COURSES OF STUDIES

PHYSICS SYLLABUS FOR M.Sc DEGREE UNDER SEMESTER SYSTEM

SCHOOL OF PHYSICS
GANGADHAR MEHER UNIVERSITY
AMRUTA VIHAR, SAMBALPUR-768004, ODISHA

18 Sep 2020

A Brief Overview of Syllabus

FIRST SEMESTER			
Course No.	**Name of Course**	**Marks**	**Credit**
PHY-101	Mathematical Methods in Physics	20+80	4
PHY-102	Classical Mechanics	20+80	4
PHY-103	Quantum Mechanics-I	20+80	4
PHY-104	Statistical Mechanics	20+80	4
PHY-105	Computational Methods in Physics Lab	100	6
SECOND SEMESTER			
PHY-201	Classical Electrodynamics	20+80	4
PHY-202	Quantum Mechanics-II	20+80	4
PHY-203	Basic Solid State Physics	20+80	4
PHY-204	Applied Optics	20+80	4
PHY-205	Modern Physics & Optics Lab	100	6
PHY-206	Open Elective (DSE) (Atomic and Molecular Spectroscopy)	20+80	4
THIRD SEMESTER			
PHY-301	Advanced Quantum Mechanics	20+80	4
PHY-302	Basic Electronics	20+80	4
PHY-303	Special Paper-I (Advanced Condensed Matter Physics)	20+80	4
PHY-304	Physics of Metamaterials	20+80	4
PHY-305	Lab:-Electronics	100	6
PHY-306	Open Elective (IDSE)(Nano Science and Nano Technology)	20+80	4
FOURTH SEMESTER			
PHY-401	Basic Nuclear Physics	20+80	4
PHY-402	Particle Physics	20+80	4
PHY-403	Special Paper:II (Advanced Condensed Matter Physics)	20+80	4
PHY-404	Project/Dissertation	100	4
PHY-405	Lab:- Special Paper	100	6
		Total Marks=2200	**Total Credit=96**

*NB** **Departmental Specific Elective**

1. Atomic and Molecular Spectroscopy (PHY-206)

*NB** **Inter Disciplinary Specific Elective**

1. Nano Science and Nano Technology (PHY-306)

PHY101: Mathematical Methods in Physics

Unit I **12 hrs**

Complex Integrations: Calculus of Residues, Cauchy's residue theorem, Evaluation of definite integrals. Evaluation of Contour integration involving branch points and cuts.

Unit II **08 hrs**

Tensor Analysis: Cartesian tensors, Rank of tensor, Operation of Tensors, Covariant and contravariant vector, covarient derivatives, Christoffel symbol and metric tensor, Riemann & Ricci tensor, Levi-Civita Tensor, Tensor form of gradient, divergence and curl.

Unit III **08 hrs**

Groups and Group Representations: Definition of groups, Sub groups and classes, Finite groups, Group representations, Characters, Infinite groups and Lie groups, Irreducible representations of SU(2), SU(3) and O(3), SO(3,1).

Unit IV **12 hrs**

Special Functions: Legendre Polynomial, Associated Legendre Polynomial, Bessel's Function of first kind and second kind, Hankel's function, Modified Bessel's function, Hypergeometric and Confluent Hypergeometric functions, Fourier and Laplace transformation.

References

Text Books:

1. Mathematical Methods for Physicists: George Arfken Hans, Weber Frank, E. Harris, (2012), 7th Edition, Academic Press.
2. Mathematical Physics: H K Das, Dr. R. Verma, (2012) S. Chand Publications, 1st Edition

Reference Books:

1. Mathematical Physics with Classical Mechanics: Satya Prakash, (2014), Sultan Chand & Sons, 6th Edition
2. Mathematical Physics: P K Chattopadhyay, (2013), New Age International, 2nd Edition.
3. Mathematical Methods for Physics and Engineering: K. F. Riley, M. P. Hobson and S. J. Bence, (2006), Cambridge University Press, 3rd Edition.

PHY-102: Classical Mechanics

Unit I **10 hrs**

Mechanics of a System of Particles, Lagrangian Formulation, Velocity-Dependent Potentials and Dissipation Function, Conservation Theorems and Symmetry Properties, Homogeneity and Isotropy of Space and Conservation of Linear and Angular Momentum, Homogeneity of Time and Conservation of Energy. Calculus of Variations and Euler-Lagrange's Equation, Brachistochrone Problem, Hamilton's Principle, Extension of Hamilton's Principle to Nonholonomic Systems,

Unit II **10 hrs**

Hamiltonian Formulation: Legendre Transformation and the Hamilton Equations of Motion, Physical Significance of Hamiltonian, Derivation of Hamilton's Equations of Motion from a Variational Principle, Routh's Procedure, Δ Variation, Principle of Least Action.

Cononical Transformations: Canonical Transformation, Types of Generating Function, Conditions for Canonical Transformation, Integral Invariance of Poincare, Poisson Bracket, Poisson's Theorem, Lagrange Bracket, Poisson and Lagrange Brackets as Canonical Invariant, Infinitesimal Canonical Transformation and Conservation Theorems.

Unit III **10 hrs**

Hamilton Jacobi Theory: Hamilton-Jacobi Equation for Hamilton's Principal Function, Harmonic Oscillator and Kepler problem by Hamilton-Jacobi Method, Action-Angle Variables for completely Separable System, Kepler Problem in Action-Angle Variables, Geometrical Optics and Wave Mechanism.

Small Oscillation: Problem of Small Oscillations, Example of Two coupled Oscillator, General Theory of Small Oscillations, Normal Coordinates and Normal Modes of Vibration, Free Vibrations of a Linear Triatomic Molecule.

Unit IV **10 hrs**

Rigid Body Motion: The Independent of Co-ordinates of a Rigid Body, Orthogonal Transformations. The Euler's angles. The Cayley-Klein parameters; Euler's Theorems on the Motion of a Rigid body, Infinitesimal Rotations, Rate of Change of a Vector, The Coriolis Force.

Rigid Body Dynamics: Angular Momentum and Kinetic Energy of Motion about a Point. The Inertia Tensor and Moment of Inertia, Eigenvalues of Inertial Tensor and the Principal Axis. Transformation. The Euler Equations of Motion, Torque-free motion of a rigid body. The Heavy Symmetrical Top with One Point Fixed.

References

Text Books:

1. Classical Mechanics, H. Goldstein, C. P. Poole and J. L. Safko, (2011), Addison Wesley, 3rd edition.
2. Mechanics, L.D. Landau and E.M. Lifshitz, (2000), Butterworth-Heinenann.
3. Classical Mechanics, Rana and Joag, (2001), Tata McGraw-Hill Education, 1st edition.

Reference Books:

1. Classical Mechanics, H. C. Corben & P. Stehle, (2013), Dover Publications, 2nd edition.
2. Analytical Mechanics, L. Hand and J. Finch, (2012), Cambridge University Press, 1st edition.
3. Classical Mechanics , J.C. Upadhyaya,(2013), Himalay Publishing House, 1st edition.
4. A Treatise on the Analytical Dynamics of Particles and Rigid Bodies, E.T.Whittaker, (1999), Cambridge University Press, 4th edition.

PHY-103: Quantum Mechanics - I (Formalism)

Unit I **10 hrs**

Linear Vector Space Formulation: Linear Vector Space (LVS) and its generality, Vectors-scalar product, basis vectors, linear independence, linear superposition of general quantum states, completeness, Closure Property, Schmidt's orthonormalisation procedure, Dual space, Bra and Ket vectors.

Operators and Matrix formalism: Eigen value and Eigen vectors of Linear, Adjoint, Hermitian, Unitary, Inverse, Antilinear, Projection, parity operators, Complete set of compatible operators, Noncommutativity and uncertainty relation, Matrix representation of vectors and operators, Eigen value equation and Expectation value, Transformation of basis vectors, Unitary transformation of vectors and operators, infinitesimal and finite unitary transformation, Continuous representation position and Momentum space wave function.

Unit II **10 hrs**

Quantum Dynamics: Time evolution of quantum states, Time evolution operator and its properties, Schrodinger/Heisenberg/ Interaction pictures, Equations of motion.

Operator method solution of 1D Harmonic oscillator: Matrix representation of creation and annihilation operators, Density matrix.

Rotation and Orbital Angular Momentum: Rotation Matrix, Angular momentum operators as the generators of rotation, L_x, L_y, L_z and L^2 and their commutator relations, Raising and lowering operators. (L^+ and L^-). L_x, L_y, L_z and L^2 in spherical polar coordinates, Eigen values and Eigen functions of L_z, L^2 (OP method) spherical harmonics, Matrix representation of L^+, L^- and L^2.

Unit III **10 hrs**

Spin Angular Momentum: Spin particles, pauli spin matrices and their properties Eigen values and Eigen functions, Spinor transformation under rotation.

Addition of angular momentum:

Total angular momentum **J**. Eigen value problem of J_z and J^2, Angular momentum matrices. Addition of angular momenta and C.G. co-efficients, Angular momentum states for composite systems in the angular momenta (1/2, 1/2) and (1, 1/2).

Unit IV **10 hrs**

Motion in Spherically Symmetric Field: Hydrogen atom, Reduction to equivalent one body problem, Radial equation, Energy eigen values and eigen functions, degeneracy, radial probability distribution. Free particle, problem incoming and outgoing spherical waves, expansion of plane waves in terms of spherical waves, Bound states of a 3-D square well, particle in a sphere.

References

Text Books

1. Quantum Mechanics Concepts and Applications - Nouredine Zettili, (2009), Wiley, 2nd Edition.
2. Introduction to Quantum Mechanics- David J. Griffith, (2004), Cambridge University Press, 2nd Edition.

Reference Books

1. Quantum Mechanics - S. Gasiorowicz, (2003), Wiley, 3rd Edition.
2. Quantum Mechanics - J. J. Sakurai, J. Napolitano, (2011), Cambridge University Press, 2nd Edition.
3. Quantum Mechanics (Non Relativistic theory) - L.D. Landau and E. M. Lifshitz, (1997), Pergamon Press, 3rd Edition.
4. Introductory Quantum Mechanics, R. L. Liboff, (2009), Pearson Press, 3rd Edition.

PHY-103 Statistical Mechanics

Unit I **10 hrs**

Classical statistical Mechanics : Postulates of classical statistical mechanics , Liouville‘s theorem micro-canonical ensemble , derivation of thermodynamics , equipartition theorem ,Classical ideal gas , Gibb‘s para-dox , canonical ensemble , density fluctuation in grand canonical ensemble , equivalence of canonical and grand canonical ensemble .

Unit II **10 hrs**

Quantum Statistical Mechanics: Postulates of quantum statistical mechanics , density matrix , Liouville‘s theorem, ensembles in quantum statistical mechanics , third law of thermodynamics , ideal gases in micro -canonical and grand canonical ensemble , particle in a box , Maxwell-Boltzmann , Boltzmann-Einstein and Fermi-Dirac distributions .

Unit III **10 hrs**

Bose and Fermi gas: Photons, phonons, Debye-specific heat, electronic specific heat, Bose-Einstein Condensation, Fermi energy, Ground state, Low temperature properties, Mean energy of fermions at absolute zero, Theory of White – Dwarfs (without derivation)

Unit IV **10 hrs**

Phase Transition and Ising model: Thermodynamics description of Phase Transitions, Phase Transitions of second kind, Landau theory of phase transition beyond mean field, Definition of the Ising model, one dimensional Ising model.

References

Text Books:

1. Statistical physics, K. Huang, (2014), Willy Student edition , 2nd edition.
2. Fundamental of statistical & thermal physics, F. Reif, (2010), Levant Books, 1st Indian edition.
3. Fundamental of statistical mechanics, B. B. Laud, (2012), New age international Pvt. Ltd, 2nd Edition.

Reference Books:

1. Statistical physics, Landau and Lifsitz, (2013), Pergamon Press, 3rd Edition, 2013
2. Elementary statistical physics, C.Kittel, (2008), John Wiley & Sons, 2nd Edition.
3. Statistical mechanics - A set of lectures, R.P.Feynman, (2008), The Benjamin publishing company, Inc.
4. Introduction to Statistical Physics, Kerson Huang, (2002), Taylor & Francis, 2nd Edition.

PHY104: Computational Methods in Physics

Laboratory (6 hrs per week)

Introduction to computer hardware and software, introduction to storage in computer memory, stored programme concepts, storage media, computer operating system, compilers, LINUX commands;

Programming with FORTAN: Programme solving on computers - algorithm and flow charts in FORTAN data types, expressions and statements, input/output commands, sub programme,

Programming with C++: Structure of C++ programme, compilation , Data types, variable and constant, declaration of variables, initializing variables, arithmetic operators, Increment and Decrement operators, I/O statements, arithmetic expressions, functions, Control statements: decision making and looping statements, array.

Exercises for acquaintance:

1. To find the largest or smallest of a given set of numbers
2. To generate and print first hundred prime numbers
3. Sum of an AP series, GP series, Sine series, Cosine series
4. Factorial of a number
5. Transpose a square matrix
6. Matrix multiplication, addition
7. Trace of a matrix
8. Evaluation of log and exponentials
9. Solution of quadratic equation
10. Division of two complex numbers
11. To find the sum of the digits of a number

Numerical Analysis:

1. Interpolation by Lagrange method
2. Numerical solution of simple algebraic equation by Newton- Raphson method
3. Numerical integration : Trapezoidal method, Simpons method, Romberg integration, Gauss quadrature method
4. Eigenvalues and eigenvectors of a matrix
5. Solution of linear homogeneous equations
6. Matrix multiplication, addition
7. Trace of a matrix
8. Matrix inversion.
9. Solution of ordinary differential equation by Runge-Kutta Method
10. Solution of Radioactive decay, Simple harmonic oscillator, Schroedinger Equation.

References

Text Books:

1. Computer Programming in FORTRAN 90 and 95: V. Rajaraman, (2018), PHI Learning Private Limited, 18th Edition

2. Fundamentals of Computers: V. Rajaraman, (2015), PHI Learning Private Limited, 6th Edition.

3. Computer Oriented Numerical Methods: R.S.Salaria, Khanna Book Publishing co. (P) LTD. 5th Edition.
4. Programming with C++: J. R. Hubbard, (2000), MCGRAW-HILL, 2nd Edition.

Reference Books:

1. Numerical Recipes in C++: The Art of Scientific Computing, W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery (2002), CAMBRIDGE UNIVERSITY PRESS, 2nd Edition.

2. Numerical Recipes in Fortran 90 The Art of Parallel Scientific Computing, W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery (1996), CAMBRIDGE UNIVERSITY PRESS, 2nd Edition.
3. Fortran 77 and Numerical Methods: C. Xavier, New Age International Publishers.

PHY-201 Classical Electrodynamics

Unit I **10 hrs**

Waves in matter: Electromagnetic waves at plane between dielectrics and dielectric- metal. Fresnel equations for normal and oblique incidence, Energy transport, Polarization by Reflection, Total Internal Reflection, Evanescent waves, Waves in a Multilayer.

Waveguides and resonators: TE & TM modes in dielectrc slab, Wave guide, Cylindrical wave-guides and cavity, modes of rectangular waveguides with conducting walls. Dispersion: The frequency dependence of permittivity, Dispersion in conductors and Kramers- Kronig relations

Unit II **10 hrs**

Potential formulation: Vector and scalars potentials, Wave equation for potentials, Gauge Transformation, Coulomb and Lorentz gauge conditions. Greens function solution of potential form of Maxwells equations, Retarded potential, retarded solutions for field, Poynting theorem in dispersive media. Lienard-Wiechert Potentials, Fields and power of an accelerated point charge, Larmours formula.

Unit III **10 hrs**

Radiation: Electric dipole, Magnetic dipole, Electric Quadrupole and any arbitrary radiation, radiation from Linear Centre-Fed Anteena, angular distribution of power radiated, radiation from circular orbits. Classical cross section for radiation, Bremstrahlung in coulomb field, Cherenkov radiation.

Unit IV **10 hrs**

Scattering: Scattering by small dielectric & perfectly conducting sphere and Conducting Cylinder, Radia- tion damping of a charged harmonic oscillator, scattering by an individual free scattering electron (Thomson Scattering), Scattering by bound electron (Rayleigh Scattering).

References

Text Books:

1. Introduction to Electrodynamics - D.J. Griffiths, (1991), Pearson Education Ltd. 3rd Edition
2. Classical Electrodynamics - J.D. Jackson, (2004), John & Wiley Sons Pvt. Ltd, New York, 3rd Edition
3. Classical Theory of Electrodynamics - L.D. Landau and E.M. Lifshitz, (1971), Addison, Wesley, 3rd Edition,

Reference Books:

1. Introduction to Electrodynamics - A. Z. Capri and P.V.Panat, (2010), Narosa Publishing House, 5th Edition
2. Classical electricity & Magnetism- Panofsky and Phillips, (1989), Addison Wesley, 2nd Edition.
3. Classical Electromagnetic Radiation - J.B. Marion, (1995), Academic Press, New Delhi, 1st Edition
4. Classical Electricity and Magnetism - Wolfgang K. H. Panofsky and Melba Phillips, (2005), Dover Publications, 2nd Edition.

PHY202: Quantum Mechanics - II

Unit I **10 hrs**

Time Independant Perturbation Theory: Rayleigh Schrodinger Method for Time-Independent Non-Degenerate Perturbation Theory, First and Second Order Correction, Perturbed Harmonic Oscillator, Anharmonic Oscillator, The Stark Effect, Quadratic Stark Effect and Polarizability of Hydrogen atom, Degenerate Perturbation Theory, Removal of Degeneracy, Parity, Parity of atomic states, Parity Selection Rule, Linear Stark Effect of Hydrogen atom.

Unit II **10 hrs**

Correction factors: Spin-Orbit Coupling, Relativistic Correction, Fine Structure of Hydrogen like Atom, Normal and Anomalus Zeeman Effect, The Strong-Field Zeeman Effect, The Weak-Field Zeeman Effect and Lande‘s g-factor.

Variational Methods: Ground State, First Excited State and Second Excited State of One-Dimensional Harmonic Oscillator, Ground State of H-atom and He-atom.

Unit III **10 hrs**

WKB Approximation Method: General Formalism, Validity of WKB Approximation Method, Connection Formulas, Bohr Somerfield Quantization Rule, Application to Harmonic Oscillator, Bound States for Potential Wells with One Rigid Wall and Two Rigid Walls, Tunneling Through a Potential Barrier, Cold Emission, Alpha Decay and Geiger-Nuttal relation.

Time Dependant Perturbation Theory: Transition Probability, Constant and Harmonic Perturbation, Fermi Golden Rule, Interaction of one electron atoms with electromagnetic radiation, Basic Principles of Laser and Maser. Electric Dipole Radiation and Selection rules. Spontaneous Emission Einstein‘s A, B-Co-efficients, radiation, Quantum description of spontaneous emission.

Unit IV **10 hrs**

Scattering Scattering amplitude and differential cross Section, Relation between Lab and CM cross sections, Born Approximation. Application to Coulomb and Screened Coulomb Potential,.Partial Wave Analysis for Elastic and Inelastic Scattering, Effective Range and Scattering Length, Optical Theorem, Black Disc-Scattering, Hard-Sphere Scattering, Resonance Scattering from a Square Well Potential, Scattering of identical particles.

References

Text Books

3. Quantum Mechanics Concepts and Applications - Nouredine Zettili, (2009), Wiley, 2nd Edition.
4. Introduction to Quantum Mechanics- David J. Griffith, (2004), Cambridge University Press, 2nd Edition.

Reference Books

1. Quantum Mechanics - S. Gasiorowicz, (2003), Wiley, 3rd Edition.
2. Quantum Mechanics - J. J. Sakurai, J. Napolitano, Cambridge University Press, (2011), 2nd Edition.
3. Quantum Mechanics (Non Relativistic theory) - L.D. Landau and E. M. Lifshitz, (1977), Pergamon Press, 3rd Edition.
4. Introductory Quantum Mechanics, R. L. Liboff, (2009), Pearson Press, 3rd Edition.

PHY203: Basic Solid State Physics

Unit I **10 hrs**

Crystal binding: Crystal of inert gases, ionic crystals, covalent crystals, Metallic binding, and hydrogen bounded crystals.

Phonons and lattice vibration: Vibrations of monatomic and diatomic lattices, dispersion, relation, optic and acoustic modes, Quantum of lattice vibration and phonon, phonon momentum, inelastic scattering of neutrons and photons by phonons.

Thermal Properties of insulators: Lattice heat capacity, Debye & Einstein model, Anharmonic crystal interactions, thermal conductivity and thermal expansion.

Unit II **10 hrs**

Free Electron Fermi Gas: Density of state in one dimension, effect of temperature on Fermi-Dirac distribution, Free electron gas in three dimensions, Heat capacity of electron gas, The Boltzmann equation, Electrical conductivity, General Transport coefficients, Thermal conductivity, Thermoelectric effect.

Band theory: Electrons in periodic potential, Bloch's theorem, Kronig Penney model, origin of band gap, Wave equation for an electron in a periodic potential, Bloch functions, Brillouin zones, E-k diagram under free electron approximation.

Unit III **10 hrs**

Semiconductors: Intrinsic and impurity semiconductors, band gap, law of mass action, intrinsic carrier concentration, mobility in the intrinsic region, p-n junction rectification.

Magnetism: Brief concept on Diamagnetism and paramagnetism, Weiss theory of ferromagnetism, Curie-Weiss Law for susceptibility, Heisenberg model- Conditions for ferro- and antiferro-magnetic order, Spin waves and magnons, Bloch's T_2 Law, Antiferromagnetic order, Neel Temperature. Diluted Magnetic Semiconductors.

Unit IV **10 hrs**

Superconductivity: Experimental survey, Meissner effect, Type-I & Type-II superconductors, thermodynamic properties of superconductors, London's theory, Isotopic effect, Flux quantization, BCS Theory, Electron-electron attractive interaction due to virtual phonon exchange, Cooper pairs and BCS Hamiltonian. Superconducting ground state and the gap equation at T = 0 K.

Josephson effect: Macroscopic quantum mechanical effect, DC Josephson effect, Effect of electric field- AC/Inverse AC Josephson effect, Effect of magnetic field, SQUID.

High Tc superconductors: Basic ideas and applications.

References

Text Books:

1. Introduction to solid state physics- C. Kittel, J(2016), John Wiley & Sons, 8th Edition.
2. Solid State physics -A. Omar, (2014), Pearson, 1st edition.
3. Semiconductor device: Physics and Technology: S. M. Sze, (2009), Wiley India Private Limited; 2nd Edition.
4. Solid State Physics- Ashcroft Mermin, (2011), Cengage Learning, India Edition, 10th Edition

Reference Books:

1. Principles of condensed matter physics- P.M. Chaikin and T.C. Lubensky, (2000), Cambridge University Press, 3rd Edition.
2. Solid state physics- S. O. Pilli, (2006), New Age International, 6th Edition.
3. Solid state physics- Dan Wei, (2008), Cengauge Learning, 1st Edition.
4. Quantum theory of solid State -J.Callaway, (1991), Academic Press, 2nd Edition.
5. Semiconductor Physics and Devices (Basic Principles), Donal A Neamen, (2012), Tata McGraw-Hill, 3rd Edition.

PHY-204: Applied Optics

Unit I **10 hrs**

Optics of solids: Plane wave in anisotropic media, types of crystal, Double Refraction at a Boundary, Optical Activity, Faraday Rotation in Solids, Magneto-optic and Electro-optic Effects, Introduction to Nonlinear Optics.

Unit II **10 hrs**

Fourier Optics: Basics of Fourier transformation operation, Definition of spatial frequency and transmittance function, Fourier transform by diffraction and by lens, Spatial frequency filtering, types of filters, Abbe-Porter experiments, phase-contrast microscope.

Holography: Principle of holography, On-axis and off-axis hologram recording and reconstruction, Types of hologram and applications.

Unit III **10 hrs**

Laser spectroscopy: Laser-induced breakdown spectroscopy (LIBS), Laser induced fluorescence spectroscopy, Nonlinear spectroscopy: linear and nonlinear absorption, saturation spectroscopy two-photon and multi-photon spectroscopy, Applications of laser spectroscopy: single molecule detection, trace level detection of explosives and hazardous gases, LIDAR.

Unit IV **10 hrs**

Optical fibers: Guided modes of step-index and graded index fibers, Propagation light in optical fibers, Numerical aperture and Applications of optical fibers in Communication and Sensing.

References

Text Books:

1. Optics- Ajay Ghatak (2012), Tata Mc-Graw Hill, 5th Edition
2. Laser Spectroscopy: Basic Concepts and Instrumentation – W. DemtrÖder (2004), Springer,, 3rd Edition.
3. Introduction to Fourier Optics- J. W. Goodman, (2005), Ben Roberts, 3rd Edition
4. Holography: A Practical Approach- G. K. Ackerman and J. Eichler, (2007), Wiley-VCH, 1st Edition

Reference Books:

1. Introduction to Modern Optics- G. R. Fowless, (2012), Dover Publications, 2nd Edition
2. Laser Spectroscopy and its Applications- R. W. Solarz and J. A. Paisner, (1986), Marcel Dekker, 1st Edition
3. Basics of Holography- P. Hariharan, (2002), Cambridge University Press, 1st Edition
4. Principles and Applications of Fourier Optics – R. K. Tyson, (2014), IOP Publishing, 1st Edition

PHY205: Optics and Modern Physics

Laboratory (6 hrs per week)

Optics:

1. Experiments with optical bench Biprism Straight edge and narrow wire.
2. Experiments with spectrometer: Single and Double split.
3. Experiments with Michelson interferometer : Determination of λ and a Thickness of mica sheet
4. Fabry Perot interferometer
5. Polarization Experiments
   - Babinet compensator
   - Edsar-Butlerbands
   - Quarter wave plate
   - Mallus Law
   - Study of elliptical polarized light
6. Constant Deviation Spectrograph
   - Calibration
   - Zeeman effect
7. Babinet Quartz Spectrography

Modern Physics:

1. e/m measurement by Braun tube
2. e/m measurement by Magnetron Valve Method
3. e/m measurement by Thomson Method
4. Magnetic field measurement by search coil
5. Ferroelectric transmission point by Dielectric Constant Measurement
6. Rectification by junction Diode using various filters
7. Characteristics of a Transistor.
8. Dielectric constant of solid (wax) by Lecher Wire
9. Verification of Richardson's $T^{\frac{3}{2}}$ law
10. Determination of Planck's constant by total Radiation Method
11. Determination of Planck's constant by Reverse Photoelectric effect method
12. Hysteresis loop tracer
13. Determination of "e" by Millikan's oil drop experiment

14. Measurement of attenuation and phase shift of A.C. in L.C.R. net work
15. RF characteristics of coil
16. Study of power supply
17. Calibration of an oscilloscope
18. Stefan's constant measurement
19. Existence of discrete energy level by Frank Hertz experiment.
20. GM counter experiments: Characteristics of the Geiger tube, Inverse Square Law, Absorption coefficient of the aluminium foil.

PHY-206: Departmental Specific Elective (DSE)
Atomic and Molecular Spectroscopy

Unit I **10 hrs**

Quantum mechanics of H atom, Atomic Orbital's and Hund's rule, Magnetic dipole moment, Electron spin and vector atom model, Spin Orbit interaction, Hydrogen Fine structure, Lamb Shift, L-S & J-J Coupling: spectroscopic terms, selection rule, Lande Interval rule, Zeeman Effect (normal and Anomalous) and Paschen-Back Effect: Splitting of spectral lines and selection rules, Hyperfine Structure Spectral Lines: Isotope Effect, Nuclear spin and Hyperfine Splitting and selection rules.

Unit II **10 hrs**

Molecular Electronic States: Molecules and Chemical bonds: Molecular Formation, Ionic binding, Covalent Binding, Valence-bond treatment of H2+, The LCAO method for H2+. The Stability of Molecular States Concept of molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function.

Unit III **10 hrs**

Rotation and Vibration of Molecules: Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential, Symmetries of electronic wave functions, Shapes of molecular orbital and bond, Term symbol for simple molecules.

Unit IV **10 hrs**

Spectra of Diatomic Molecules: Transition matrix elements, Vibration-rotation spectra: Pure vibrational trans- itions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra.

References

Text Books

1. Physics of Atoms and Molecules - Bransden and Joachain, (2003), Prentice Hall, 2nd Edition.
2. Atomic and Molecular Spectra: Laser, Raj Kumar, (2012), KNRN, India, 6th Edition.
3. Introduction to Atomic and Molecular Spectroscopy - V. K. Jain, (2007), Narosa, 4th Edition.

Reference Books:

1. Fundamentals of Molecular Spectroscopy- C. N. Banwell, (2012), Tata McGraw Hill, 4th Edition.
2. Molecular spectroscopy, J.M. Brown, (1998), Oxford University Press, 1st edition.
3. Molecular spectroscopy, Jeanne, L. McHale, (2017), CRC press, 2nd Edition.
4. Spectra of atoms and molecules, P. F. Bemath, (2016), Oxford University Press, 3rd Edition.
5. Modern spectroscopy, J.M. Holias, (2004), John Wiley and Sons ltd., 4th edition.

PHY301: Advanced Quantum Mechanics
(Relativistic Quantum Mechanics)

Unit I **08 hrs**

Klein-Gordon Equation: Need for a relativistic equation, Klein-Gordon equation and its drawbacks, Real and Complex Klein-Gordon fields, Klein-Grdon equation with electromagnetic field.

Unit II **12hrs**

Dirac Equation: Dirac equation, Magnetic moment of electron, Spin-Orbit coupling, Darwins term, Non-relativistic reduction of Dirac equation, Properties of Dirac gamma-matrices, Free particle and plane wave solution of Dirac equation with physical interpretation, Normalized Dirac spinors.

Unit III **12 hrs**

Covariance of Dirac equation and Hole Theory: Lorentz transformation, Covariance of Dirac equation and bilinear covariant, Projection operator for Energy and spin, Zitterbewegung, Dirac Hole theory.

Unit IV **08 hrs**

Symmetry in Dirac equation: Charge conjugation, space reflection, time reversal symmetries of Dirac equation, Continuous systems and fields, Real (Classical) and Dirac fields, Lagrange and Hamiltonian formulation, Noether's theorem, Second Quantization, Gordon decomposition, Normal ordering.

References

Text Books:

1. Lectures on Quantum Field Theory - Ashok Das (2008), World Scientific, 2nd Edition.
2. Advanced Quantum Mechanics- J. J. Sakurai (2002), Pearson Education India, 4th Edition
3. Relativistic Quantum Mechanics- J. D. Bjorken and S. D. Drell (1964), Mc-Graw Hill, 1ST Edition

Reference Books:

4. Relativistic Quantum Mechanics- L. Maiani and O. Benhar (2012) CRC Press, 1st Edition
5. Relativistic Quantum Physics- Tommy Ohlsson (2011) Cambridge University Press, 1st Edition
6. Quantum Field Theory- L. H. Ryder (2017) Cambridge University Press, 2nd Edition
7. Advanced Quantum Mechanics- F. Schwabl (2005), Springer, 3rd Edition

PHY302: Basic Electronics

Unit I **10 hrs**

Network Theory: T and PI network, their inter conversations, Foster's reactance theorem, Thevenin's theorem and Norton's theorem, Reciprocity theorem, superposition and compensation theorem, maximum power transfer theorem.

Amplifiers: Frequency response of linear amplifiers through h-parameters, amplifier pass band, RC, LC. and transformer coupled amplifiers and their frequency response, gain band-width product, Millers theorem, Feedback amplifiers, effects of negative feedback, Boot-strapping the FET, Multistage feedback, Cascaded amplifier, stability in amplifiers, noise in amplifiers.

Unit II **10 hrs**

Operational amplifiers: The differential amplifiers, integral amplifier, rejection of common mode signals. The operational amplifier input and output impedances, application of operational amplifiers, unit gala buffer, summing, integrating and differentiating amplifiers, comparators and logarithmic amplifiers.

Unit III **12 hrs**

Oscillator/ Multivibrator Circuits: Feedback criteria for oscillation, Hartley oscillator, Colpitt's oscillator, phase shift, Wien bridge oscillator, crystal controlled oscillator, klystron oscillator, Principle of multivibrator, Multivibrator circuits (Astable, Monostable, bistable).

Digital Circuits: Logic fundamentals, Boolean theorem, Logic gates - RTL, DTL and TTL gates, CMS switches, RS flip-flop, JK flip-flops

Unit IV **08 hrs**

Radio Communication: Ionospheric propation, Antennas of different types, super heterodyne, receiver (Block diagram). Various types of optical fibers and optical communications.

References

Text Books:

1. The art of electronics - Paul Horowitz, Winfield Hill, (1989), Cambridge University Press, 2nd Edition.
2. Electronic Devices and Circuit Theory - Robert L. Boylestad, (1996), Louis Nashelsky, Prentice Hall, 6th Edition.
3. Hand Book of Electronics- Gupta and Kumar (2016), Pragati Prakashan, 43rd edition

Reference Books:

1. Electronic Devices and Circuits - Millman, Halkias and Jit, (1988), Tata McGraw Hill, 1st Edition.
2. Op-amps and linear integrated circuits - R.A.Gayakwad, (2000), Prentice Hall of India, 6th Edition.
3. Principle of Electronics, V.K.Mehta, R. Mehta, (1980), S. Chand, 3rd Editon.
4. Electronic Principles - Malvino and Bates, (2016), McGraw Hill. 8th Edition.

PHY-303: Special paper- I
Advanced Condensed Matter Physics

Unit I **12 hrs**

Lattice Vibrations: Born-Oppenheimer Approximation, Hamiltonian for lattice vibrations in the harmonic approximation, Normal modes of the system and quantization of lattice vibrations-phonons. Electron-phonon interaction, Second quantized form of Hamiltonian for electrons and phonons in interaction.

Energy Bands: Nearly free electron approximation - Diffraction of electrons by lattice planes and opening of gap in E-K diagram. Effective mass of electrons in crystals, Holes, Tight binding approximation, S and P state band, Warnier functions ,Equation of motion in the Wannier representation, The equivalent Hamiltonian-Impurity levels, Density of states

Unit II **10 hrs**

Fermi Surface: Characteristics of fermi surfaces, construction of the Fermi surfaces, case of metals, experimental studies of the fermi surfaces, De Hass Van Alphen effect, Cyclotron resonances in metals.

Beyond the Independent Electron Approximation: Hartree and Hartree-Fock equation, correlation, Screening, Thomas Fermi Theory of dielectric function.

Unit III **08 hrs**

Electron Interaction: Perturbation formulation, Dielectric function of an interacting electron gas (Lindhard's expression), Static screening, Screened impurity, Kohn effect, Friedel Oscillations and sum rule, Dielectric constant of semiconductor, Plasma oscillations

Unit IV **10 hrs**

Electronic and Lattice defects: Lattice defects, Frenkel and Schottky defects. Line Defects, edge and screw dislocations - Burger's Vector, planner (stacking) faults-twin planes and grain boundaries Color centers-mechanism of coloration of a solid, F-center, Other color centers.

Excitons: Loosely bound, tightly bound, Excitonic waves, electron-hole droplets.

Hall effect: Elementary ideas on Quantum Hall Effect, Magnetoresistance, Elementary ideas on Giant magneto-resistance and Colossal magneto resistance.

References

Text Books:

1. Principles of the Theory of Solids - J.M. Ziman (2013), Cambridge University Press, 2nd Edition.
2. Introduction to Solid State Physics- C. Kittel (2004), Wiley 8th Edition.
3. Advanced Solid State Physics - Philip Phillips (2012), Overseas Press, India Pvt. Ltd, 2nd Edition.

Reference Books:

1. Electronic Devices and Circuits - Millman, Halkias and Jit, (1988), Tata McGraw Hill, 1st Edition.
2. Solid State physics -A. Omar, (2014), Pearson, 1st Edition.
3. Principles of condensed matter physics- P.M. Chaikin and T.C. Lubensky, (2000), Cambridge University Press, 3rd Edition.
4. Introduction to Modern Solid State Physics - Yuri M. Galperin (2014), CreateSpace Independent Publishing Platform, 2nd Edition.
5.Solid State Physics - N. W Aschroff & N D Mermin (1976), Hercourt College Publishers, 1st Edition.
6. Introduction to Solids - L.V. Azaroff (1993), Mc-Graw Hill Publisher, 1st Edition.

PHY-304: Physics of Metamaterials

Unit I **8 hrs**

Metamaterials and Homogenization: Introduction to Metamaterial, Optical Properties of Dielectric and Metallic Materials, Metal-Dielectric Composites and Mixing Rules, Maxwell–Garnett and Bruggeman theory of homogenization.

Unit II **12 hrs**

Metamaterial with Negative Material parameters: Metals and plasmons at optical frequencies, Wire mesh structures as low frequency plasmas, photonic metallic wire materials, Metamaterials with negative magnetic permeability, metallic cylinders, Split-ring resonator media, Pendry's split rings, Swiss Roll media for radio frequencies, Negative refractive index at optical frequencies.

Unit III **12 hrs**

Theory of Media with $\varepsilon < 0$ and $\mu < 0$: Origins of negative refraction, Dispersion relation, Anisotropic media with positive constitutive parameters, Anisotropic media with positive constitutive parameters, Left-handed media, Moving media, Modified Snell's law of refraction. Plasmonics of media with negative material parameters.

Unit IV **8hrs**

Perfect lens, Superlens and Invisibility: Near-field information and diffraction limit, Mathematical demonstration of the perfect lens, "Near-perfect" lens with an asymmetric slab, Elementary idea of Superlens and electromagnetic invisibility.

References

Textbook

1. Physics and Applications of Negative Refractive Index Materials– S. Anantha Ramakrishna and Tomasz M. Grzegorczyk, (2008), SPIE , 1st editions.

2. Optical Metamaterials: Fundamentals and Applications- Wenshan Cai and Vladimir Shalaev (2010), Spinger, 1st editions

Reference book

1. Phenomena of Optical Metamaterials- Tatjana Gric and Ortwin Hess, (2019), Elsevier, 1st editions.

2. Waves in Metamaterials-L. Solymar and E. Shamonina, (2009), Oxford, 1st editions.

PHY 305: Electronics

Laboratory (6 hrs per week)

1. Characteristics of Diode and Zener diode.
2. Study of different gates
3. Making AND, OR, NOT Gates using NAND Gates.
4. verification of Boolean Algebra.
5. Verification of Dual nature.
6. Characteristics of FET (Field Effect Transistor).
7. Setting of a transistor amplifier and determination of the amplification factor at various frequencies
8. Frequency response of transister amplifier with the without feedback
9. Characterstics of Harteley oscillator
10. Determination of different parameters of transistor
11. Study of multivibrator - Astable
12. Study of multivibrator - Bistable
13. Study of multivibrator - Monostable
14. VSWR in a microwave transmission line
15. Study of squarewave response of R.C. Network
16. Modulation of detection
17. Lock-in-amplifier
18. Design of operational amplifier circuit
19. Design of a field-effect transistor crystal oscillator
20. Study of digital voltmeter and frequency counter.

PHY-306: Inter-disciplinary Elective Course
(Nano-Science and Nanotechnology)

Unit I **10 hrs**

Background to Nanoscience and nanotechnology: Definition of Nano, Scientific revolution-Atomic Structure and atomic size, emergence and challenges of nanoscience and nanotechnology, large surface to volume ratio for nano materials, influence of nano over micro/macro, size effects and crystals.

Unit II **10 hrs**

Moore's law, Classification of nanomaterials: 0D, 1D, 2D, 3D; Characteristic feature of nanomaterials, Density of states for various classes of nano materials, quantum confinement effect on nanomaterials, 2D- Quantum well, 1D-Quantum wire, OD-Quantum dot, Surface and physical properties of nanomaterials.

Unit III **10 hrs**

Nanomaterials fabrication: Different approach of synthesis, Bottom-up approach (Coprecipitation, Sol-Gel Process, Hydrothermal/Solvothermal Methods, Thin-Film Deposition Mechanism, Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD)), Top-Down approach (Powder metallurgy, Lithography), characterization of nano materials.

Unit IV **10 hrs**

Basic features of CNT and Graphene, Application of Nanomaterial: Ferroelectric materials, coating, molecular electronics and nanoelectronics, biological and environmental, Nano composites.

References

Text Books

1. Nanoparticles: From theory to applications – G. Schmidt (2004), Wiley Weinheim, 1st Edition.

2. An Introduction to Nanomaterials and Nanoscience- A.K. Das, D. Mahua (2017), CBS Publishers. 1st Edition

Reference Books:

1. Foundations for Nanoscience and Nanotechnology – Nils O Peterson (2017), CRC Press, 1st Edition

2. A Textbook of Nanoscience and Nanotechnology – T. Pradeep (2012), Tata McGraw-Hill, 1st Edition

3. Introduction to Nanoscience and Nanotechnology – K. K. Chattopadhyay and A. N. Banerjee (2009) PHI Learning Pvt Ltd, 1st Edition

4. Essentials in Nanoscience and Nanotechnology – N. Kumar and S. Kumbhat (2016), Wiley, 1st Edition

PHY-401: Basic Nuclear Physics

Unit I **10 hrs**

Brief Discussion of Nuclear Properties: Nuclear Radius, Nuclear Mass, and Binding Energy, Angular Momentum, Parity and Symmetry, Magnetic Dipole Moment and Electric Quadruple Moment.

Two Nucleons Bound State Problem: Central and noncentral forces, deuteron and its magnetic moment and quadrupole moment; Force dependent on isospin, exchange force, charge independence and charge symmetry of nuclear force, mirror nuclei.

Unit II **10 hrs**

Nuclear Structure: Form factor and charge distribution of the nucleus, Hofstadter form factor.

Nucleon Scattering Problem: n-p scattering at low energy, scattering cross section and scattering length, effective range theory. Nuclear force: Meson theory of nuclear force, Yukawa interaction.

Unit III **10 hrs**

Nuclear Models: Single particle model of nucleus, Liquid drop model, Bohr-Wheeler theory of fission, nuclear fusion, Shell model, analysis of shell model predictions, magic numbers, spin-orbit coupling, angular moment and parities of nuclear ground states, magnetic moments and Schmidt lines, Collective model of Bohr and Mottelson.

Unit IV **10 hrs**

Nuclear Reactions and nuclear energy: Energetics of nuclear reaction, compound nucleus theory, resonance scattering, Breit-Wigner formula, Alpha decay, Fermi's theory of beta decay, Selection rules for allowed transition, parity violation.

References

Text Books:

1. Nuclear Physics- Dr. S. N. Ghosal, (2016), S. Chand, Revised Enlarged edition.
2. Nuclear Physics - R. R. Roy and B. P. Nigam, (1996), New Age International, 2nd Edition.
3. Nuclear Physics- Satya Prakash , (2015), Pragati Prakashan, 4th Edition.

Reference Books:

1. Atomic and Nuclear physics - Shatendra Sharma, (2008), Pearson India, 1st Edition.
2. Theoretical Nuclear Physics - J. M. Blatt and V. F. Weisskopt, (1979), Wiley, New York, 1st Edition
3. Introductory Nuclear Physics- Samuel S. Wong, (1990), Prentice Hall International Inc., 1st Edition

PHY- 402: Particle Physics

Unit I **10 hrs**

Histrorical introduction to the Elementary Particles, The Standard model of particle physics, Classification of elementary particles and their interactions, fermions and bosons, lepton flavors, quark flavors, electromagnetic, weak and strong processes, Lepton number , Baryon number, color quantum number, Strangeness quantum number.

Unit II **10 hrs**

Two nucleon state vectors, Isospin, Strangeness and Hypercharge, Lepton and Baryon number conservation, Yukawa's theory, Neutrinos, Charge independence of nuclear forces, Isospin, Test for isospin conservation, Associated production of strange particles, Gell-Mann Nishijima scheme, conservation laws in relation to particle reaction particle reactions and decays.

Unit III **10 hrs**

Discrete Symmetry: Parity(P): Parity in quantum mechanics Parity, Parity conservation and nonconservation, Time reversal, Consequences of time reversal invariance, Charge conjugation, G-parity, Statement of CPT theorem and its consequences, Proof of equality of mass and life time for particle and anti particle.

Unit IV **10 hrs**

Relativistic Kinematics:

Lorentz transformations, four vector, Energy and momentum, Collisions, Examples and application.

Unitary symmetry: Unitary Symmetry and the classification of state, Hadrons and SU (3) multiplets, concept of I-Spin ,U-spin ,V-Spin, Su(3) quark model, the Eight fold way, Mesons and Baryons in the octet representation , the baryon Decouplets, Evidence of color, Baryon Meson coupling.

References

Text Books:

1. Introduction to elementary particles: D. Griffiths (2008), Wiley-VCH, 2nd Edition.
2. Elementary particles physics by Stephen Gasiorowicz (1966), Wiley, New York, 1st Edition
3. Introduction to High energy Physics, Donald H Perkins (2000), CAMBRIDGE UNIVERSITY, 4th Edition.

Reference Books:

1. Quarks and leptons by F. Halzen and A.D. Martin (1984), Wiley, 1st Edition.
2. Modern elementary particle physics by G.Kane (2017), Cambridge University, 2nd Edition.

PHY-403: Special paper II
Advanced Condensed Matter Physics

Unit I **10 hrs**

Dielectric Properties: Definitions, local field, Clausius-Mossotti relation, Polarizability (Brief Idea)

Ferroelectricity: Ferroelectric crystals, Classification of ferroelectric crystals, Polarization catastrophe, Soft optical phonons, Landau theory of phase transition - second and first order transition

Multiferroics - Basic ideas, preparations and applications.

Unit II **10 hrs**

Piezoelectricity: Peizoelectirc Materials, Mechanism, and Mathematical description, Types of piezoelectric materials: Crystals, Ceramics, Polymers, Composite materials, Application: Sensor, Actuators, Piezoelectric motors

Nanoscale Systems: Classification of nanostructures, Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Quantum confinement: Quantum mechanical aspect of nanostructures and its consequences.

Unit III **10 hrs**

Synthesis of Nanostructure 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 of Nanostructure Materials: X-Ray Diffraction. Optical Microscopy, Scanning Electron Microscopy. Transmission Electron Microscopy. Atomic Force Microscopy. Scanning Tunneling Microscopy. Band gap measurement by UV-visible spectroscopy.

Unit IV **10 hrs**

Applications of Nanostructure Materials: Photonics and optoelectronics (laser, solar cells, photocatalysis), applications of nanoparticles, quantum dots, nanorods, nanowires and nanostructured thin films.

Nanomaterial Devices: Quantum dots heterostructure lasers, optical switching and optical data storage. Magnetic quantum well ; magnetic dots - magnetic data storage. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS)

References

Text Books:

1. Introduction to solid state physics- C. Kittel (2016), John Wiley & Sons, 8th Edition.
2. Nano Materials (An Introduction to Synthesis, Properties and Applications)- D. Vollath (2013), Wiley-VCH, 2nd Edition.
3. Introduction to Nanoscience and Nano Materials, D. C. Agrawal, (2013), World Scientific, 1st Edition

Reference Books:

1. Introduction to Nano (Basics to Nanoscience and Nanotechnology) – A. Sengupto and C. K. Sarkar, (2015), Springer, 1st Edition.
2. Ferroics and Multiferroics – Edited by H. S. Virk and W. Kleeman, (2012), Trans Tech Publisher, 1st Edition.
3. Multiferroic Materials –Edited by J. Wang, (2017), CRC Press, 1st Edition.

PHY-404: Project/Dissertation

PHY 405: Condensed Matter Physics

Laboratory (6 hrs per week)

1. Study of energy gap of Germanium by four-probe method.
2. Callibration of magnetic field using Hall apparatus.
3. Determination of Hall Voltage and Hall coefficients.
4. Measurement of Hall angle and mobility.
5. Determination of ferroelectric transition point(Curie temperature) of the given sample.
6. Determination of magnetoresistance of bismuth.
7. Study of Laue's spot of mica sheet using X-ray diffraction technique.
8. Study of the dispersion relation for the monoatomic and lattices using the given electrical transmission line.
9. Find the Young's modulus for the given metal using composite piezoelectric oscillator technique.
10. Determination of magnetic susceptibility by Guoy-balance.
11. Velocity of ultrasonic waves in a given medium at different temperatures.
12. Measurement of Lande's g factor of DPPII by ESR at Microwave frequency.
13. Study of thermoluminescence of F-centre in alkali halide crystals.
14. Study of phase transition using feed back amplifier circuit.

References

1. Introduction to solid state physics- C. Kittel, J(2016), John Wiley & Sons, 8th Edition.
2. Solid State physics -A. Omar, (2014), Pearson, 1st edition.
3. Semiconductor device: Physics and Technology: S. M. Sze, (2009), Wiley India Private Limited; 2nd Edition.