PUNYASHLOK AHILYADEVI HOLKAR SOLAPUR UNIVERSITY, SOLAPUR

NAAC Accredited-2022

'B++'Grade (CGPA2.96)

Name of the Faculty: Science & Technology

Syllabus: PHYSICS

(Materials Science)

Choice Based Credit System

As Per NEP-2020

Name of the Course: M.Sc. Part- II (SEM III and SEM IV)

(Syllabus to be implemented from w.e.f. June 2024)

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ ॥ विद्यया संपन्नता ॥ NAAC Accredited-2022 'B++' Grade (CGPA-2.96)	**Punyashlok Ahilyadevi Holkar Solapur University, Solapur** **Faculty of Science & Technology** **Choice Based Credit System Nep 2020** **Compliant Curriculum** **M.Sc. Physics** **(Materials Science)** **Program Preamble**

The Master of Science (M.Sc.) in Physics is a comprehensive and dynamic program designed to provide students with a deep understanding of the fundamental principles of physics and its applications in different scientific technologies, along with the practical skills. Aligned with the vision of the National Education Policy (NEP) 2020, the program offers a flexible, multidisciplinary, and learner-centric curriculum that encourages critical thinking, innovation, internship and skill development. The M.Sc. Physics program with Materials Science specializations, offers a progressively advanced curriculum designed to build a strong foundation in physics which allowing for interdisciplinary learning Material properties and characterization.

Materials Science is recent developments in Physics have been included in the M.Sc. Physics. Now a day it's need of Academic and Research Institutions and Industries. An important objective of the course is to develop an understanding of core physics at deeper levels, each stage revealing new phenomena and greater insight into phenomenon of materials synthesis, properties and analysis with advanced characterization techniques (SEM, TEM, FTIR, XRD…)

This course also aims to consolidate the skill and knowledge of physics by providing much more logical and analytical framework which will be essential for the Materials Science specialization course in the third and fourth semester. In advanced course number of recent topics broaden the perspective of the student to understand the fundamental principles, properties & behaviors of materials to appreciate the great flexibility, generality, analysis, interpretation and applications within areas like Nanomaterials. Biomaterials & advanced composites with use of advance Technology to study electric, magnetic, structural, sensing and capacitive properties, field project, major project, internship and skill development.

PUNYASHLOK AHILYADEVI HOLKAR SOLAPUR UNIVERSITY

Syllabus of M.Sc. Physics (Choice Based Credit System, As Per NEP-2020)

1) **Title of the course:** M.Sc. in Physics (Materials Science)
2) **Duration of the course**: Two years.
3) **Pattern:**CBCS-NEP-2020

A Four Semester M.Sc. Physics Course

Semester	No. of Papers/ Practical's	Marks	Credits
Semester I			
• Theory Papers	04	400	16
• Practical Papers	03	150	06
Semester II			
• Theory Papers	03	300	12
• Practical Papers	03	150	06
• On Job Training / Field Project	01	100	04
Semester III			
• Theory papers	03	300	12
• Practical Papers	03	150	06
• Research Project	01	100	04
Semester IV			
• Theory papers	03	300	12
• Practical Papers	02	100	04
• Research Project	01	150	06
Total marks and credits for M.Sc. Course		**2200**	**88**

Punyashlok Ahilyadevi Holkar Solapur University, Solapur
M.Sc. Physics Choice Based Credit System, As Per NEP-2020

Course Structure

M.Sc. Part-II Physics (Materials Science) w.e.f. 2024-25

M.Sc. Physics, Semester -III

Course/Paper Code	Title/Course	Semester Examination			L	P	Credits
		UA	CA/SA	Total			
DSC-5-2321301	Statistical Physics	60	40	100	4	--	4
DSC-6-2321302	Atomic and Molecular Physics	60	40	100	4	--	4
DSE-3A 2321306	Microcontroller and Interfacing	60	40	100	4	--	4
DSE-3B-2321307	Physics of Nanomaterials						
DSE-3C-2321308	Energy Harvesting Devices						
DSE-3D-2321309	Semiconductor Physics						
RP1-2321303	Research Project	60	40	100	4	--	4
Lab 7-2321304	Practical-7: (Based on DSC5)	30	20	50	--	2	2
Lab 8-2321305	Practical-8: (Based on DSC6)	30	20	50	--	2	2
Lab 9-DSE-3	Practical-9: (Based on DSE3)	30	20	50	--	2	2
Total for Semester-III		**330**	**220**	**550**	**16**	**6**	**22**

Note- Select any one course/paper from DSE(3A, 3B, 3C & 4D)

M.Sc. Physics, Semester -IV

Course/Paper Code	Title/Course	Semester Examination			L	P	Credits
		UA	CA/SA	Total			
DSC-7-2321401	Physics of Semiconductor Devices	60	40	100	4	--	4
DSC-8-2321402	Nuclear and Particle Physics	60	40	100	4	--	4
DSE-4A-2321405	Communication System	60	40	100	4	--	4
DSE-4B-2321406	Advanced Techniques of Materials Characterization						
DSE-4C- 2321407	Nanomaterials Characterization Techniques						
RP-2-2321403	Research Project	90	60	150	--	6	6
Lab 10-2321404	Practical-10: (Based on DSC7)	30	20	50	--	2	2
Lab 11-DSE-4	Practical-11: (Based on DSE4)	30	20	50	--	2	2
Total for Semester-IV		**330**	**220**	**550**	**12**	**10**	**22**

Note- Select any one course/paper from DSE(4A, 4B,& 4C)

DSC: Discipline Specific Course **DSE: Discipline Specific Elective**

RP: Research Project:

Evaluation Scheme:

Each theory paper/course (DSC/DSE) will have 100 marks out of which 60 marks will be for Term End examination(UE) and 40 marks for Internal Assessment (CA/SA). The candidate must appear for internal evaluation of 40 marks and external evaluation (University Examination) of 60 marks for each theory paper.

Each practical paper/course will have 50 marks out of which 30 marks will be for Term End examination and 20 marks for Internal Assessment. i.e (30 UA+20 CA/SA).

Internal Evaluation:

- In case of theory papers/course internal examinations will be conducted by department / school.
- In case of practical papers/course, 5 marks shall be for day-to-day journal and 15 marks shall be for internal practical exam, which will be conducted by the department / school.

Research Project: It will start from III semester (4 Credit- 60UA + 40CA/SA) and it is continued for IV semester (6 Credit- 90UA + 60CA/SA).

External Evaluation (End of Term University Examination):

I) Nature of Theory question paper:

1) Each Theory paper/course (DSC/DSE) is of 60 marks of 2 hours duration

II) Nature of Practical question paper: (End of Term Examination)

Sem-III and IV: Practical examination (Performing of Experiments) will be conducted for 30 marks and is of two hours duration.

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	Punyashlok Ahilyadevi Holkar Solapur University, Solapur **M. Sc. -II, SEM- III, PHYSICS** **(Materials Science)** **As per NEP 2020** **(w. e. f. June 2024-2025) Vertical: DSC** **Vertical: DSC** **Course Code: 2321301** **Course Name: DSC-5: STATISTICAL PHYSICS**

***Teaching Scheme** **Lectures:04 Hours/week, 04 Credits**	***Examination Scheme** **UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: This course is designated to study the basic concepts in statistical mechanics. Statistical mechanics used for different methods of probability to extend the mechanics to many-body systems to make statistical predications about their collective behavior. It also acts as bridge between thermodynamics and mechanics of constituent particles. Statistical mechanics of ideal gas systems provide basic functioning of the formalisms of statistical mechanics.

Course Objectives:

During this course, the student is expected to understand:

Statistical Mechanics is one of the fundamental mechanics. The aim of statistical mechanics is the evaluation of the laws of classical thermodynamics for macroscopic systems using the properties of its atomic particles.

In addition to the classical TD the statistical approach provides information on the nature of statistical errors and variations of thermodynamic parameters.

Course Outcomes:

At the end of this course, students will be able to learn:

This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, Gibbs paradox, and phase space, statistical interpretation of thermodynamics, micro canonical, canonical and grant canonical ensembles; the methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and

photon gases; selected topics from low temperature physics .Energy fluctuation, Entropy fluctuations, Einstein theory of Brownian motion, Langiviens theory of Brownian motion and fluctuation-dissipation theorem. Phase transition theories, critical indices and their evaluation.

Unit I: Statistical Thermodynamics:	**No. of lectures-20**	**Weightage: 20-27Marks**
Thermodynamic systems and equilibria, Laws of thermodynamics and their consequences, Nernst heat theorem, Microstates and microstates, Postulate of equal priori probability, Probability calculations, Thermodynamic potentials and Maxwell's relations, Chemical potential, phase equilibria, Black Body radiation and planks distribution, Phase equilibria, Free energy and its connection with thermodynamic quantities, entropy of mixing and Gibbs and paradox.		
Unit-II: Classical statistical mechanics:	**No. of lectures-15**	**Weightage: 15 -20 Marks**
Statistical ensembles, Microcanonical ensemble- system in contact with heat revisor, Condition for thermal equilibrium, canonical ensemble – molecular ideal gas and grand canonical ensemble, Liouville's theorem, Ensembles, Maxwell Boltzmann distribution, classical ideal gas		
Unit-III: Quantum Statistical Mechanics	**No. of lectures-15**	**Weightage: 15 -20Marks**
Phase space (Diagram of an oscillator), Maxwell- Boltzmann statistics, Fermi-Dirac statistics and Bose- Einstein statistics, Liouville's theorem, Ideal Bose gas, Ideal Fermi gas-weekly and strongly degerate, Bose- Einstein condensation.		
Unit-IV: Phase transitions and critical phenomena	**No. of lectures-10**	**Weightage: 10 -13 Marks**
Phase transition, Triple Point, Condition for phase equilibrium, First order phase transition, Ehrenfests equations, Clausius- Clayperon equation, Second latent heat equation, Examples, Second order phase transition, Critical indices, The law of corresponding states.		
Above Unit Weightage is given for 60% marks of UA assessment only. There could be variation of 10-15% in the Unit wise weightage distribution.		

Reference Books	
1.	Introduction to Statistical Mechanics by B.B.Laud
2.	Statistical Mechanics by S.K.Sinha
3.	Statistical Mechanics by I.D. Landau &F.M.Lifshitz
4.	Text Book of statistical mechanics. Suresh Chandra, CBS Publications
5.	Elementary Statistical Mechanics Gupta, Kumar, PragatiPrakashan.

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

M. Sc. -II, SEM- III, PHYSICS

(Materials Science)

As per NEP 2020

(w. e. f. June 2024-2025)

Vertical: DSC

Course Code:2321302

Course Name:DSC-6: Atomic and Molecular Physics

***Teaching Scheme**	***Examination Scheme**
Lectures:04 Hours/week, 04 Credits	**UA: 60 Marks** **CA/SA: 40 Marks**

Course Preamble: This course is introducing the basic ideas of atomic and molecular physics. It teaches students how to apply quantum mechanics and extract information from many-electrons atoms and molecules. Introduction to microwave, infra-red and Raman spectroscopy, NMR and ESR, Symmetry and Spectroscopy is also provided.

Course Objectives:

During this course, the student is expected to understand:

1.To describe the atomic spectra of one and two valance electron atoms.

2.To explain the change in behavior of atoms in external applied electric and magnetic field.
3.To explain rotational, vibrational, electronic and Raman spectra of molecules.
4.To describe electron spin and nuclear magnetic resonance spectroscopy and their applications.
Course Outcomes: At the end of this course, students will be able to learn:
1. Understand the atomic spectra with alkali metals.
2. Understand the selection rules and intensity rules.
3. Understand the anomalous Zeeman effect, Paschen Back effect, stark effect with solving their problems.
4. Understandthe characteristics properties of Raman lines and classical theory of Raman effect.

Unit-I: Atomic Spectra:	**No. of lectures-15**	**Weightage:15 -20Marks**
Quantum states of an electron in an atom, electron spin, spectrum of helium and alkali atom. Relativistic corrections for energy levels of hydrogen atom, ll-coupling, ss-coupling, LS or Russell - Saunder's coupling; the Pauli exclusion principle, Coupling schemes for two electrons, Γ- factors for LS coupling, Lande interval rule, jj-coupling, branching rules, selection rules, Intensity relations.		
Unit-II: Effect of magnetic and electric field on atomic spectra :	**No. of lectures-15**	**Weightage:15-20 Marks**
The magnetic moment of the atom, Zeeman effect for two-electrons, Intensity rules for Zeeman effect, Paschen-Back effect for two electrons, Stark effect of hydrogen, weak field Stark effect in hydrogen, strong field Stark effect in hydrogen, origin of hyperfine structure, Inner shell vacancy, X- ray and Auger transitions, Compton effect.		
Unit-III: Molecular spectra	**No. of lectures-15**	**Weightage:15-20 Marks**
Molecular physics – covalent, ionic and Vander Waal's interaction, Classification of molecules: linear, symmetric tops, spherical tops, asymmetric tops; rotational spectra: the rigid diatomic molecule, the non-rigid rotator, spectrum of a non-rigid rotator, techniques and instrumentation of microwave spectroscopy, chemical analysis by microwave spectroscopy, the vibrating diatomic molecule: the energy of a diatomic molecule, the simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating-rotator, vibrational rotational spectra, techniques and instrumentation of infra-red spectroscopy,		

chemical analysis by infra-red spectroscopy.		
Unit-IV: Electronic, Nuclear and Raman spectra	**No. of lectures-15**	**Weightage:15-20 Marks**
Revision on electronic spectra of diatomic molecules, electron spins resonance, nuclear magnetic resonance, chemical shift. Frank-Condon principle, dissociation energy and dissociation products, rotational fine structure of electronic-vibration, transitions. Born-Oppenheimer approximation, separation of electronic and nuclear motions in molecules, band structures of molecular spectra. Raman spectra: Pure rotational Raman spectra, vibrational Raman spectra, polarization of light and Raman effect, techniques, and instrumentation of Raman spectroscopy.		

1	Introduction to Atomic Spectra – H.E. White, McGraw Hill (1934).
2	Fundamentals of Molecular Spectroscopy, 4th Edition. – C.N. Banwell, Tata McGraw Hill (2008).
3	Molecular Structure and Spectroscopy, G. Aruldhas, PHI Learning Pvt. Ltd. Spectra of diatomic Molecules, Vol. I – G. Herzberg, N.J.D. van Nostrand (1950).
4	Spectroscopy, Vol. I, II and III – B.P. Straughan and S. Walker, Chapman, and Hall (1976).
5	Introduction to Molecular Spectroscopy – G.M. Barrow, McGraw Hill (1962).
6	Molecular Spectroscopy – J.M. Brown, Oxford University Press (1998).

	Punyashlok Ahilyadevi Holkar Solapur University, Solapur **M. Sc. -II, SEM- III, PHYSICS** **(Materials Science)** **As per NEP 2020** **(w. e. f. June 2024-2025)** **Vertical: DSE** **Course Code: 2321306** **Course Name:DSE-3A: Microcontroller and Interfacing**

***Teaching Scheme**	***Examination Scheme**
Lectures:04 Hours/week, 04 Credits	**UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: This course introduces the basics of microcontroller and its features. It teaches students to write the Assembly Language Programming and Embedded C programming for microcontroller 8051. It help to understand the hardware and software part of interfacing devices.

Course Objectives: During this course, the student is expected to understand:
1.To explain the microcontroller 8051 architecture and its features.
2.To explain the instructions and assembly language programming of 8051 microcontroller.
3.To use the C language programming for 8051 microcontroller.
4.To use the C language programming for interfacing of 8051 microcontroller.
Course Outcomes: At the end of this course, students will be able to learn:
1. Understand the internal blocks and its function of 8051 microcontroller.

2. Understand the instructions and their uses in ALP.
3. Understand the embedded C programming for 8051 controller to solve problems.
4. Understand the embedded C programming for 8051 controller to solve interfacing problems..

Unit-I: 8051 Architecture and Hardware	**No. of lectures-15**	**Weightage:15-20 Marks**
Introduction, 8051 microcontroller family, Pin configuration, Architecture, Program status word, Internal registers of 8051, Memory organization, Programming model of 8051, Special function registers (SFR's), Input /Output ports, Timers/counters, Interrupts and Serial Communication.		
Unit-II: Instruction Set and Assembly Language Programming of 8051	**No. of lectures-15**	**Weightage:15-20 Marks**
Instruction set: data transfer instructions, arithmetic instructions, logical instructions, program control instructions, stacks operations, data pointer instructions, addressing modes. Assembly Language Programming: Port programming, timer /counter, interrupts, serial communication programming, induction to Keil integrated development environment (IDE)		
Unit-III: Embedded C programming for 8051	**No. of lectures-15**	**Weightage:15-20 Marks**
Embedded C general program structure, data types in embedded C, I/O programming, arithmetic and logical operations in embedded C, loops and decision programming (While, for, if else, and case structure), data serialization, data conversation in embedded C.		
Unit-IV: Interfacing and Programming with Hardware (With Assembly and C)	**No. of lectures-15**	**Weightage:15-20 Marks**
LED, seven segment, switch, relay, DC Motor, Stepper motor, servo motor, LCD, ADC0804, LM35, DAC 0808 (square wave, triangular wave, saw tooth wave and Sin wave generation), serial communication and interrupts programming		

Reference Books

1	The 8051 microcontroller and embedded systems using assembly and C by Muhammad Ali Mazidi, Janice GillispieMazidi, RolinD.McKinlayPerson publication
2	The 8051 Microcontroller by Kenneth Ayala Cengage Learning publication
3	Programming And Customizing The 8051 Microcontroller MykePredko , Publication
4	8051 Microcontrollers: an Applications Based Introduction by David Calcutt, Frederick Cowan, and G. Hassan Parchizadeh, publication Elsevier Science
5	8051 Microcontroller-Internals,Instructions,Programming& Interfacing by SubrataGhoshal Person publication.

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ ।। विद्यया संपन्नता ।। NAAC Accredited-2022 'B++' Grade (CGPA-2.96)	**Punyashlok Ahilyadevi Holkar Solapur University, Solapur** **M. Sc. -II, SEM- III, PHYSICS** **(Materials Science)** **As per NEP 2020** **(w. e. f. June 2024-2025)** **Vertical: DSE** **Course Code: 2321307** **Course Name:DSE 3B-PHYSICS OF NANO MATERIALS**
***Teaching Scheme** **Lectures:04 Hours/week, 04 Credits**	***Examination Scheme** **UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: The course is designed to understand low dimensional structure of materials and different types of nanomaterials. It is helpful to study the various synthesis

methods of nanomaterials and their types. It is also useful to understand the different structural, optical and electrical properties of nanomaterials

Course Objectives: During this course, the student is expected to understand:
1. This course is the cornerstone class of the new emphasis in Nanoscience and Nanotechnology within the Materials Science and Engineering major.
2. This course also covers the different classes of nanomaterials that have been developed in recent years in light of various technological applications.
3. 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.
Course Outcomes: At the end of this course, students will be able to learn:
1. 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.
2. Students will gain an ability to critically evaluate the promise of a nanotechnology devices.
3. Students should apply the fundamental scientific principles that form the basis of behavior of nanomaterials and their electronic, magnetic, optical and mechanical properties.
4. These concepts will provide them with skills for engineering practice, particularly those associated with materials selection and engineering analysis.

Unit-I: Low Dimensional Structures:	**No. of lectures-13**	**Weightage:13-18 Marks**
Quantum nanostructures - size and dimensionality effects - size effects - potential wells - partial confinement - conduction electrons and dimensionality - Fermi gas and density of states - properties dependent on density of states - excitons – applications: infrared detectors, quantum dot lasers, Microelectromechanical Systems - Nanoelectromechanical Systems –Fabrication of nanodevices and nanomachines - Molecular and Supramolecular Switches.		

Unit-II: Carbon Nanostructures:	No. of lectures-13	Weightage:13-18 Marks
Carbon Structures - Small Carbon Clusters - Structure of Carbon Nanotubes- Structure of Single-Walled and Multiwalled Carbon Nanotubes; Spectroscopic Properties of Carbon Nanotubes- Raman and Infrared Spectroscopy of Carbon Nanotubes, Absorption and Emission Spectroscopy of Carbon Nanotubes, ESR-Spectroscopic Properties of Carbon Nanotubes.		
Unit-III: Synthesis of Nano materials:	**No. of lectures-10**	**Weightage:10-12 Marks**
Top-down techniques, Bottom-up techniques, Pattern replication techniques, Pattern transfer and enhancement techniques.		
Unit-IV: Preparation and Types of Nanomaterials:	**No. of lectures-11**	**Weightage:11-15 Marks**
Physical- chemical and mechanical methods of preparation – Top-down approach: Sputtering processes – Pulsed laser deposition – Rapid solidification –Physical Vapor Deposition. Bottom-up approaches: Polyol route– Colloidal precipitation.Wet chemical methods – ball milling- Nanostructure through Lithography		
Unit-V: Properties of Nanomaterials	**No. of lectures-13**	**Weightage:13-18 Marks**
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.		

Reference Books	
1	Introduction to Nanoscience and Nanotechnology:K.K. Chattopadhyay an 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

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ ॥ विद्यया संपन्नता ॥ NAAC Accredited-2022 'B++' Grade (CGPA-2.96)	**Punyashlok Ahilyadevi Holkar Solapur University, Solapur** **M. Sc. -II, SEM- III, PHYSICS** **(Materials Science)** **As per NEP 2020** **(w. e. f. June 2024-2025)** **Vertical: DSE** **Course Code: 2321308** **Course Name: DSE 3C-ENERGY HARVESTING DEVICES**
***Teaching Scheme** **Lectures:04 Hours/week, 04 Credits**	***Examination Scheme** **UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: This course is introducing the principles of energy harvesting technologies, their mechanisms, designs, applications, current commercial products, and future development. The course deals with introduction of unique ways of the energy generating from surroundings. Currently remote electronics, autonomous low power devices and wireless sensors are powered by batteries.

Course Objectives: During this course, the student is expected to understand:
1.Understand a systematic approach to analyzing energy harvesting problems. Study the

techniques to design of energy harvesting devices.
2.To study the construction working and characterizations of various energy harvesting devices including Solar cells, Super capacitors, Fuel Cells and piezoelectric devices.
3.Specify capabilities and limitations of energy harvesting for a given energy device and a target applications.
Course Outcomes: At the end of this course, students will be able to learn:
1.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.
2.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.
3.All these studies will be useful for the project and their research

Unit-I: Solar Cells	**No. of lectures-15**	**Weightage:15-20 Marks**
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-II: Super Capacitors	**No. of lectures-15**	**Weightage:15-20 Marks**
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-III: Fuel Cells	**No. of lectures-15**	**Weightage:15-20 Marks**
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-IV: Piezoelectrics	**No. of lectures-15**	**Weightage:15-20 Marks**
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 Fibers, 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 ClaudyRayanSerrao, 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

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ ॥ विद्यया संपन्नता ॥ NAAC Accredited-2022 'B++' Grade (CGPA-2.96)	**Punyashlok Ahilyadevi Holkar Solapur University, Solapur** **M. Sc. -II, SEM- III, PHYSICS** **(Solid State Physics)** **As per NEP 2020** **(w. e. f. June 2024-2025)** **Vertical: DSE** **Course Code: 2321309** **Course Name:DSE- 3D-SEMICONDUCTOR PHYSICS**

***Teaching Scheme** **Lectures:04 Hours/week, 04 Credits**	***Examination Scheme** **UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: Semiconductor Physics provides students with an in-depth understanding of the fundamental principles governing semiconductors, their crystal structures, electronic properties, and practical applications. The course focuses on the solid-state physics of semiconductors, from the growth of semiconductor crystals to the intricacies of semiconductor junctions and interfaces. Students will explore theoretical models, quantum mechanical principles, and the fabrication techniques that drive modern semiconductor devices. As the field of semiconductor physics plays a pivotal role in technology and innovation, this course is designed to prepare students for advanced research and industrial applications.

Course Objectives:

During this course, the student is expected to understand:

1. To introduce the fundamental properties of semiconductors – understanding their crystal structures, growth methods, and doping processes.
2. To provide a foundation in quantum mechanics and its application to semiconductor materials – exploring physical models like the Bohr model, Schrödinger wave equation, and concepts such as the photoelectric effect.

3. To study the fabrication and functioning of semiconductor junctions – understanding the principles of p-n junction formation, carrier injection, and breakdown mechanisms.
4. To delve into the operation and characteristics of semiconductor interfaces – examining metal-semiconductor junctions, heterojunctions, and their implications in device performance.
5. To develop practical knowledge related to semiconductor technology – preparing students for careers in research, development, and applications of semiconductors in fields such as electronics, photovoltaics, and telecommunications.
Course Outcomes: At the end of this course, students will be able to learn:
1. Have a thorough understanding of the crystal properties of semiconductors – including bulk crystal growth and epitaxial techniques used in semiconductor manufacturing.
2. Be able to apply quantum mechanical principles – to explain the behaviour of electrons in atoms and the formation of energy bands in semiconductors.
3. Gain proficiency in the fabrication and analysis of p-n junctions – understanding the conditions that influence current flow, breakdown mechanisms, and their use in diodes and rectifiers.
4. Comprehend the complexities of semiconductor interfaces – including the effects of stored charge, capacitance, and recombination processes in device operation.
5. Be equipped with the knowledge to pursue research or careers in the semiconductor industry – applying theoretical and practical skills to the development of new semiconductor materials and devices.

Unit-I: Crystal Properties and Growth of Semiconductors	**No. of lectures-15**	**Weightage:15-20 Marks**
Materials; Crystal Lattices- Periodic Structures, Cubic Lattices, Planes and Directions, The Diamond Lattice; Bulk Crystal Growth- Starting Materials, Growth of Single-Crystal Ingots, Wafers, Doping; Epitaxial Growth- Lattice-Matching in Epitaxial Growth, Vapor-Phase Epitaxy, Molecular Beam Epitaxy.		

Unit-II: Atoms and Electrons	No. of lectures-15	Weightage:15-20 Marks
Introduction to Physical Models; Experimental Observations- The Photoelectric Effect, Atomic Spectra; The Bohr Model- Quantum Mechanics; Probability and the Uncertainty Principle; The Schrodinger Wave Equation; Potential Well Problem, Tunneling; Atomic Structure and the Periodic Table- The Hydrogen Atom, The Periodic Table.		
Unit-III: Semiconductor Junctions	**No. of lectures-15**	**Weightage:15-20 Marks**
Fabrication of p-n Junctions- Thermal Oxidation, Diffusion, Rapid Thermal Processing, Ion Implantation, Chemical Vapor Deposition (CVD), Photolithography, Etching, Metallization; Equilibrium Conditions, The Contact Potential, Equilibrium Fermi Levels, Space Charge at a Junction; Forward- and Reverse-Biased Junctions; Steady State Conditions- Qualitative Description of Current Flow at a Junction, Carrier Injection, Reverse Bias; Reverse-Bias Breakdown- Zener Breakdown, Avalanche Breakdown, Rectifiers, The Breakdown Diode;		
Unit-IV:Semiconductor Interfaces	**No. of lectures-15**	**Weightage:15-20 Marks**
Transient and A-C Conditions, Time Variation of Stored Charge, Reverse Recovery Transient, Switching Diodes, Capacitance of p-n junctions, The Varactor Diode; Deviations from the Simple Theory- Effects of Contact Potential on Carrier Injection, Recombination and Generation in the Transition Region, Ohmic Losses, Graded Junctions; Metal-Semiconductor Junctions- Schottky Barriers, Rectifying Contacts, Ohmic Contacts, Typical Schottky Barriers; Heterojunctions.		

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
(Materials Science)
Vertical: DSC 5 and 6 practical (Lab 7 and 8)

***Teaching Scheme** **Practical:02Hours/week, 01Credit** **Course Code: 2321304**	***Examination Scheme** **UA:30 Marks** **CA/SA: 20 Marks**
***Teaching Scheme** **Practical:02Hours/week, 01Credit** **Course Code: 2321305**	***Examination Scheme** **UA:30 Marks** **CA/SA: 20 Marks**

Practical 7, 8 (DSC 5 and DSC 6)

1. Twin T Networks.
2. Butter worth low pass filter using IC- 741
3. Variable Duty cycle MV using Op. amp. (IC- 741)
4. Constant current source (Floating load) Using Op-Amp.
5. Constant current source (Grounded load). Using Op-Amp
6. Measurement of self-inductance of a coil
7. Op-Amp Parameters (Slew rate, power band width, CMMR) .
8. Voltage regulator using IC 723.
9. Constant Voltage Source with Fold back Current Limit.
10. Constant Voltage Source (Precision Voltage Regulator) with Constant Current Limit.
11. Measurement of capacitance
12. AC Bridges (Maxwell, DeSauty, Maxwell-Wein)

M.Sc.-II, SEM- III, PHYSICS
(Materials Science)
Vertical: DSE 3A practical (Lab 9)

***Teaching Scheme**	***Examination Scheme**
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321310	**CA/SA: 20 Marks**

Practical- 9 (DSE 3A)

1. Digital Multiplexer Demultiplexer.
2. Microcontroller – I Port Programming -I
3. Microcontroller – II Port Programming -II
4. Microcontroller –III-DC motor interface with µc-8051.
5. Microcontroller – IV-Servo motor interface with µc-8051.
6. Microcontroller – V-Study the serial communication of µc-8051
7. Microcontroller – VI- Stepper motor interface with µc-8051.
8. Microcontroller – VII- Relay interface with µc-8051.
9. Microcontroller – VII- ADC interface with µc-8051.
10. Op-Amp application (Design of differentiator and integrator for sine wave at 1 KHz)

M.Sc.-II, SEM- III, PHYSICS (Material Science)
Vertical: DSE 3B, 3C practical (Lab 9)

***Teaching Scheme**	***Examination Scheme**
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321311	**CA/SA: 20 Marks**
***Teaching Scheme**	***Examination Scheme**
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321312	**CA/SA: 20 Marks**

Practical- 9 (DSE 3B and 3C)

1) Susceptibility measurement of $FeCl_3 6H_2O$ solution.
2) Thin film by Successive Ionic Layer Adsorption and Reaction (SILAR).
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) Auto combustion synthesis of $CoFe_2O_4$.

M.Sc.-II, SEM- III, PHYSICS
(Materials Science)
Vertical: DSE 3D practical (Lab 9)

***Teaching Scheme**	***Examination Scheme**
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321313	**CA/SA: 20 Marks**

Practical- 9 (DSE 3D)

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. Growth of single crystal
7. Laue diffraction analysis
8. Thin film deposition by Thermal evaporation
9. Study of material data sheet
10. Passive filters

M.Sc.-II, SEM- III, PHYSICS
(Materials Science)
Research Project (RP-1)

***Teaching Scheme**	***Examination Scheme**
RP-1:04Hours/week, 04Credit	**UA:60Marks**
Course Code: 2321303	**CA/SA: 40 Marks**

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ ॥ विद्यया संपन्नता ॥ NAAC Accredited-2022 'B++' Grade (CGPA-2.96)	**Punyashlok Ahilyadevi Holkar Solapur University, Solapur** **M. Sc. -II, SEM- IV, PHYSICS** **(Materials Science)** **As per NEP 2020** **(w. e. f. June 2024-2025)** **Vertical: DSC** **Course Code:2321401** **Course Name:DSC-7 - Physics of Semiconductor Devices**

***Teaching Scheme** **Lectures:04 Hours/week, 04 Credits**	***Examination Scheme** **UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: This course is designed for students to learn & understand the band structure of semiconductor. The physical properties of semiconductor & apply them in various applications. This course build the knowledge base of the physics of semiconductors as related to the characteristics and design of solid-state opto-electronic devices.

Course Objectives: During this course, the student is expected to understand:
1.To understand fundamentals band theory of semiconductors
2.To understand Excess Carriers in Semiconductors and their properties.
3. To understand fundamentals metal- semiconductors interface
4.To understand power semiconductorsdevices.
Course Outcomes: At the end of this course, students will be able to learn:
1.Students will come to know fundamentals of semiconductors band theory and behavior of electrons in conduction band.
2.Students will know the interaction between photons and semiconductors materials
3.Students will understand the band relation at metal-semiconductor contact.
4.Students will understand the characteristics of power, optoelectronic and advanced-semiconductors devices

<table>
<tr><td>Unit-I: Energy Bands and Charge Carriers in Semiconductors</td><td>No. of lectures-15</td><td>Weightage:15-20 Marks</td></tr>
<tr><td colspan="3">Direct and Indirect semiconductors, variation of energy bands with alloy composition, Charge carriers in semiconductors: electrons and holes, effective mass, intrinsic and extrinsic materials, electrons and holes in quantum wells, The Fermi level, carrier concentration at equilibrium, temperature dependence, space charge neutrality, conductivity and mobility, Drift and resistance, effects of temperature and doping on mobility, the Hall effect.</td></tr>
<tr><td>Unit-II: Excess Carriers in Semiconductors</td><td>No. of lectures-15</td><td>Weightage:15-20 Marks</td></tr>
<tr><td colspan="3">Optical absorption, Luminescence: photoluminescence and electroluminescence, Direct recombination of electrons and holes, Indirect recombination and trapping, steady state carrier generation and Quasi Fermi levels, Diffusion processes, Diffusion and Drift of carriers, built-in fields, The continuity equation, steady state carrier injection, diffusion length</td></tr>
<tr><td>Unit-III: Metal & Metal Insulator Semiconductor Devices</td><td>No. of lectures-15</td><td>Weightage:15-20 Marks</td></tr>
<tr><td colspan="3">Schottky effect, Energy Band relation at metal semiconductor contact, Ideal condition and surface states depletion Layer, General expression for barrier height Current Transport Theory in Schottky barrier, Thermionic Emission Theory, Diffusion theory. Measurement of Schottky barrier height, current voltage measurement, Forward characteristics. Reverse characteristics, Ideal MIS diode, surface states, surface charges and space charges, Effects of metal work function. Transfer electron effect, Gunn diode</td></tr>
<tr><td>Unit-IV: Power, Optoelectronic and Advanced Solid-State Devices</td><td>No. of lectures-15</td><td>Weightage:15-20 Marks</td></tr>
<tr><td colspan="3">Power devices: Power diode, Reverse recovery characteristics,SCR-Construction, two transistor model, I-V Characteristics, Turn ON-OFF methods, Thyristors types, Construction working and characteristics of DIACs, TRIACs, Programable UJT, LASCR-C</td></tr>
</table>

Optoelectronic and Advanced Solid-State Devices:

Principle, working and characteristics of LED, LASER, Photoconductor, Photodiode and Solar Cells.

Reference Books	
1	Physics of Semiconductor Devices – S.M. Sze
2	Physics Solid State Devices – Streetman B.G.
3	Semiconductor Physics – Smith
4	Fundamentals of Semiconductor Devices – J. Lindmayer and C.Y. Wrigley
5	Physics of Semiconductor Devices – Michael shur
6	Introduction to Semiconductor Devices – K.J.M. Rao

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ
॥ विद्यया संपन्नता ॥
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Punyashlok Ahilyadevi Holkar Solapur University, Solapur

M. Sc. -II, SEM- IV, PHYSICS

(Materials Science)

As per NEP 2020

(w. e. f. June 2024-2025)

Vertical: DSC

Course Code: 2321402

Course Name:DSC-8–Nuclear and Particle Physics

***Teaching Scheme**	***Examination Scheme**
Lectures:04 Hours/week, 04 Credits	**UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: This course was designed for students to learn & understand the principles & concepts governing nuclear & particle physics & the scientific & technological applications of nuclear physics, concepts of elementary particles.

Course Objectives: During this course, the student is expected to understand:
1.One of the main objectives of the study of nuclear physics is the understanding of the ‘Structure of Nuclei.
2.This includes all aspects of the motion of the nucleons, their paths inspace, their momenta, the correlations between them, the energies binding them to each other.
3.Understand most basic property of a nucleus is its binding energy.
4.This brought about by the specific nuclear forces, counteracted partially by the interaction of different types of neutron and proton scattering.
5.To understand nature of nuclear forces
Course Outcomes: At the end of this course, students will be able to learn:
1.Students will understand the nuclear structure and properties with nuclear reactions.
2. Students will understand the nuclear energy level and theory of elementary particles.
3. Students will understand the various nuclear models and nuclear reactions.
4. Students will understand the particle physics and cosmic rays.

Unit-I: Unit I. Properties of Nucleus & Nuclear Forces:	**No. of lectures-15**	**Weightage:15-20 Marks**
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-II: Nuclear models:	**No. of lectures-15**	**Weightage:15-20 Marks**
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-III: Nuclear reactions:	No. of lectures-15	Weightage:15-20 Marks
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-IV: Particle Physics & Cosmic rays:	**No. of lectures-15**	**Weightage:15-20 Marks**
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.		

Reference 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)

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

M. Sc. -II, SEM- IV, PHYSICS

(Materials Science)

As per NEP 2020

(w. e. f. June 2024-2025)

Vertical: DSE

Course Code: 2321405

Course Name:DSE-4A: COMMUNICATION SYSTEMS

***Teaching Scheme**	***Examination Scheme**
Lectures:04 Hours/week, 04 Credits	**UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: The course is designed to understand the concept of AM & FM transmitter & receiver and their types. It also helps to understand the Digital modulation and demodulation technique along with different multiplexing techniques.

Course Objectives:

During this course, the student is expected to understand:

Communication is an inseparable part of modern life. The use of analog communication in detail with block diagram, detail circuits and introduction to digital communication are highlights of this course. The syllabus designed in this paper is useful to science student to understand the application of Electronics Communication.

Course Outcomes:

At the end of this course, students will be able to learn:

The Student will be aware of analog and digital communication systems after pursuing this course. Student will able to understand applications of communication system.

Unit-I: A.M. Transmitters	No. of lectures-15	Weightage:15-20 Marks
Block diagram of High and Low level modulated A.M. Transmitters. The exciter, Class A, Class B, Class C modulated power amplifier circuits of sidebands and sideband transmission, Balanced modulators. Block diagram of A.M. receiver and A.M. Detector, (circuits to be discussed), Class B audio amplifier.		
Unit-II: F.M. Transmitters and Receivers	**No. of lectures-15**	**Weightage:15-20 Marks**
F.M. radio frequency band, Block diagram of F.M. transmitter, block diagram of VCO, frequency doubler, tripler. Block diagram of F.M. receiver, F.M. detector (Slope and dual slope detector), PLL as FM detector. (Circuits to be discussed)		
Unit-III: Digital Modulation and Techniques	**No. of lectures-15**	**Weightage:15-20 Marks**
Pulse: Modulation systems: Sampling theorem, low pass and band pass signals (PAM, PWM, PPM, Amplitude shift keying, Frequency shift keying, Phase shift keying, Differential phase shift keying. Quantization of signals, Delta modulation (Basic introduction).Modulation and Demodulation Circuits, TDM, FDM, Cross talk in TDM , Pulse time modulation , Generation of PTM , Demodulation of PTM , Transponder, TDMA, PDMA, CDMA		
Unit-IV: Multiplexing & Multiple Access Techniques	**No. of lectures-15**	**Weightage:15-20 Marks**
Unipolar, Bipolar, RZ, NRZ, Transmission modes, Simplex, Half duplex, full duplex, Asynchronous transmission.		

Text Books	
1	Communication System, Analog and Digital R.P. Singh and S.D. Sapre (THM)
2	Electronic Telecommunication System (4th Edition) George Kennedy and

	Bernard Devise (MGH)
Reference Books	
1	Digital and analog communication system – Sam Shanmugam, Wiley Student Edition, 2008 reprint.
2	Data communication – William Schweber, McGraw-Hill, 1988
3	Digital communication – Simon Haykin, Wiley, 1988.
4	Digital communication fundamentals and applications - Sklar, 2nd edition, Prentice Hall, 2001.
5	Electronics communication systems – Fundamentals to advanced: wayneTomasi, Pearson Education, 5th edition, 2009.
6	Wireless communications and networking – Vijay K Garg, Elseiver, 2007.

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

M. Sc. -II, SEM- IV, PHYSICS

(Materials Science)

As per NEP 2020

(w. e. f. June 2024-2025)

Vertical: DSE

Course Code: 2321406

Course Name:DSE-4B–ADVANCED TECHNIQUES OF MATERIALS CHARACTERIZATION

***Teaching Scheme**	***Examination Scheme**
Lectures:04 Hours/week, 04 Credits	**UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: Advanced Techniques of Materials Characterization to Physics students offer an integrated understanding of modern material analysis techniques. This course aims to introduce advanced microscopy and spectroscopy methods used in material science for analysis and characterization of materials at the micro and nano scale. Given the interdisciplinary relevance of these techniques in fields like Applied Electronics, Materials Science, Energy Studies, and Solid-State Physics, the course ensures that students are equipped with both theoretical knowledge and practical skills. This course is designed to meet the evolving needs of industry and research.

Course Objectives: During this course, the student is expected to understand:
1. To understand the working principles of various optical and electron microscopy techniques and their application in material characterization.
2. To explore the advanced capabilities of scanning probe microscopy, focusing on STM and AFM, and their roles in surface analysis.
3. To provide detailed knowledge on X-ray photoelectron spectroscopy (XPS) and its utility in surface analysis and material composition studies.
4. To offer an in-depth understanding of vibrational spectroscopy, including Raman and FTIR techniques, for identifying molecular structures and bonds in materials.
5. To ensure students can practically apply these advanced techniques for material research and industrial applications.
Course Outcomes: At the end of this course, students will be able to learn:
1. Microscopy Knowledge: Students will gain a clear understanding of the physical principles behind optical and electron microscopy, including the limitations and applications of each method in material science.
2. Understanding of SEM and TEM: Students will become proficient in Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM), understanding image formation, electron interactions with materials, and sample preparation techniques.
3. Expertise in Scanning Probe Microscopy: Students will develop expertise in Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM) for high-resolution imaging and surface analysis.
4. Surface Analysis Competency: Students will be able to perform surface characterization using XPS, with a thorough understanding of its instrumentation, vacuum requirements, and data interpretation.

5. Vibrational Spectroscopy Skills: Students will become skilled in interpreting Raman and FTIR spectra for material identification, learning to analyze molecular vibrations and rotations for various applications in materials science.
6. Application of Knowledge: By the end of the course, students will be able to select and apply the appropriate technique for a given material analysis task, contributing to research in fields like nanotechnology, electronics, and energy materials.

Unit-I: Microscopic Techniques:	**No. of lectures-10**	**Weightage:10-13 Marks**
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	**No. of lectures-20**	**Weightage:20-27 Marks**
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: -Ray Photoelectron Spectroscopy	**No. of lectures-15**	**Weightage:15-20 Marks**
Definition of surface, Different Probes for Surface-characterization. Necessity of Ultra High Vacuum, Photoelectron, 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 FTIR Spectroscopy:	**No. of lectures-15**	**Weightage:15-20 Marks**
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. **FTIR Spectroscopy:**Basic principle, instrumentation configuration date interpretation and analysis, and special techniques such as Attenuated Total Reflection (ATR).		

. Reference Books	
1	Handbook of Applied Solid State Spectroscopy, D. R. Vij, Springer
2	Photoelectron and Auger Spectroscopy, T.A.Carlson, Plenum Press , 1975
3	Practical Guide to Surface Science and Spectroscopy,Yip-Wah Chung, Academic Press
4	Fundamental of Molecular Spectroscopy, C.N.Banwell, TataMc-Graw Hill.

पुण्यश्लोक अहिल्यादेवी होळकर सोलापूर विद्यापीठ ।। विद्यया संपन्नता ।। NAAC Accredited-2022 'B++' Grade (CGPA-2.96)	**Punyashlok Ahilyadevi Holkar Solapur University, Solapur** **M. Sc. -II, SEM- IV, PHYSICS** **(Materials Science)** **As per NEP 2020** **(w. e. f. June 2024-2025)** **Vertical: DSE** **Course Code: 2321407** **Course Name:DSE-4C–NANOMATERIAL CHARACTERIZATION TECHNIQUES**

***Teaching Scheme** **Lectures:04 Hours/week, 04 Credits**	***Examination Scheme** **UA:60 Marks** **CA/SA: 40 Marks**

Course Preamble: The course is designed to understand the various techniques for nanomaterials characterizations. It helps to understand the nanomaterials morphology, compositional and structural analysis of materials by using different characterizations techniques. It also helpful to study the mechanical, thermal & optical properties of different types nanomaterials

Course Objectives: During this course, the student is expected to understand:
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.
Course Outcomes: At the end of this course, students will be able to learn:
1. Understand the electron microscopic techniques with different instruments.
2. Understand the Spectroscopic techniques
3. Understand the mechanical, thermal & optical property characterization of nanomaterials
4. Understand the x-ray photoelectron spectroscopy, Auger electron spectroscopy, Resonance spectroscopy.

Unit-I: Unit-I: Electron Microscopic characterization of nanomaterials	**No. of lectures-12**	**Weightage:12-16 Marks**
Fundamentals of the techniques – experimental approaches, sample preparation and data interpretation – applications/limitations of Microscopic equipment: SEM, EDAX, STM, TEM and AFM. SEM/TEM – high resolution imaging – defects in Nanomaterials.		
Unit-II: Spectroscopic characterization of nanomaterials	**No. of lectures-18**	**Weightage:18-24 Marks**
Spectroscopy: – electron energy-loss mechanisms – electron filtered imaging – prospects of scanning probe microscopes – optical spectroscopy of metal/semiconductor nanoparticles. Spectroscopic equipment**:** UV-VIS Spectroscope, XRD. RAMAN		

Spectroscope, DPI (Dual Polarization Interferometry), FTIR, Nano-lithographic technique and Surface area measurement & analysis technique. Analysis for evaluating Optical absorption and Nonlinear Kerr effect, Photoluminescence and Optical band gap Analysis for evaluating Optical absorption & Nonlinear Kerr effect, Photoluminescence & Optical band gap		
Unit-III: Mechanical, Thermal & Optical Property Characterization of Nanomaterials	**No. of lectures-15**	**Weightage:15-20 Marks**
Fundamentals and need of characterization of Nano-materials: Identification of pertinent parameters amenable to characterization. Mechanical properties characterization: Young's Modulus, Poisson Ratio, Bulge Test and Surface Tension. Thermal & Optical effect characterization: Thermal conductivity, TGA and Thermal stability		
Unit-IV: X-Ray Photoelectron Spectroscopy	**No. of lectures-15**	**Weightage:15-20 Marks**
Definition of surface, Different Probes for Surface-characterization. Necessity of Ultra High Vacuum, Photoelectron 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.		

. Reference Books	
1	Handbook ofApplied Solid State Spectroscopy, D. R. Vij, Springer
2	Photoelectron and Auger Spectroscopy,T.A.Carlson, Plenum Press , 1975
3	Zhong Lin Wang, Handbook of Nanophase and Nanomaterials (Vol 1 and II) Springer
4	C.R. Brundle, C.A. Evans Jr., and S. Wilson (eds), Encyclopedia of Materials Characterization, Butterworth Heinemann, Stoneham, Ma
5	J.C.Vickerman, Surface Analysis: The Principal Techniques, John Wiley and Sons
6	Roland Wiesendanger, Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Cambridge Univ press
7	T. Pradeep, Nano: The essentials, understanding Nanoscience and Nanotechnology, Tata McGraw Hill, 2007.
8	Willard, "Instrumental Methods of Analysis", Van Nostrand, 2000

9	J. Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lyman et.al, Scanning Electron Microscopy and X-ray Microanalysis, Springer Publications, 2003.
10	S.L. Flegler, J.W. Heckman and K.L. Klomparens, Scanning and Transmission Electron Microscopy: An Introduction, Oxford University Press, 1993.
11	P.J. Goodhew, J. Humphreys, R. Beanland, Electron Microscopy and Analysis, Taylor and Francis, 2001
12	R. Haynes, Optical Microscopy of Materials, International Textbook Co, 1984.
13	Zhong Lin Wang, Characterization OfNanophase Materials, Wiley-VCH, Verlag GmbH, Germany (2004).
14	W.R. Fahrner, Nanotechnology and Nanoelectronics Materials, Devices, Measurement Techniques, Springer-Verlag Berlin, Germany (2006).
15	Hans P.O., and Hopster H., ―Magnetic Microscopy of Nanostructures‖, Springer (2004)
16	Vladimir G. Bordo and Horst-Günter Rubahn; Optics and Spectroscopy at Surfaces and Interfaces, John-Wiley and Sons, Inc., (2005).
17	William W. Parson, Modern Optical Spectroscopy, Springer, (2007).
18	Collin Banwell, Mc Cash, Fundamentals of Molecular Spectroscopy, McGraw Hill (1994).
19	Harvey Elliot White, Introduction to Atomic Spectra, McGraw Hill, (1934).
20	Francis Rouessac and AnnickRouessac, Chemical Analysis-Modern Instrumentation Methods and Techniques, (2000)
21	Joseph. R. LakowiczPrinciples of fluorescence spectroscopy, Springer, (2010).
22	Pavia Lampman, Kriz, Vyvyan, Introduction to spectroscopy, Cengage learning, (2009).

M.Sc.-II, SEM- IV, PHYSICS
(Materials Science)
Vertical: DSC 7 practical/(Lab 10)

***Teaching Scheme**	***Examination Scheme**
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321404	**CA/SA: 20 Marks**

Practical 10 (DSC 7)

1. Calibration of Silicon diode and a copper constantan thermocouple as temperature sensors
2. Load regulation of constant current source
3. Temperature coefficient of resistance of copper
4. Energy band gap of Silicon using Silicon diode
5. Passive filters
6. Active Filter (High Pass)
7. Study of material data sheet
8. Thermoelectric power measurement.

M. Sc.-II, SEM- IV, PHYSICS
(Materials Science)
Vertical: DSE 4A practical (Lab 11)

***Teaching Scheme**	***Examination Scheme**
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321408	**CA/SA: 20 Marks**

Practical 11- (DSE 4A)

1. Astable and Monostable Multivibrator using IC-741.
2. Study of digital to analogconversion (DAC) using Op.Amp (IC-741).

3. Study of Amplitude modulation and demodulation.
4. Study of Frequency modulation and demodulation.
5. Inverting & Non-inverting Adder for two inputs.
6. Op-Amp integrator & Differentiator.
7. Op-Amp instrumentation amplifier with IC 324.
8. VCO as a triangular wave generator.

M. Sc.-II, SEM- IV, PHYSICS
(Materials Science)
Vertical: DSE 4B practical (Lab 11)

*Teaching Scheme	*Examination Scheme
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321409	**CA/SA: 20 Marks**

Practical 11 (DSE 4B)

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.

M. Sc.-II, SEM- IV, PHYSICS
(Materials Science)
Vertical: DSE 4C practical (Lab 11)

*Teaching Scheme	*Examination Scheme
Practical:02Hours/week, 01Credit	**UA:30 Marks**
Course Code: 2321410	**CA/SA: 20 Marks**

Practical 11 (DSE 4C)

1. Case study of SEM Images
2. Case study of TEM Images
3. Susceptibility measurement magnetic material
4. Analysis of XRD
5. Kerr Effect.
6. GM Counter I
7. GM Counter II
8. Electrical conductivity measurement by four probe method and determination of activation energy

M.Sc.-II, SEM- IV, PHYSICS
(Materials Science)
Research Project (RP-2)

*Teaching Scheme	*Examination Scheme
RP-2:06Hours/week, 06Credit	**UA:90 Marks**
Course Code: 2321403	**CA/SA: 60 Marks**