Punyashlok Ahilyadevi Holkar Solapur University, Solapur

NAAC Accredited-2015
'B' Grade (CGPA 2.62)

Name of the Faculty: Science & Technology

Choice Based Credit System (CBCS)

Syllabus: Condensed Matter Physics

Name of the Course: M. Sc. II (Sem.– III & IV)

(Syllabus to be implemented with effect from June 2021)

PUNYASHLOK AHILYADEVI HOLKAR SOLAPUR UNIVERSITY, SOLAPUR
M.Sc – Physics (Condensed Matter Physics)
Choice Based Credit System
w.e.f June 2021-2022

Semester	Code	Title of the Paper	Semester exam				L	T P	Credits
Third		**Hard core**							
CMP	**HCT3.1**	Semiconductor Physics	80	20	100	4		-	4
	HCT3.2	Atomic and Molecular Physics	80	20	100	4		-	4
		Soft core (Any one)							
	SCT3.1	Soft Condensed Matter Physics	80	20	100	4		-	4
	SCT3.2	Thin Film Physics & Technology	80	20	100	4		-	
		Open elective (Any one)							
	OET3.1	Energy Harvesting Devices	80	20	100	4		-	4
	OET3.2	Medical Physics	80	20	100	4		-	
		Tutorial			25		1	-	1
		Practical							
	HCP 3.1	Practical HCP 3.1	40	10	50	-	-	2	2
	HCP3.2	Practical HCP 3.2	40	10	50	-	-	2	2
	SCP 3.1	Practical SCP 3.1	40	10	50	-	-	2	2
		Open elective (Any one)							
	OEP3.1	Practical OEP3.1	40	10	50	-	-	2	2
	OEP3.2	Practical OEP3.2	40	10	50	-	-	2	
		Total for third semester	**480**	**120**	**625**				**25**
		Skill Enhancement Course							
	SEC	Materials Characterization Tools	--	--	--	--	--	--	4*
Four		**Hard core**							
CMP	**HCT4.1**	Semiconductor Devices	80	20	100	4		-	4
	HCT4.2	Nuclear and Particle Physics	80	20	100	4		-	4
	HCT 4.3	Physics of Nano Materials	80	20	100	4		-	4
		Soft core (Any one)						-	4
	SCT4.1	Properties of Solids	80	20	100	4		-	
	SCT4.2	Experimental Techniques in Physics	80	20	100	4		-	
		Tutorial			25		1	-	1
	MP4.3	Major Project/ Internship*	160	40	200	-	-	-	8
		Total for four semester	**480**	**120**	**625**				**25**
		Total							**100**

L = Lecture T = Tutorials P = Practical   IA=Internal Assessment
4 Credits of Theory = 4 Hours of teaching per week
2 Credits of Practical = 4 hours per week
HCT = Hard core theory
SCT = Soft core theory
HCP = Hard core practical
SCP = Soft core practical
OET = Open elective theory
OEP = Open elective practical
MP = Major project (In-house/ Industry sponsored)
***SEC: Skill Enhancement Course -04 Credits**
***Internship: Internship at any Condensed Matter Physics /National/ International Research Laboratory / Company**
***MOOC/ SWYAM Course: Student can opt from MOOC/ SWYAM platform as an Add on Course**

***MP = Major project Assessment**

- **160 Marks-University Examinations (Viva Dissertation, Project Progress, evaluation)**
- **40 Marks- Internal Performance Evaluation (15 Marks: Presentations, 15 Marks :Performance & 10 Marks: Attendance)**

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

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

- To understand fundamentals of semiconductor physics.
- To understand basic knowledge of energy bands and charge carriers in semiconductors.
- To understand role of excess carriers in semiconductors.
- To understand dynamics of charge carriers and lattice and semiconductor interfaces.
- To understand semiconductor crystal growth process.

Learning outcomes:
Students should be able to

- Students will come to know fundamentals of semiconductors, bonding forces, energy bonds, carrier concentrations, electrical conductivity and mobility.
- Students will know optical absorption phenomenon, recombination of electrons and holes, diffusion process of carriers.
- Students will know behaviour of periodic potential, group velocity of electrons, inverse effective mass, force equation, dynamics of electronics and holes, Schottky barriers surfaces and interfaces.

Unit 1. Energy bands and charge carriers in semiconductors (15)

Bonding forces and energy bands, direct and indirect band gap semiconductors, variation of energy bands with alloy composition, effective mass, electrons and holes in quantum wells, the Fermi level, electron and hole concentrations at equilibrium, temperature dependence of carrier concentrations, electrical conductivity and mobility, high field effects.

Unit 2. Excess carriers in semiconductors (15)

Optical absorption, direct recombination of electrons and holes, indirect recombination, trapping, steady state carrier generation, quasi Fermi levels, diffusion process of carriers, diffusion and drift of carriers, diffusion and recombination: the continuity equation, steady state carrier injection, diffusion length, the Haynes-Shockley experiment.

Unit 3. Dynamics of charge carriers and lattice, and Semiconductor Interfaces

(15)

Electrons in a periodic potential, group velocity of electrons, inverse effective mass tensor, force equation, dynamics of electrons and holes, effective mass theory of impurities, the vibrational specific heat, thermal expansion, thermal conductivity. Schottky barriers, rectifying contacts, ohmic contacts, surface and interface states and their effects on barrier height, acceptor and donor surface states, Fermi level pinning

Unit 4. Semiconductor crystal growth process (15)

Nucleation and growth theory, atomic bonding, formation energy of clusters, supersaturation, supercooling and volume energy, stability of small nuclei, the formation energies of liquid nuclei and crystalline nuclei, nucleation rates, the growth of crystal surfaces, growth of bulk semiconductors by zone melting and zone refining, Czochralski and liquid encapsulation techniques, growth of epitaxial layers by LPE, VPE and MBE techniques**.**

Reference Books

1. Physics of Semiconductor Devices by Dilip K. Roy, Univ. Press (India) Pvt. Ltd., 1992.
2. Physics of Semiconductor Devices by S.M. Sze
3. Solid state electronic devices by B. G. Streetman.
4. Semiconductors by R. A. Smith, Cambridge Univ. Press.
5. Solid state electronics by Wang, Mc. Graw Hill.
6. Crystal Growth by B. R. Pamplin (ed.)
7. Growth of Single Crystal by R. A. Laudise.
8. Growth of crystals from solutions by J. C. Brices
9. Solid State and Semiconductor Physics by M.C. Kelvey.
10. Modern techniques in metallography – D.G. Brandon, Butterworths (1966)

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

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

Course Objective

- To describe the atomic spectra of one and two valance electron atoms.
- To explain the change in behaviour of atoms in external applied electric and magnetic field.
- To explain rotational, vibrational, electronic and Raman spectra of molecules.
- To describe electron spin and nuclear magnetic resonance spectroscopy and their
- applications.

Learning Outcome

Students are able to

- Master both experimental and theoretical working methods in atomic and molecular physics for making correct evaluation and judgments.
- Developing analytical, laboratory and computing skills through problem solving, laboratory & computer based exercises which involve the applications of atomic and molecular physics.
- Carry out experimental and theoretical studies on atomic and molecular physics with focus on structure & dynamics of atoms and molecules.
- Account for theoretical models, terminology & working methods used in atomic and molecular physics.
- To successfully apply the theoretical techniques presented in course to practical problems.

Unit-I Atomic structure and Atomic Spectra (20)

Revision of hydrogen atom (wave functions, orbital and spin angular momentum, Quantum states of an electron in an atom, magnetic dipole moment, Electron spin, spin-orbit interaction, fine structure, spectroscopic terms). Origin of spectral lines, selection rules, Stern Gerlach experiment, some features of one-electron spectra. Relativistic corrections for energy levels of hydrogen atom, Multi-electron atoms: Exchange symmetry of wave functions, Pauli`s exclusion principle, electron configuration, Hund's rule etc. L-S coupling, J-J coupling.

Unit-II Atoms in an electromagnetic field (10)

Spectral lines, Selection rules, Some features of two-electron spectra, fine structure spectra, hyperfine structure spectra, X-ray spectra, Stark effect, Zeeman effect and Paschen-Back effect

Unit-III Molecular Structure and Molecular Spectra (20)

Covalent, ionic and van der Waal bonding, Valence bond and molecular orbital approach for molecular bonding and electronic structure of homonuclear diatomic molecules, pairing and valency, heteronuclear diatomic molecules, hybridization, ionic bonding, electro-negativity, electron affinity. Electronic structure of polyatomic molecules: hybrid orbitals, bonding in hydrocarbons.

Rotational levels in diatomic and polyatomic molecules: Born – Oppenheimer approximation, Rigid and non-rigid rotation, selection rules. Vibrational levels in diatomic and polyatomic molecules: Morse oscillator model for vibrational levels. Vibration spectrum of diatomic molecule, vibration-rotation spectra (P, Q, R branches). Electronic spectra of diatomic molecules: Frank-Condon principle.

Unit-IV Atomic and molecular spectroscopic methods (10)

Atomic and Molecular Polarizability, Molecular vibrations and group theoretical selection rules for infra-red and Raman transitions, Infra-red spectroscopy and Raman spectroscopy for vibrational level determination. Microwave spectroscopy and Rotational Raman spectroscopy for rotational level determination, Electronic spectroscopy for molecular structure determination. Nuclear Magnetic resonance and Electron spin resonance

Text Book: (Unit-I &II)

1. Quantum Physics, Robert Eisberg and Robert Resnick, (John Wiley and Sons).

Reference Books: (Unit-I &II)

1. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
2. Perspectives of Modern Physics, Arthur Beiser, (McGraw Hill International Ed.)
3. Physics of Atoms and Molecules, B.H. Bransden and C.J. Joachain (Pearson).
4. The Physics of Atoms and Quanta Introduction to Experiments and Theory Authors: Haken, Hermann,
   Wolf, Hans Christoph

Text Book: **(Unit-III & IV)**

1. Molecular Spectra and Molecular Structure, Gerhard Herzberg, (D. Van Nostrand Company, Inc.)

Reference Books: (Unit-III & IV)

1. Molecular Spectra and Molecular Spectroscopy (Vol. 1), G. Herzberg
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGrawHill Publishing Company Limited)
3. Molecular Spectroscopy – J.M. Brown, Oxford University Press (1998).
4. Modern Spectroscopy, J.M. Hollas (John Wiley).
5. Molecular Quantum Mechanics, P.W. Atkins and R. Freidman (Oxford University Press)
6. Quantum Chemistry, I. N. Levine (Wiley).

M.Sc-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)

SCT - 3.1: SOFT CONDENSED MATTER PHYSICS

Choice Based Credit System (CBCS)

(w. e. f. June 2021-2022)

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 - 1: Introduction to Soft Matter (20)

Review of concepts of thermal equilibrium, Thermodynamics of solutions, phase separation. Mean Field Theories of phase-transition, Vaan der Waals equation, Critical phenomenon in fluids and Soft Matter systems, Landau Theory of phase transition.

Unit -2: Liquid crystals. **(13)**

Basic definitions and terminology. Liquid crystal phases and phase transitions. Orientational order and order parameters. Mean-field theories of liquid-crystalline order.

Unit - 3: Supramolecular self-assembly in soft-condensed matter (12)

Supramolecular self-assembly in soft-condensed matter, Amphiphilic molecules in solutions –aggregation and phase separation. Micellization process. Bilayers, vesicles and membranes.

Unit -4: Non-equilibrium systems (15)

(i) Driven lattice gas models (iii) Percolation phenomenon.

Books:

1. Soft-Condensed Matter by R. A. L. Jones, (Oxford University Press).

2. Structured Fluids by T. Witten and P. Pincus, (Oxford University Press).

4. Soft Matter Physics: An Introduction by M. Kleman and O. D. Lavrentovich, (Springer).

5. The Colloidal Domain by F. Evans and H. Wennerstrom, (Wiley – VCH).

6. Soft Matter Physics by Masao Doi, (Oxford University Press).

9. An Introduction to Polymer Physics by D. I. Bower, (Cambridge University Press).

10. The Physics of Polymers by G. Strobl, (Springer).

11. Scaling Concepts in Polymer Physics by P. de Gennes, (Cornell University Physics).

12. Liquid Crystals by S. Chandrasekhar, (Cambridge University Press).

13. Intermolecular and surface forces (3rd Ed), Jacob N. Israelachvili (Elsevier).

PHY-P328 Experiments based on PHY-T328 (2.5 Credits):

Computational Experiments/Exercises/Mini Projects.

M.Sc-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)
SCT – 3.2: THIN FILM PHYSICS AND TECHNOLOGY
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: SCT – 3.2 (60 Lectures, 4 Credits)

Course Objectives:
The objectives of this course are to:
- Acquit the students with the basic knowledge of the chemical and physical methods and the fabrication of thin films materials
- Provide students with opportunities to develop basic skills with respect to safety precautions in the vacuum system workshop

Learning outcomes:
Upon successful completion of this course, the student will be able to:

- Identify, explain and handle different types of methods of thin film deposition
- Identify different parameters of deposition techniques
- Study physics of surfaces, interfaces and thin films
- Know how to fabricate thin films materials using different fabrication techniques;
- Characterize the properties of the fabricated devices
- Identify various forms of heat treatment of thin films and
- Discuss the industrial applications of thin films.

Unit - I Chemical Methods of Thin films synthesis (15)

Chemical vapor deposition: Common CVD reactions, Methods of film preparation, laser CVD, Photochemical CVD, Plasma enhanced CVD. Chemical bath deposition: ionic and solubility products, preparation of binary semiconductors, Electrodeposition: Deposition mechanism and preparation of compound thin film Spray pyrolysis: Deposition mechanism and preparation of compound thin Films.Ion-assisted deposition (IAD), Laser ablation, Longmuir Blochet film, Sol-gel film deposition.

Unit -II Physical Methods of Thin Film Synthesis (15)

Introduction to Thin Films, Thermal evaporation methods: Resistive heating, Flash evaporation, Laser evaporation, Electron bombardment heating, Arc evaporation, Sputtering process: Glow discharge, DC sputtering, Radio frequency sputtering, Magnetron sputtering, Ion beam sputtering.

(15)

Unit -III Physics of Surfaces, Interfaces and Thin films

Mechanism of thin film formation: Formation stages of thin films, Condensation and nucleation, Thermodynamic theory of nucleation, Growth and coalescence of islands, Influence of various factors on final structure of thin films, Crystallographic structure of thin films. Properties of thin films: Conductivity of metal films, Electrical properties of semiconductor thin films, Transport in dielectric thin films, Dielectric properties of thin films, Optical properties of thin films. Thin films of high temperature superconductors, Diamond like carbon thin films

Unit -IV Thin films for Devices & other Applications (15)

Dielectric deposition- silicon dioxide, silicon nitride, silicon oxynitride, polysilicon deposition, metallization, electromigration, silicides. Thin film transistors, thin film multilayers, optical filters, mirrors, sensors and detectors.

References:

1. LudmilaEckertova, Physics of thin films, 2^{nd} Revised edition, Plenum Press, New York, 1986 (Reprinted 1990),
2. K.L. Chopra, Thin film phenomena, Mc-Graw Hill, New York, 1969.
3. L. C. Feldman and J.W. Mayer, Fundamentals of surface and Thin Films Analysis, North Holland, Amsterdam, 1986.
4. S.M. Sze, Semiconductor Devices-Physics and Technology, John wiley,1985.

Additional References:

1. R.W. Berry, P.M.Hall and M.T. Harris, Thin film technology, Van Nostrand, New Jersey, 1970, K.L.Chopra and LK.Malhotra (ed),
2. Thin Film Technology and Applications, T.M.H. Publishing Co., New Delhi (1984).

M.Sc-II, SEME. III, PHYSICS (CONDENSED MATTER PHYSICS)
OET - 3.1: MEDICAL PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

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

Course Objectives:

To get

- Knowledge of the normal structure and function of the body and its major organ systems with emphasis on content applicable to clinical diagnostic imaging and/or radiation oncology.
- Knowledge of radiation and radioactivity, its properties, units of measure, dosimetry measurement concepts and methods.
- Knowledge of the radiation safety practices and procedures including the determination of radiation shielding requirements.
- Knowledge of the biological effects of radiation and its application for radiation safety and for radiation treatment.
- Knowledge of the operation and principles used in the systems and procedures associated with the clinical track.

Learning outcomes:

- The ability to perform the clinical support procedures required of a medical physicist.
- The ability to design and complete independent research projects.
- The ability to retrieve, manage, and utilize information for solving problems relevant to completion of research projects, or for the implementation of clinical operations or procedures.

Unit-I: Forces acting on body and Physics of the skeleton (15)

Statics, Frictional forces, Dynamics, Conservation of Energy in the body, Heat losses from body, Pressure in the body. Physical properties of bone, Mechanics of joints,

Unit-II: Electricity within the body (15)

Nervous system and neuron, Electric properties of Nerve, Electrical potential of nerve, Nernst Equation, Bio potentials EMG, ECG, EEG, EOG, ERG, Magnetic signals from heart and Brain

Unit-III: Physics of hearing (15)

Basic definition of Audibility, Physics of ear, Human Audibility Curve, Sensitivity of ear, Testing of hearing. Deafness and hearing aids, Sound in medicine, Sound pollution, Effects of sound pollution on living body, Methods to minimize sound pollution.

Unit-IV: Physics of vision (15)

Optics of eye, Diffraction effects of eye, Refractive effect in eye and its correction, Contact Lenses, Color vision and chromatic aberration, Instruments used in Ophthalmology.

Reference Books:

1. Medical Physics by John R. Cameron, J. G. Skofronick, John Wiley and Sons,Inter.Publ.
2 .Essential of Biophysics by Narayanan, New age Publication.
3. Radiation Biophysics by Edward Alphan, prentice Hall Advance Referes.
4. T.B. of Biophysics by R.N. Roy , Central Publication.
5. Medical Informatics by Smita Mishra and K. C. Mishra, ICFAI university.
6. Fundamental of Bioinformatics by Harisha. S.
7. Biomedical Engineering by S.N. Sarbadhikari, University press.
8. Principles of medical electronics &Biomedicalinstrumentation by c. Raja Rao, S. K. Guha , University press.
9. Electronics in medicine & Biomedical instrumentation by NandiniJog ,
10. Websites of the related topics

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 3.2 (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. IV, PHYSICS (CONDENSED MATTER PHYSICS)
HCT -4.1: SEMICONDUCTOR DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

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

Course Objectives:

- To understand basic knowledge and description to the field of semiconductor theory, operation, designof 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 activatedthyristors, 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 gunn 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 2^{nd} 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. IV, PHYSICS (CONDENSED MATTER PHYSICS)
HCT - 4.2: NUCLEAR AND PARTICLE PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: HCT 4.2 (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 1. Properties of Nucleus & Nuclear Forces (15)

Shape and Size, mass, spin and parity, masses and relative abundances, binding energy & nuclear stability, nuclear compositions, quantum properties of nucleon states, Radioactivity; Laws of radioactivity, radioactive dating, radioactive series, theory of alpha, beta & gamma decays and their properties. Nuclear forces: Properties of nuclear forces, two nucleon systems deuteron with potentials, n-p and p-p/n-n interactions at different energies, Yukawa's hypothesis, Meson theory of nuclear force.

Unit 2. Nuclear models: (15)

Fermi gas model, liquid drop model and Bethe-Weizsacker formula, their applications;shell model and shell structure , extreme single particle shell model with potentials – square well, harmonic oscillator, spin orbit interaction, Magic numbers, Predictions of the shell model; collective nuclear model;
superconductivity model (ideas only).

Unit 3. Nuclear reactions: (15)

Types of nuclear reactions, conservation laws, Nuclear reaction kinematics, nuclear scattering cross section determinations, compound nucleus disintegration, Breit Wigner dispersion formula (one level), direct reactions, nuclear transmutation reactions, nuclear fission and fusion,

Unit 4. Particle Physics & Cosmic rays: (15)

Broad classification of elementary particles and particle interactions in nature, conservation laws, symmetry classifications of elementary particles- Gell-Mann-Nishijima scheme,CPT conservation, Quark hypothesis & Quantum chromodynamics (ideas only); Cosmic rays: origin of cosmic rays, nature of primary cosmic rays and its energy distribution, its geomagnetic ,latitude effect, east-west asymmetry, origin of secondary rays, collision with electrons,. Particle accelerators and detectors: linear accelerators, cyclotron, synchrotron, colliding beam accelerators (LHC), gas-filled counters, scintillation detectors, semiconductor detectors.

Recommended Books:

1. Atomic and Nuclear Physics: Gopalakrishnan (MacMillan)

2. Concepts of Modern Physics: A.Beiser.

3. Concepts of Nuclear Physics: Bernard L Cohen.

4. Nuclear Physics: D C Tayal.

5. Subatomic Physics, Frauenfelder and Henley. (Prentice-Hall)

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

Learning 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, spinglasses.

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:

1. 1. 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, SEME. 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-IV 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

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

COURSE CODE: SCT 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)

M.Sc, PHYSICS (CONDENSED MATTER PHYSICS)
Choice Based Credit System (CBCS)
(w. e. f. June 2021-2022)

Practical List

HCP 3.1/3.2

1) Susceptibility measurement of $FeCl_36H_2O$ solution.
2) Successive Ionic Layer Adsorption and Reaction.
3) Chemical Bath deposition of PbS.
4) Chemical Bath deposition of CdS.

5) Strain gauge II.
6) Optical studies on CdS thin film (α vs λ, determination of E_g and m).
7) LVDT II.
8) Band gap determination using four probe method.
9) Hydroxide co-precipitation of $Ba_{0.8}Sr_{0.2} TiO_3$
10) Electrodeposition of Ni.
11) Ceramic synthesis of PZT.
12) Antocombustionsyrthesis of $Cofe_2O_4$.

SCP 3.1

1) Faraday Effect.
2) Kerr Effect.
3) Pockel Effect.
4) Electrical conductivity measurement and determination of activation energy.
5) Thermoelectric power measurement.
6) Determination of curie temperature.
7) Particle size estimation.