersion. Cauchy and Sellmeier relations. Langevin-Debye equation. Complex Dielectric Constant, Ferroelectric Properties of Materials: Structural phase transition, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

Elementary band theory

Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of electrical conductivity (04 probe method) and Hall coefficient.

Superconductivity

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)

Reference Books

- Introduction to Solid State Physics, C. Kittel, 8th edition, 2004,Wiley India Pvt. Ltd.
- Elements of Solid State Physics, J. P. Srivastava, 4th edition, 2015, Prentice Hall of India
- Introduction to Solids, L. V. Azaroff, 2004, Tata McGraw Hill
- Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning
- Solid-State Physics, H. Ibach and H. Luth, 2009, Springer
- Solid State Physics, R. John, 2014, McGraw Hill
- Elementary Solid State Physics, M. A. Omar, 1999, Pearson India
- Solid State Physics, M. A. Wahab, 2011, Narosa Publications

UPHYMAJ-12 (Practical): Solid State Physics Lab

30 Lectures	**1 Credit**

List of Experiments

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 study the PE Hysteresis loop of a Ferroelectric Crystal.
6. To draw the BH curve of Fe using Solenoid and determine energy loss from Hysteresis.
7. To determine the energy gap of a semiconductor using a pn junction diode.
8. 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.
9. To determine the Hall coefficient of a semiconductor sample.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted1985, Heinemann Educational Publishers.
- A TextBook of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal
- Elements of Solid State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice Hall of India.

Semester VI

UPHYMAJ-13 (Theory): Electromagnetic Theory

45 Lectures	3 Credits

Maxwell's Equations

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.

EM Wave Propagation in Unbounded Media

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.

EM Wave in Bounded Media

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

Polarization of Electromagnetic Waves

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 and extraordinary refractive indices. Production and 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

Rotatory Polarization: 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.

Reference Books

- Introduction to Electrodynamics, D. J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
- Optics, E.Hecht, 2016, Pearson.
- Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
- Introduction to Electromagnetic Theory, T. L. Chow,2 006, Jones & Bartlett Learning
- Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill
- Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning
- Engineering Electromagnetic, W. H. Hayt, 8th edition, 2012, McGraw Hill.
- Electromagnetic Field Theory for Engineers and Physicists, G. Lehner, 2010, Springer
- Electromagnetic Fields and Waves, P. Lorrain and D. Corson, 1970, W. H. Freeman & Co.
- Electromagnetics, J. A. Edminster, SchaumSeries, 2006, Tata McGraw Hill.
- Electromagnetic field theory fundamentals, B. Guru and Hiziroglu, 2004, Cambridge University Press

UPHYMAJ-13 (Practical): Electromagnetic Theory Lab

30 Credits	1 Credits

List of Experiments

1. To verify the Malus law for plane polarized light.
2. To determine the specific rotation of sugar solution using a Polarimeter.
3. To analyze elliptically polarized Light 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 determine Stefan constant.
12. To determine the Boltzmann constant using V-I characteristics of a p-n junction diode.

Reference Books

- Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
- Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted1985, Heinemann Educational Publishers
- A TextBook of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal
- Electromagnetic Field Theory for Engineers and Physicists, G. Lehner, 2010, Springer

UPHYMAJ-14 (Theory + Tutorial): Statistical Mechanics

45 Lectures (Theory) 15 Lectures (Tutorial)	Theory: 3 Credits Tutorial: 1 Credit

Classical Statistical Mechanics

Macrostate and Microstate, Elementary Concept of Ensemble, Microcanonical ensemble, Phase Space, Entropy and Thermodynamic Probability, Canonical ensemble, 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. Grand canonical ensemble and chemical potential.

Quantum Statistics

Identical particles and symmetry requirements, derivation of Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac statistics as the most probable distributions, Classical limit of quantum mechanics

Bose-Einstein Statistics

Bose-Einstein 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 of blackbody radiation. Spectral Distribution of Black Body Radiation. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law.

Fermi-Dirac Statistics:

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.

Reference Books

- Statistical and ThermalPhysics, S. Lokanathan and R. S. Gambhir, 1991, Prentice Hall
- Thermodynamics, KineticTheory, and Statistical Thermodynamics, F. W. Sears and G. L. Salinger, 1986, Narosa.
- Modern Thermodynamics with Statistical Mechanics, C. S. Helrich, 2009, Springer
- An Introduction to Statistical Mechanics and Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press
- Statistical Mechanics–an elementary outline, A. Lahiri, 2008, Universities Press
- Statistical Mechanics, R. K. Pathria, and B. Heinemann,1996,Oxford University Press.
- Statistical Physics, Berkeley Physics Course, F.Reif, 2008, Tata McGraw Hill

UPHYMAJ-15 (Theory): Digital Electronics

45 Lectures	3 Credits

Integrated Circuits

Active and 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.

Digital Circuits

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 and application as Parity Checkers.

Boolean algebra

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.

Data processing circuits

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

Circuits

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

Sequential Circuits: 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.

Timers

IC555: block diagram and applications: A stable multivibrator and Mono stable multivibrator.

Shift registers

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

Counters (4 bits)

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

Reference Books

- Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha,7th Ed.,2011,Tata McGraw Hill
- Fundamentals of Digital Circuits, A. Kumar ,2nd edition, 2009, PHI Learning Pvt. Ltd.
- Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
- Digital Electronics, G. K. Kharate, 2010, Oxford University Press
- Digital Systems: Principles and Applications, R. J. Tocci and N. S. Widmer, 2001, PHI Learning
- Logic circuit design, S. P. Vingron, 2012, Springer.
- Digital Electronics, S. Ghoshal, 2012, Cengage Learning.
- Digital Electronics, S. K. Mandal, 2010, 1st edition, McGraw Hill
- Microprocessor Architecture Programming and applications with 8085, 2002, R.S. Gaonkar, Prentice Hall

UPHYMAJ-15 (Practical): Digital Electronics Lab

30 Lectures	1 Credit

List of Experiments

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. To minimize a given logic circuit.
8. Half Adder, Full Adder, and 4-bit binary Adder.
9. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
10. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
11. To build JK Master-slave flip-flop using Flip-Flop ICs
12. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagrams.
13. To make a 4-bit Shift Register (serial and parallel) using D-type/ JK Flip-Flop ICs.
14. To design an astable multivibrator of given specifications using 555 Timer.
15. To design a monostable multivibrator of given specifications using 555 Timer.

Reference Books

- Modern Digital Electronics, R. P. Jain, 4th edition, 2010, Tata McGraw Hill.
- Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, and M. A. Miller, 1994, McGraw Hill.

UPHYMAJ-16 (Theory + Tutorial): Nuclear and Particle Physics

45 Lectures (Theory) 15 Lectures (Tutorial)	Theory: 3 Credits Tutorial: 1 Credit

General Properties of Nuclei

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excited states.

Nuclear Models

Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate Fermi gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force.

Radioactive decay

(a) Alpha decay: basics of α-decay processes, theory of α- emission, Gamow factor, Geiger-Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission and kinematics, internal conversion.

Nuclear Reactions

Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

Interaction of Nuclear Radiation with matter

Energy loss due to ionization (Bethe-Bloch formula), energy loss of electrons, Cerenkov radiation. Gamma ray interaction through matter, pair production, neutron interaction with matter.

Detector for Nuclear Radiations

GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility).

Particle Accelerators

Linear accelerator, Cyclotron, Synchrotrons.

Particle Physics

Particle interactions; basic features, types of particles and their families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, colour quantum number and gluons.

Reference Books

- Introductory Nuclear Physics, K. S. Krane, 2008, Wiley India Pvt. Ltd.
- Concepts of nuclear physics by B. L. Cohen, 1998, Tata Mcgraw Hill.
- Introduction to the physics of nuclei and particles, R. A. Dunlap, 2004, Thomson Asia, 2004.
- Introduction to High Energy Physics, D. H. Perkins, Cambridge Univ. Press
- Introduction to Elementary Particles, D. Griffith, John Wiley & Sons
- Quarks and Leptons, F. Halzen and A.D. Martin, Wiley India, New Delhi
- Basic ideas and concepts in Nuclear Physics-An Introductory Approach,
- K.Heyde, 2004, IOP-Institute of Physics Publishing.
- Radiation detection and measurement, G. F. Knoll, 2000, John Wiley & Sons.
- Physics and Engineering of Radiation Detection, S. N. Ahmed, 2007, Academic Press, Elsevier..
- Theoretical Nuclear Physics, J. M. Blatt and V. F. Weisskopf, 1991, Dover Pub. Inc.