Punyashlok Ahilyadevi Holkar Solapur University, Solapur

पुण्यश्लोक अहिल्यादेवी होळकर
सोलापूर विद्यापीठ
।। विद्यया संपन्नता ।।

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

Name of the Faculty: Science and Technology

CHOICE BASED CREDIT SYSTEM

Structure and Syllabus: Physics (Materials Science)

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

(Syllabus to be implemented from w.e.f. June 2021)

PUNYASHLOK AHILYADEVI HOLKAR SOLAPUR UNIVERSITY, SOLAPUR

M.Sc. II – Physics (Materials Science)

Choice Based Credit System

W.e.f June 2021-22

Semester	Code	Title of the Paper	Semester exam			L	T	P	Credits
Third		**Hard core**							
MS	**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	Dielectric & Ferroelectric Properties of Materials	80	20	100	4		-	4
	SCT3.2	Materials Processing	80	20	100	4		-	
	SCT3.3	Materials Characterization	80	20	100	4			
		Open elective (Any one)							
	OET3.1	Energy Harvesting Devices	80	20	100	4		-	4
	OET3.2	Nuclear Radiations & Effects	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**
	SEC	Materials Characterization Tools	-	--	--	--	--	--	4*
Four		**Hard core**							
MS	**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	Advanced Techniques of Materials Characterization	80	20	100	4		-	
	SCT4.2	Magnetic Materials	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 Materials Science /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 (MATERIALS SCIENCE)
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 (MATERIALS SCIENCE)
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 behavior 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 (MATERIALS SCIENCE)
SCT– 3.1 (MS): DIELECTRIC AND FERROELECTRIC PROPERTIES OF MATERIALS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

Unit I: Introduction (10)

Maxwells equations, Amperes law, Faradays law, Gauss law in presence of dielectric, Electric field, Electric flux density, Polarization, Permittivity, electric susceptibility, Dipole moment , Polar and non-polar dielectrics.

Unit II: Electric Polarization and Relaxation (20)

Fundamentals: Force acting on the boundary between two different dielectric materials, Force elongating a dielectric fluid, Dielectrophoretic force, Electrostriction force, Electrostatic induction , Electric polarization and relaxation in static electric fields, Vacuum space, Conducting materials.

Dielectric Materials and its Polarization: Mechanism of electric polarization, Electronic polarization, Classical and Quantum Mechanical Approach, Atomic or Ionic Polarization, Orientational polarization, Polarizability, Spontaneous polarization, Space charge polarization, Hopping polarization, Interfacial polarization, Classification of dielectric materials, Non-ferroelectric and ferro-electric materials, Internal fields, Local fields for Non-dipolar materials, Clausius-Mosotti Equation.

Dielectrics in AC field: Lorentz - Lorenz equation, Reaction Field for dipolar materials, Electric polarization and relaxation in time -varying electric fields, Time domain approach and the frequency - domain approach, Complex permittivity, Time dependent electric polarization, Kramers - Kronig equations, Debye equations, Absorption, and Dispersion for dynamic polarizations, Effects of the local field, Effects of DC conductivity, Cole - Cole plot, Temperature dependence of complex permittivity, Field dependence of complex permittivity of ferroelectric materials, Insulating materials, Dielectric relaxation phenomena.

Unit III: Optical and Electro-Optic Processes (10)

Modulation of light, Double refraction and birefringence, Quarter - Wave plate, Electro - Optic effects: Linear Electro – Optic effect, Photorefractive effect, Magneto - Optic effect, Faraday effect, Voigt effect, Acousto-Optic effect.

Unit IV: Ferroelectrics, Piezoelectrics and Pyroelectrics (20)

Ferroelectrics: Ferroelectric phenomena, Representative crystal, types of ferroelectrics: Properties of Rochelle salt, $BaTiO_3$, Theory of ferroelectric displacive transitions, Thermodynamic theory, Ferroelectric and antiferroelectric transition, Formation and dynamics of ferroelectric domains, Experimental evidence of domain structure, Applications of ferroelectric materials

Piezoelectrics: Piezoelectric phenomena, Phenomenological approach to piezoelectric effects, Piezoelectric parameters and their measurements, Piezoelectric materials and their applications.

Pyroelectrics: Pyroelectric phenomena, Phenomenological approach to pyroelectric effects, Pyroelectric parameters and their measurements, Pyroelectric and thermally sensitive materials, NTC and PTC materials, Applications of pyroelectric materials.

References Books:

1. Kwan Chi Kao and F. R. de Boer; Dielectric Phenomena in Solids, Elsevier Academic Press (2004).
2. J. P. Srivastava, Elements of Solid State Physics, 2nd Edi Prentice – Hall of India(P) Ltd. (2007)
3. Charles Kittle; Introduction to Solid State Physics, 7th Edition, John Wiley & Sons, (1996).
4. Saxena, Gupta, Saxena; Fundamentals of Solid State Physics, Pragati Prakashan, (2012).
5. M.A.Wahab; Solid State Physics: Structure and Properties of Materials, Alpha Science International (2005)
6. S.O. Pillai; Solid State Physics, 6th Ed., New Age International (p) Ltd publishers, (2005)
7. Neil W. Ashcroft, N. David Mermin, Solid State Physics; Saunders College, (1976).
8. A. J. Dekkar; Solid State Physics, 1st Ed. Macmillan (2000).

M.Sc-II, SEME. III, PHYSICS (MATERIALS SCIENCE)
SCT– 3.2 (MS): MATERIAL PROCESSING
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

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

Course Objective

- Obtain basic knowledge of materials processing, vacuum technology Comprehension of thermal and flow behaviour of gases at very low pressures.
- Students will study thin film deposition techniques
- Acquire the knowledgeof electrical discharges used in thin film deposition, as well types of sputtering technique for synthesis of thin films
- Awareness of conditions for the formation of thin films and their properties and applications.

Learning Outcome

- After the completion of this course students should be able to be engaged in advanced research and development in materials science and engineering,
- Student will get aware with different types of materials synthesis/or processing,
- Student will able to get professional disciplines that benefit from an understanding of vacuum techniques and materials processing.

Unit I : Vacuum Technology (12)
Principles of vacuum pump – principle of different vacuum pumps : roots pump, rotary, diffusion turbo molecular pump, cryogenic-pump, ion pump, ti-sub limitation pump, importance of measurement of vacuum, Concept of different gauges, bayet - albert gauge, pirani, penning, pressure control.

Unit II: Physical Vapor Deposition & CVD Techniques (12)
Thermal evaporation, resistive evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition, laser ablation, laser pyrolysis, molecular beam epitaxy, electro deposition.

Chemical Vapor Deposition Techniques (12)
Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types boundaries and flow, Different kinds of CVD techniques: Atmospheric pressure CVD (APCVD) – Low pressure CVD (LPCVD) – Plasma enhanced chemical vapor deposition (PECVD) or –The HiPCO method – Photo-enhanced chemical vapor deposition (PHCVD) – LCVD Laser –Induced CVD, Metallorganic CVD (MOCVD), Thermally activated CVD, Spray pyrolysis,etc.

Unit III : Electrical Discharges used in Thin Film Deposition(10) Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion plating, oxidizing and Nitriding, Atommic layer deposition (ALD), Importance of ALD technique, Atomic layer growth.

Unit IV: Conditions for the Formation of Thin Films (12)

Environment for thin film deposition,deposition parameters and their effects on film growth, formation for thin films (sticking coefficient, formation of thermodynamically stable cluster – theory of nucleation), capillarity theory, microstructure in thin films, adhesion, properties of thin films, Mechanical ,Electrical, and optical properties of thin films, few applications of thin films in various fields, Quartz crystal thickness for measurement of film thickness.

Unit V: Adsorption And Diffusion in Thin Films (12)

Physisorption – Chemisorption –Work function changes induced by induced by adsorbates – Two dimensional phase transititions in adsorbate layers – Adsorption kinetics – Desorption techniques. Fundamentals of diffusion – Grain Boundary Diffusion –Thin Film Diffusion Couples –Inter Diffusion –Electromigration in thin films –Diffusion during film growth, Stress in Thin Films.

Reference Books:

1. Hand book of Thin films Technology: L I Maissel and R Clang.
2. Thin film Phenomena: K L Chopra.
3. Physics of thin films,vol.12,Ed George Hass and others.
4. Vacuum deposition of thin films – L Holland.
5. Milton Ohring,Materials Science of Thin films Published by Academic Press Limited (1991)
6. L.B.Freund and S.Suresh, Thin Film Materials,(2003)
7. Hans Luth, Solid Surfaces, Interfaces and Thin Films' 4^{th}edition,Springer Publishers (2010)
8. HaraldIbach, Physics of Surfaces and Interfaces, Springer Publishers (2006).

AMY R L Banshow

M.Sc-II, SEME. III, PHYSICS (MATERIALS SCIENCE)
SCT –3.3: MATERIALS CHARACTERIZATION
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: SCT 3.3 (60 lectures, 4 credits)

Course Objectives:

- To provide concepts on the several materials characterization techniques at the morphological, structural and chemical level, the acquisition of skills in the use and selection of advanced experimental techniques for characterization of materials and application of these techniques to solving problems in materials science and engineering.
- To introduce the working principles, instrumentation and interpretation of the characterization technique outputs of main techniques.

Learning Outcomes:

- Students will be able to identify suitable techniques for specific materials characterization as per requirement.
- Students will be able to do the various practical for measurement of several materials properties such as, optical and electrical measurements etc.
- The materials analysis and characterization will allow the students to select the material properly based on the performance of the system under study.
- For this reason, advanced techniques for materials characterization are exposed, particularly of the most widely used materials as thin films, nanomaterials and advanced materials.

Unit I: **(12)**
Introduction to the Common Concepts in Materials Characterization:
Measurements of Mass and Density, Different kinds of Balances. Roughness, Porosity and Surface area measurement. Microscopic tools and necessity, Spectroscopic tools and necessity, Resonance techniques and necessity, Surface properties and the necessary tools, Understanding Crystallinity, Thermal properties and thermal analysis like thermal conductivity ,specific heat, melting temperature and other phase transitions using TG,DTG,DTA etc. Methods of Temperature measurements, Hardness of material measurements and associated Physics, Materials aspects: particles, bulk, thin and thick films, gel, suspension and rheological properties. General behavior of metals, ceramics, semiconductors, polymers and tools required to characterize them, Methods of Sample preparation: polishing, grinding, sectioning, annealing, sintering, etching.
Errors in measurements, Analysis of errors, Curve Fitting. Standard Distribution functions, International Standards: ASTM and other standards

UnitII : Vacuum Techniques **(12)**
Fundamental concept of vacuum, units of measurements, Kinetic theory of gases. practical aspects of vacuum technology: vapor pressure, out-gassing, seals, pumping

speeds, conductance, through puts. Order of vacuum and necessity during the material characterization
Vacuum pumps: Mechanical pumps ,Water pumps, Rotary oil pumps, Roots pumps,

Unit III: Structural analysis of materials by X-ray diffraction analysis (12)
Introduction to generation and detection of X-rays, Crystalline, polycrystalline ,nano-crystalline and amorphous solids. Laue method for single crystal structural analysis. Powder diffraction methods, Analysis of cubic structures, introduction to crystal symmetry and crystal structure, Factors affecting the intensity in Powder XRD, Structure factor , few examples of NaCl, KCl, KBr etc.. Different X-Ray Cameras and geometries.

Unit IV: Characterization of Electrical Properties (12)
Electrical transport in metals, semiconductors and insulators and difficulty in measurements, Bulk conductivity , practical aspects of methods , Surface conductivity measurements ,Four probe method of conductivity measurement,Van der Pauw measurement for an arbitrary shape ,Practical aspects and problems, Non contact mode of conductivity measurement.Microwave techniques, Hall effect in semiconductors, Hall mobility measurements. Measurement of Introduction to Deep Level Transient Spectroscopy (DLTS).Electrical conductivity with temperature ,Defects in semiconductors and their measurements .Estimation of mobility band gap in semiconductors, Photoconductivity,

Unit V: Characterization of Optical Properties (12)
Introduction to electromagnetic (EM) spectrum Energy wavelength and frequencies of EM radiations. Interaction of EM radiations with matter in different regions of EM spectral regions. Absorption. Reflection and Transmission in materials, Beer Lambert Law. Laboratory sources of EM radiations, Basic definition of spectrometer .and its components. Vibrational spectroscopy for determining the molecular bonds and structure, UV-Visible absorption spectroscopy, Its use to determine the Band gap of semiconductors ,Refractive index of thin films, Factors affecting the absorption. Photoluminescence (PL) spectroscopy for understanding the band gap solids.

Reference Books:
1)"Charecterization of Materials", Elton N.Kaufmann,Vol I & II ,Wiley Interscience,2003.
2)Elements of X-Ray Diffraction",CulityB.D.,Addison Wesley Publishing Company.
3)"Fundamentals of Molecular Spectroscopy" ,C.N.Banwell,Tata McGraw–Hill Publishing Company Limited
4)"Instrumental Methods of Analysis" ,H.H.Willard, L.L.Merritt, J.A.Dean, F.A.Settle, CBS Publishers & Distributors, Delhi.
5)"X-Ray Diffraction", C.Suryanarayana and Grant Norton,SpringerScience+Business Media, LLC
6) Absorption Spectroscopy, Bauman R.P., Wiley .New York

M.Sc-II, SEME. III, PHYSICS (Materials Science)
OET - 3.1: 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 characterizationsof 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 (MATERIALS SCIENCE)
OET - 3.2: NUCLEAR RADIATION & EFFECTS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-21)

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

Course Objectives:

- Demonstrate an understanding of nuclear processes, and the application of general science and engineering principles to the analysis and design of nuclear and related systems of current and/or future importance to society.
- Produce high quality nuclear and radiological engineering graduates in order to help meet the manpower needs of our state, region, nation and the international community.
- Conduct nuclear and radiological engineering related research to help meet the needs of society

Learning Outcomes:

- The ability to apply knowledge of mathematics, science and engineering to the analysis of nuclear and other systems.
- The ability to identify, formulate and solve nuclear engineering problems.
- The ability to design integrated systems involving nuclear and other physical processes.
- The ability to design and perform laboratory experiments to gather data, test theories, and solve problems.
- The ability to learn and work independently, and to practice leadership and teamwork in and across disciplines.

Unit-1: Interaction of Charged Particles with Matter (10)

Introduction to Charged Particles, Theory and general features for charged particles - the Bethe-Bloch equation, Photon interactions - photoelectric effect, Compton scattering, Pair production, Neutron scattering and absorption, Attenuation and shielding. **(J S Lilley),** Interaction of Heavy Charged Particles, Interaction of Fast Electrons, Interaction of Gamma Rays, Interaction of Neutrons **(Glenn F Knoll)**

Unit-2: Nuclear Radiation Units (08)

The Roentgen and the Rad, Photon Flux and Radiation Dose, Dose rate and radioactive source strength, Radiation dose from internal source, The Rem, Gray, Rad to Gray Conversion, Fluence **(Samuel Glasstone)**

Unit-3: Radiation effects on Semiconductor Materials (12)

Basic Radiation Damage Mechanisms in Semiconductor Materials and Devices:Introduction. Fundamental Damage Mechanisms: Ionization Damage, Displacement Damage. Impact ofRadiation Damage on Device Performance: Spectroscopic Study of Microscopic Radiation Damage: Electron Paramagnetic Resonance (EPR), Deep Level Transient Spectroscopy (DLTS), Photo-luminescence Spectroscopy (PL)

Displacement Damage in Group IV Semiconductor Materials: Introduction, Displacement Damage in Silicon: Radiation Defects in Silicon, Impact of Radiation

Defects on Silicon Devices, Substrate and Device Hardening, Displacement Damage in Germanium: Potential Applications of Ge, Cryogenic Irradiation of Ge, Room Temperature Irradiation of Ge, Impact Radiation Damage on Ge Materials and Device Properties, Displacement Damage in SiGe Alloys: SiGe Material Properties and Applications, Radiation Damage in SiGe, Processing-Induced Radiation Damage in SiGe, Radiation Damage in SiGe Devices **(C. Claeys)**

Unit-4: Biological Effects of Radiation (15)
Introduction, Somatic effects of radiation, genetic effects of radiation, The radiation back ground, Radiation dose from nuclear power operations, estimates of biological consequences. **Radiation Hazards:** Health-physics activities, Effects of different types of radiation, External and internal radiation sources, Protection from radiation hazards. **(Samuel Glasstone)**

Unit-5: Useful Applications of Nuclear Radiation: Nuclear Medicine (15)
Production of various radioactive isotopes, application of the isotope in therapeutic process like gamma ray therapy, boron neutron capture therapy, heavy ion therapy applications of radioisotopes in imaging process like, gamma camera, positron emission tomography and magnetic resonance imaging are discussed. **(Fieldmen &Soete)**

TEXT BOOKS

1. Gnell F Knoll, Radiation Detectibn and Measurement, Third Edition, John Willey, 2000
2. John S Lilley, Nuclear Physics Principles and Applications, Willey, 2001
3. C. Claeys E. SimoenRadiation Effects in Advanced Semiconductor Materials and Devices, Springer
4. S. Glasstone and A. Sesonske, Nuclear Reactor Engineering, D. Van Nostrand Company, INC. 1967.
5. De Soete, D. R. Gijbels and J. Hoste, Neutron Activation Analysis. John Wiley and Sons: New York, NY. (1972).
6. L. C. Feldmen and J. W. Mayer, Fundamentals of surface and thin films analysis, North-Holland, Elsevier, 1986.

REFERENCE BOOKS

1. Robley D Evans, The Atomic Nucleus, TMH, 1955
2. L. Cohen, Concepts of Nuclear Physics, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004.

M.Sc-II, SEME. IV, PHYSICS (MATERIALS SCIENCE)
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 (MATERAILS SCIENCE)

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 (MATERIALS SCIENCE)
HCT - 4.3: PHYSICS OF NANO MATERIALS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

COURSE CODE: HCT 4.3 (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-II, SEME. IV, PHYSICS (Materials Science)
SCT - 4.1: ADVANCED TECHNIQUES OF MATERIALS CHARACTERIZATION
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

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

Course Objectives:

- To provide concepts on the several materials characterization techniques at the morphological, structural and chemical level, the acquisition of skills in the use and selection of advanced experimental techniques for characterization of materials and application of these techniques to solving problems in materials science and engineering.
- To introduce the working principles, instrumentation and interpretation of the characterization technique outputs of main techniques.

Learning Outcomes:

- Students will be able to identify suitable techniques for specific materials characterization as per requirement.
- Students will be able to do the various practical for measurement of several materials properties such as, optical and electrical measurements etc.
- The materials analysis and characterization will allow the students to select the material properly based on the performance of the system under study.
- For this reason, advanced techniques for materials characterization are exposed, particularly of the most widely used materials as thin films, nanomaterials and advanced materials.

Unit I: Microscopic Techniques: (10)

Optical Microscopy and limitations: Principle of Diffraction of light, Airy Disc, Resolution and magnification; Rayleigh Criteria, Numerical aperture, Major lens defects. Different kinds of optical microscopes (Bright field, Stereo, Phase contrast, Differential Interference Contrast, Fluorescence, Confocal, Polarizing light microscope)

Unit-II: Electron Microscopy (20)

Limitations of Light microscopy and advantages of electron microscopy. Wavelength of electrons, Theoretical Resolving power, Source of electron emission .Electron Focusing, Effect of magnetic fields, Electrostatic and magnetic focusing, Optical Column, Magnetic lenses. Vacuum requirements. Schematic of complete SEM
Scanning Electron Microscopy (SEM): Interaction of electrons with matter. Secondary electron emission (SEE), Yield of SEE, Universal yield curve, Beam scanning and Magnification in SEM, Secondary electrons Detector, Back scattered electrons detector. Electronics. Image analysis. Size histogram. Sample preparation.
Transmission Electron Microscopy(TEM) : Principle of operation, Lens systems, Schematic of TEM ,Apertures, Bright Field Image, Dark Field Image ,.Electron

Diffraction, Bragg's Condition, Selective Area Electron Diffraction (SEAD), Image analysis. Sample preparation

Scanning Tunneling Microscopy

Historical perspective, Electron tunneling ,Principle of STM imaging , STM image interpretation ,STM implementation in instrument , Piezoelectric drive, Tip preparation, Vibration isolation, Data acquisition and analysis, Application of STM , high resolution imaging of surfaces, Spectroscopy, Lithography, Current fluctuation, Limitation of STM and solution,

Atomic Force Microscopy: Principle and equations of force curves, Contact and Non contact modes, Amplitude modulation and Frequency modulation, Force versus distance curve, Experimental details of AFM, Practical applications.

Unit III: X-Ray Photoelectron Spectroscopy (15)

Definition of surface, Different Probes for Surface-characterization. Necessity of Ultra High Vacuum, Photoelecton Emission, Introduction and Basic Theory, Historical Perspective, Instrumentation, Vacuum System. Energy analyzers, X-Ray Source, Electron Energy Analyzer. Sample Selection and Preparation , Sample Charging .X-Ray Beam Effects., Spectral Analysis ,Core Level Splitting .,Linewidths. Elemental Analysis: Qualitative and Quantitative, Secondary Structure, Angle-Resolved XPS, Depth profiling.

Unit IV. Raman and Resonance spectroscopy: (15)

Raman Effect and Raman spectroscopy: Classical and Quantum theory of Raman Effect, Rotational and vibrational structure of Raman spectrum - pure rotational Raman spectra of diatomic molecules, vibration rotation Raman spectrum of diatomic molecule, intensity alterations, Application of Raman spectroscopy.

Resonance Technique: NMR – nuclear spin magnetic moment, interaction of nuclear magnet with external field. Quantum description of N.M.R., NMR spectrometer, Chemical shift, Spin–spin interaction, Applications of NMR spectroscopy.

Reference Books:

1. Handbook of Applied 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 (MATERIALS SCIENCE)
SCT - 4.2: MAGNETIC MATERIALS
Choice Based Credit System (CBCS)
(w. e. f. June 2020-2021)

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

Course Objective

- Vital objective of this course to introduce students distinguished types of magnetic materials and properties variance with respect to each type
- To aware student effects of external physical parameters on the behaviours of magnetic materials
- To understand behaviour of crystals due to magnetic anisotropy, magnetostriction
- To acquire with the concept of domain and its contribution for the magnetization process.

Learning Outcome

- Student will be able to explain types of magnetic materials and how to distinguish them.
- Student will be able to explain magnetism in magnetic materials with classical and quantum theories.
- Student will get acquainted with the knowledge of effects of magnetic forces in different types of crystal structures and their behaviour under stress.
- Student will able to explain nature of hysteresis loop and their properties under different magnetic fields

Unit I: Introduction (15)

Measurement of Field Strength, Hall Effect, Electronic Integrator or Flux meter, Magnetic Measurements in Closed Circuits, Demegnetizing Fields, Magnetic Shielding, Demagnetizing Factors, Magnetic Measurements in Open Circuits, Instruments for Measuring Magnetization, Vibrating - Sample Magnetometer, Altering (Field) Gradient Magnetometer - AFGM or AGM, (also called Vibrating Reed Magnetometer), Magnetic Circuits and Parameters, Permanent Magnet Materials, Susceptibility Measurements.

Unit II: Magnetism in Materials (20)

Diamagnetism and Para magnetism:

Introduction, Magnetic Moments of Electrons, Magnetic Moments of Atoms, Theory of Diamagnetism, Diamagnetic Substances, Classical Theory of Para magnetism, Quantum Theory of Para magnetism, Gyro magnetic Effect, Magnetic Resonance

Ferromagnetism: Introduction, Molecular Field Theory, Exchange Forces, Band Theory, Ferromagnetic Alloys, Theories of Ferromagnetism

Antiferromagnetism: Introduction, Molecular Field Theory, Above $T_{N,}$ Below $T_{N,}$ Comparison with Experiment, Neutron Diffraction, Antiferromagnetic, Ferromagnetic, Rare Earths , Antiferromagnetic Alloys.

Ferrimagnetism: Introduction, Structure of Cubic Ferrites, Saturation Magnetization, Molecular Field Theory, Above Tc, Below Tc, General Conclusions, Hexagonal Ferrites, Other Ferromagnetic Substances, y - Fe_2O_3, Garnets, Alloys.

Unit III: Magnetic Anisotropy, Magnetostriction and the Effects of stress **(15)**

Magnetic Anisotropy: Introduction, Anisotropy in Cubic Crystals, Anisotropy in Hexagonal Crystals, Physical Origin of Crystal Anisotropy, Anisotropy Measurement, Torque Curves, Torque Magnetometers, Anisotropy Measurement (from Magnetization Curves), Fitted Magnetization Curve, Anisotropy Constants, Polycrystalline Materials

Magnetostriction: Introduction, Magnetostriction of Single Crystals, Cubic Crystals, Magnetostriction of Polycrystals, Physical Origin of Magnetostriction, Form Effect, Effect of Stress on Magnetic Properties, Effect of Stress on Magnetostriction, Applications of Magnetostriction, ΔE Effect, Magnetoresistance.

Unit IV: Domains and the Magnetization Process **(10)**

Introduction, Domain Wall Structure, Neel Walls, Magnetostatic Energy and Domain Structure, Uniaxial Crystals, Cubic Crystals, Domain Wall Motion, Magnetization in Low Fields, Magnetization in High Fields, Shapes of Hysteresis Loops.

Reference Books:

1. K. H. J. Buschow& F. R. de Boer: Physics of Magnetism and Magnetic Materials.
2. C. Kittle: Introduction to Solid State Physics.
3. Azoroff : Introduction to Solids.
4. Saxena, Gupta, Saxena: Fundamentals of Solid-state Physics.
5. R. L. Singhal: Solid State Physics.
6. V. Raghavan: Materials Science and Engineering.
7. A. J. Dekkar: Solid-state Physics.

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

Practical List

HCP 3.1/3.2

1) Susceptibility measurement of $FeCl_3 6H_2O$ 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) Antocombustion synthesis 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.