**DEPARTMENT OF PHYSICS**

**Detail Syllabus**

**4 years UG Programme**

**Semester I**

**PHIN101: Physics-I (L3-T0-P1-CH4-CR4)**

**Theory (L3-T0-CH3-CR-3)**

**Course Outcomes:**

CO1: The students will be able to understand the basics of vectors and matrices, introductory mechanics andproperties of matter.

CO2: The students will learn the detail of the coordinate systems: plane polarized, cylindrical and spherical;along with various vector and scalar properties.

CO3: The students will be able to extensively use vectors and matrices in solving various problems in anintended learning outcome.

CO4: The students are also expected to understand the basic mechanics in both inertial and non-inertialframes, motion under a central force and the mechanics of a system of particles.

**Course Content:**

**Unit 1(6 lectures)**

Coordinate systems, plane polar, cylindrical and spherical polar; line element, surface element and volumeelement; gradient, divergent and curl.Line, surface and volume integrals.

**Unit 2(8 lectures)**

Mechanics: Work-energy theorem, conservative forces and potential energy; energy diagram; non-conservative forces;motion in non-inertial frames; uniformly rotating frame; centrifugal and Coriolis forces. Motion under a central force.

**Unit 3(10 lectures)**

System of particles; Centre of mass, equation of motion of the Centre of mass; laboratory and Centre of massframe of references; elastic and inelastic collisions; linear and angular momentum and their conservationlaws; fixed axis rotation; moment of inertia; theorem of parallel and perpendicular axes; compoundpendulum, Kater’s and bar pendulum.

**Unit 4(8 lectures)**

Properties of Matter:Elasticity; elastic constants; Hooke’s law; torsional oscillation; bending of a beam; cantilever; surfacetension; viscosity; kinematics of moving fluids.

**Unit 5(810lectures)**

Ideal fluids, Equation of continuity, Streamline flow, Rotational and irrotational flows, Euler’s equation of motion, Bernoulli’s Theorem, Viscous fluids, Poiseuille’s equation, Viscosity by rotating cylinder method.

**Text Books:**

1. Potter M. C., Goldberg J., *Mathematical methods*, 2nd edition (Phi Learning Pvt. Ltd., 2008).
2. Kleppner, D. and Kolenkow, R., *Introduction to Mechanics*, (McGraw-Hill, 1973).
3. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003)

**Suggested Readings:**

1. Harper C., *Introduction to Mathematical Physics*, 1st edition (Phi Learning Pvt. Ltd., 2008).
2. Chow, T. L., *Mathematical Methods for Physicists: A concise introduction*, 1st edition(Cambridge Univ. Press, 2000).
3. Takwale R., Puranik P., *Introduction to Classical Mechanics*, (McGraw Hill, 2017).
4. Young, H. D. and Freedman, R. A., *University Physics*, 12th edition (Pearson, 2009).
5. Spiegel M., *Vector Analysis: Schaum’s Outlines Series*, 2nd edition (McGraw Hill, 2017).
6. Mathur, D. S., *Mechanics*, (S. Chand & Co. Ltd., 2000).

**Practicals (L0-T0-P1-CH2-CR1)**

1. Familiarization with equipment and components:
2. Familiarization of different Electrical and Electronic components and hence identification & determination of values of unknown components
3. Familiarization of different Optical components and hence show different optical behavior & pattern by using different optical components and optical sources (white light, laser, sodium light etc.)
4. Familiarization of Microsoft excel, Origin and other software for data analysis
5. Soldering & de-soldering of components in a circuit board
6. Use of equipment:
7. Multimeter and its uses
8. Function generator and its uses
9. CRO and its use to measure the wavelength, frequency, amplitude etc. of a given electrical signal
10. Study of Lissajous figure of two different waves using CRO and find out the unknown frequency of an electrical signal.
11. Determine the value of the acceleration due to gravity (on Earth) by using Kater's pendulum.
12. To determine the surface tension of the given liquid (water/ CCl4) by capillary tube method.
13. Design a LCR circuit with the given components and to measure the resonance frequency of the circuit.
14. Determine the co-efficient of linear expansion of the given metal sample by optical lever method.
15. Verification of Basic Digital Gates: AND, NOT, OR, NAND, NOR, XOR, XNOR

**Extra reading:**

Laboratory related Instructions:

1. Laboratory safety measures; handling of chemicals; electrical and electronics items & instruments; handling of laser and laser related instruments and experiments; handling of Radioactive samples and related instruments; general safety measures etc.
2. Management and maintenance of laboratory room, equipment etc.
3. Techniques of data collection, data analysis, measurement of error and error analysis etc.
4. Technique/ method of notebook record.
5. To calculate mean, standard deviation for a given measurement data

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**Semester II**

**PHYSICS-II (L3-T0-P1-CH4-CR4)**

**Theory (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: The students will have a good idea on relativity, electricity, magnetism and electronics.

CO2: The student will be able to study the advanced courses like General relativity, Electrodynamics, Digital electronics etc.

**Course Content:**

**Unit 1 (9 Lectures)**

Special Theory of Relativity: Frames of reference, relative velocity and accelerations, Concept of ether, Michelson-Morley experiment,elements of special theory of relativity, the postulates, Galilean and Lorentz transformations, equivalence ofmass and energy, time dilation, length contraction, simultaneity, Doppler effect, twin paradox.

**Unit 2(9 Lectures)**

Electromagnetism: Coulomb’s law (electric), electric field due to a system of charges, Gauss’s law in differential and integralforms, electric dipole, its electric field and potential, capacitance of parallel plates.Coulomb’s law (magnetic), Biot-Savart law, force on a current and on moving charges in a B-field.

**Unit 3(9 Lectures)**

Electronics:Kirchhoff’s law, network theorem, nodal analysis, mesh analysis, maximum power transfer theorem, seriescircuits, parallel circuits (DC analysis only), semiconductors, p-type, n-type semiconductors, p-n junction,.

**Unit 4(9 Lectures)**

Equivalence of heat and energy, Reversible,Irreversible and cyclic processes,The laws of Thermodynamics, Entropy and Thermodynamic potentials

**Text Books:**

1. Beiser A., *Concepts of Modern Physics*, 6th edition (Tata McGraw Hill, 2008).
2. Rakshit, P. C. and Chattopadhaya, D., *Electricity and Magnetism*, (New Central Book Agency, 2012).
3. Robbins, A. H. & Miller, W. C., *Circuit Analysis* (Delmar Cengage Learning, 2003).

**Suggested Readings:**

1. Resnick, R., *Introduction to Special Relativity*, 1st edition (Wiley, 2007).
2. Griffith, D. J., *Introduction to Electrodynamics*, 3rd edition (Prentice Hall of India, 1999).
3. Edminister, J. A., *Electrical Circuits*- Schaum’s Outline series, 2nd edition (McGraw Hill,1983).

**Practicals (L0-T0-P1-CH1-CR1)**

1. Determination of the co-efficient of viscosity of water by Poiseulle's method.
2. Measurement of frequency of an unknown tuning fork using a sonometer.
3. Determination and plot I-V characteristics of a LED.
4. Determine the Mechanical/ Electrical equivalent of heat by Joule’s calorimeter.
5. Thermal conductivity measure by Searle’s method.
6. To verify Biot Savart’s law using Helmholtz’s coil.
7. To measure the wavelength of sodium light by Newton's Ring method.
8. To measure the inductance of a given inductor using Anderson bridge

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**Semester III**

**PHIN201: Classical Mechanics-I**  **(L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: Students will understand concepts of generalized coordinates and constrained motion.

CO2: They will be able to apply Newtonian as well as Lagrangian and Hamiltonian mechanics to describe motion of physical systems, including systems involving central potential.

**Course Content:**

Mechanics of a Particle: Conservation theorems for a particle, motion of a particle under damping forces, motion of a particle under central force, motion of a body in a resisting medium, Kepler's laws of planetary motion, moving co-ordinate systems, Galilean transformation, Coriolis force, Foucault's pendulum.

Mechanics of a System of Particles: Centre of mass and its motion, conservation theorems for a system of particles, collision problems, constraints, generalised co-ordinates, configuration space, principle of virtual work, D'Alembert's principle.

Lagrangian Formulation: Lagrange's equation, the rules of forming Lagrange's equation, Lagrange's equations for non-conservative forces, spherical and cylindrical co-ordinates, Hamilton's principle and Lagrange's equation, application of Lagrange's equation, motion of charged particle in an electromagnetic field, superiority of Lagrange’s approach over Newtonian approach.

Hamiltonian Formulation: Phase space, Hamiltonian function and Hamiltonian equation, application of Hamiltonian equation, Harmonic oscillator, compound pendulum, cyclic co-ordinates, Liouville's theorem, Routh's procedure.

Variational Principles: Derivation of Euler-Lagrange differential equation, Hamilton’s principle and its deduction, derivation of Lagrange’s equation from Hamilton’s principle, modified Hamilton’s equation (vibrational principle) and derivation of Hamilton’s principle from it, principle of least action, method of Lagrange’s undetermined multipliers.

**Text Books:**

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (PragatiPrakashan).

**Reference Books:**

1. Goldstein, H., *Classical Mechanics*, (Narosa, 2001).
2. Rana N. C., and Joag, P. S., *Classical Mechanics,* (Tata McGraw-Hill, 1991).
3. Takwale, R. G. and Puranik, P. S., *Introduction to Classical Mechanics,* (Tata McGraw-Hill, 1978).
4. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).

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**PHIN202: Mathematical Physics-I**  **(L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: Students should be able to understand basic theory of vectors analysis, curvilinear coordinate systems, differential equations, matrices, Fourier series and probability theory.

CO2: Successful students should be able to apply methods of vector differentiation and integrals as well as separation of variables to solve differential equations, expansion of Fourier and Taylor series, various integrals to special functions, solve differential equations using matrix methods.

CO3: Learn the use basic probability theory to analyze experimental data.

**Course Content:**

Greens, Gauss’s and Stokes theorems and their applications, transformations of coordinate systems and vector components, metric coefficients, curvilinear coordinates, expressions for grad., div., and curl, Helmholtz equation in three-dimensions and separable variables in various coordinate systems, matrices and determinants.

Beta, gamma and error functions, relationship between the beta and gamma functions, reduction of some classes of integrals to gamma functions, Sterling’s formula; derivation of values of gamma functions.

Fourier Series: Evaluation of coefficients, graphical representations, even and odd functions, properties of Fourier series, Fourier integrals.

Elements of Probability: Mathematical probability, compound probability, total probability, sample space, random variables, expectation value, averages, mean, standard deviation, binomial distribution, normal distribution; variance, covariance and correlation; theory of errors, central limit.

Random Process: Random variables to random process, statistical averages, stationary processes.

**Text Books:**

1. Harper, C., *Introduction to Mathematical Physics, (*Prentice Hall, 2009).
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005).
3. Spiegel, M. R., *Vector Analysis*, Schaum's outline series, (Tata McGraw-Hill 1979).

**Reference Book:**

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry,* (Young Press, 2009).

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**PHIN203: Optics and Laser Physics (L3-T0-P0-CH3-CR3)**

**Course Objective:**

The present course offers an all-encompassing survey of the basic principles of optics and Laser, building upon the fundamental knowledge gained in previous educational endeavors. Furthermore, the present course explores the creation of innovative ideas within this particular area of study.

**Course Outcomes:**

At the end of the course the following concepts will be clear to the students

CO1: Understand Interference as superposition of waves from coherent sources derived from same parent source

CO2: Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhoffer and Fresnel Diffraction.

CO3: Polarisation and Scattering concepts.

CO4: Fundamental principles of lasing mechanism and identifying various types of lasers,

CO5: Analyzing the attributes of laser lightin terms of its coherence property, output power and wavelength.

CO6: Working of lasers and important applications of laser in various fields starting from material science to biological science.

**Course Contents:**

**Unit 1 (7 Lectures)**

Electromagnetic nature of light.Definition and Properties of wave front.Huygens Principle. Interference: Division of amplitude and division of wavefront. Lloyd’s Mirror and Fresnel’s Biprism. Phase change on reflection: Stokes’ treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton’s Rings: measurement of wavelength and refractive index.

**Unit 2 (5 Lectures)**

Diffraction: Fraunhofer diffraction- Single slit, Double Slit, Multiple slits and Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate.Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis.

**Unit 3 (8 Lectures)**

Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization (General idea).Scattering, Elastic and Inelastic scattering and their applications.Resolving power of optical equipment.

**Unit 4 (5 Lectures)**

*Lasers:*An introduction, Planck’s radiation law (qualitative idea), Energy levels, Absorption process, Spontaneous and stimulated emission processes, Theory of laser action, Population of energy levels, Einstein’s coefficients and optical amplification, two-level atomic systems, light amplification, threshold condition.

**Unit 5(6 Lectures)**

Ruby Laser, He-Ne laser, neodymium-based lasers, CO2 laser, dye laser, fiber laser,semiconductor lasers; DFB and DH lasers

**Unit 6(5 Lectures)**

Generation of ultra-fast optical pulses, pulse compression, femto-second laser and its characteristics.Applications of lasers like laser cooling, laser tweezers, material processing (Qualitative only).

**Text Books:**

1. Ghatak, A. K. and Thyagarajan, K., *Optical Electronics*, (Cambridge University Press, 2009).
2. Svelto, O., *Principles of Lasers*, 3rd edition, (Springer, 2007).

**Suggested Readings:**

1. Milonni, P. W. and Eberly, J. H., *Laser Physics*, (John Wiley & Sons, 2010).
2. Yariv, A., *Quantum Electronics*, 3rd edition, (Wiley Eastern Ltd.).
3. Davis, J. H., *Introduction to Low Dimension Physics*, (Cambridge University Press, 1997).

Siegman, A. E., Lasers, (University Science Books, 1986).

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**Semester IV**

**PHIN205: Electrical Networks and Device Electronics** **(L2-T0-P1-CH4-CR3)**

**Course Objectives:**

To develop understanding of principles of electricity and practical adaptation of electric circuits. The course will familiarize and teach basics of solid state devices and their applications.

**Course Outcomes:**

At the end of this course, the student will acquire the knowledge to

CO1: To analyze and evaluate schematics of power efficient electrical circuits, Star and delta connections, voltage drop and losses.

CO2: Insight into tracking of interconnections within elements(R,L,C) and identifying current flow and voltage drop.

CO3: Understanding working of some basic solid-state devices.

**Course Content:**

**Unit 1 (8 Lectures)**

Circuit parameters, R, L, and C, Kirchoff’s Law for a loop and junction, Solutions by Determinant andmatrix method: application to T, π and bridge circuits, Norton and Thevenin’s Theorem, Maximum power, transfer Theorem.

Difference between steady state and transient, Growth and decay of current in an inductive circuit.

**Unit 2 (6 Lectures)**

Semiconductors: p and n Type Semiconductors. Energy Level Diagram, Mobility and conductivity, transportphenomenon due to donor and acceptor impurities, Fermi level, Hall Effect, conductivity measurement

**Unit 3 (8 Lectures)**

Diodes: Barrier Formation in pn Junction Diode (Simple Idea). Current Flow Mechanism in Forward and, Reverse Biased Diode (Recombination, Drift and Saturation of Drift Velocity). Derivation of Mathematical, Equations for Barrier Potential, Barrier Width and Current for Step Junction.pn junction and its, characteristics. Static and Dynamic Resistance.Diode Equivalent Circuit.Ideal Diode. Load Line Analysisof Diodes and Q-point.

**Unit 4 (6 Lectures)**

Two-terminal Devices and their Applications: (1) Rectifier Diode. Half-wave Rectifiers.Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification.

Efficiency. Qualitative idea of C, L and π - Filters. (2) Wave shaping circuits (3) Zener Diode and VoltageRegulation. (4) Photo Diode, (5) Varactor Diode.

**Unit 5 (8 Lectures)**

Bipolar Junction Transistors, n-p-n and p-n-p transistors. Characteristics of CB, CE and CC Configurations.Current gains α, β and γ and Relations between them. Load Line Analysis of transistors. DC Load line andQ-point.Physical Mechanism of Current Flow.Active, Cutoff, and saturation Regions.Transistor in ActiveRegion and Equivalent Circuit.

**Text Books:**

1. Robbins, A. H. & Miller, W.C., *Circuit Analysis*, (Delmar Cengage Learning., 2003).
2. Hayt, W. H. &Kemmerly, J. E., *Engineering Circuit Analysis*, (McGraw Hill, New York, 1993).

**Suggested Readings:**

1. Millman, J., Halkias, C.C. and Jit, S., *Electronic Devices and Circuits*, (McGraw Hill Education,India,2016).
2. Toro,V. Del, *Electrical Engineering Fundamentals*, (Prentice Hall, 1994).
3. Edminister, J.A., *Electrical Circuits*- Schaum’s Outline series, 2nd edition (McGraw Hill,1983).
4. Smith, R.J. and Dorf, R.C., *Circuits, Devices and Systems*, (John Wiley & Sons, 1992).
5. Morris, J. *Analog Electronics*, (Arnold Publishers, 1991).
6. Mottershead, A. *Electronic Circuits and Devices*, (Prentice Hall, 1997).
7. Streetman, B.G. & Banerjee, S., *Solid State Electronic Devices*, (Pearson Prentice Hall, 2006).
8. Bhargava, N. N., Kulshreshtha D.C. & Gupta S.C., *Basic Electronics & Linear Circuits*, (Tata McGrawHill, 2006).
9. Boylestad, R. &Nashelsky, L. *Electronic Devices and Circuit Theory*, 8th edition, (PearsonEducation, India, 2004).
10. Malvino A. P., *Electronic Principals*, (Glencoe, 1993).

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**PHIN206: Electromagnetic Theory-I (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: The students will be able to build up strong creativity, analytical capability and innovativeness.

CO2: The students will be able to improve potentiality via diversified exercises of mathematical physics, vector operation, and electromagnetism.

CO3: The students will be able to explore the physical universe from a new perspective of electromagnetic origin eventually after judging the applicability of the various model theories competently.

**Course Content:**

**Unit – 1**

Electrostatics : Charges, fields and associated potentials. Chanrge distributions, flux, Gauss Law: Integral and differential form and its physical interpretaion, Electric Field due to point charge, line charge, infinite flat sheet, and uniform charge distribution of solid and spherical shell; 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.

**Unit – 2**

Derivation of fields from Potentials, Laplace equations, Method of images, boundary value problems, Laplace equation in rectangular, cylindrical and spherical coordinates, multipole expansion.Dielectric medium, Polarisation, Displacement vector.Gauss’s theorem in dielectrics. Parallel plate capacitor completely filled with dielectric. Energy associated with electric field. Dielectrics and Polarization, Induced dipoles and Bound charges; Electric displacement vectors, Dielectric, para electric and Ferroelectrics.

**Unit – 3**

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, Electrostatic and magnetostatic fields in matter, Boundary conditions fields and potentials, Diamagnetism, Paramagnetism and Ferromagnetism, Fields due magnetised objects, Magnetic Suspectibility.

**Unit – 4**

Faraday’s laws of electromagnetic induction, Lenz’s law, self and mutual inductance; Energy stored in magnetic field; Equation of continuity of current, Displacement current, Maxwell’s equations, conservation of energy and momentum in electrodynamics, Poynting Theorem,

**Unit – 5**

Gauge transformation, Coulomb and Lorentz gauges, Maxwell’s stress tensor. Wave equation, reflection, refraction and propagation of electromagnetic waves in dispersive media, wave equation in a conducting medium.

**Unit – 6**

Electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization; Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

**Text Books:**

1. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice Hall India, 2009).
2. Jackson, J. D., *Classical Electrodynamics*, 3 rd edition, (Wiley, Eastern Ltd, 1998).

**Suggested Readings:**

1. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
2. Slater, J. C., and Frank, N. H., *Electromagnetism*, (Dover Publications, 2011).
3. Miah, W., *Fundamentals of Electromagnetism*, (Tata McGraw-Hill, 1982).
4. Feynman, R. P., *Feynman Lecture Series Volume II*, (Addison Wesley Longman, 1970).

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**PHIN207:Thermodynamics and Statistical Mechanics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** The students will be able to explain fundamental concepts relevant to thermodynamics and thermo dynamical systems, work, power and heat in thermodynamic systems, explain thermo dynamical laws in Isolated, Closed and Open systems and the concept of Entropy.

**CO2:** The students will be able to explain phase transitions and derive thermo dynamical laws form microscopic description in ideal fluid systems.

**Course Content:**

**Unit – 1**:Macroscopic description of a state, extensive and intensive thermodynamic variables, Thermal equilibrium and equation of state; Thermal conductivity; Zeroth law of thermodynamics, Concept of temperature and temperature scales; Concept of heat, work and its equivalance; State and Path Functions; Internal energy.

**Unit – 2**: First law of thermodynamics and its applications, Specific heat capacity, Relation between Cp and Cv; Workdone during Isothermal and Adiabatic Processes; Compressibility and Expansion coefficient; Joule's free expansion; Enthalpy.

**Unit – 3**: Thermodynamic processes: reversible, irreversible, quasi-static; Conversion of Work and Heat. Heat Engines; Carnot cycle and Kelvin temperature scale; Carnot engine and effciency. Refrigerator and coeffcient of performance; The Second Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Clausius’ theorem, entropy and its physical interpretation, entropy change for simple processes; The third law of thermodynamics.

**Unit-4:** Free energies: Helmholtz free energy, Gibbs free energy, Legendre transformations, conditions of equilibrium, Maxwell’s relations, phases and phase transitions, equilibrium between two-phases, general equilibrium conditions, Derivations and applications of Maxwell’s Relations, the ClausiusClapeyron equation, and Ehrenfest equations; phase transformation of substances, van der Walls gas and the liquid gas transition, thermodynamics of magnetic systems; the Gibbs-Duhem relation;

**Unit – 5**: Microscopic versus macroscopic points of view, Kinetic theory of gases and Maxwell-Boltzmann statistics; Calculation of pressure, kinetic interpretation of temperature, mean free path, Maxwell’s distribution, equi-partition of energy; Gibbs paradox.

**Unit – 6**: Concept of ensembles: micro, canonical, grand canonical ensembles; phase-space trajectories and Liouville’s equation, probabilities in each ensembles, partition function, postulates of classical statistical mechanics, derivation of thermodynamics from statistical mechanics principles, equation of state for ideal and real gases.

**Text Books:**

1. Callen, H. B., *Thermodynamics and Introduction to Thermostatistics*, 2ndedition, (Wiley Student Edition).

2. Zemansky, M. W. and Dittman, R. H., *Heat and Thermodynamics*, 7thedition, (Tata McGrawHill International, 2007).

**Suggested Readings:**

1. Reif, F., *Fundamentals of Statistical and Thermal Physics*, (Tata McGraw-Hill, 1985).

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**Semester V**

**PHIN301: Waves & Acoustics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** To be able to learn the physical treatment of vibrating systems.

**CO2:** To be able to analyze different types of wave motion through matter.

**CO3:** To acquire an understanding of acoustics.

**Course contents:**

Vibratory systems.Simple harmonic vibration, equilibrium position, Potential energy vs. displacement relation.The general force equation.Simple harmonic vibration in electrical circuits.Anharmonic oscillator.Superposition of parallel and perpendicular vibrations. Beat. Lissajous figures.Fourier treatment of oscillatory systems.Damped oscillations and their motion equations in mechanical and electrical systems.Heavy, light and critical damping.Forced oscillations.Resonances.

Progressive wave in one-dimension and in three-dimensions, wave equation, plane wave and spherical wave, intensity, dispersion, group velocity, phase velocity. Transverse waves in a string, the wave equation its solution. Characteristic Impedance, Reflection and Transmission at a boundary.Normal modes and Eigen frequencies.Energy and Intensity.

Longitudinal waves in solids and fluids. Sound waves, wave equation. Energy distribution, Intensity.Reflection and Transmission at a boundary.Doppler effect & Shock waves. Bel and phon scales. Ultrasound: production, detection and application. SONAR system.

Musical and speech Acoustics.Psycho-acoustic parameters (Loudness, Pitch, Tone, Timbre, Combinational tone), Quality of sound.Acoustic Noise (White, Brown, Pink). Sources of musical sound, Sound in musical instruments, Octave Scale. Human voice classification.Sound recording and playback, Acoustic Transducers.Digital music.

Hall acoustics, reverberation and Sabine’s formula.Qualities for a good auditorium.

**Text Books:**

1. Pain, H. I., *The Physics of Vibrations and Waves, 6th edition* (John Wiley & Sons Ltd., 2005).
2. Main, I. G., *Vibrations and Waves in Physics, 2nd edition* (Cambridge University Press, 1984).

**Reference Books:**

1. Randall, R. H., *An Introduction to Acoustics*, Sect. 7-21, 7-22, (Addison-Wesley, 1951).
2. Wood, A. B., *A Textbook of Sound, 3rd Edition*, (Bell & Sons, 1955).
3. Crawford, F. S., *Waves, Berkeley Physics Course*, Vol. 3, (Tata McGraw-Hill, 1968).
4. Chattopadhyay, D., *Vibration, Waves and Acoustics*, (New Central Book Agency, 2010).
5. White, H. E, White D. H*,, Physics and Music: The Science of Musical Sound* (Dover 2014)

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**PHIN302: Atomic Physics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** Students will be familiar with the fundamentals of atomic physics.

**CO2:** Students are expected to learn the structure of atoms, their behavior in presence of electric and magnetic fields.

**CO3:** Students will learn about the significance of angular momentum coupling scheme in controlling energy levels of atoms.

**Course Content:**

Particle-like properties of electromagnetic radiation: Electromagnetic spectrum, Electromagnetic Waves, Blackbody radiation.

Planck's quantum hypothesis, The photoelectric effect, The Compton effect, Bremsstrahlung and X-ray production.

Models of the atom: Thompson model, Rutherford model, line spectra, Bohr model, Sommerfeld model.

Franck-Hertz experiment, the correspondence principle, deficiencies of Bohr atomic model, hydrogen atom energy levels, fine structure, electronic states in many-electron atom.

Atoms in Electric & Magnetic Fields: 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.

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

Scattering of light: Rayleigh scattering formula, colour of the sky, polarisation of the scattered light.

Spectral Notations for Atomic States, Total angular momentum, Vector Model, Spin-orbit coupling in atoms(qualitative treatment), L-S and J-J couplings.

**Text Books:**

1. Herzberg, G., *Atomic Spectra and Atomic Structure,* 2nd edition, (Dover Publications, 2010).

2. White, W. H., *Introduction to Atomic Spectra*, (McGraw-Hill, 1934).

**Reference Books:**

1. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta* (McGraw-Hill, 1930).
2. Harris, R., *Modern Physics*(Pearson, 2016)

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**PHIN303: Basic Material Science (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** The students will be able to qualitatively describe the bonding scheme and its general physical properties, as well as possible applications.

**CO2:** The students will be able to qualitatively derive a material's elastic property.

**CO3:** The students will be able to do simple crystallography and diffusion problems. Course Content:

**Unit – 1**: Fundamentals of crystallography: Amorphous and Crystalline materials, Lattice Translational vectors, Symmetry operations, Lattice with a Basis, Unit Cell, Bravais lattice, Crystal Systems in 2D and 3D. Crystal planes and directions, Miller indicies, Point groups and Space groups.

**Unit – 2**: Typical crystal structures: Simple (sc) cubic, body centered (bcc) cubic and face centered (fcc), cubic structures, Hexagonal closed packed (hcp), Diamond and Zinc blende (ZnS) closed packed structures, packing factors, NaCl, CsCl and cubic perovskite and wurtzite structures. Structure of solids: linear and planar density, ligancy, packing efficiency, closed pack planes and directions, voids. Crystal imperfections: point imperfections (vacancies and interstitials), Frenkel and Schottky defects, colourcentres, linear and edge dislocations, Bergers’ vector, grain boundary, grain growth and surface energy calculation.

**Unit -3:** Crystal binding: Primary and secondary bondings, bond length and bond energy, van der Waals bonding, inert gas crystals, ionic, covalent and metallic bondings, Madelung constant, Madelung energy.

**Unit – 4**: Reciprocal lattice, Di raction of X-rays by Crystals. Bragg’s Law. Atomic and Geometrical Factor, ff atomic form factor, structure factor and Debye-Waller factor, x-ray, electron and neutron diffractions. Experimental methods: Laue method, Rotating crystal method, Powder method Brillouin Zones. Lattice vibration in solids: Enumeration of modes, monoatomic linear chain, infinite and finite boundary conditions, dispersion relation, diatomic chain, acoustical and optical modes, quantization of lattice vibrations (phonons), Einstein and Debye theory of specific heat of solids.

**Unit – 5**: Diffusion: Fick’s first and second laws, thermal diffusion. Phase and phase transformation: Melting point of crystalline and amorphous solids, degrees of freedom, phase rule, binary alloys, nucleation and phase transformation, Elastic properties, Young, bulk and rigidity moduli, yield stress, Poisson’s ratio, compressibility, creep and fatigue, plasticity.

**Unit**-6: Low dimensional Nanomaterials-cocepts,principles and formation mechanism,0-D,1-D and 2-D structure,Density of states,Application and chalages

**Text Books**:

1. Marder, M, *Condensed Matter Physics, 2nd Edition*, (John Weilly& Sons, 2010)

2. Callister, W. D., *Materials Science and Engineering, 5th edition* (John Wiley, 2000). 3. Raghavan, 3. *Materials Science and Engineering, 4th edition* (Prentice Hall India, 1991).

4. Ashcroft, N. W. and Mermin, N. D., *Solid State Physics*, (Saunders, 1976).

**Suggested Readings:**

1. Kittel, C., *Introduction to Solid State physics, 7 th edition*, (Wiley Eastern Ltd.,1996).

2. Burns, G., *Solid State Physics*, (Academic press, 1995).

3. Dekker, A. J., *Solid State Physics*, (Macmillan India Ltd., 2003).

4. Smith, W. F., *Principles and Materials Science and Engineering, 2 nd edition* (Tata McGraw-Hill Inc., 1990).

5. Patterson, J. D. and Bernard, B., *Introduction to the Theory of Solid State Physics, 2 nd edition*, (Springer, 2007).

6. Ghatak, A. K. and Kothari, L.S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).

7. Hall, H. E. and Hook J. R., *Solid State Physics, 2 nd edition*, (Wiley, 1991).

8. Azaroff, L. V., *Introduction to Solids*, (Tata McGraw-Hill, 1977).

9. Ibach, H. &Luth, H., *Solid State Physics*, (Springer-Verlag, 2009.

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**PHIN304: Analog Electronics and Communications (L2-T0-P1-CH4-CR3)**

**Course Objectives:**

This course imparts basic knowledge of operational amplifiers. It also emphasizes on developing concepts of electronics in communication and communication techniques based on Analog Modulation.

**Course Outcomes:**

At the end of this course, the following concepts will be learnt

CO1: Ideal and practical op-amps: Characteristics and applications.

CO2: Understand of fundamentals of electronic communication system and electromagnetic communication spectrum with an idea of frequency allocation for radio communication system.

CO3: Gain an insight on the use of different modulation and demodulation techniques used in analog communication

**Course Content:**

**Unit 1 (10 Lectures)**

Op-Amp with and without feedback: Open loop considerations-inverting, non-inverting, differential,feedback-voltage follower, Practical op-amps: Offset considerations-input offset voltage, input bias current,input offset current, thermal drift, effect of power supply voltage, other temperature sensitive parameters,noise, CMRR, maximum common mode input voltages, op-amp instrumentation circuits.

**Unit 2 (8 Lectures)**

Introduction to communication systems: Elements of a Communication System, terminologies in

Communication systems, basics of signal representation and analysis. Noise: external, internal, noisecalculations, noise figure. Amplitude modulation techniques: Theory and generation of AM, DSBSC, SSB,VSB.

**Unit 4 (6 Lectures)**

Angle modulation techniques: theory, practical issues and generation of Frequency Modulation (FM) andPhase Modulation.

**Unit 5 (6 Lectures)**

Radio transmitters and receivers: Introduction to – AM, SSB, FM Transmitters. Receiver Types: tunedradio-frequency (TRF) and superheterodyne receiver (schematic only), AM and FM Receivers.

**Unit 6 (6 Lectures)**

Radiation and propagation of waves -Electromagnetic Radiation, Effects of the Environment, Propagation ofWaves - Ground (Surface) Waves, Sky Waves and Space Waves.

**Text Books:**

1. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits, 3rd Edition*, (PHI, 2001).
2. Kennedy, G., Bernard D. and Prasanna, S. R. M., *Electronic Communication Systems*, (McGraw-HillGlobal Education India, 5th edition, 2011).

**Suggested Readings:**

1. Hambley, A. R., *Electronics, 2nd Edition*, (Prentice Hall, 2000).
2. Horowitz, P. and Hill, W. *The Art of Electronics, 2nd Edition*, (Cambridge University Press, 1995).

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**Semester VI**

**PHIN306: Introduction to Nuclear & Particle Physics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO 1:** Students will learn basic concepts and methods in nuclear physics, the stability of nucleons and classification of interactions.

**CO2:** Students will get an overview of the particle detectors.

**CO3:** Aims at preparing the students for further study in experimental and theoretical high energy physics.

**Course Contents:**

General properties of nuclei (nuclear size, spin, parity).Magnetic moments (dipole and quadrupole). Stability of nuclei, packing fraction and binding energy, magic number, binding energy curve and its significance. Nuclear models: shell model, liquid drop model.

Natural radioactivity and radioactive decay: Types of radioactive decay, radioactive disintegration, radioactive constants, mean-life and half life, radioactive equilibrium, decay constant.

Direct Nuclear reactions: Types of nuclear reactions, conserved quantities, energy, Q-value, exoergic & endoergic reactions, nuclear fusion and fission processes, Breit-Wigner dispersion formula.

Nucleon-nucleon interaction.  Different types of interactions and forces. Basics of weak interactions (nuclear and particle decays).

Detectors: Principles of detection of particles. Gaseous ionization detectors, their construction and working, Gamma-ray detectors. GM counters, spark chambers, cloud chambers, bubble chambers. Semiconductor detectors, scintillation counters, photodiodes, photomultiplier tubes, Cherenkov detectors.

Principles of accelerators, cyclotron, synchrotron, linear accelerators, colliding beam accelerators.

Symmetries and conservation laws, quantum numbers, strange mesons and baryons, Eightfold way and Quark Model

**Text Books:**

1. *Introductory Nuclear Physics* by K.S. Krane
2. *Structure of Nucleus* by M. A. Preston and R. K. Bhaduri
3. *Nuclear Physics* by Irving Kaplan

**Reference Books:**

1. *Nuclear Physics* by D.C. Tayal
2. *Introduction to Nuclear Physics* by R. R. Roy and B. P. Nigam
3. *Introduction to Particle Physics* by D. J. Griffitth

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**PHIN307: Introduction to Plasma and Astrophysics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** The course is expected to provide basic understanding of the plasma state of matter and its possible applications in laboratory and astrophysical environments.

**CO2:** To provide an introduction to observational Astronomy, stellar structure and evolution, the solar system and galaxies.

**Course Contents:**

Basic plasma concepts: Plasma state of matter, Quasi neutrality of plasma,Debye shielding,  Plasma parameters, Occurrence of plasma, Single particle motion:  Motion of charged particle in electromagnetic field; Plasma confinement schemes: Plasma in magnetic field, Magnetic mirror, Confinement of plasma under radiation pressure.

Fluid description of plasma; Waves in plasma, electron and ion plasma waves, their dispersion relations and properties; Electromagnetic waves in plasma.

Plasma Applications: Thermonuclear fusion. Tokamak, Inertial fusion, Magnetospheric Physics, Heliospheric Plasma, Plasma in astrophysical Systems.

Observational astronomy: Celestial coordinate systems (Horizontal and Equatorial coordinate systems).  Basics of astronomical telescopes: Operational principle, different types and mounting systems. Introduction to Radio, UV, IR and X-ray telescopes. Observational characteristics: Brightness,Magnitude, Mass, Radius, Luminosity. Stellar measurement techniques using astrometry, photometry, spectrometry and polarimetry.

Stellar structure and evolution: Stellar Classification systems: Harvard, Yerkes, Morgan Keenan. HR diagram.Stellar structure and their different types.Hydrostatic equilibrium.Eddington model.Polytropic stars, Lane Emden equation. Energy Production in stars: PP cycle, CNO cycle, triple alpha process.

Sun & the Solar system: The solar interior, energy production and transfer in the sun, the solar surface. The origin of the solar system,  Terrestrial and Jovian planets, Asteroid belt, Kuiper belt, Comets, Asteroids, Meteoroids, Oort cloud. Galaxies: classification, structure and evolution, Hubble’s tuning fork diagram.

**Text Books:**

1. Bellan, P.M*.,Fundamentals of Plasma Physics*(Cambridge)
2. Chen, F.F., *Introduction to plasma physics and controlled fusion. Volume* 1
3. Vitense, E. B., *Stellar Physics* (Cambridge University Press, USA, 1992)
4. Basu B., Chattopadhyay T., Biswas S.N.; *An Introduction to Astrophysics* (Prentice Hall India, 2010)

**Reference Books:**

1. Krishan, V.,*Astrophysical Plasmas and Fluids*
2. Kippenhahn R. A., and Weigert, A., *Stellar Structure and Evolution* (Springer, Berlin, 1994).
3. Abhyankar K. D., *Astrophysics: Stars and Galaxies* (Universities Press, 2009).

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**PHIN308: Quantum Mechanics I (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO 1:** To be able to understand the initial build up of quantum theory.

**CO 2:** To be able to treat simple systems with quantum theory.

**CO 3:** To understand the quantum treatment of the Hydrogen atom.

**CO 4:** To be able to relate and use linear algebra for quantum mechanical systems.

**Course Contents:**

A brief overview of the developments leading to quantum theory.Wave-particle duality, deBroglie's hypothesis, Davisson Germer experiment, Thompson experiment. Heisenberg’s Uncertainty Relation. Wave functions, probability amplitude and normalization.Basic postulates of Quantum Mechanics.Schrodinger equation, time independent and time dependent forms.

One dimensional problems: Free particle, Potential Barrier and Tunneling Effect. The infinite and finite square wells, the quantum harmonic oscillator. Three dimensional problems: General treatment, the Free Particle, the Box potential, the Harmonic oscillator.

Quantum treatment of the hydrogen atom. The schrodinger equation in spherical polar coordinates, separation of radial and angular part and the detailed solution. Significance of the associated quantum numbers.Orbital Angular momentum in spherical polar coordinates.Radial wavefunctions, Eigenvalues and eigenfunctions of orbital angular momentum.

Mathematical tools for Quantum Mechanics: The Hilbert Space & Wave functions, Dimensions & Basis, Dirac Notation. Operators (linear, Hermitian, Unitary, projection), eigenvalues and eigenstates.Matrix representation.

**Text Books:**

1. Griffiths D.J.; *Quantum Mechanics*; (Pearson Prentice Hall).
2. Zettili, N., *Quantum Mechanics*: Concepts and Applications (Wiley).

**Reference Books:**

1. Feynman R.P., Leighton R.B., Sands, M; *Lectures on Physics*; (Addison-Wesley)
2. Schiff, L. S., *Quantum Mechanics*, (Tata McGraw-Hill Education).
3. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002)
4. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (Tata McGraw-Hill, 2007)
5. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press)
6. Shankar R. , *Principles of Quantum Mechanics*, (Springer)
7. Sakurai J.J., Napolitano J., *Modern Quantum Mechanics*, (Addison-Wesley)

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**PHIN309: Operational Amplifier and Digital Electronics (L2-T0-P1-CH4-CR3)**

**Course Objective:**

This course lays the foundation for understanding non-linear and linear applications of Op amps and the digital logic circuits and their use in combinational and sequential logic circuit designslike registers, counters, and other flip-flop-based devices.

**Course Learning Outcomes:**

At the end of the course following concepts will be learnt

CO1:Applications of practical op-amps.

CO2: Combinational Circuits: addition, subtraction, multiplexer, decoders etc.

CO3: Sequential Circuits: Basic memory elements Flips-Flops, shift registers and 4-bits counters leading to the concept of RAM, ROM and memory organization.

CO4: Timer circuits using IC 555 providing clock pulses to sequential circuits and develop multivibrators.

**Unit 1 (8 Lectures)**

Op-amp non-linear applications: Voltage limiters, comparators, zero detector, Schmitt trigger, voltage to frequency and frequency to voltage converter, small-signal diodes, sample-and-hold circuits and signal generators: oscillators-square-wave, Wien bridge, phase shift.

Frequency response of an op-amp and active filter: Gain and phase shift vs. frequency, Bode plots, compensated frequency response, slew rate, active filter, first and second order low pass and high pass, Butterworth filter, band reject filter.

**Unit 2(5 Lectures)**

Linear Applications: Op-amp as ac amplifiers, summing and averaging circuits, integrators, differentiators,voltage-current converter, current-to voltage converter, analog computers, voltage regulators

**Unit 3(7 Lectures)**

Review of Boolean Algebra, Combinatorial digital systems: arithmetic functions, decoder/demultiplexer, data selector/multiplexer, encoder, ROM and applications

**Unit 4(7 Lectures)**

Sequential digital systems: flip-flops, shift registers and counters, random access memory (RAM), dynamic MOS circuits, MOS shift registers, MOS Read Only Memory, D/A and A/D systems, digital-to-analog converters, analog-to-digital converters, character generators.

**Unit 5(3 Lectures)**

IC 555 block diagram and applications: Astablemultivibrator and Monostable

**Unit 6 (6 Lectures)**

Serial Communications: RS232, Handshaking, Implementation of RS232 on PC, Universal Serial Bus (USB), USB standards, Types and elements of USB transfers. Parallel communications: General Purpose Interface Bus (GPIB), GPIB signals and lines, Handshaking and interface management, Implementation of a GPIB on a PC. Basic idea of sending data through a COM port.

**Text Books:**

1. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003)
2. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits*, 3rd Edition, (PHI, 2001).
3. Gaonkar R.S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th Edition, (Prentice Hall, 2002).

**Reference Books:**

1. MalvinoA.P.and Leach D.J., *Digital Principles and Applications,* (Tata McGraw Hill 1994).
2. Milliman, J. &Halkias, C.C., *Integrated Electronics,* (Tata McGraw Hill, 2003).
3. Tocci R.J., *Digital Systems,* (Pearson/Prentice Hall, 2004).
4. Bartee T.C., *Digital Computer Fundamentals,* (Tata McGraw Hill Publishing Company, 1985).

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**PHIN310: Mathematical Physics-II**  **(L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: Students should be able to solve the ordinary and partial differential equations, differential equations with special functions and their uses in physics.

CO2: Students will also learn the use of integral transforms in physical problems.

**Course Content:**

Ordinary differential equations, second-order homogeneous and inhomogeneous equations, Wronskian, general solutions, adjoint of a differential equation, ordinary and singular points, series solution, Legendre, Hermite, Laguerre and the associated polynomials, their differential equations, generating functions, Bessel functions, spherical Bessel equations, integral representation of special functions.

Generating functions, Recurrence relations, Rodrigue's formulae and orthogonality of the special functions, Sturm-Liouville problem, elements of hyper-geometric functions, Gauss hyper-geometric and confluent hyper-geometric equations, Dirac delta function, Green function.

Partial differential equations in physical problems: Laplace's equation, Poisson's equation, Heat flow equations, Wave equations, Helmholtz equations, solutions of these equations, eigenvalue problems, boundary value problems, method of separation of variables.

Integral transforms: Laplace transform, Hankel transform, Mellin transform, Fourier transform.

Properties of Laplace and Fourier transforms, application of Laplace and Fourier transforms.

**Text Books:**

1. Harper, C., *Introduction to Mathematical Physics, (*Prentice Hall, 2009).
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005).
3. Spiegel, M. R., *Vector Analysis*, Schaum's outline series, (Tata McGraw-Hill 1979).

**Reference Book:**

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry,* (Young Press, 2009).

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**Semester VII**

**PHIN401: Statistical Physics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: The students, after successfully completing the course, are expected to be able to explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics.

CO2: The students are expected to be able to apply the principles of statistical mechanics to selected problems, apply techniques and methodologies, language and conventions from statistical mechanics to arange of physical systems to test and communicate ideas and explanation, in particular condensed matter and low-dimensional systems in thermo dynamical limits.

CO3: The students will also be able to explain equilibrium phase transitions in various physical systems.

**Course Content:**

**Unit – 1**

Review of Thermodynamics and Free enegies; Introduction to probability theory: Continuosu and Discrete; Binomial, Gaussian and Poisson distributions; Central limit theorem and law of large numbers; Application of probability theory to Random walk, Brownian Motions.

**Unit – 2**

Microstate and Macrostate; Introduction to Phase space, Dynamics in phase space, ergodicity and Liouville theorem; Fundamental postulate of equilibrium statistical mechanics; Ensembles and Independent thermodynamic variables;

**Unit – 3**

Microcanonical ensemble, Boltzman definition of entropy, Canonical ensemble, partition function, calculation of thermodynamic quantities, Partition functions and few examples: Classical ideal gas, two level system, Harmonic oscillator, Paramagnetism, Curie's law, generalized expression for entropy, Gibbs entropy and mixing of entropy. Grand canonical ensemble, the grand partition function, grand potential and thermodynamic variables.

**Unit – 4**

Introduction to Quantum Statistics, Density Matrix, Ideal Quantum Gases and their properties, Bose-Einstein Condensation, Black body radiation spectrum, non-interacting free Electron gas, Einstein and Debye model of specific heat, Pauli paramagnetism and negative temperature, diamagnetism, photons, phonons and White Dwarft.

**Unit – 5**

Phase transitions, symmetry, order of phase transitions and order parameter, Landau's mean-field theory, Symmetry breaking. Elementary ideas on Ising, Heisenberg models of ferromagnetism, Critical point, critical exponents and their scaling.

**Text Books:**

1. Karder M. *Statistical Physics of Particles*, Cambridge University Press, 2007.

2. Pathria, R.K., *Statistical Mechanics,* Butterworth Heinemann, Second Edn, 1996.

**Suggested Readings:**

1. Huang, K., *Statistical Mechanics*, 2 nd Edition (Wiley,1987).

2. Reif, F., *Statistical Physics*, (Tata McGraw Hill, 2008).

3. Landau and Lifshitz, *Statistical Physics*, 3 rd edition (Butterworth-Heinemann;1980).

4. *Statistical Mechanics of Phase Transitions*: J. Yeomans (1992) Oxford University Press.

5. *Introduction to Modern Statistical Mechanics*: D. Chandler (1979) Oxford University Press

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**PHIN402: Classical Mechanics-II**  **(L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: Students will be able to use the calculus of variations to solve real physical problems.

CO2: Students will be able to describe and understand the motion of mechanical systems using Lagrange and Hamilton formalism.

CO3: Students will understand Poisson brackets, canonical transformations and will be able to solve small oscillation problems.

**Course Content:**

Two-body Central Force Problems: Reduction of two-body problems to equivalent one body problem, equation of motion under central force, equation for an orbit, inverse square law of force, Kepler's laws of planetary motion and their deduction, Virial theorem, scattering in a central force field and Rutherford scattering.

Canonical Transformations and Brackets: Canonical and Legendre transformations, generating function, procedure for application of canonical transformation, condition for canonical transformation, bilinear invariant condition, integral invariant of Poincaré, Poisson brackets and Lagrange’s brackets and their properties, relation between Poisson and Lagrange’s brackets, application of Poisson bracket to mechanics, Liouville’s theorem.

Hamilton-Jacobi Theory: Hamilton-Jacobi (HJ) equation, Hamilton’s characteristic and principal function, HJ equation for Hamilton’s characteristic function, solution of Kepler's problem by HJ method, action-angle variable and harmonic oscillator problem, separation of variables in HJ equation, transition from classical to quantum mechanics.

Mechanics of a Rigid Body: Generalised co-ordinates of a rigid body, body and space reference system, Eulerian angles, orthogonal transformations, infinitesimal rotations, kinematics of a rigid body, moving frame of reference, Euler equation, spinning top, gyroscope.

Small Oscillations: One dimensional oscillator; stable, unstable and neutral equilibriums, double pendulum, vibration of a linear triatomic molecule, general case- system with ‘n’ degrees of freedom.

**Text Books:**

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Goldstein, H., *Classical Mechanics*, (Narosa Publishing House).

**Reference Books:**

1. Takawale, R. G. and Puranik, P. S., *Introduction to Classical Mechanics*, (Tata McGraw Hill).
2. Rana, N. C. and Joag, P. S., *Classical Mechanics*, (Tata McGraw Hill).
3. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).
4. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (PragatiPrakashan).

**PHIN403: Mathematical Physics-III** **(L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: Students will learn how to use matrix mechanics in quantum mechanics, use of group theory in explaining symmetry in condensed matter physics and particle physics, uses of tensor calculus in electrodynamics and general relativity.

CO2: This course will also help the students to evaluate the complicated integrals using complex variables theory arises in different physical problems.

**Course Content:**

Linear equations of homogeneous and inhomogeneous types, linear vector spaces, scalar product, linear independence, change of basis, Schmidt orthogonalisation, special matrices, diagonalization, orthogonal and unitary transformations, functions of complex variables, limit, continuity, analytic function, Cauchy formula, Laurent series, isolated and essential singularities, contour integrations, conformal transformations.

Complex variables: Complex algebra, graphical representation, analytical functions, Cauchy-Riemann conditions, complex integrations, Cauchy's theorem, Cauchy's integral formula, residue, Cauchy's residue theorem.

Tensor analysis: Tensor in three and/or four dimensions, rank of tensors, covariant and contravariant tensors, symmetric and antisymmetric tensors, metric tensors, mathematical operations involving tensors.

Group theory: Group representation, reducible and irreducible representation, unitary group, special unitary group, Lorentz group, rotation group, direct product, Young Tableau, Dynkin diagrams.

**Text Books:**

1. Joshi, A. W., *Group Theory for Physicists,* (Wiley Eastern, 2008).
2. Brown, J. W. and Churchill, R. V., *Complex Variables and Applications*, 6th edition, (McGraw-Hill International, 1996).
3. M R Spiegel, S Lipschutz, J J Schiller and D Spellman, *Schaum’s Outline of ComplexVariables*.

**Reference Books:**

1.Ablowitz, M. J. and Fokas, A. S., *Complex Variables, 1stSouth Asian paperback edition,(*Cambridge University Press, 1998).

2.Joshi, A. W., *Matrices and Tensors in Physics*.

3.Hoffman, K. and Kunze, R., *Linear Algebra*, (Prentice Hall India).

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**PHIN404: ElectromagneticTheory-II (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1**:** The students are expected to collect sufficient preparation on macroscopic and microscopic descriptions of electromagnetic radiation with in depth understanding.

CO2: The students are expected to get trained with the problem sets related to Advanced Electrodynamics.

CO3: The students are expected to be trained with many examples to develop additional material, or to apply the theory to topics of contemporary interest.

**Course Content:**

**Unit – 1**

Maxwell’s equations and electromagnetic wave propagation in infinite medium, Electromagnetic wave inside conductors, reflection and refraction of electromagnetic waves at an interface, electromagnetic wave propagation through wave guides, rectangular cavity resonator, theory of optical dispersion, inhomogeneous wave equations, different modes of EM waves.

**Unit – 2**

Electromagnetic fields of time varying sources, Retarded potentials, Lenard-Wiechert potentials and electromagnetic fields of a moving point charge and uniformly moving charges, Electromagnetic Radiation due to non-relativistic moving charge particles, electric and magnetic dipole radiations, power radiated by a moving point charge.

**Unit – 3**

Radiation from Oscillating current, accelerated charge, Larmor formula of radiation, antennas and arrays, Dipole approximation, Radiation due to oscillating electric dipole, Hertzian dipole, halfwave dipole, Loop current element, Radiation damping.

**Unit – 4**

Motion of charged particles in electromagnetic fields, Cherenkov radiation, transmission lines, impedance of line, scattering and diffraction.

**Unit – 5**

Lorenz transformations, Lorentz Four vectors, Doplar effect of light, relativistic electrodynamics, field tensor, energy-momentum tensor, interdependence of electric and magnetic fields, transformation of electromagnetic fields under Lorentz transformation, invariance of Maxwell’s equations,

**Unit – 6**

Action principle formulation of electrodynamics, Lagrangian for electromagnetic fields, Maxwell’s equations from least action principle, Non relativistic Hamiltonian of charge particle in EM fields.

**Text Books:**

1. Jordan, E. K. and Balmain, K. G., *Electromagnetic waves and Radiating systems*, (Prentice Hall, 1971).

2.Nasar, S. A., 2000 *Solved Problems in Electromagnetics*, Schaum's series, (McGraw- Hill, 1992).

**Suggested Readings:**

1. Puri, S. P., *Classical Electrodynamics*, 2 nd edition, (Tata McGraw-Hill Pub., 1997).

2. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).

3. Jackson, J. D., *Classical Electrodynamics*, 3 rd edition, (Wiley Eastern Ltd, 1998).

4. Panofsky, W. K. H. and Phillips, M., *Classical Electricity and Magnetism*, 2ndedition, (AddisonWesley, 1962).

5. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice Hall of India, 2009).

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**PHIN405: Quantum Mechanics-II                                                       (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** Acquire mathematical skills such as use of complex variables, differential equations, Gaussian integrals, linear algebra, matrix formalism etc. to solve various quantum mechanical problems.

**CO2:** Draw a correlation between mathematical techniques and underlying physical concepts behind angular momenta for elementary particles, approximation techniques and scattering theory and apply to solve atomic and molecular physics problems.

**CO3:** Calculate C.G. coefficients of addition of angular momenta of two electron systems and learn matrix formalism of spin angular momenta.

**CO4:** Apply relativistic quantum mechanics to the world of elementary particles.

**Course Content:**

General formalism of angular momentum.Spin Angular Momentum and Pauli’s Spin matrices.  Addition of angular momenta, Clebsch-Gordon coefficients, Spin-orbit and hyperfine interactions.

Time-independent perturbation theory for non-degenerate case, first-order and second-order perturbations,  Time-independent perturbation theory for degenerate cases, first-order Stark effect in hydrogen atom. Time-dependent perturbation theory, Fermi’s golden rule, Transition probability,WKB approximation, Ritz variational method, Scattering theory, Partial wave analysis and phase shift.

Many electron atoms: Pauli’s Exclusion Principle. Symmetric & Antisymmetric Wave Functions.

Relativistic quantum mechanics: Relativistic wave equation: Klein-Gordon, Dirac equation, Covariance of Dirac’s equation, Free particle solution of Dirac’s equation,Positive and negative energy states, Concept of Positron.

**Text Books:**

1.   Schiff, L.S., *Quantum Mechanics,* (Tata McGraw-Hill, 2004).

2.   Zettili, N., *Quantum Mechanics*, (John Wiley & Sons, 2001).

3. Griffiths D.J.; Quantum Mechanics; (Pearson Prentice Hall)

4. Sakurai, J.J., *Modern Quantum Mechanics*, (Pearson Education, 2020)

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**Semester VIII**

**PHIN407: NumericalAnalysis (L2-T0-P1-CH4-CR3)**

**Course Outcomes:**

**CO1:** The primary objective of the course is to develop basic understanding required in numerical methods, their applicability and approximations coupled with the limitations. The course prepare the students to enhance their skilled in effective use of computation and data analysis that requires both theoretical knowledge and computational experience. The course emphasizes both theoretical knowledge and computer programming that enable them to solve numerical problems that are frequently used in physics using computer programs.

**Course Content:**

**Unit – 1 : [4 Lectures + 1 Practical]**

Introduction to basic Programming Language- C/Fortran/C++/Matlab/ Python (Any one) : Basic Unix Commands, Variables: integer, float, double; array and array manipulations; conditional statements; loops : for, do-while etc; pointers and files. Preliminaries of Computations: round-off errors, significant digits, floating point arithmetic, Convergence, matrix multiplication.

**Unit – 2 : [5 Lectures + 1 Practical]**

Numerical Solutions of Nonlinear Equations : Bisection method, Newton’s method, Method of false position (regular falsi), Secant method, Fixed-point iteration, order of convergence, Newton-Raphson Method, Error analysis for Iterative Methods, Computing roots of polynomials.

**Unit – 3 : [ 8 Lectures + 2 Practicals]**

Interpolation and Polynomial Approximation: Newton’s interpolation formula, Lagrange Polynomial, Divided Differences, Hermite Interpolation, Error of interpolation, Cubic Spline, Least-Square approximations, Chi -Square test. Solution of a system of linear equations - Gaussian elimination, Partial Pivoting, Singular matrices, Determinants and Matrix inversions, Tridiagonal systems, Iterative methods (Jacobi and Gauss- Seidel methods), numerical factorizations, Eigenvalue problems, Approximating Eigenvalues: Power method, Householder’s\* method .

**Unit – 4 : [ 8 Lectures + 2 Practicals]** Numerical integration and differentiation: Simpson’s rule, trapezoidal rule, quadrature formula, Gaussian quadrature and Euler-Maclaurin\* formula. Numerical solution of ordinary differential equations – Euler’s Forward and Backward method, Taylor series method, Runge-Kutta methods, and multistep methods: Milne’s and Adams- Moulton method, System of equations and Higher order equations, Finite difference and Shooting methods\* for Boundary value problem.

**Unit – 5 : [ 3 Lectures + 2 Practicals]**

Simulation: Basics of simulation, simulation of continuous and discrete systems with suitable examples, Stochastic simulation - generation of random numbers with different probability distributions, Monte-Carlo simulation in physics with phase transition example. (\*- If time permits)

**Text Books:**

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall, 1997). 2. Atkinson, K. E., *An Introduction to Numerical Analysis, 2nd Edition*, (John Wiley, 2008).

3. NarsinghDeo, *System Simulation with Digital Computers*, (Prentice Hall, 1979).

**Suggested Readings:**

1. Kanetkar, Y; Let us C, (BPB Publications, 2012).

2. Gottfried, B .S.,*Schaum's outline of theory and problems of programming with C*, (McGrawHill Professional, 1996).

3. Press, W.H., Teukolsky, S.A., Vetterling WT, Flannery, B.P., *Numerical Recipes in C, 2nd Edition* (Cambridge University Press, 2005

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**PHIN408 : SemiconductorDevices (L3-T0-P0-CH3-CR3)**

**Course Objectives:**

The prime objective of the paper is to familiarize advanced electronics comprising components including the UJT, JFET, MOSFET, and CMOS etc. Attain knowledge of fabrication of IC’s. Along with an understanding of display devices, photonic devices are comprehensively described.

**Course Outcomes:**

The students will be able to

CO1: Comprehend the functioning and working of of electronic components, Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) with different bias circuits, HEMT, Tunnel Diodes etc. (including but not limited to).

CO2: Acquire the ability to understand working of Power semiconductor devices

CO3: Grasp the basics of semiconductor based display devices and photonic devices

CO4: Get acquainted with the intricacies of IC fabrication technology, with a focus on the various processes involved such as diffusion, implantation, oxidation, and etching.

**Unit 1 (8 Lectures)**

MESFET, MOSFET, HEMT, HBT, Tunnel Diodes.

**Unit 2 (10 Lectures)**

Optical Devices: Solar Cells, LED, Photovoltaic Cells, Organic Solar Cell, Perovskite, Semiconductor Laser, VCSEL, SET etc.

**Unit 3 (6 Lectures)**

Power semiconductor devices: SCR, UJT, Thyristors, Diacs, and Triacs

**Unit 4 (6 Lectures)**

Display devices: Active and passive, construction of display devices, applications of LCD, ECD, In Plane Switching, AMOLED, QLED, UHD

**Unit 5 (6 Lectures)**

Semiconductor Fabrication Technique: Diffusion, Epitaxy growth, Ion Implantation, Optical and Electron lithographical Technique, etching process, dielectric and polysilicon film depositions, metallization.

**Text Books:**

1. Neaman D.A. and Biswas,D., *Semiconductor Devices* (Tata McGraw Hill, 2012).
2. Kano, K., *Semiconductor Devices*, (Prentice Hall of India, 1998)

**Reference Book:**

1. Milliman J. &Halkias C.C., Integrated*Electronics* (Tata McGraw Hill, 2003)
2. Milliman J. &Halkias C.C, *Electronic Devices and Circuits* (Tata McGraw Hill, 2003)
3. Malvino, A.P., *Electronic Principles*, (McGraw-Hill Education (India) Pvt Limited, 2007)
4. Allison J., *Electronic Engineering Semiconductors and Devices*, Edition 2, (McGraw-Hill, 1990)

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**PHIN409: Atomic and Molecular Spectroscopy (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:**  Able to calculate energy levels, frequencies of spectral lines of alkali and alkaline earth spectra and learn to apply quantum mechanical processes in the field of spectroscopy.

**CO1:** Able to apply the knowledge of molecular spectroscopy as a tool in understanding the material properties and for analyzing the data received from astrophysical objects.

**Course Content:**

The Central field approximations, Multi-electron system, Geoss energy level structure of Alkali elements

The quantum theory of Spin-orbit interaction, Spin-orbit splitting in Alkalis,

Two electron system, LS and jj coupling, Hund’s rule, Series spectra of Alkali and Alkaline Earths;

Atoms in magnetic fields: Spin and orbit interaction in weak field, Anomalous Zeeman pattern, Spin-orbit interaction in strong field

Spectra of diatomic molecules, pure rotation, pure vibration; vibration-rotation and electronic spectra, Born-Oppenheimer approximation and its application to molecular spectroscopy, formation of bands, structure of bands, dissociation and pre-dissociation, valence-bond theory, molecular orbital theory, bonding and anti-bonding of electrons for equal nuclear charges, energy level of symmetric top molecules, potential energy function.

Morse potential function, Raman spectroscopy, Electron spin resonance (ESR) spectroscopy, Nuclear magnetic resonance (NMR) spectroscopy, Mossbauer spectroscopy.

**Text Books:**

1. White, H. E., *Introduction to Atomic Spectra,* (McGraw-Hill, New York, 1934).
2. Herzberg, G., *Atomic Spectra and Atomic Structure,* 2nd edition, (Dover Publications, 2010).
3. Banwell, C. N. and McCash E. M., *Fundamentals of Molecular Spectroscopy,* (McGraw-Hill, 1994).
4. Bransden, B.H. and Joachain, C.J., *Physics of Atoms and Molecules*, (Pearson, 2005)

**Reference Books:**

1. Kuhn, H. G., *Atomic Spectra,* (Longmans, 1969).
2. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta* (McGraw-Hill, 1930).
3. Siegman A. E., *Lasers*, (University Science Books, 1986).

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**PHIN410: Condensed Matter Physics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** The students should be able to connect material properties and solid state phenomena with the theoretical models.

**CO2:** The students are expected to familiarize with various experimental characterization techniques to ensure structure-property relationship.

**Course Content:**

**Unit – 1 :** ( 3 Lectures )

Condensed Matter Physics and its importance, Review of Reciprocal Lattice, Brilloine Zones, Lattice vibration in solids, Einstein and Debye theory of specific heat of solids.

**Unit – 2 :**( 8 Lectures )

Free electron Theory of metals: Electrons in Metals, Drude’s model; Application of Drude’s model: Hall effect and Magneto-resistance; Electronic specific heat, Exposure of electrons to Electromagnetic fields, Complex Dielectric Constant; Plasma Oscillations, Plasma Frequency, Plasmons; electrical and thermal conductivity of metals, Wiedemann-Franz law.

**Unit – 3 :**( 8 Lectures )

Band Theory of Solids: Motion of electrons in periodic potential, Bloch theorem, Kronig Penney model; Band Gap; Insulators, semiconductors and conductors; Fermi surface, holes, intrinsic and extrinsic semiconductors; Conductivity of Semiconductor, mobility, Hall Effect.Measurement of conductivity (4-probe method) & Hall coefficient.concept of effective mass and law of mass action,Qualitative idea of high symmetric points in reference to E-K diagram

**Unit – 4 :** ( 8 Lectures )

Properties of materials: Polarization, Depolarizing field, Electric Susceptibility and Polarizibility. Claussius-Mossoti equation; Classical Theory of Electric Polarizability; Langevin-Debye equation.Dia, Para and Ferro electric materials and their properies; Dia, Para and Ferro magnetic 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; Hysteresis and Energy Loss.

**Unit – 5** : ( 6 Lectures )

Physics of Low Temperature: Introduction to superductivity, Critical Temperature, Meissner effect, Critical Magnetic field, Type-I and Type-II Superconductors, London equation and Penetration Depth, Josephson effect, Quantum Hall Effect and Topological States, Preparation of Qubit.

**Unit – 6 :**( 3 Lectures )

Inelastic neutron scattering, analysis of data by generalized Ewald construction, dispersion relations, frequency distribution function, thermal conductivity of insulators, Normal and umklapp processes, thermo-luminescence.

**Text Books:**

1. Marder, M, *Condensed Matter Physics, 2nd Edition*, (John Weilly& Sons, 2010)

2. Kittel, C., *Introduction to Solid State physics 7 th Edition* (Wiley, Eastern Ltd., 1996).

3. Burns, G., *Solid State Physics* (Academic press, 1995).

4. Ashcroft, N. W. &Mermin, N. D., *Solid State Physics* (Saunders, 1976).

**Suggested Readings:**

1. Dekker, A. J., *Solid State Physics* (Macmillan India Ltd., 2003).

2. Ibach, H. &Luth, H., *Solid State Physics*, (Springer-Verlag).

3. Patterson, J. D., *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971).

4. Ghatak, A. K. and Kothari, L. S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).

5. Hall, H. E. and Hook J. R., *Solid State Physics, 2 nd Edition*, (Wiley, 1991).

6. Azaroff, L.V., *Introduction to Solids*, (Tata McGraw Hill, 1977)

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**Elective(DSE papers)**

**PHIN412: Modern Developments in Particle Physics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** Students will get a general overview of the recent and ongoing developments in the fields of theory, phenomenology and experiments in Particle Physics.

**CO2:** Students will be motivated for further exploration in theoretical & experimental high energy physics.

**Course contents:**

Elementary particles and their classification and properties.Fundamental interactions (strengths and ranges).Natural units.Symmetry and Conservation rules in fundamental interaction.Quark model.

Discovery of fundamental particles (electron, positron, proton, neutron, muon, taon etc.).

Cosmic Rays: sources, flux and properties. Extensive air showers.Status of Cosmic Ray experiments.

Introduction to the Standard Model.Developments beyond the standard model.

Collider & Accelerator experiments: principle, particle detection, working. HERA, LHC. Overview and discovery of Higgs boson.

Postulation and discovery of Neutrinos.Solar and Atmospheric neutrino anomalies. Neutrino oscillations and neutrino mass. Different sources of neutrinos. Overview of neutrino experiments.

Introduction to data analysis techniques for particle physics.

**Text Books:**

1. Griffiths, D., *Introduction of Elementary Particles*, (John Wiley and Sons, 1987)
2. Tayal, D. C., *Nuclear Physics* (Himalaya Publishing House, 2021)
3. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008)

**Reference Books:**

1. Perkins, D. H., *Introduction to High Energy Physics*, (Cambridge University Press, 2000)
2. Dey, T., *Particle Physics A Primer* (Levant Books)
3. Sakurai, J. J., *Invariance principle and elementary particles*, (Princeton Univ. Press, 2016)
4. Lyons, L., *Statistics for Nuclear and Particle Physicists*, (Cambridge University Press, 1989)

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**PHIN411: Statistical Methods for Data Analysis (L2-T0-P1-CH4-CR3)**

**Course Outcomes:**

**CO1:** Students will be able to get a general overview of the statistics based data analysis techniques for Physics.

**CO2:** Students will be able to statistically interpret, analyze and categorize any given data against a physics model.

**CO3:** Students will be given a brief overview of the use of machine learning techniques in physics.

**Course contents:**

Definition and interpretation of Probability.Bayes’ theorem.Random variables (discrete and continuous). Probability distribution functions (Binomial, Poisson, Exponential, Gaussian) with examples of physical processes. Uncertainties/errors in measurements.Precision and Accuracy.Systematic and Random uncertainties.Propagation of errors. **[Accompanied by Hands-on sessions\*]**

Interpretation of data and statistical representation.Mean, median, standard deviation. Expectation values of a random variable and their statistical significance. Statistical tests: Introduction, motivation and significance of tests. Building hypotheses for data modeling.Null hypothesis and testing, choice of critical value.Construction of test statistics.Testing goodness-of-fit via Student’s t-test and chi^2-test, significance of p-values. **[Accompanied by Hands-on sessions\*]**

Parameter estimation: Introductory concepts. Samples, estimators, bias. Example: Estimators for mean, variance, covariance. The method of maximum likelihood: The likelihood function, maximum likelihood estimators and their variance. Linear regression. The method of least squares: Introductory concept, connection to maximum likelihood. **[Accompanied by Hands-on sessions\*]**

The Monte Carlo method: Introduction, Random number generators, the transformation method, the acceptance-rejection method. **[Accompanied by Hands-on sessions\*]**

Data analysis with object oriented programming. **[Hands-on sessions\*]**

Introduction to machine learning. Linear classification, Logistic regression, optimization, decision trees.Deep learning, convolutional neural networks. **[Accompanied by Hands-on demonstrations\*\*]**

* \*In these sessions, the students will be familiar with real and simulated data from different experiments and will develop statistical algorithms to utilize the concepts discussed in the classes to analyze the data.
* \*\*In these sessions, students will use some given dataset for training, validation and testing of ML models and will get an idea of the optimization procedure.

**Text Books:**

1. Cowan G., *Statistical Data Analysis* (Oxford science Publications).
2. Bevington, P.R. and Robinson D.K., *Data Reduction and Error Analysis for the Physical*

*Sciences* (McGraw Hill).

1. Barlow R.J., *A Guide to the Use of Statistical Methods in the Physical Sciences* (Wiley).

**Reference Books:**

1. Lyons L., *Statistics for Nuclear and Particle Physicists* (Cambridge University Press).
2. Fernow R., *Introduction to Experimental Particle Physics* (Cambridge University Press).
3. Leo W.R., *Techniques for Nuclear and particle Physics Experiments: A How-to Approach*

(Springer).

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**PHIN413: Fundamentals of Nanomaterial and Applications** (**L3-T0-P0-CH3-CR3)**

Nanoscale systems: Length scales, 1D, 2D and 3D nanostructures (nanodots, nanowires, nanorods, thin films,), Band structure and density of states of materials at nanoscale, Size effects in nano systems, Quantum confinement: Applications of Schrodinger equation- Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences.

Synthesis of nanostructured materials: Top down and Bottom up approach, Photolithography. Ball milling.Gas phase condensation.Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD).Sol-Gel.Electro deposition. Spray pyrolysis. Hydrothermal synthesis.Preparation through colloidal methods.MBE growth of quantum dots.

Characterization: X-Ray Diffraction, Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy.

Properties of nanomaterials: Dielectric constant for nanostructures. Excitons in direct and indirect band gap semiconductor nanocrystals, absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures.Electron transport in nanostrcutures, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects. Mechanical and thermal properties of nanomaterials.

Applications: Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron devices. CNT based transistors. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS).

**Text Books:**

1. C.P. Poole, Jr. Frank J. Owens, *Introduction to Nanotechnology* (Wiley-Interscience, May 2003).

2. S.K. Kulkarni, *Nanotechnology: Principles & Practices* (Capital Publishing Company, 2007).

3. K.K. Chattopadhyay and A. N. Banerjee, *Introduction to Nanoscience and Technology* (PHI Learning Private Limited, 2009).

4. Richard D. Booker, Earl Boysen, *Nanotechnology* (John Wiley and Sons, 2005).

**Reference Books:**

1. M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, *Nanoparticle Technology Handbook* (Elsevier, 2007).

2. Bharat Bhushan, *Handbook of Nanotechnology* (Springer-Verlag, Berlin, 2004).

3. Cao Guozhong and Wang Ying, *Nanostructures and Nanomaterials –Sysnthesis, Properties and Applications*, World Scientific Publishing, 2nd edition, 2011.

4. Dieter Vollath, *Nanomaterials: An Introduction to Synthesis, Properties and Applications*, Wiley, 2008.

5. *Nanoscale Materials in Chemistry*, edited by Kenneth J. Klabunde& Ryan Richards, John Wiley & Sons, 2nd edition, 2009.

6. *Nanomaterials: Synthesis, properties and Applications*, Ed. A. S. Edelstein and R.C.Cammarata, IOP (UK, 1996). Characterization of nanophase materials: Ed. Z.L.Wang, Willey-VCH (New York, 2002).

7. *Naostructured Materials*, Ed. Jackie Yi-Ru Ying (Academic Press, Dec 2001).

8. *Nanotechnology: Basic Science and emerging technologies*, Ed. Michael Wilson, K.Kannangara, G. Smith, M. Simmons, and C. Crane (CRC Press, June 2002).

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**PHIN414: Earth Science (L3-T0-P0-CH3-CR3)**

**Structure:**The Solid Earth: Mass, dimensions, shape and topography, internal structure, Magnetic field, Gravity field, Thermal structure and Heat Flow. Earth’s Interior.

The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.

The Atmosphere: variation of temperature, density and composition with altitude, clouds.

The Cryosphere: Polar caps and ice sheets. Mountain glaciers.

Dynamical Processes:Concept of plate tectonics, sea-floor spreading and continental drift. Earthquake and earthquake belts, Seismic waves, Volcanoes and Tsunamis.

The Atmosphere: Atmospheric circulation. Weather and climatic changes and. Cyclones.

I Climate: Earth’s temperature and greenhouse effect, The Indian monsoon system.

Geophysical Exploration:Basic principles of Gravity, Magnetic, Electrical and Seismic Explorations.

**Reference Books:**

1. *Planetary Surface Processes*, H. Jay Melosh, Cambridge University Press, 2011.
2. *Consider a Spherical Cow: A course in environmental problem solving*, John Harte.University Science Books.
3. *Holme’s Principles of Physical Geology*. 1992. Chapman & Hall.
4. Emiliani, C, 1992. Planet Earth, Cosmology, *Geology and the Evolution of Life and Environment*. Cambridge University Press.

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**Minors**

**PHIN209: Fundamentals of Optics (L3-T0-P0-CH3-CR3)**

**Course Objective:**

The present course offers an all-encompassing survey of the basic principles of optics and Laser, building upon the fundamental knowledge gained in previous educational endeavors. Furthermore, the present course explores the creation of innovative ideas within this particular area of study.

**Course Outcomes:**

At the end of the course the following concepts will be clear to the students

CO1: Understand Interference as superposition of waves from coherent sources derived from same parent source

CO2: Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhoffer and Fresnel Diffraction.

CO3: Polarisation and Scattering concepts.

CO4: Fundamental principles of lasing mechanism and identifying various types of lasers,

CO5: Analyzing the attributes of laser lightin terms of its coherence property, output power and wavelength.

CO6: Working of lasers and important applications of laser in various fields starting from material science to biological science.

**Course Contents:**

**Unit 1 (7 Lectures)**

Electromagnetic nature of light.Definition and Properties of wave front.Huygens Principle. Interference: Division of amplitude and division of wavefront. Lloyd’s Mirror and Fresnel’s Biprism. Phase change on reflection: Stokes’ treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton’s Rings: measurement of wavelength and refractive index.

**Unit 2 (5 Lectures)**

Diffraction: Fraunhofer diffraction- Single slit, Double Slit, Multiple slits and Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate.Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis.

**Unit 3 (8 Lectures)**

Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization (General idea).Scattering, Elastic and Inelastic scattering and their applications.Resolving power of optical equipment.

**Unit 4 (8 Lectures)**

*Lasers:*An introduction, Planck’s radiation law (qualitative idea), Energy levels, Absorption process, Spontaneous and stimulated emission processes, Theory of laser action, Population of energy levels, Einstein’s coefficients and optical amplification, two-level atomic systems, light amplification, threshold condition.

**Unit 5(8 Lectures)**

Ruby Laser, He-Ne laser, neodymium-based lasers, CO2 laser, dye laser, fiber laser,semiconductor lasers; DFB and DH lasers

**Text Books:**

1. Ghatak, A. K. and Thyagarajan, K., *Optical Electronics*, (Cambridge University Press, 2009).
2. Svelto, O., *Principles of Lasers, 3rd edition*, (Springer, 2007).

**Suggested Readings:**

1. Milonni, P. W. and Eberly, J. H., *Laser Physics*, (John Wiley & Sons, 2010).
2. Yariv, A., *Quantum Electronics, 3rd edition*, (Wiley Eastern Ltd.).
3. Davis, J. H., *Introduction to Low Dimension Physics*, (Cambridge University Press, 1997).

Siegman, A. E., Lasers, (University Science Books, 1986).

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**PHIN212: Basic Electrodynamics (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

CO1: The students will be able to build up strong creativity, analytical capability and innovativeness.

CO2: The students will be able to improve potentiality via diversified exercises of mathematical physics, vector operation, and electromagnetism.

CO3: The students will be able to explore the physical universe from a new perspective of electromagnetic origin eventually after judging the applicability of the various model theories competently.

**Course Content:**

**Unit – 1**

Electrostatics : Charges, fields and associated potentials. Chanrge distributions, flux, Gauss Law: Integral and differential form and its physical interpretaion, Electric Field due to point charge, line charge, infinite flat sheet, and uniform charge distribution of solid and spherical shell; 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.

**Unit – 2**

Derivation of fields from Potentials, Laplace equations, Method of images, boundary value problems, Laplace equation in rectangular, cylindrical and spherical coordinates, multipole expansion.Dielectric medium, Polarisation, Displacement vector.Gauss’s theorem in dielectrics. Parallel plate capacitor completely filled with dielectric. Energy associated with electric field. Dielectrics and Polarization, Induced dipoles and Bound charges; Electric displacement vectors, Dielectric, para electric and Ferroelectrics.

**Unit – 3**

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, Electrostatic and magnetostatic fields in matter, Boundary conditions fields and potentials, Diamagnetism, Paramagnetism and Ferromagnetism, Fields due magnetised objects, Magnetic Suspectibility.

**Unit – 4**

Faraday’s laws of electromagnetic induction, Lenz’s law, self and mutual inductance; Energy stored in magnetic field; Equation of continuity of current, Displacement current, Maxwell’s equations, conservation of energy and momentum in electrodynamics, Poynting Theorem,

**Unit – 5**

Gauge transformation, Coulomb and Lorentz gauges, Maxwell’s stress tensor. Wave equation, reflection, refraction and propagation of electromagnetic waves in dispersive media, wave equation in a conducting medium.

**Unit – 6**

Electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization; Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

**Text Books:**

1. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice Hall India, 2009).
2. Jackson, J. D., *Classical Electrodynamics, 3 rd edition*, (Wiley, Eastern Ltd, 1998).

**Suggested Readings:**

1. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
2. Slater, J. C., and Frank, N. H., *Electromagnetism*, (Dover Publications, 2011).
3. Miah, W., *Fundamentals of Electromagnetism*, (Tata McGraw-Hill, 1982).
4. Feynman, R. P., *Feynman Lecture Series Volume II*, (Addison Wesley Longman, 1970).

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**PHIN312:The theory of waves (L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** To be able to learn the physical treatment of vibrating systems.

**CO2:** To be able to analyze different types of wave motion through matter.

**CO3:** To acquire an understanding of acoustics.

**Course contents:**

Vibratory systems.Simple harmonic vibration, equilibrium position, Potential energy vs. displacement relation.The general force equation.Simple harmonic vibration in electrical circuits.Anharmonic oscillator.Superposition of parallel and perpendicular vibrations. Beat. Lissajous figures.Fourier treatment of oscillatory systems.Damped oscillations and their motion equations in mechanical and electrical systems.Heavy, light and critical damping.Forced oscillations.Resonances.

Progressive wave in one-dimension and in three-dimensions, wave equation, plane wave and spherical wave, intensity, dispersion, group velocity, phase velocity. Transverse waves in a string, the wave equation its solution. Characteristic Impedance, Reflection and Transmission at a boundary.Normal modes and Eigen frequencies.Energy and Intensity.

Longitudinal waves in solids and fluids. Sound waves, wave equation. Energy distribution, Intensity.Reflection and Transmission at a boundary.Doppler effect & Shock waves. Bel and phon scales. Ultrasound: production, detection and application. SONAR system.

Musical and speech Acoustics.Psycho-acoustic parameters (Loudness, Pitch, Tone, Timbre, Combinational tone), Quality of sound.Acoustic Noise (White, Brown, Pink). Sources of musical sound, Sound in musical instruments, Octave Scale. Human voice classification.Sound recording and playback, Acoustic Transducers.Digital music.

**Text Books:**

1. Pain, H. I., *The Physics of Vibrations and Waves, 6th edition* (John Wiley & Sons Ltd., 2005).
2. Main, I. G., *Vibrations and Waves in Physics, 2nd edition* (Cambridge University Press, 1984).

**Reference Books:**

1. Randall, R. H., *An Introduction to Acoustics*, Sect. 7-21, 7-22, (Addison-Wesley, 1951).
2. Wood, A. B., *A Textbook of Sound, 3rd Edition*, (Bell & Sons, 1955).
3. Crawford, F. S., *Waves, Berkeley Physics Course, Vol. 3*, (Tata McGraw-Hill, 1968).
4. Chattopadhyay, D., *Vibration, Waves and Acoustics*, (New Central Book Agency, 2010).
5. White, H. E, White D. H,, *Physics and Music: The Science of Musical Sound* (Dover 2014)

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**PHIN313: Modern Physics(L3-T0-P0-CH3-CR3)**

**Course Outcomes:**

**CO1:** Students will be familiar with the fundamentals of atomic physics.

**CO2:** Students are expected to learn the structure of atoms, their behavior in presence of electric and magnetic fields.

**CO3:** Students will learn about the significance of angular momentum coupling scheme in controlling energy levels of atoms.

**Course Content:**

Particle-like properties of electromagnetic radiation: Electromagnetic spectrum, Electromagnetic Waves, Blackbody radiation.

Planck’s quantum hypothesis, The photoelectric effect, The Compton effect, Bremsstrahlung and X-ray production.

Models of the atom: Thompson model, Rutherford model, line spectra, Bohr model, Sommerfeld model.

Franck-Hertz experiment, the correspondence principle, deficiencies of Bohr atomic model, hydrogen atom energy levels, fine structure, electronic states in many-electron atom.

Atoms in Electric & Magnetic Fields: 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.

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

Scattering of light: Rayleigh scattering formula, colour of the sky, olarization of the scattered light.

**Text Books:**

1. Herzberg, G., *Atomic Spectra and Atomic Structure,* 2nd edition, (Dover Publications, 2010).

2. White, W. H., *Introduction to Atomic Spectra*, (McGraw-Hill, 1934).

**Reference Books:**

1. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta* (McGraw-Hill, 1930).
2. Harris, R., *Modern Physics*(Pearson, 2016)

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**PHIN415: Basic Electronics devices** **(L3-T0-P0-CH3-CR3)**

**Course Objectives:**

To develop understanding of principles of electricity and practical adaptation of electric circuits. The course will familiarize and teach basics of solid state devices and their applications.

**Course Outcomes:**

At the end of this course, the student will acquire the knowledge to

CO1: To analyze and evaluate schematics of power efficient electrical circuits, Star and delta connections, voltage drop and losses.

CO2: Insight into tracking of interconnections within elements(R,L,C) and identifying current flow and voltage drop.

CO3: Understanding working of some basic solid-state devices.

**Course Content:**

**Unit 1 (8 Lectures)**

Circuit parameters, R, L, and C, Kirchoff’s Law for a loop and junction, Solutions by Determinant andmatrix method: application to T, π and bridge circuits, Norton and Thevenin’s Theorem, Maximum power, transfer Theorem.

Difference between steady state and transient, Growth and decay of current in an inductive circuit.

**Unit 2 (6 Lectures)**

Semiconductors: p and n Type Semiconductors. Energy Level Diagram, Mobility and conductivity, transportphenomenon due to donor and acceptor impurities, Fermi level, Hall Effect, conductivity measurement

**Unit 3 (8 Lectures)**

Diodes: Barrier Formation in pn Junction Diode (Simple Idea). Current Flow Mechanism in Forward and, Reverse Biased Diode (Recombination, Drift and Saturation of Drift Velocity). Derivation of Mathematical, Equations for Barrier Potential, Barrier Width and Current for Step Junction.pn junction and its, characteristics. Static and Dynamic Resistance.Diode Equivalent Circuit.Ideal Diode. Load Line Analysisof Diodes and Q-point.

**Unit 4 (6 Lectures)**

Two-terminal Devices and their Applications: (1) Rectifier Diode. Half-wave Rectifiers.Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification.

Efficiency. Qualitative idea of C, L and π - Filters. (2) Wave shaping circuits (3) Zener Diode and VoltageRegulation. (4) Photo Diode, (5) Varactor Diode.

**Unit 5 (8 Lectures)**

Bipolar Junction Transistors, n-p-n and p-n-p transistors. Characteristics of CB, CE and CC Configurations.Current gains α, β and γ and Relations between them. Load Line Analysis of transistors. DC Load line andQ-point.Physical Mechanism of Current Flow.Active, Cutoff, and saturation Regions.Transistor in ActiveRegion and Equivalent Circuit.

**Text Books:**

1. Robbins, A. H. & Miller, W.C., *Circuit Analysis*, (Delmar Cengage Learning., 2003).
2. Hayt, W. H. &Kemmerly, J. E., *Engineering Circuit Analysis*, (McGraw Hill, New York, 1993).

**Suggested Readings:**

1. Millman, J., Halkias, C.C. and Jit, S., *Electronic Devices and Circuits*, (McGraw Hill Education,India,2016).
2. Toro,V. Del, *Electrical Engineering Fundamentals*, (Prentice Hall, 1994).
3. Edminister, J.A., *Electrical Circuits- Schaum’s Outline series, 2nd edition* (McGraw Hill,1983).
4. Smith, R.J. and Dorf, R.C., *Circuits, Devices and Systems*, (John Wiley & Sons, 1992).
5. Morris, J. Analog *Electronics*, (Arnold Publishers, 1991).
6. Mottershead, A. *Electronic Circuits and Devices*, (Prentice Hall, 1997).
7. Streetman, B.G. & Banerjee, S., *Solid State Electronic Devices*, (Pearson Prentice Hall, 2006).

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