Punyashlok Ahilyadevi Holkar Solapur University, Solapur

पुण्यश्लोक अहिल्यादेवी होळकर
सोलापूर विद्यापीठ
।। विद्यया संपन्नता ।।

NAAC Accredited-2022
'B^{++}' Grade (CGPA 2.96)

Name of the Faculty: Science & Technology

CHOICE BASED CREDIT SYSTEM

Syllabus: Physics

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

(Syllabus to be implemented from w.e.f. June 2022)

Punyashlok Ahilyadevi Holkar Solapur University, Solapur
M.Sc. Physics Choice Based Credit System (CBCS)
Course Structure

M.Sc. Part-II Physics (Energy Studies) w.e.f. 2022-23

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	Energy Resources	80	20	100	4		-	4
	SCT3.2	Materials Characterization	80	20	100	4		-	
		Open elective (Any one)							
	OET3.1	Energy Harvesting Devices	80	20	100	4		-	4
	OET3.2	Energy Storage Systems	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	
	SEC	**Skill Enhancement Course (Add on)**							
	SEC3.1	Materials Characterization Tools	-	--	--	--	--	--	4*
		Total for third semester	**480**	**120**	**625**				**25**
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	Energy Conversion Devices	80	20	100	4		-	
	SCT4.2	Advanced Energy Technologies	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**

***MOOC/ SWYAM Course: Student can opt from MOOC/ SWYAM platform as an Add On Course of 4 – Credits**

***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 (ENERGY STUDIES)
HCT - 3.1: SEMICONDUCTOR PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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 (ENERGY STUDIES)
HCT - 3.2: ATOMIC and MOLECULAR PHYSICS
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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 (ENERGY STUDIES)
SCT– 3.1: ENERGY RESOURCES
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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

Unit I Energy Resources (15)

Environment and sustainable development - Energy sources - Classification of energy sources – Fossil fuel reserves and resources - Overview of global/ India's energy scenario.

Solar Energy

Sun as the source of energy and its energy transport to the earth, Extraterrestrial and terrestrial solar radiations, solar spectral irradiance, solar radiation geometry, Measurement techniques of solar radiations, Estimation of average solar radiation.

Unit II Wind Energy (15)

Origin and classification of winds, Advantages & Disadvantages of Wind Energy, Aerodynamics of windmill: Maximum power, and Forces on the Blades and thrust on turbines; Wind data collection and field estimation of wind energy, Site selection, Basic components of wind mill, Types of wind mill, Wind energy farm, Hybrid wind energy systems: wind + PV; The present Indian Scenario.

Unit III Thermal Energy (15)

Introduction, working principle, types (conduction, convection and radiation), thermal conductors, thermal insulators, heat engines and their forms, heat pumps, properties of thermal energy, applications of thermal energy. Vapor power cycles - Boiler systems - Types of boilers; Fuel handling systems - Degasifies and Deaerators

Unit-IV Nuclear Energy (15)

Nuclear energy – Potential, challenges and opportunities - Nuclear fuels - Nuclear fusion and fission technologies - Breeder technology - Nuclear fuel enrichment - Nuclear reaction control - Types of Nuclear Reactor - Recent developments in nuclear reactors - Reactor safety and safety measures.

Reference Books

1. Non-conventional energy sources, GD Rai, Khanna Publishers, Delhi, 1998.
2. Wakil M, Power Plant Engineering, McGraw Hill, 2004.
3. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
4. Solar Energy and Rural development- S.H. Pawar, C.D. Lokhande and R.N. Patil.
5. Solid State Energy Conversion-S.H. Pawar, C.H. Bhosale, and R.N. Patil
6 Solar Energy Conversion-A.E. Dixon and J.D. Leslie.
7. Advances in Energy systems and technology- Peter Auer.

M.SC-II, SEME. III, PHYSICS (ENERGY STUDIES)

SCT –3.2: MATERIALS CHARACTERIZATION
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

COURSE CODE: SCT 3.2 (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 (ENERGY STUDIES)
OET - 3.1: ENERGY HARVESTING DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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

Course Objectives:

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

Learning Outcomes:

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

Unit -1: Solar Cells (15)

Photovoltaic effect, Solar cell characterization, Types of Solar cells, Solid state solar cells Silicon solar cell, CdTe based solar cells, CdS/Cu_2S solar cells, $CuInSe_2$ based solar cells, Metal-semiconductor solar cells, photoelectrochemical and photo electrolysis cells, Solar cells based on thin film heterojunctions, Ultra thin absorber solar cells, Nanostructured solar cells, Dye sensitised solar cells: basic concepts, working and materials. Organic Solar cells: basic concepts, working and materials.

Unit -2: Super Capacitors (15)

Comparison of battery and super capacitors, Super capacitor characterization, Types of super capacitors, double layer and pseudo capacitance, hybrid super capacitors, Recent status of carbon, RuO_2 and polyaniline based super capacitors, different methods for preparation of cathodic and anodic electrode materials, Fabrication of super capacitors with examples, Applications of supercapacitors

Unit -3: Fuel Cells (15)

Comparison between fuel cells and batteries, fuel cell characterizations, Types of fuel cells: Metal oxide, proton exchange membrane, Phosphoric acid, Solid oxide fuel cells, working of fuel cells, Materials for fuel cells, applications of fuel cells

Unit -4: Piezoelectrics **(15)**

Piezoelectric Energy Harvesting: Energy harvesting basis, case study

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

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

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

Reference Books

1. Semiconductor Sensors, S M Sze, A Wiley- Interscience Publication, John Wiley and Sons, NY1994
2. Electrochemical Supercapacitors, B E Conway, Kluwer Academic/ Plenum publishers, NY 1999.
3. C. N. R. Rao and Claudy Rayan Serrao, J. Mater. Chem., 2007, 17, 4931–4938
4. Solar Cells by Martin Green.
5. Photoelectrochemical Solar Cells by S. Chandra, Gordon &Breach Science Publisher, UK
6. Energy Harvesting Technologies, ShashankPriya, Daniel J. Inman Springer

M.SC-II, SEME. III, PHYSICS (ENERGY STUDIES)
OET - 3.2: ENERGY STORAGE SYSTEMS
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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

Objectives
- To understand the concept of understand / analyses the various types of energy storage.
- To study the various applications of energy storage systems

Outcome
- Students will be Able to analyses various types of energy storage devices and perform the selection based on techno economic view point

Unit I : Basic Concepts and Energy Storage (15)
Definition and units of energy, parameters (power, energy, efficiency and time), temporal classification, spatial classification, economic classification, conservation of energy, second law of thermodynamics, renewable energy resources**,** energy storage - need of energy storage; different modes of energy storage. Capacitors, electrochemical storage, electrical and magnetic storage, chemical energy storage, hydrogen for energy storage.

Unit II: Batteries
Electrochemical energy storage systems batteries: primary, secondary, lithium, solid-state and molten solvent batteries; lead acid batteries; nickel cadmium batteries; advanced batteries. Role of carbon nano-tubes in electrodes.

Unit-III: Supercapacitor
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 IV: Hybrid Energy Systems
Concept of hybrid energy systems - Supercapacitors – Fundamentals and types - Battery/supercapacitors hybrid systems – Example – Applications - Hybrid fuel cell/battery systems – Example – Applications.

Reference Books

1. R.A. Huggins, Energy Storage, 1st Ed., Springer, 2010.
2. J.-M.Tarascon, and Patrice Simon, Electrochemical Energy Storage, 1stEd., Wiley, 2015.
3. F.Díaz-González, A. Sumper and O.Gomis-Bellmunt, Energy storage in power systems, 1st Ed., Wiley, 2016.

4. N. Kularatna, Energy Storage Devices for Electronic Systems: Rechargeable Batteries and Supercapacitors, Academic Press, 2014**.**
5. X. Feng, Nanocarbons for advanced energy storage, Vol. 1, John Wiley and Sons, 2015.
6. M.Sylvin, Fundamentals of electrochemistry, 1st Ed., Sarup Book Publishers Pvt. Ltd., 2009.
7. A.G. Ter-Gazarian, Energy Storage for Power Systems, IET, 1994.
8. David Linden, Hand Book of Batteries, McGraw-Hill, Inc, 4th edition, (2010) New York.
9. Handbook of energy storage demand technology integration, Editor: Michael Sterner and Ingo Stadler, 2019, Springer
10. Electrochemical supercapacitors for energy storage and delivery fundamentals and applications, Aiping Yu, Victor Chabot, and Jiujun Zhang, 2013, CRC Press

M.SC-II, SEME. III, PHYSICS (ENERGY STUDIES)
Choice Based Credit System (CBCS)
(w. e. f. June 2022-2023)

Practical List

HCP 3.1/3.2

1) Optical studies on CdS thin film (α vs λ, determination of E_g and m).
2) Electrical Conductivity measurement.
3) Electrical conductivity measurement and determination of activation energy
4) Vacuum Deposition System
4) Spray Pyrolysis System
5) Chemical bath deposition
6) Electrodeposition

SCP 3.1/3.2

1) Solar Cell Characteristics
2) Wind Data analysis
3) Air mass Ratio
4) Fuel Cell
5) Photoelectrochemical Solar Cell
6) Thermoelectric Power
7) Measurement of parameters of battery
8) Measurement of parameters of supercapacitor
9) Fabrication of supercapacitor (pouch cell)

M.SC-II, SEME. IV, PHYSICS (ENERGY STUDIES)
HCT -4.1: SEMICONDUCTOR DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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

Course Objectives:

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

Learning Outcomes:

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

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

Unit I: MIS Structure and MOS FETs (15)

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

Unit II: Power Devices (15)

Power diodes, ratings, reverses recovery characteristics, fast recovery diodes, Power transistors,Switching characteristics, construction of SCR, two transistors analogy, I - V characteristics, gate trigger characteristics, turn on and turn - off times, losses, reverse recovery characteristics, SCR ratings, dv/dt and di/dt characteristics, thyrister types, construction and characteristics of DIACs and TRIACs, static induction thyristors, , light 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 2nd edition..
6. A Dir - Bar - Lev: Semiconductor and Electronic Devices.
7. M. H. Rashid: Power Electronics.
8. P. C. Sen: Power electronics
9. B. G. Streetman and S. Banergee : Solid state Electronic Devices

M.SC-II, SEME. IV, PHYSICS (ENERGY STUDIES)
HCT - 4.2: NUCLEAR AND PARTICLE PHYSICS

Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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 (ENERGY STUDIES)
HCT - 4.3: PHYSICS OF NANO MATERIALS
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

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 (ENERGY STUDIES)
SCT - 4.1: ENERGY CONVERSION DEVICES
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

Unit 1. Photovoltaics (15)

Interaction of solar radiations with semiconductors, photovoltaic effect, types of solar cell, equivalent circuit diagram of a solar cell, determination of series resistance (Rs) and shunt resistance (Rsh), ideal properties of semiconductor for use its solar cell, carrier generation and recombination, dark and illuminated characteristics of solar cell, solar cell output parameters: RL, Voc, Isc, Pm, FF, efficiency, performance dependence of a solar cell on band gap energy, diffusion length and carrier life time,

Advances in photovoltaics:

Types of heterojunction, construction of energy band diagram of heterojunctions, origin of capacitance in a heterojunction, expression for junction capacitance, Mott – Schottky relation,

Materials and Solar cell Technology

Single, poly – and amorphous silicon, GaAs, CdS, Cu2S, CuInSe2, CdTe etc. technologies for fabrication of single and polycrystalline silicon solar cells, amorphous silicon solar cells and tandem cells,

Unit 2: Photochemical Converters (15)

Semiconductor – electrolyte interface, photoelectrochemical solar cells, conversion efficiency in relation to material properties, photoelectrolysis cell, driving force of photoelectrolysis, semiconductor- septum storage cell

Unit-3: Fuel Cells (15)

Working principle of fuel cell, 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. Advantages and disadvantages of fuel cell, Power generation with fuel cells.

Unit 4: Thermoelectric Converters (15)

Thermoelectric effects, solid state description of thermoelectric effect, Kelvin’s thermodynamic relations, analysis of thermoelectric generators, basic assumptions, temperature distribution and thermal energy transfer for generator, co-efficient of performance for thermoelectric cooling.

Reference Books:

1. Solar energy conversion: The solar cell, by Richard C. Neville.
2. Photoelectrochemical solar cells – Suresh Chandra
3. Solar energy conversion – A. E. Dixon and J. D. Leslie.
4. Solar cells – Martin A.Green
5. Heterojunction and metal – semiconductor junctions – A.G. Milnes and D. L. Feucht.
6. Solid state electronic devices - B.G. Streetman.
7. Principles of solar engineering – Frank Kreith and Janf Kreider.
8. Direct energy conversion (4th edition) – Stanley W Angrist.
9. Handbook of Batteries and Fuel Cells- David Linden.

10. Fuel Cell Fundamentals, R. O’Hayre, S.-W. Cha, W. Colella, F. B. Prinz 2016, Wiley

Topics for tutorials:

1. Construction of energy band diagram- examples
2. Examples on photovoltaic converters
3. Maintenance of photovoltaic systems
4. Energy bands diagrams for photoelectrochemical and photoelectrolysis cells
5. Design of thermoelectric cooler
6. Solar energy storage in the form of chemical energy

M.SC-II, SEME. IV, PHYSICS (ENERGY STUDIES)
SCT - 4.2: ADVANCED ENERGY TECHNOLOGIES
Choice Based Credit System (CBCS)
(w. e. f. June 2022-23)

Unit I Environmental Impacts of Renewable Energy Sources (15)

Energy flow diagram to the earth, Carbon cycle, Ecological Niche, Green house effect. Energy Consumption in India, Environmental degradation due to conventional energy production and utilization: Asian Brown Cloud Effect, Environmental impacts of Biomass energy, solar energy systems, wind energy and ocean thermal energy. Power co-generation.

Unit II Hydrogen as clean source of Energy (15)

Sources of hydrogen, Thermodynamics of water splitting, Hydrogen production methods, Photoelectrolysis of water, Direct decomposition of water, Thermochemical production of hydrogen; Hydrogen storage methods: Conventional, Liquid Hydrogen storage, Metal Hydrides, and Cryo-adsorbing storage.

Unit III Fuel Cell Technology (15)

Comparison between fuel cells and batteries, working principle of fuel cell, 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. Advantages and disadvantages of fuel cell, Power generation with fuel cells.

Unit IV Batteries and Supercapacitors (15)

Energy storage systems, Faradaic and non-Faradaic processes, Types of capacitors and batteries, Comparison of capacitor and battery, Charge discharge cycles, experimental evaluation using Cyclic voltammetry, and other techniques, Energy and entropy stored by capacitor, Electrochemical behaviour of RuO2, IrO2, and mixed oxides, Energy density and power density, Applications for electric vehicle drive systems.

Reference Books

1) Biological paths to self reliance- Russell E. Anderson.
2) Encyclopaedia of Environmental Energy Resources- G.R. Chhatwal Vol. 1 & 2.
3) Renewable Energy Sources and their Environmental Impacts- S.A. Abbasi & N. Abbasi.
4) Electrochemical supercapacitors by B. E. Conway, Kluwer Academic Press.
5) Hydrogen as an Energy Carrier- T. Carl-Jochen Winter, Joachim Nitsch (eds.)
6) Advances in Renewable Energy Technologies- S.H. Pawar, and L. A. Ekal (eds.)
7) Handbook of Batteries and Fuel Cells- David Linden.

8) Fuel Cell Fundamentals, R. O'Hayre, S.-W. Cha, W. Colella, F. B. Prinz 2016, Wiley

Major Project