Punyashlok Ahilyadevi Holkar Solapur University, Solapur

NAAC Accredited-2015
‘B’ Grade (CGPA 2.62)

Name of the Faculty: Science & Technology

CHOICE BASED CREDIT SYSTEM

Syllabus: Physics (Solid State)

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

(Syllabus to be implemented from w.e.f. June 2019)

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

M. Sc – Physics (Solid State)
Choice Based Credit System
w.e.f. June 2019-20

Semester	Code	Title of the Paper	Semester exam			L	T	P	Credits
First		**Hard core**	**Theory**	**IA**	**Total**				
SS	**HCT1.1**	Mathematical Techniques	70	30	100	4		-	4
	HCT1.2	Condensed Matter Physics	70	30	100	4		-	4
	HCT1.3	Analog& Digital Electronics	70	30	100	4		-	4
		Soft Core (Any one)							
	SCT1.1	Classical Mechanics	70	30	100	4		-	4
	SCT1.2	Elements of Material Science	70	30	100	4		-	
		Tutorial			25		1	-	1
		Practical							
	HCP 1.1	Practical HCP 1.1	35	15	50	-	-	2	6
	HCP1.2	Practical HCP 1.2	35	15	50	-	-	2	
	HCP1.3	Practical HCP 1.3	35	15	50	-	-	2	
		Soft core (Any one)							
	SCP1.1	Practical SCP1.1	35	15	50	-	-	2	2
	SCP1.2	Practical SCP1.2	35	15	50	-	-	2	
		Total for first semester	**420**	**180**	**625**				**25**
Second		**Hard core**							
SS	**HCT2.1**	Quantum Mechanics	70	30	100	4		-	4
	HCT2.2	Electrodynamics	70	30	100	4		-	4
		Soft core (Any one)							
	SCT2.1	Statistical Mechanics	70	30	100	4		-	4
	SCT2.2	Analytical Techniques	70	30	100	4		-	
		Open elective (Any one)							
	OET2.1	Fundamentals of Electronics	70	30	100	4		-	4
	OET2.2	Conventional & Non conventional Energy	70	30	100	4		-	
		Tutorial			25		1	-	1
		Practical							
	HCP 2.1	Practical HCP 2.1	35	15	50	-	-	2	4
	HCP2.2	Practical HCP 2.2	35	15	50	-	-	2	
		Soft core (Any one)							
	SCP1.1	Practical SCP2.1	35	15	50	-	-	2	2
	SCP1.2	Practical SCP2.2	35	15	50	-	-	2	
		Open elective (Any one)							
	OEP2.1	Practical OEP2.1	35	15	50	-	-	2	2
	OEP2.2	Practical OEP2.2	35	15	50	-	-	2	
		Total for second semester	**420**	**180**	**625**				**25**
Third		**Hard core**							

SS	**HCT3.1**	Semiconductor Physics	70	30	100	4		-	4
	HCT3.2	Atomic and Molecular Physics	70	30	100	4		-	4
		Soft core (Any one)							
	SCT3.1	Advanced Condensed Matter Physics	70	30	100	4		-	4
	SCT3.2	Experimental Techniques for Physics	70	30	100	4		-	
	SCT3.3	Properties of Solids	70	30	100	4			
		Open elective (Any one)							
	OET3.1	Nanoscience &Technology	70	30	100	4		-	4
	OET3.2	Energy Harvesting Devices	70	30	100	4		-	
		Tutorial			25		1	-	1
		Practical							
	HCP 3.1	Practical HCP 3.1	35	15	50	-	-	2	2
	HCP3.2	Practical HCP 3.2	35	15	50	-	-	2	2
	SCP 3.1	Practical SCP 3.1	35	15	50	-	-	2	2
		Open elective (Any one)							
	OEP3.1	Practical OEP3.1	35	15	50	-	-	2	2
	OEP3.2	Practical OEP3.2	35	15	50	-	-	2	
		Total for third semester	**420**	**180**	**625**				**25**
Four		**Hard core**							
SS	**HCT4.1**	Semiconductor Devices	70	30	100	4		-	4
	HCT4.2	Nuclear and Particle Physics	70	30	100	4		-	4
	HCT 4.3	Thin Film Physics and Technology	70	30	100	4		-	4
		Soft core (Any one)						-	4
	SCT4.1	Materials Characterization Techniques	70	30	100	4		-	
	SCT4.2	Physics of Nano Materials	70	30	100	4		-	
		Tutorial			25		1	-	1
	MP4.3	Major Project	140	60	200	-	-	-	8
		Total for four semester	**420**	**180**	**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

MP = Major project

- **140 Marks-University Examinations (Viva Dissertation, Project Progress, evaluation)**
- **60 Marks- Internal Performance Evaluation (20 Marks: Presentations, 20 Marks :Performance & 20 Marks: Attendance)**

M.Sc-II, SEM. III, PHYSICS (Solid State)

HCT - 3.1: SEMICONDUCTOR PHYSICS
Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

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, SEM. III, PHYSICS (Solid State)

HCT - 3.2: ATOMIC and MOLECULAR PHYSICS

Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit 1. Atomic Physics: (15)

Vector atom model and quantum numbers, Larmar precession, spectroscopic terms, Lande's g factor, fine structure of hydrogen atom- relativistic correction, spin-orbit interaction, intensity of fine structure lines, Lamb shift, hyperfine structure of spectral lines, determination of nuclear spin, ground state of one-electron and two-electron atoms and their spectra– perturbation theory and variational method, para and ortho states, pauli exclusion principle, Excited states, doubly excite states, Auger effect,resonance. Many electron atoms: Central field approximation, Thomas-Fermi model, Hartee-Fock method and self-consistent field, Hund's rule, L-S and j-j coupling schemes, fine structure of sodium d line, Lande interval rule, the idea of Hartee-Fock equations. The spectra of alkalis using quantum defect theory, selection rules for electronic and magnetic multiple radiations, Oscillator strengths and Thomas Reich-Kuhn sum rule.

Unit 2. Interaction of atoms with Electromagnetic fields: **(15)**

Spectra of alkali and alkaline earths elements -complex spectra - multiplet structure, Zeeman effect, Paschen-Back Effect, Stark effect, hyperfine structure of spectral line, broadening of spectral lines, X-ray spectra.

Unit 3. Molecular Physics: (15)

Born-Oppenheimer approximation, rotation and vibration of diatomic molecules,electronic spin and Hund's cases and nuclear spin, electronic structure of diatomic molecules, structure of polyatomic molecules. Rotational spectra: Intensity of rotational spectra, Isotopic effect of rotational spectra, non-rigid rotator, and vibrational spectra: anharmonic effect, Diatomic Vibrating rotator,Breakdown of Born-Openhemer approximation – interaction of rotational vibration, Electronic spectra,Fortrant diagram. Atomic collisions: Types of collisions, channels, thresholds, cross-sections, potential scattering, general features, Born approximation.

Unit 4. Raman spectra 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 IR & 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. Quantum mechanical treatment of Electronic spin resonance (ESR) - Nuclear interaction and hyperfine structure -Relaxation effects - Basic principles of spectrographs - Applications of ESR method. Mossbauer spectra and its applications.

Recommended Books:

1) Introduction to Atomic Spectra – White.
2) Introduction to Atomic Spectra –Herberg.
3) Physics of Atoms and Molecules by B H Bransden and C J Jocachin
4) Laser: Theory and Application, K.Thyagarajan and A.K. Ghatak.
5) Lasers and Non-linear Optics, B.B. Laud.

M.Sc-II, SEM. III, PHYSICS (Solid State)

SCT– 3.1 (SS): ADVANCED CONDENSED MATTER PHYSICS
Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit 1. Energy bands in solids: (15)

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

Practical DFT in a many body calculation and its reliability.

Unit 2. Magnetism: (15)

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

Unit 3. Dielectrics and Ionics: (15)

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

Unit 4. Polymers, Composites and Soft matters: (15)

Polymer and their classification, Molecular weight, degree of polymerization, techniques of polymerization, crystallinity of polymers, applications of polymers. Polymer electrolyte, Conducting polymers- concept of solitons, polarons, biolarons, Doping in conducting polymers,

Common conducting polymers, Properties and applications of conducting polymers: PLED, sensors actuators.Composite Materials- various types of composites, microcomposites and mactrocomposites, fiber composites, and matrix materials, Different kinds of soft matters, Symmetry and order parameters,Dispersion colloids, liquid crystal, biological membranes, macromolecules- DNA condensation, bilayer, Marcelja's molecular field theory mesosphere.

Recommended Books:

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

M.Sc-II, SEM. III, PHYSICS (Solid State)

SCT– 3.2 (SS): EXPERIMENTAL TECHNIQUE IN PHYSICS

Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit 1. 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 2. 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 3(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, otational/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.

3(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 4. 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, SEM. III, PHYSICS (Solid State)

SCT– 3.3 (SS): PROPERTIES OF SOLIDS
Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit - 1 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 - 2 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 - 3 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 - 4 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, SEM. III, PHYSICS (Solid State)

OET– 3.1 (SS): NANOSCIENCE AND TECHNOLOGY
Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit 1. Nanoscience and semiconductor nanostructures: (15)

Conceptual development of nanoscience, Nanoscience in nature, Clusters, artificial atomic clusters,– clusters to solids, effect on structures, ionization potential, melting etc. Electronic states in semiconductor, Concepts of 2D nanostructures (quantum wells),1D nanostructures (quantum wires) 0D nanostructures (quantum dots), Quantum mechanical treatment of quantum wells, wires and dots, Variation of electronic structure with size of semiconductor nanostructures, Widening of band gap, Effective mass approximation theory and other models for determination of electronic structures in semiconductor nanostructures, Strong and weak confinement in semiconductor nanostructures. Various classes of semiconductor nanostructures, optical properties of semiconductor nanostructures, Phonons in nanostructures.

Energy at nanoscale: surface energy, surface tension, particle curvature and the Young-Laplace equation, chemical potential, DLVO theory, nucleation, ostwald ripening, sintering

Unit 2.Malterials at nanoscale: (15)

Metallic nanostructures- Surface Plasmon's, permittivity and permeability based on Lorentz oscillator model, Properties of metallic nanoparticles, surface Plasmon resonance, idea of Mie theory, stability of metal nanoparticles,

Carbon nanostructures-Carbon nanomaterial, Fullerene, Carbon cluster, Carbon nanotubes, SWCNT, MWCNT, graphene, application of carbon nanotube.

Magnetic nanostructures-magnetism in small and nanoparticles, superparamagnetism, introduction to spintronics,spin valve, magnetic tunnel junction, memory elements.

Unit 3. Synthesis and Analysis of nanomaterials : (15)

Various synthesis process, lithography, Ball milling, Atom manipulation by SPM, Microcontact printing, Ion beam deposition, chemical bath deposition , selfassembled mono layers, Molecular beam epitaxy, chemical vapor deposition (CVD) based techniques,pulsed laser deposition, ion beam assisted techniques including embedded nanoparticles, RF sputtering, Characterization of nanomaterial - X-ray diffraction, Transmission electron microscopy, Scanning electron microscopy, Energy dispersive analysis, electron energy loss microscopy, Atomic force microscopy,Magnetic Force Microscopy, Scanning tunneling microscopy, optical and vibrational spectroscopy, Scanning near-field optical microscopy, Raman Spectroscopy.

Unit 4 (a) Quantum Transport in nanostructures: (15)

Ballistic transport, Phase coherence, Aharonv-Bohm effect,quantized conductance, Landauer formula, conductance behavior of quantum point contact, Landauer Buttiker formula for multileads, edge state – quantum Hall effect, single electron transport – coulomb blockage, coulomb diamond, SET, molecular electronics, Kondo effect in nanostructures

(b) Applications of nanomaterials and challenges: Application nanostructured material in electronics,photonics, biotechnology, nano-electromechanical systems, Nanocatalysis, nanocompsties and fibers, challenges of nanotechnology.

Recommended Books:

1) Introduction to Low Dimensional Semiconductors- J.H.Davis, Cambridge Press, 1998.

2) Optical Properties of Semiconductors- U.Woggon, Springer-Verlag, 2000.

3) Hand Book of Nanostructured Materials and Technology- Canham.

M.Sc-II, SEM. III, PHYSICS (Solid State)

OET - 3.2: ENERGY HARVESTING DEVICES
Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

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 Plezoelectric Fibbers, Piezoelectric Microcantilevers, Energy harvesting circuits, Multimodal 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, SEM. IV, PHYSICS (Solid State)
HCT -4.1: SEMICONDUCTOR DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2019-2020)

Unit 1: Physics of Semiconductor Devices (15)

Carrier transport phenomena in semiconductor solids: drift and diffusion process, Carrier Diffusion, Diffusion Current Density, total Current Density, Graded Impurity Distribution, transport in crystalline and amorphous semiconductors, Induced Electric Field, The Einstein Relation, Temperature dependence of semiconductor conductivity, Carrier life, Shockley-Read-Hall theory

MIS Structure and MOS FETs

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 2: 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 3: Charge Coupled and Transferred Electron Devices (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 4:Optoelectronic and Advanced Solid State Devices (15)

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

Reference Book/Text Book:

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

M.Sc-II, SEM. IV, PHYSICS (Solid State)

HCT - 4.2: NUCLEAR AND PARTICLE PHYSICS

Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

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 systemsdeuteron 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, SEM. IV, PHYSICS (Solid State)

HCT - 4.3: THIN FILM PHYSICS AND TECHNOLOGY

Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit - 1 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 -2 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.

Unit -3 Physics of Surfaces, Interfaces and Thin films (15)

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 - 4 Thin films for Devices & other Applications (15)

Dielectric deposition- silicon dioxide, silicon nitride, silicon ox nitride, polysilicon deposition, metallization, electro migration, silicide’s. Thin film transistors, thin film multilayers, optical filters, mirrors, sensors and detectors.

Main References:

1. Lyudmila Eckert ova, Physics of thin films, 2nd Revised edition, Plenum Press, New York, 1986 (Reprinted 1990),
2. K.L. Chopra, Thin film phenomena, Mc-Grew 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 No strand, 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, SEM. IV, PHYSICS (Solid State)

SCT - 4.1: MATERIALS CHARACTERIZATION TECHNIQUES

Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit 1: Microscopic Techniques I (15)

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)

Electron Microscopy: 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.

Unit 2: Microscopic Techniques II (15)

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 (STM):

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 (AFM):

Priciple and equations of force curves ,Contact and Non contact modes, Amplitude modulation and Frequency modulation ,Forfe versus distance curve,,Experimental details of AFM, Practical applications .

Unit 3: 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.

Auger Electron Spectroscopy

Basic principle, Auger Transitions, Kinetic Energies of Auger Electrons, Sensitivity of detection, Instrumentation, Electron Energy Analyzers ,Electron Detector, Sample preparation, Data analysis, Qualitative and Quantitative analysis.

Unit 4: Resonance spectroscopy (15)

Nuclear magnetic resonance and Electron Spin Resonance Spectroscopies.
Properties of Nuclear Spins ,Nuclear Spin Interactions in Solids General Structure of the Internal Hamiltonians , Quantum Mechanical Calculations, Quantum Mechanical Description of NMR , The NMR Signal—Zeeman Interaction ,High Resolution Solid State NMR Methods , Dipolar Decoupling ,Magic-Angle Spinning (MAS), Cross-Polarization (CP) The CP-MAS Experiment ,NMR Spectra.
EPR Condition, Continuous Wave-EPR, EPR Lineshape: Relaxation Times, Electron-Nuclear Interactions: Hyperfine Structure

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, SEM. IV, PHYSICS (Solid State)

SCT - 4.2: PHYSICS OF NANO MATERIALS

Choice Based Credit System (CBCS)

(w. e. f. June 2019-2020)

Unit 1: 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 2: 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 3: 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.

Unit 4: 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, PHYSICS (SOLID STATE)
Choice Based Credit System (CBCS)
(w. e. f. June 2019-2020)
Sem. III
Practical List

HCP 3.1,3.2

1. Calibration of Silicon diode and a copper constantan thermocouple as temperature sensors
2. Thermal diffusivity of Brass
3. Load regulation of constant current source
4. Temperature coefficient of resistance of copper
5. Energy band gap of Silicon using Silicon diode
6. Measurement of self inductance of a coil
7. Measurement of capacitance
8. Growth of single crystal
9. Laue diffraction analysis
10. Thin film deposition by Chemical bath deposition
11. Case Study of SEM micrograph
12. Case Study of NMR pattern
13. Case Study of Raman Spectra
14. Case Study of IR Spectra
15. Case Study of FESEM Spectra
16. Study of material data sheet

SCP 3.1

1. Passive filters
2. AC Bridges (Maxwell, DeSauty, Maxwell-Wein)
3. Dielectric constant of non-polar liquid
4. Dipole moment of an organic molecule, acetone
5. Biprism
6. Thin film deposition by Electrodeposition method
7. Thin film deposition by SILAR method
8. Thickness measurement of thin film

OEP 3.1/3.2

1. Measurement of thermal relaxation time constant of a serial light bulb
2. Mutual inductance with a lock-in amplifier
3. Measurement of low resistance
4. Constant deviation spectrometer
5. Fiber optic communication
6. Michelson's interferometer
7. Curve fitting for given data using Origin
8. To plot XRD of given data using Origin

SEM-IV- MP 4.3-
Major Project