Department of Physics (Condensed Matter Physics)

Objective of the programme:

The major objective of the programme is to up bring the students of careers in teaching, research. It also aims to develop through and in-depth knowledge of various core subjects in Physics; Mathematical Physics, classical mechanics, condensed matter physics, quantum mechanics, electrodynamics, statistical physics, electronics, atomic molecular and nuclear physics etc. The M.Sc. physics will inculcate student competencies in physics and its applications in a technology rich, interactive environment through elective and value added skill based courses.

Programme Outcome:

- PG grandaunts demonstrated the desired sense of being experienced with excellent qualities & productive contribution to the society and nation in the field of science and technology.
- PG grandaunts are trained so that they execute leadership in the chosen fields with dedication to novely
- PG grandaunts are able to gather information from different kinds of sources and gain understanding of the subject.

Programme Specific Outcome:

The curriculum developed includes local, national and global needs relevant in creating knowledge on the concepts of physics both in theoretical and experimental physics. The carrier opportunities to the students after completing M.Sc. programme would be to join research institutes and academic institutions.

After completion of course, students will gain knowledge on:

- Fundamentals in core and applied physics
- They will be exposed to concepts of mathematical physics, classical physics, classical physics, quantum physics, statistical physics, electrodynamics, condensed matter physics, atomic molecular & nuclear physics.
- Research orientation in both theory and experimental physics
- Hand on experiments in allied subject.

M.Sc-I, SEM. I, PHYSICS (Condensed Matter Physics)
HCT -1.1: MATHEMATICAL TECHNIQUES
Choice Based Credit System (CBCS)
(w. e. f. June 2016-2017)

COURSE CODE: HCT 1. 1 (60 lectures, 4 credits)

Course Objectives:

The purpose of the course is to introduce students to methods of mathematical physics and to develop required mathematical skills to solve problems in quantum mechanics, electrodynamics and other fields of theoretical physics.

Upon completion of the course, the student should be able to understand basic theory of:

- Operator and Matrix Analysis
- Functions of complex variables
- Elements of distribution theory
- Fourier Series

Learning Outcomes:

Successful students should be able to:

- Apply methods of functions of complex variables for calculations of integrals
- Expand functions in Fourier Series
- Work with vectors
- Work with Operators
- Work with Integral Transforms

Unit I: Calculus of Residues (15)

COMPLEX VARIABLE AND REPRESENTATIONS: Algebraic Operations, Argand Diagram: Vector Representation, Complex Conjugate, Euler's Formula, De Moiver's Theorem, The n^{th} Root or Power of a complex number.

ANALYTICAL FUNCTIONS OF A COMPLEX VARIABLE : The Derivative of f(Z) and Analyticity, Harmonic Functions, Contour Integrals, Cauchy's Integral Theorem, Cauchy's Integral Formula,

Zeros, Isolated Singular points, Evaluation of Residues, Cauchy's Residue theorem.

Unit II: Operator and Matrix Analysis (15)

Vector Space and its dimensionality, Vector Spaces and Matrices, Linear independence; Bases; Dimensionality, linear dependence, Inner product Hilbert space, linear operators.

Matrix operations, properties of matrices, Inverse, Orthogonal and unitary matrices; Independent elements of a matrix Diaglonization; Complete orthogonal sets of functions, special square matrices, Eigen values and eigenvectors; Eigen value problem.

Unit III: Ordinary Differential Equations (14)

First-Order homogeneous and non homogeneous equations with variable coefficients. The superposition principle, Second-order homogeneous equations with constant coefficient. Second-order non homogeneous equations with constant coefficients.

Unit IV: Fourier Series, Integral Transforms and Laplace transform (16)

Fourier Series: Fourier's theorem; Cosine, Sine and complex Fourier series, Applications to saw tooth and square waves and full wave rectifier. FS of arbitrary period; Half wave expansions; Partial sums Fourier integral and transforms; cosine since complex forms, Parsevals relation, Application to Gaussian distribution, box and exponential functions; FT of delta function.

Laplace transforms: Laplace transforms of common functions, First and second shifting theorems; inverse LT by partial fractions; LT of derivative and integral of a function.

Reference Books:

1. Introduction to Mathematical Physics by C. Harpcr, Prcnticc - Hall of India Ltd. N.Delhi 1993, (Chapters 2, 4, 6, 9)

2. Mathematical Physics by A.G. Ghatak, I.C.Goyal and S.J.Chua, McMillan India Ltd. New Delhi 1995 (Chapters 4, 7,9,10)

3. Matrices and Tensors for Physicists,by A W Joshi
4. Advanced Engineering Mathematics, by E Keryszig
5. Mathematical Method for Physicits and Engineers, by K F Reily, M P Hobson and S J Bence

6. Mathematics for Physicists by Mary L B
7. Mathematical Methods for Physics, by G Arfken

M.SC-I, SEME. I, PHYSICS (Condensed Matter Physics)

HCT - 1.2: CONDENSED MATTER PHYSICS

Choice Based Credit System (CBCS)

(w. e. f. June 2016-2017)

COURSE CODE: HCT 1. 2 (60 lectures, 4 credits)

Course objectives: To study some of the basic properties of the condensed phase of matter especially solids. Condensed matter physics (CMP) is the fundamental science of solids and liquids. As the largest branch of physics, it has the greatest impact on our daily lives by providing foundations for technology developments.

Learning outcomes: Students get in detail idea about

Basic structures, packing fraction, Millar indices, Brillion zones, Defect in solids using X-ray diffraction. Energy well, Bloch function, construction of Fermi surfaces, calculation of band gap energy, direct and indirect semiconductors, effective mass, rectifier, Scottky barrier. Different types of polarizations, Dielectric constant, relaxation time, Dielectric loss. Missner's effect, London theory, Properties of superconductor, flux quantization, BCS theory, high Tc superconductors.

Unit I: Crystal Structure (15)

Basic Structures; symmetry properties, packing fractions, directions and position-orientation of planes in crystal, concept of reciprocal lattice, concept of brillouin zones, closed packed structure, and structures of some binary/ternary compounds. Elementary concepts of polycrystalline, nanocrystalline and amorphous materials. Elementary concepts of defects in solids. X-ray scattering from solids including Laue conditions and line intensities.

Unit II : Energy bands and Semiconductors (15)

Energy bands: Electron in periodic potential, Bloch function, solution of wave equation of electron in periodic potential, reduced, periodic and extended zone schemes. Construction of Fermi surfaces in brillouin zones for two - dimensional lattices, Introduction to methods for calculations of energy bands and their features. **Semiconductors:** Direct and indirect band gap semiconductors effective mass, intrinsic carrier concentration, impurity conductivity thermal ionization Revision on p-n junction and rectification, metal- semiconductor contacts, schotky barrier.

Unit III : Dielectric properties of Solids (15)

electronic, ionic, orientational, polarzabilities, static dielectric constant for gases, internal field in solids, dielectric constant of solids, dielectric relaxation in alternating fields, dielectric losses, complex dielectric constant.

Unit IV: Superconductivity (15)

Basic concepts, Meissner effect, heat capacity, energy gap, London equation, coherence length Josephson effect (flux quantization), type I and II superconductors, BCS theory, Introduction to high Tc Superconductors.

Reference Books:

1) Introduction to Solid State Physics 4 th Ed. C.Kittel,

2) Solid State Physics by A.J.Dekker

3) Solid State Physics by N.W.Ashoroff&N.D.Mermin

4) Solid State Physics S.O.Pillai

5) Solid state Physics by R.L.Singhal

M.Sc-I, Sem. I, PHYSICS (Condensed Matter Physics)

HCT - 1.3: ANALOG & DIGITAL ELECTRONICS

Choice Based Credit System (CBCS)

(w. e. f. June 2016-2017)

COURSE CODE: HCT1. 3 (60 lectures, 4 credits)

Course Objectives:

- To understand the fundamentals analog and digital electronics.
- To understand the differential amplifier and its types.
- To understand the building blocks of operational amplifiers 741, characteristics, parameters.
- To understand applications of operational amplifiers as multivibrators, Instrumentation amplifier, comparators, voltage regulator, power supplies.
- To understand the digital devices like flip flops, MUX and DEMUX ,shift registers, counters
- To understand the architecture, instruction set and different modes of addressing of 8085 microprocessor.

Learning Outcomes: After completion of this course, the students should be able…

- To design analog circuits using Op amp 741.
- To design digital circuits using combinational sequential logic.
- To write the simple assembly language programs using microprocessor

Unit I: Operational Amplifiers (15)

Differential amplifier Circuit Configurations, Dual Input Balanced Output Differential amplifier , DC analysis, AC analysis, Inverting and Non Inverting Inputs, Constant Current Bias Circuit.

Block diagram of a typical Op-Amp, Open loop configuration, Inverting and Non-inverting amplifiers, Op-amp with negative feedback, Voltage Series Feedback, Effect of feedback on closed loop gain, Input resistance, Output resistance, Bandwidth and Output offset voltage, Voltage follower.

Practical Op-amp, Input Offset Voltage, Input bias current- input offset current, total output offset voltage, CMRR frequency response.

Unit II: Applications of Op amps (15)

DC and AC amplifier, Summing, Scaling and Averaging Amplifiers, Instrumentation amplifier, Integrator and Differentiator.

Oscillator: Principles , Oscillator types, Frequency stability, Response , Phase Shift oscillator ,Wein Bridge Oscillator, LC Tunable Oscillator , Multivibrators, Monostable and Astable, Comparators, Square Wave and Triangle wave generators.

Voltage regulations: Fixed regulators, Adjustable voltage regulators, Switching regulators.

Unit III: Combinational & Sequential Logic Circuits (15)

Combinational logic:

The transistor as a switch, OR AND NOT gates- NOR And NAND gates Boolean algebra- Demorgans theorems- exclusive OR gate, Decoder/ Demultiplexer Date selector/ multiplexer - Encoder.

Sequential Logic:

Flip- Flops: RS Flip- Flop, JK Flip- Flop, JK master slave Flip-Flops Flip-Flop, D Flip- Flop, Shift registers Synchronous and Asynchronous counters.

Unit IV: Microprocessors (15)

Architecture of 8085, Signals and timing diagram of 8085, Demultiplexing Address and Data bus, Instruction Set, Addressing modes, Assembly Language Programming of 8085 (Sum of an array, Minimum and Maximum of an array, Multiplication & Division of 4 & 8 bit numbers) .

Reference Books:

1) OP Amp amplifiers by RamakantGaikwad

2) Integrated Circuits by K.R.Botkar

3) Modern Digital Electronics by R.P.Jain

4) Digital Principle and Application by Malvino&Leeach

5) Digital Fundamentals by Floyd

6)8085 Microprocessor by Ramesh Gaonkar

M.SC-I, SEME. I, PHYSICS (Condensed Matter Physics)

SCT - 1.1: CLASSICAL MECHANICS

Choice Based Credit System (CBCS)

(w. e. f. June 2016-2017)

COURSE CODE: SCT 1. 1 (60 lectures, 4 credits)

Course Objectives:

i. To focus on understanding of the motion and equation of motion of macroscopic bodies.

ii. To learn to use the functional mathematical notations that's allows precise understanding of fundamental properties of classical mechanics.

iii. To study the demerits and to overcome them for further development in classical mechanics.

Learning Outcomes:

i. Provides the difference between the equation of motion of the one body and many bodies systems as well as the basic formulations such Lagrangian and Hamilton, canonical transformation etc.

ii. Students can understand how to apply these formulations to the systems to obtain their equation of motions.

iii. Further, the problems solved during the course will be helpful for SET/NET.

Unit I : Mechanics of Particles and Rigid Bodies (15)

Mechanics of Particle and system of Particles using vector algebra and vector calculus, Conversion laws, work-energy theorem, open systems (with variable mass), Gyroscopic forces; dissipative systems, Jacobi integral, gauge invariance, integrals of motion; symmetries of space and time with conservation laws; invariance under Galilean transformations.

Unit II: Lagrangian Formulation and Motion Under Central Force (15)

Constrainsts, Generalised co-ordinates, D Alemaberts Principle, Lagranges equations of motion, Central Force, definition and characteristics, Reduction of Two-bod problem into equivalent One-body problem, General analysis of orbits, Keplers laws and equations, Artificial satellites, Rutherford Scattering.

Unit III: Variational Principle (15)

Introduction to Calculus of variation, Variational technique for many independent variables, Eulers Lagrange differential equation, Hamilton's principle, Deduction f Lagrange's equation of motion from Hamilton's principle.

Hamilton, Generalized momentum, Constant of motion, Hamilton's canonicl equations of motion, Deduction of canonical equations from Variations principle.

Applications of Hamilton's equations of motion, Principle of least action, Proof of principles of least action, Problems.

Unit IV: Canonical Transformations and Hamilton's - Jacobi Theory (15)

Canonical Transformations, Condition for Transformation to be Canonical, Illustration of Canonical Transformation, Poisson's Brackets, Properties of Poisson's Brackets, Hamilton's Canonical equations in terms of Poisson's Brackets. Hamilton's - Jacobi Theory, Solution of harmonic oscillator problems by HJ Method, Problems.

Texts and Reference Books:

1. Classical Mechanics, By Gupta, Kumar and Sharma (Pragati Prakashan2000).
2. Introduction to Classical Mechanics, by R.G. Takwale and P S Puranik(Tata McGraw Hill 1999).
3. Classical Mechanics, by H Goldstein (Addison Wesley 1980).
4. Classical Mechanics, by N C Rana and P S Joag(Tata McGraw Hill 1991).
5. Mechanics, by A Sommerfeld (Academic Press 1952)

M.SC-I, SEME. II, PHYSICS (Condensed Matter Physics)

HCT - 2.1: QUANTUM MECHANICS

Choice Based Credit System (CBCS)

(w. e. f. June 2016-2017)

COURSE CODE: HCT 2. 1 (60 lectures, 4 credits)

Course Objectives:

- To study the fundamental postulates of quantum mechanics and to apply them for microscopic bodies.
- To review the relevant concepts in classical physics before corresponding concepts are developed in quantum mechanics.
- To provide an understanding of the power and elegance of quantum mechanics.

Learning Outcomes:

- Provides a qualitative description of the remarkable concepts of quantum mechanics such as de-Broglie theory, Heisenberg uncertainty principle, Schrodinger equation, operators, etc.
- Students can gain the idea of applying these concepts to simple systems such as 1D box, 1D harmonic oscillator, hydrogen like atoms and many electron systems as helium atom etc.
- The complete Born-Oppenheimer approximation and Hartee-Fock theories gives the students some understanding of the molecular orbital as well as the current methods of performing electronic structure calculation.
- The problems solved during the course will be helpful for SET/NET.

Unit I : Introductory Quantum Mechanics (16)

Waves and quanta: Wave and particle nature of radiation, Wave equation, Interpretation and properties of wave function; Heisenberg uncertainty principle. Operators, postulates of quantum mechanics, some important theorems, Eigen functions of the position operator and Dirac delta function.

Unit II: Wave Mechanics of simple systems (16)

One dimensional Box, Normalization and orthogonality, Discussion of the factors influencing colour. One dimensional harmonic oscillator, Normalization and Characteristics of eigen functions of harmonic oscillator, Hydrogen - like atoms, Total wave function of hydrogen- like atom, Prob. Density of 1s atomic orbital, shape of atomic orbital, physical interpretation of hydrogenic orbital, space quantization, electronic spin, Vibration and vibrational spectra of diatomic molecules

Unit III : Many electron atoms (12)

Wave function of many electron systems, Helium atom, Many electron atoms, Hartree and HartreeFockself consistent field methods.

Unit IV: Molecular Orbitals **(16)**

The Born- Oppenheimer approximation, Molecular orbital theory, Hydrogen molecule ion, Hydrogen Molecule - Molecular Orbital -Valance Band methods. [AKC, pp: 151-180]

Text Books:

1. Introductory Quantum Chemisty (3rd Ed^{n}), A. K. Chandra (Tata McGraw Hill).
2. Quantum Chemistry (4th Edition) - Ira N. Levine (Prentice Hall) of India Pvt. Ltd. New Delhi. 1995.
3. A textbook of Quantum Mechanics - P M Mathews, K Venkatesan. (Tata McGraw Hill).

M.Sc-I, SEM. II, PHYSICS (Condensed Matter Physics)
HCT - 2.2: Electrodynamics
Choice Based Credit System (CBCS)
(w. e. f. June 2016-2017)

COURSE CODE: HCT 2.2 (60 lectures, 4 credits)

Course Objectives:
This course develops concepts in electric field and scalar potential, magnetic field and vector potential, Maxwell's equations, electromagnetic boundary conditions, electromagnetic wave equation, waveguides, energy in electromagnetism. Electromagnetic wave propagation in vacuum, conducting and dielectric media, and at interfaces.

Learning outcomes: Students will have achieved the ability to:
1. use Maxwell equations in analysing the electromagnetic field due to time varying charge and current distribution.
2. describe the nature of electromagnetic wave and its propagation through different media and interfaces.
3. explain charged particle dynamics and radiation from localized time varying electromagnetic sources.

Unit I: Multipole expansions and time varying fields (15)

Multipole expansions for a localized charge distribution in free space, linear quadrupole potential and field, static electric and magnetic fields in material media, boundary conditions, Time dependent fields, Faraday's law for stationary and moving media, Maxwell's displacement current, differential and integral forms of Maxwell's equations, Maxwell's equations for moving medium.

Unit II: Energy, force, momentum relations and electromagnetic wave equations (15)

Energy relations in quasi-stationary current systems, Magnetic interaction between two current loops, Energy stored in electric and magnetic fields, Poynting's theorem, General expression for electromagnetic energy, Electromagnetic wave equations, Electromagnetic plane waves in stationary medium, Reflection and refraction of electromagnetic waves at plane boundaries (Oblique incidence), Electromagnetic waves in conducting medium, Skin effect and skin depth.

Unit III: Inhomogeneous wave equations (15)

Inhomogeneous wave equations, Lorentz's and Coulomb's gauges, Gauge transformations, Wave equations in terms of electromagnetic potentials, D'Alembertian operator, Hertz potential and its use in computation of radiation fields.

Unit IV: Radiation emission (15)

Radiation from an oscillating electric dipole, radiation from a half wave antenna, radiation from a group of moving charges, radiation damping, Thomson cross-section.

Text Book:

1. Introduction to Electrodynamics, (3rd Edition) by David J. Griffith Publication: Prentice-Hall of India, New Delhi.

Reference Books:

2. Introduction to Electrodynamics, by A.Z.Capri and P.V.PanatNarosa Publishing House.

3. Classical electricity & Magnetism, by panofsky and Phillips, Addison Wesley.

4. Foundations of Electromagnetic theory, by Reitz & Milford, World student series Edition.

5. Classical Electrodynamics, by J.D.Jackson, 3rd Edition John Wiley.

6. Electromagnetic theory and Electrodynamics, by Satya Prakash, KedarNath and Co.Meerut.

7. Electromagnetics by B.B.Laud, Willey Eastern.

8. Electrodynamics by Kumar Gupta and Singh.

M.SC-I, SEME. II, PHYSICS (Condensed Matter Physics)

SCT - 2.2: STATISTICAL MECHANICS

Choice Based Credit System (CBCS)

(w. e. f. June 2016-2017)

COURSE CODE: SCT 2.2 (60 lectures, 4 credits)

Course objectives: Statistical Mechanics is one of the fundamental mechanics .The aim of statistical mechanics is the evaluation of the laws of classical thermodynamics for macroscopic systems using the properties of its atomic particles. In addition to the classical TD the statistical approach provides information on the nature of statistical errors and variations of thermodynamic parameters.

Learning outcomes: Students get in detail idea about

This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, Gibbs paradox, and phase space, statistical interpretation of thermodynamics, micro canonical, canonical and grant canonical ensembles; the methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and photon gases; selected topics from low temperature physics. Energy fluctuation, Entropy fluctuations, Einstein theory of Brownian motion, Langiviens theory of Brownian motion and fluctuation-dissipation theorem. Phase transition theories, critical indices and their evaluation.

Unit I: Foundations of statistical Mechanics and Classical Statistical Mechanics

Thermodynamics, Laws of thermodynamics, Contact between statistics and thermodynamics, the classical ideal gas, entropy of mixing and Gibbs and paradox. Classical statistical mechanics: Phase space, statistical ensembles, Liouville’s theorem, Micro canonical ensemble-condition for equilibrium, canonical ensemble-partition function, energy fluctuations, Grand canonical ensemble-partition function, density and number fluctuations.

Unit II: Quantum Statistical Mechanics

Phase space and quantum states, density matrix, Liouvilles theorem, ensembles, various statistics in quantum mechanicsMaxwell- Boltzmann, Fermi-Dirac and Bose-Einstein statistics, Ideal Bose gas, Fermi gas, Bose- Einstein condensation.

Unit III: Phase transitions and critical phenomena

Phase transition, condition for phase equilibrium, first order phase transition, Clausius Clayperon equation, second order phase transition, Critical indices, Properties of matter near the critical point. The law of corresponding states.

Unit IV: Fluctuations

Thermodynamic fluctuations, spatial correlations in a fluid, Einstein - Smoluchowski theory of Brownian motion, Langevin theory of Brownian motion, The fluctuation-deposition theorem, The Fokker-Plank equation.

Reference Books:

- Introduction to Statistical Mechanics by B.B.Laud
- Statistical Mechanics by S.K.Sinha
- Statistical Mechanics by I.D. Landau & F.M.Lifshitz

M.SC-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)
HCT - 3.1: SEMICONDUCTOR DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: HCT 3.1 (60 lectures, 4 credits)

Course Objectives:

- To understand basic knowledge and description to the field of semiconductor theory, operation, design of devices and their Applications.
- To implement mini projects based on concept of electronics circuit concepts.
- To understand the details the various bias circuits of FET, MOSFET, BJT, CCD, SCR, LED, LASER etc.

Learning Outcomes:

After the completion of this course students should be able to:

- Students will come to know the fundamentals of the operation of the p-n junction in forward and reverse bias including knowledge of drift and diffusion currents, generation and recombination currents, contact potential, reverse bias capacitance and breakdown.
- Students will know basic operation of optical p-n junction devices including, FET, MOSFET, photo-detectors, solar cells, CCD, LEDs and LASER diodes.
- Also, the basic operation of the MOSFET including depletion, inversion, drain current, drain and gate voltages will be understood.

Unit I: MIS Structure and MOS FETs (15)

Schottky diode, MIS structures, basic equations in flat band conditions, MIS capacitances, current flow mechanisms in MS junction and MIS junction, depletion and enhancement type MOS FETS, capacitances in MOS FETs, quantitative analysis of I - V characteristics, thresholds in MOSFETS, charge trapping and flat band voltage, study of CMOS devices.

Unit II: Power Devices (15)

Power diodes, ratings, reverses recovery characteristics, fast recovery diodes, Power transistors, Switching characteristics, construction of SCR, two transistors analogy, I - V characteristics, gate trigger characteristics, turn on and turn - off times, losses, reverse recovery characteristics, SCR ratings, dv/dt and di/dt characteristics, thyrister types, construction and characteristics of DIACs and TRIACs, static induction thyristors, , light activated thyristors, Gate turn off thyristors (GTO), MOS controlled thyristors, programmable Unijunction transistors, Silicon Unidirectional switch (SUS) , IGBT

Unit III: Charge Coupled and Transferred Electron (15)

Charge storage, surface potential under depletion, construction of basic two and three phase of CCD, mechanism of charge transfer, Oxide Charges, charge trapping and transfer efficiency, dark current, buried channel CCD, application of CCD, Transferred Electron Effect, NDR (Negative differential resistivity of voltage and current controlled devices), formation of gun domains, uniform and accumulation layer, operation modes, transistors and quenched diodes, layers and modes of operation, LSA mode of operation, frequency responses and overall device performance of Gunn devices.

Unit IV: Optoelectronic and Advanced Solid State Devices (15)
Light emitting diodes, Performance of LEDs, emission spectra, visible and IR LEDs, semiconductor LASER: p-n junction lasers, heterojunction lasers, materials for semiconductor LASER, threshold current density, effect of temp. Quantum well hetero structures,
Detectors: photoconductors, photocurrent gain and detectivity, photodiodetypes : p-n junction, p-i-n, avalanche characteristics, quantum efficiency, response speed, noise and optical absorption coefficient, efficiency, Solar cells – current voltage characteristics

Reference Book/Text Book:

1. D.A. Roustan: Bipolar Semiconductor Devices.
2. Mauro Zambuto: Semiconductor Devices.
3. D. Nagchoudhari: Semiconductor Devices.
4. Karl Hess: Advanced theory of semiconductors devices.
5. S. M. Sze: Physics of Semiconductor Devices 2nd edition..
6. A Dir - Bar - Lev: Semiconductor and Electronic Devices.
7. M. H. Rashid: Power Electronics.
8. P. C. Sen: Power electronics
9. B. G. Streetman and S. Banergee : Solid state Electronic Devices

M.SC-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)
HCT - 3.2: ATOMIC MOLECULAR AND NUCLEAR PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: HCT 3.2 (60 lectures, 4 credits)

Course Objective

- One of the main objectives of the study of nuclear physics is the understanding of the 'Structure of Nuclei'.
- This includes all aspects of the motion of the nucleons, their paths in space, their momenta, the correlations between them, the energies binding them to each other.
- Understand most basic property of a nucleus is its binding energy.
- This brought about by the specific nuclear forces, counteracted partially by the interaction of different types of neutron and proton scattering.
- To understand nature of nuclear forces

Learning Outcome

- Student will get acquainted with external and internal properties of the atomic nucleus.
- Describe properties of deuteron and neutron proton forces, scattering at different energies.
- Classify and describe types of nuclear reactions as well properties of the resulting components.

Unit I: Atomic structure and Atomic Spectra (10)

Quantum states of an electron, Quantum numbers, spectroscopic terms and selection rules, Pauli's Exclusion principle, Electron spin, Vector atom model, Spin-orbit coupling (LS and JJ coupling), fine structure, Hund's rule etc. Features of one electron and two electron spectra, hyperfine structure, Lande splitting factor (g), Zeeman effect (Normal and Anomalous).

Unit II: Molecular Spectra (10)

Molecular energy states and associated spectra, Types of molecular spectra. Pure rotational; spectra, Diatomic molecule as a rigid rotator, Diatomic molecule as a nonrigid

rotator, its Energy levels, Spectra, Rotation spectra of polyatomic molecules, Linear, Spherical top, Symmetric top, Asymmetric molecules, Vibrating diatomic molecule as a Harmonic and Anharmonic oscillator, Vibration-Rotation Spectra, molecule as vibrating rotator, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Franck-Condon principle.

Unit III: Nuclear Forces and Nuclear Models (16)

Nuclear Forces:

Introduction, Nature of nuclear force, Deuteron (Properties, non-excited and excited states), elements of deuteron problem, Neutron-Proton (n-p) scattering at low energies, Theory of n-p scattering, proton-proton (p-p) scattering at low energies; its theory, Low energy n-n scattering, Charge Independence and charge symmetry of nuclear forces. Similarities between n-n and p-p forces, Non-central forces, its properties, Ground state of deuteron, Magnetic moment, Electric Quadrupole moment, Saturation of Nuclear forces, High energy n-p and p-p scattering.

Nuclear Models:
Constitution of the nucleus; neutron-proton hypothesis, Nature of nuclear force, stable nuclides, Liquid drop model: Semi-empirical mass formula, applications of semiempirical mass formula, Limitations of liquid drop model, Nuclear shell model: Shell model and it's evidence, Limitations of shell theory, Fermi gas model, Extreme Single Particle model, Individual Particle model, Superconductivity model.

Unit IV: Nuclear Reactions (12)
Types of Nuclear Reactions, Conservation laws, Nuclear reaction kinematics, Nuclear Transmutations, Charged particle reaction spectroscopy, Neutron spectroscopy, Nuclear reactions-Q values and kinematics of nuclear cross-sections, Analysis of cross section classical and partial analysis, its energy and angular dependence, Thick Target yield, Requirements for a reaction, Reaction mechanism, General features of crosssection, Inverse reaction, Compound Nucleus – introduction, its reactions and disintegration, Different stages of a Nuclear Reactions, Statistical Theory of Nuclear Reactions, Direct reactions, stripping reactions and shell model, Giant Resonance, Heavy ion reactions, Nuclear shock waves.

References:
1. Introduction to atomic spectra, H. E.White, Mc-Graw hill, International Edition.1962.
2. Molecular structure and spectroscopy 2ndEdi., G. Aruldhas, PHI learning Pvt. Ltd. NewDelhi.
3. Fundamentals of Molecular Spectroscopy, Colin Banwell, McGraw-Hill Publishing Company.
4. Introduction to Atomic and nuclear Physics, Harvey E. White, Van Nostrand Reinhold Company, 1964.
5. Nuclear Physics, D.C. Tayal, Himmalaya Publishing House, 5th Edi. 2008.
6. Introductory nuclear Physics, Kenneth S. Krane, John Wiley and Sons, 1988.
7. Nuclear Physics, Irving Kaplan, Addison-wesley publishing company, Inc,1962.
8. Concepts of Nuclear Physics, Bernard L Cohen, Tata McGraw-Hill publishing company limited, 1971.
9. Nuclear Physics, S. N. Ghoshal, S. Chand and company limited, 1994

M. Sc. – II SEM. III PHYSICS (CONDENSED MATTER PHYSICS)
SCT – 3.1 SOFT CONDENSED MATTER PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: SCT – 3.1 (60 Lectures, 4 Credits)

Course Objectives:

The intentions towards the adoption of the current course in the Condensed Matter Physics program is to introduce the students to various fundamental laws, principles, theorems, approximations, etc. that are present in the science of the condensed matter. The theoretical and experimental aspects of the different properties of the condensed matter, energy bands in solids, soft magnetic materials, ionic conduction mechanism, polymers, composites and soft matters, etc.

Upon completion of the course, the students should be able to understand the various aspects like:

- The different approximations of energy bands in solids,
- Magnetic behaviour and properties of the materials
- Different dielectric properties
- Ionic conduction mechanism in solids
- Various properties of the Polymers, composites and soft matters

Learning outcomes:

Successful students should be able to:

- Apply the different approximations for the determination of the bands in solids
- Understand the properties of different magnetic materials and apply them in various applications where the soft magnetic materials were preferred
- Able to modify the ionic conductivity properties as per the role and conduction mechanism to be utilised in the solid oxide fuel cells
- Familiar with the polymer, composite and soft matter properties to use in PLED, sensors and actuators etc.

Unit-I Energy bands in solids (15)

The basic Hamiltonian in solid, Reduction to one electron problem for determining bands in solids (single particle approximation) - variational principle, Hartree approximation, Hartee-Fock approximation, Density functional approximation- Comparison with conventional wave function approach, Hohenberg-Kohn Theorem; Kohn-Sham Equation; Thomas-Fermi approximation and beyond; Practical DFT in a many body calculation and its reliability.

Unit-II Magnetism (15)

Origin of magnetism, quantum theory of diamagnetism, Landau diamagnetism,

Paramagnetism: Classical and quantum theory, magnetism in rare-earth and iron group atoms, quenching of orbital angular momentum, Van-Vleck Paramagnetism and Pauli Paramagnetism, Ferromagnetism: Cuire Weiss Law, temperature dependence of magnetization, Heisenberg exchange interaction, Ferromagnetic domains, Magnetic domains – exchange energy, magnetostatic energy, wall energy, magnetostrictive energy, Neel and Bloch wall, the Bloch T3/2 law, Neel model of antiferromagnetism and ferrimagnetism. Magnetic anisotropy and magnetostatic interactions- Direct, exchange, indirect exchange and itinerant exchange, (double exchange and RKKY interactions). Spin waves in ferromagnets - magnons, Spin waves in lattices –
ferri and antiferromagnetism, Measurement of magnon spectrum. Magnetic resonance and crystal field theory, Jahn-Teller effect; Hund's rule and rare earth ions in solids. Pinning effects, The Kondo effect, spin glass, solitons, Magneto resistance – spin valves and spin switches, giant magneto resistance (GMR), spintronics.

Unit-III Dielectrics and Ionics: Dielectric properties in solid **–** polarization, electrical conduction, dielectric loss, breakdown of dialectics, nonlinear dielectrics – ferroelectrics, junction capacitor, piezoelectric, electrets , impedance spectroscopy, complex dielectrics, eclectic modulus. Ionic conduction in solid: defect in solid, conduction mechanism, Nernst Einstein equation, cataonic, protonic and anionic conductor, temperature and frequency dependent of conductivity, hopping mechanism, universal power law (Jonscher's Power Law) oxygen ion conductor, solid electrolyte, fuel cell, SOFC.

Unit-IV Polymers, Composites and Soft matters (15)

Polymer and their classification, Molecular weight, degree of polymerization, techniques of polymerization, crystallinity of polymers, applications of polymers. Polymer electrolyte, conducting polymers- concept of solitons, polarons, biolarons, Doping in conducting polymers, Common conducting polymers, Properties and applications of conducting polymers: PLED, sensors actuators.Composite Materials- various types of composites, microcomposites and mactrocomposites, fibre composites, and matrix materials, Different kinds of soft matters, Symmetry and order parameters, Dispersion colloids, liquid crystal, biological membranes, macromolecules- DNA condensation, bilayer, Marcelja's molecular field theory mesosphere.

Recommended Books:

1) The Modern Theory of Solids- F.Sitz
2) Solid State Theory-W. Harrison, TMH,
3) Introduction to Solid State Physics by C. Kittel.
4) Solid State Physics – A.J. Dekker.
5) Introduction to Solid State Physics – H.P. Myers.

6) Solid state Physics – N.N. Ashcroft and N.D. Mermin.

M.Sc-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)
OET - 3.2: ENERGY HARVESTING DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)
COURSE CODE: OET 3.1 (60 lectures, 4 credits)

Course Objectives:

- Understand a systematic approach to analyzing energy harvesting problems. Study the techniques to design of energy harvesting devices.
- To study the construction working and characterizations of various energy harvesting devices including Solar cells, Super capacitors, Fuel Cells and piezoelectric devices.
- Specify capabilities and limitations of energy harvesting for a given energy device and a target applications.

Learning Outcomes:

- By the end of this course, students will be able to:
- The deposition of thin films via various deposition methods, preparation of nanomaterial's, measurement of different performance parameters of the energy harvesting devices will be understood.
- Students will understand the operation of various solar cells including multijunction, quantum dots, dye sensitized, and organic solar cells, supercapacitors, fuel cells etc, the parameters affecting the behaviour of various devices.

All these studies will be useful for the project and their research

Unit -1: Solar Cells (15)
Photovoltaic effect, Solar cell characterization, Types of Solar cells, Solid state solar cells Silicon solar cell, CdTe based solar cells, CdS/Cu_2S solar cells, $CuInSe_2$ based solar cells, Metal-semiconductor solar cells, photoelectrochemical and photo electrolysis cells, Solar cells based on thin film heterojunctions, Ultra thin absorber solar cells, Nanostructured solar cells, Dye sensitised solar cells: basic concepts, working and materials. Organic Solar cells: basic concepts, working and materials.
Unit -2: Super Capacitors (15)
Comparison of battery and super capacitors, Super capacitor characterization, Types of super capacitors, double layer and pseudo capacitance, hybrid super capacitors, Recent status of carbon, RuO_2 and polyaniline based super capacitors, different methods for preparation of cathodic and anodic electrode materials, Fabrication of super capacitors with examples, Applications of supercapacitors
Unit -3: Fuel Cells (15)
Comparison between fuel cells and batteries, fuel cell characterizations, Types of fuel cells: Metal oxide, proton exchange membrane, Phosphoric acid, Solid oxide fuel cells, working of fuel cells, Materials for fuel cells, applications of fuel cells
Unit -4: Piezoelectrics (15)
Piezoelectric Energy Harvesting: Energy harvesting basis, case study

Piezoelectric Materials: Piezoelectric polycrystalline ceramics,Piezoelectric Single Crystal Materials, Piezoelectric and Electrostrictive Polymers, Piezoelectric Thin Films.

Piezoelectric transducers, Mechanical energy harvester using Laser Micromachining, Mechanical energy harvester using PlezoelectricFibers, Piezoelectric Microcantilevers, Energy harvesting circuits, Multimadal energy harvesting, Mangetoelectric composites,

Introduction to Piezoelectric bulk Power generators, Piezoelectric Micro Power Generators, Conversion efficiency, Power storage circuits

Reference Books

1. Semiconductor Sensors, S M Sze, A Wiley- Interscience Publication, John Wiley and Sons, NY1994

2. Electrochemical Supercapacitors, B E Conway, Kluwer Academic/ Plenum publishers, NY 1999.

3. C. N. R. Rao and Claudy Rayan Serrao, J. Mater. Chem., 2007, 17, 4931–4938

4. Solar Cells by Martin Green.

5. Photoelectrochemical Solar Cells by S. Chandra, Gordon &Breach Science Publisher, UK

6. Energy Harvesting Technologies, ShashankPriya, Daniel J. Inman Springer

M.SC-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)
SCT - 4.1: MICROELECTRONICS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-21)

COURSE CODE: SCT 4.1 (60 lectures, 4 credits)

Course Objective

- Outline the properties of silicon materials and its processing
- To understand epitaxial growth processes
- To provide knowledge of the manipulation of the properties of materials with impurity incorporation as well as oxidation of materials.
- A sound knowledge of the fundamental scientific principles involved in the operation, design, and fabrication of integrated circuits.
- A comprehensive understanding of relevant technologies such as integrated circuit process integration and manufacturing.
- This includes photolithography, electron beam lithography and the application of engineering principles to the design and development of current and future semiconductor technologies.

Learning Outcome

- Student will able to explain MOS technology fabrication and device characteristics.
- Student will able to distinguish between different deposition techniques for polysilicon and metals.
- Student will able to design digital logic gates and standard cells at transistor schematic and corresponding layouts level in MOS technology using nMOS,and pMOS.

Student will able to describe device fabrication, assembling and packaging processes.

Unit I: Single crystalline Silicon and crystal structure (15)
(111) and (100) planes, Characteristics of substrates: physical (dimensional), electrical, dielectric, mechanical, Wafer cleaning process and wet chemical etching techniques, Environment for VLSI technology: clean room and safety requirements.
Epitaxial Process: Epitaxial Growth: VPE, LPE and MBE techniques, Mechanism, Chemistry and growth kinetics, evaluation of grown layer.
Unit II: Oxidation and Impurity Incorporation (15)
Oxide growth: dry, wet, rapid thermal oxidation; Deal Grove model of thermal oxidation, plasma oxidation,orientation dependence of oxidation rate, electronic properties of oxide layer, masking characteristics, oxide characteristics.
Impurity Incorporation: Interstitial and substitutional diffusions, diffusivity, laws governing diffusion, constant source and instantaneous source diffusion, Solid Source, liquid source and gas source Boron and Phosphorus diffusion systems, Ion implantation, annealing; Characterization of impurity profiles, buried layers
Unit III: Lithographic and Deposition Techniques (15)
Lithography: Types, Optical lithography –contact, proximity and projection printing, masks, resists: positive and negative, photo - resist pattering, characteristics of a good

photo - resist, Mask generation using co-ordinaton graph and electron beam lithography.

Deposition Techniques for polysilicon and metals

Chemical Vapour deposition techniques: CVD technique for deposition of polysilicon, silicon dioxide and silicon nitride films; Metallisation techniques: Resistive evaporation and sputtering techniques. (D.C. and magnetron), Failure mechanisms in metal interconnects; multilevel metallisation schemes.

Unit IV: Device fabrication, Assembling and Packaging (15)

Masking Sequence and Process flow for pnp and npn devices , p-MOS and n-MOS, Die separation, bonding and attachments, encapsulation, package sealing, flat package, PGA (Printed Grid Array), BGA (Ball Grid Array)

Reference Books:

1. S.M.Sze (Ed), "VLSI Technology", 2nd Edition, McGraw Hill, 1988.

2. Streetman," VLSI Technology". Prentice Hall, 1990

3. C.Y. Chang and S.M. Sze (Ed), "VLSI Technology", McGraw Hill Companies Inc., 1996.

4. S.K.Gandhi, "VLSI fabrication Principles", John Wiley Inc., New York, 1983.

5. Sorab K. Gandhi, "The Theory and Practice of Microelectronics", John Wiley & Sons

6. A.S Grove, "Physics and Technology of semiconductor devices", John Wiley & Sons,

7. Integrated Ckts: Design principles and Fabrication: Warner.

Topics for Tutorials/Seminars: The problem/ exercise / short questions answers/ block diagrams given in the reference books will from the Tutorial Course.

M.Sc-II, SEME. IV, PHYSICS (CONDENDED MATTER PHYSICS)
HCT - 4.2: PHYSICS OF NANO MATERIALS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: HCT 4.2 (60 lectures, 4 credits)

Course Objectives:

- This course is the cornerstone class of the new emphasis in Nanoscience and Nanotechnology within the Materials Science and Engineering major.
- This course also covers the different classes of nanomaterials that have been developed in recent years in light of various technological applications.
- In particular, properties that exhibit size effects (including electronic, magnetic, photonic, and mechanical) at the nanometer length scale will be presented so that nanomaterials becoming increasing relevant to modern technologies can be better understood.

Learning Outcomes:
By the end of this course, students will be able to:

- Student will know the structure-property relationships in nanomaterials as well as the concepts, not applicable at larger length scales that need to be taken into consideration for nanoscience and nanotechnology.
- Students will gain an ability to critically evaluate the promise of a nanotechnology devices.
- Students should apply the fundamental scientific principles that form the basis of behavior of nanomaterials and their electronic, magnetic, optical and mechanical properties.
- These concepts will provide them with skills for engineering practice, particularly those associated with materials selection and engineering analysis.

Unit I: Introduction (15)
Background of Nanoscience and Nanotechnology, Definition of Nanoscience and Nanotechnology, Possible Applications of Nanotechnology, Top-down and Bottom-up approach (Brief).
Band Structure and Density of States at Nanoscale: Introduction, Energy Bands, Density of States at Low - dimensional Structures, Quantum confinement – semiconductors, quantum wells, quantum wires, quantum dots, quantum rings. Manifestation of quantum confinement, quantum confinement effect, dielectric quantum confinement, effective mass approximation, core-shell quantum dots.
Unit II: Properties of Nanomaterials (15)
Optical properties: Absorption, transmission, Beer-Lamberts law (derivation), Photoluminscence, Fluorescence, Phosphorescence,Cathodoluminscence, Electroluminescence, Surface Plasmon resonance (SPR), effect of size of nanoparticles (metal, semiconductor) on absorption and SPR spectra.
Electrical transport: Electrical Conduction in Metals, Classical Theory - The Drude Model Quantum Theory - The Free Electron Model Conduction in Insulators/Ionic Crystals, Electron Transport in Semiconductors, Various Conduction Mechanisms in 3D (Bulk), 2D(Thin Film) and Low – dimensional

Systems, Thermionic Emission Field – enhanced Thermionic Emission (Schottky Effect), Field - assisted Thermionic Emission from Traps (Poole - Frenkel Effect), Hopping Conduction, Polaron Conduction.

Unit III: Growth Techniques and Characterization Tools of Nanomaterials (20)

Growth techniques: Introduction, Top - down vs. Bottom - up Technique, Lithographic Process and its limitations , Nonlithorgraphic Techniques ,Plasma Arc Discharge Sputtering ,Evaporation, Chemical Vapour Deposition ,Pulsed Laser Deposition ,Molecular Beam Epitaxy, Sol - Gel Technique , Electrodeposition , Different chemical routes, Other Processes.

Characterization Tools of Nanomaterials: Scanning Probe Microscopy (SPM): Introduction, Basic Principles of SPM Techniques, The Details of scanning Tunneling Mocroscope (STM), General Concept and Definite Characteristics of AFM, Scanned - Proximity Probe Microscopes Laser Beam Deflection, AFM Cantilevers ,Piezoceramics, Feedback Loop Alternative Imaging Modes. Electron Microscopy: Introduction, Resolution vs. Magnification Scanning Electron Microscope SEM Techniques, Electron Gun Specimen Interactions Environmental SEM (FESEM), Transmission Electron Microscope, High Resolution TEM Contrast Transfer Function. Near-field scanning optical microscopy (SNOM/NSOM), UV-Vis single and dual beam spectrophotometer, photoluminescence spectrometer, X-ray diffractometer. Surface area and Pore size measurements (BET analysis)

Unit IV: Some Special Topics in Nanotechnology (10)

Introduction ,The Era of New Nanostructure of Carbon Buckminsterfullerene, Carbon Nanotubes, Nanodiamond, BN Nanotubes Nanoelectronics ,Single Electron Transistor, Molecular Machine, Nano-biometrics.

Reference Books:

1) **Introduction to Nanoscience and Nanotechnology:** K.K. Chattopadhyay and A.N. Banerjee, PHI Publisher
2) **Nanoscience and Technology:** V. S. Murlidharan, A. Subramanum.
3) **Nanotubes and Nanofibers:**YuryGogotsi
4) **A Handbook of Nanotechnology :** A. G. Brecket
5) **Instrumentations and Nanostructures:** A. S. Bhatia
6) **Nanotechnology: Nanostructures and Nanomaterials** - M. B. Rao
7) **Nanotechnology-Principles and practices** - S. K. Kulkurni (Capital Publication Company)

Reference Books:

1) Handbook ofApplied Solid State Spectroscopy, D. R. Vij, Springer
2) Phtoelectron and Auger Spectroscopy,T.A.Carlson, Plenum Press , 1975
3) Practical Guide to Surface Science and Spectroscopy,Yip-WahChung,Academic Press
4) Fundamental of Molecular Spectroscopy, C.N.Banwell,TataMc-Graw Hill.

M.SC-II, SEME. IV, PHYSICS (CONDENSED MATTER PHYSICS)
HCT - 4.3: PROPERTIES OF SOLIDS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: HCT – 4.3 (60 Lectures, 4 Credits)

Course Objectives:

The major objective of the current course is to make the students well familiar with the properties of the solids. The main focus of the current course is on the optical and dielectric properties, transport properties magnetism concept and materials, superconductivity phenomenon and different theories followed by their applications.

Upon completion of the course, the students should be able to understand the various aspects like:

- Optical behaviour of the solids
- Electronic transport in solids
- Magnetic phenomenon of solids
- Magnetic phase transition
- Superconductivity theories and materials

Course Outcome:

Successful students should be able to:

- Analyse the optical characteristics of the materials
- Analyse the transport behaviour of the materials
- Analyse the magnetic transitions involved in the and their applications
- Apply the superconducting materials in the various applications

Unit - I **Optical and Dielectric properties** **(15)**

Maxwell's equations and the dielectric function, Lorentz oscillator, the Local field and the frequency dependence of the dielectric constant, Polarization catastrophe, Ferroelectrics Absorption and Dispersion, Kraemers' Kronig relations and sum rules, single electron excitations and plasmons in simple metals, Reflectivity and photoemission in metals and semiconductors Interband transitions and introduction to excitons, Infrared spectroscopy.

Unit -II **Transport Properties** **(15)**

Motion of electrons and effective mass, The Boltzmann equation and relaxation time, Electrical conductivity of metals and alloys, Mathiessen's rule, Thermo-electric effects, Wiedmann-Franz Law, Lorentz number, ac conductivity, Galvanomagnetic effects.

Unit -III	**Magnetism and Magnetic materials**	**(15)**

Review: Basic concepts and units, basic types of magnetic order Origin of atomic moments, Heisenberg exchange interaction, Localized and itinerant electron magnetism, Stoner criterion for ferromagnetism, Indirect exchange mechanism: superexchange and RKKY.

Magnetic phase transition: Introduction to Ising Model and results based on Mean field theory, Other types of magnetic order: superparamagnetism, helimagnetism, metamagnetism, spin glasses.

Magnetic phenomena: Hysteresis, Magnetostriction, Magnetoresistance, Magnetocaloric and magneto-optic effect.

Magnetic Materials: Soft and hard magnets, permanent magnets, media for magnetic recording.

Unit -IV	**Superconductivity**	**(15)**

The phenomenon of superconductivity: Perfect conductivity and Meissner effect.

Electrodynamics of superconductivity: London's equations, Thermodynamics of the superconducting phase transition: Free energy, entropy and specific heat jump.

Ginzburg-Landau theory of superconductivity: GL equations, GL parameter and classification into Type I and Type II superconductors, The mixed state of superconductors.

Microscopic theory: The Cooper problem, The BCS Hamiltonian, BCS ground state Josephson effect: dc and ac effects, Quantum interference.

Superconducting materials and applications: Conventional and High Tc superconductors, superconducting magnets and transmission lines, SQUIDs.

Assignments: should be based on numerical problems related to the syllabus.

Main References:	Solid State Physics, H. Ibach and H. Luth, *Springer(Berlin)* 2003 (IL)
2.	Solid State Physics, Neil Ashcroft and David Mermin (AM)
3.	Introduction to Solid State Physics (7th/ 8th ed) Charles Kittel (K)
4.	Principles of Condensed Matter Physics, Chaikin and Lubensky (CL)
Additional References:	
1.	Principles of Condensed Matter Physics, Chaikin and Lubensky (CL)
2.	Intermediate theory of Solids, Alexander Animalu (AA)
3.	Optical Properties of Solids, Frederick Wooten, Ac Press (New York) 1972 (FW)
4.	Electrons and Phonons, J M Ziman, Electron transport in metals, J.L. Olsen

5.	Physics of Magnetism and Magnetic Materials, K.H.J. Buschow and F.R. de Boer Introduction to Magnetism and Magnetic Materials
6.	Magnetism and Magnetic Materials, B. D. Cullity
7	Solid State Magnetism, J. Crangle
8	Magnetism in Solids, D. H. Martin

M.Sc-II, SEM. IV, PHYSICS (CONDENSED MATTER PHYSICS)
SCT - 4.1: EXPERIMENTAL TECHNIQUES IN PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: SCT 4.1 (60 lectures, 4 credits)

Course Objectives:

- The prime purpose of the course is to provide to an intensive experience on advanced experimental techniques.
- The further objective is to provide in-depth knowledge of analyses/ characterizations of the materials in view of condensed matter physics.
- To introduce the working principle and instrumental science of electronic/ optical/ analytical Instruments.

Learning Outcomes:

- Students will get the knowledge of various experimental/analytical instruments and their techniques.
- Student will get the knowledge of:
  - ➢ Electronic Instrumentations
  - ➢ Laser and Optoelectronic Instrumentations
  - ➢ Different characterization techniques (structural, morphological, chemical etc.)

Unit-I Electronic instrumentations (15)

Measurement system- mechanical and electrical, Transducers and its types, sensors, differential output transducer, LVDT, Hygrometers, Measurement of thermal Conductivity (gas analyzer), Physiological transducers Bio-potential electrodes. Digital and analog measuring instruments – voltmeter, ammeter, oscilloscope, power meter, LCR meter, instrumentation amplifier, filtering and noise reduction in instruments, shielding and grounding, lock-in detector, box-car integrator, interfacing sensors and data acquisition, Integrated circuits technology – fabrications, Power supplies- primary and secondary cell, regulated power supply, SMPS, UPS, Step down switching regulator, Inverters- voltage driven inversion, current driven inversion.

Unit-II Lasers and Optoelectronic instrumentation (15)

Lasers: - Temporal and special coherence, Einstein coefficients, The threshold condition, two, three and four level laser systems, Modes of a rectangular cavity

and open planar resonator, Quality factor, mode selection, The Ruby laser, The Helium-Neon laser, the carbon dioxide (CO_2)laser. Optoelectronic devices : Photoconductivity, LDR, photodiode, phototransistor, solar cell, metal semiconductor detector, LCD, CCD , LED, Laser diode, PIN photodiode, Avalanche photodiode, Heterojunction photodiode, Organic light emitting diodes,. Optical fiber- ray propagation Step –index and graded-index fibers, dispersion and attenuation in fiber optics, Dispersion compensation mechanism, Erbium-doped fiber amplifiers, Optoelectronic modulators.

Unit III (a). X-ray analysis (15)

Origin of X-rays, X-ray generators. Scattering of X-ray, atomic scattering factor,

Diffraction of X-ray, various X-ray diffraction methods, X-ray powder diffraction method -indexing of powder lines, Laue's method, rotational/oscillation method, X-ray diffractormeter, determination of crystal structure and lattice parameter, small angle x-ray diffraction and its applications. XPS, XRF and its applications.

(b).Low pressure and Low temperature: Production of low pressure -Rotary, oil diffusion, turbo molecular, getter and cryo pumps; gauges – Macleod thermoelectric (thermocouple, thermistor and pirani), penning, hot cathode partial pressure measurement; leak detection; gas flow through pipes and apertures; effective pump speed; vacuum components. Production of Low temperature**:** Gas liquifiers; Cryo -fluid baths; liquid He cryostat design; closed cycle He refrigerator; low temperature measurement.

Unit-I Analytical Instrument (15)

Electron Microscopy (SEM, TEM, HRTEM), Scanning probe microscopy (AFM, MFM, STM), UV-Vis, spectroscopy and its applications. FT-IR spectroscopy, Luminescence spectroscopy techniques- Fluorescence spectroscopy, Raman spectroscopy, Thermal analysis using DTA, TGA, DSC; Electronic transport analysis using Current vs Voltage characteristics – two probe and four probe techniques - various types of contacts, Dielectric and impedance spectroscopy, spectrum analyzer,

fluorescence and Raman spectrometer, Interferometers for different analytical study.

Recommended Books:

1) Electronic Instrumentation - Kalsi H S
2) X-Ray Crystallography – B.E. Warren.
3) Materials Characterization: Introduction to Microscopic and Spectroscopic Methods,
4) Materials Characterization Techniques Sam Zhang, Lin Li, Ashok Kumar