Anekant Education Society's

TULJARAM CHATURCHAND COLLEGE OF ARTS, SCIENCE AND COMMERCE, BARAMATI

(Autonomous Status)

(Affiliated to Savitribai Phule Pune University, Pune)

Faculty of Science

Department of Physics

Syllabus Submitted to BOS

For

M.Sc. in Physics

Academic Year 2022-2025

INDEX

PREAMBLE

Physics, a core discipline, is the fundamental and foremost to all natural sciences. It has been significant and influential through advances in its understanding that have translated into new technologies. Physics interact with the society and other discipline such as Medicine, Chemistry, Agriculture, Engineering etc. in many important ways. Physics department in Tuljaram Chaturchand College has highly qualified faculty members and support staffs and is committed towards the development of innovative and handy ways of teaching at graduate, post graduate and developing a core research group for carrying out cutting edge research in various research fields like Condensed Matter Physics, Solid State Physics, Electronics, Theoretical Physics, Atomic & Molecular Physics and Nuclear Physics. The department also offers Doctoral Programme in order to nurture young minds towards embracing various scientific challenges. Extra care is taken to pay individual attention to the students in their laboratory work and tutorial sessions. Project work and problem sessions are encouraged to develop innovative and analytical approach to physics learning.

GOALS

The goal of the Physics education is to provide the student with a broad understanding of the physical principles of the universe, to help them develop critical thinking and quantitative reasoning skills, to empower them to think creatively and critically about scientific problems and experiments. It's provide training for students and planning careers in physics including research, teaching, industrial jobs, government jobs or other sectors of our society.

OBJECTIVES

1. To endow with a conducive and friendly environment that nurtures excellence and high standards of professionalism in teaching, learning and research.
2. To augment the level of participation in research, dissemination and preservation of knowledge for both academic and social development.
3. Prepare the student in assets of Physics and the principles of analytical methods required for the conclusion of physical tests.
4. Provide an opportunity for students to deepen his/her knowledge in the branches of Physics so that views on the outskirts of contemporary science.

5. Training the students on the way of scientific research and enable it to contribute to it under the supervision.
6. Continued development of faculty members by sending them for training courses so as to maintain a high degree of efficiency and performance.
7. Support and encourage the scientific cooperation between faculty members in the department and co-operation with other departments in the field of multi-purpose research.
8. Spread the spirit of competition and encouragement and give the opportunity to all members.
9. Preparation of national cadres by basic physics and knowledge that contribute to community service.
10. To establishes collaborations with other eminent institution.

Proposed Structure of M.Sc. Physics and syllabus for M.Sc. II Physics Third semester as follows:

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M.Sc. I & II Course Structure

M.Sc.-I

Semester-I

Course Number	Course Code	Course Name	Credit
1	PSPH 111	Mathematical Methods in Physics	4
2	PSPH 112	Classical Mechanics	4
3	PSPH 113	Quantum Mechanics-I	4
4	PSPH 114	Electronics	4
5	PSPH 115	Electronics Laboratory-I	4
6	PSPH 116	Basic Physics Laboratory-I	4
Total Credit			**24**

Semester-II

Course Number	Course Code	Course Name	Credit
7	PSPH 121	Physics of Semiconductor Devices	4
8	PSPH 122	Atoms, Molecules & Laser	4
9	PSPH 123	Quantum Mechanics-II	4
10	PSPH 124	Electrodynamics	4
11	PSPH 125	Electronics Laboratory-II	4
12	PSPH 126	Basic Physics Laboratory-II	4
Total Credit			**24**

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M.Sc. II Course Structure

Semester-III

Course Number	Course Code	Course Name	Credit
1	PSPH 231	STATISTICAL PHYSICS	4
2	PSPH 232	SOLID STATE PHYSICS	4
3	PSPH 233	EXPERIMENTAL TECHNIQUES IN PHYSICS- I	4
4	PSPH 234	**CBCS Group I** A) NANO TECHNOLOGY I OR B) ENERGY STUDIES-I OR C) BIOPHYSICS-I OR D) PHYSICS OF THIN FILMS-I OR E) ELECTRONIC INSTRUMENTATION-I OR F) DFT -I	4
5	PSPH 235	SPECIAL LAB– I	4
6	PSPH 236	SPECIAL LAB– II PYTHON PROGRAMMING IN PHYSICS	4
Total Credit			**24**

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M.Sc. II Course Structure

Semester-IV

Course Number		Course Name	Credit
7	PSPH 241	Nuclear & Particle Physics	4
8	PSPH 242	Material Science	4
9	PSPH 243	Experimental Techniques in Physics-II	4
10	PSPH 244	**CB Group –II** A) NANO-TECHNOLOGY-II OR B) ENERGY STUDIES- II OR C) BIOPHYSICS-II OR D) PHYSICS OF THIN FILMS-II OR E) ELECTRONIC INSTRUMENTATION-II OR F) DFT-II	4
11	PSPH 245	Special Lab-III	4
12	PSPH 246	Project	4
Total Credit			**24**

Programme Outcomes (PO)

PO1: To develop an ability to become a specialist in various areas of Physics and apply the same in day to day life.

PO2: To acquire knowledge about the nature, concepts, methods, techniques and objectives in the core physics subjects.

PO3: To make the students in mastering in the field of materials science and prepare them for research.

PO4: Identify, formulate, and analyse complex problems using basic principles of mathematics, physics, and statistics.

PO5: Design, construct and analyse basic electronic and digital circuits. Understand the basics of programming language and apply it to various numerical problems.

PO6: To cultivate scientific approach and culture of research aptitude.

PO7: To enhance the problem-solving skills of the students so that they will be able to tackle the national level competitive exams like NET, GATE and SET etc.

PO8: To understand the links of Physics to other disciplines and also to the societal issues.

PO9: To train the students to develop their skill development, employability and entrepreneurship skills

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)
Academic Year 2023-2024
M. Sc-II (Physics) Semester-IV
PSPH 241: NUCLEAR PHYSICS

Credit: 04 **Total No. of Lectures: 60**

Learning Objectives:

On successful completion of this course students will be able to:

1. Describe the structure of the atom.
2. Describe the constituents of the nucleus, and different types of radiation.
3. Give definitions of basic nuclear physics terms and units of measure.
4. Use a periodic table and chart of the nuclides to identify specific isotopes and elements and their properties.
5. Explain the interactions of radiation with matter and the physics of nuclear fission.
6. Complete simple calculations using energy and mass relationships, atomic density, and radioactive decay.
7. Use the basic laws in determination of particle properties and properties of processes in the subatomic world.
8. Describe the particle interactions with matter and basic models of the atomic nucleus.
9. Learn the concepts of the radiation detectors and accelerators.
10. Describe the Nuclear Physics applications.

Learning Outcomes: Students

1. Can express the basic concepts of nuclear physics.
2. Can tell a chronology of some of the major events in nuclear physics.
3. Can express the radioactive decays.
4. Can state some quantities characterizing the decay such as half-life, decay constant.
5. Can list the types of decay.
6. Can express the alpha decay.
7. Can express reaction equation and Q values and Energy of alpha particles.
8. Can explain the alpha process by using quantum theory.
9. Can calculate the half-times based on quantum theory.
10. Can express the beta decays.

UNIT 1: General Properties and Concepts of Nuclei **(15L)**

Introduction, Basic properties of nucleus: Composition, charge, size, density of nucleus, Nuclear Angular momentum, Nuclear magnetic dipole moment, Electric quadrupole moment, parity and symmetry, Mass defect and Binding energy, packing fraction, classification of nuclei, stability of nuclei, Problems.

Radioactivity: law of radioactive decay-half life, mean life, Unit of Radioactivity, Alpha Decay: range of Alpha Particles and Geiger-Nuttall law, Range-Energy Relationship, Geiger-Nuttal Law, Beta Decay: Conditions for Spontaneous Emission of β-& β+, Applications of radioactivity, Selection Rules, Origin of Beta Spectrum-Neutrino Hypothesis, Gamma Decay. Problems

UNIT 2: Nuclear Models, Nuclear Accelerators and Nuclear Detectors **(15L)**

Introduction, Shell model-assumptions and limitations of shell model, liquid drop model, Semi-empirical mass formula, Detectors: Gas filled detectors, Ionisation chamber, Geiger-Mueller counter, Scintillation counter, Bubble Chamber, Cloud Chamber, Spark Chamber, Linear Accelerator, Collective Model, problems.

UNIT 3: Reaction Dynamics and Accelerators **(15L)**

Introduction, Reaction Dynamics: Types of Nuclear Reactions, Conservation Laws in Nuclear Reactions, Q value of Nuclear Reaction, Compound Nucleus Hypothesis, Fission and Fusion Reactions, Four Factor Formula General Properties and Concepts of Nuclear Reactors, Reactor Materials, Types of Reactors, List of Different Types of Reactors, Accelerators: Van de Graff, Microtron, Electron & Proton Synchrotron, Pelletron, Cyclotron, Problems.

UNIT 4: Elementary Particle Physics **(15L)**

Classification of Elementary Particles and their Quantum Numbers (Charge, Spin, Parity, Iso Spin, Strangeness, Baryon number, Hypercharge etc.), conservation laws, Classification of Quarks, Their masses and spins, Quark contents of particles, Parity non conservation in weak interactions, Gell-Mann-Nishijima formula.

Reference Books:

1. K.S. Krane, Introductory Nuclear Physics, Wiley, India, 1988

2. B.L. Cohen, Concepts of Nuclear Physics, Tata McGraw Hill

3. I. Kaplan, Nuclear Physics, 2nd Edition, Narosa, New Delhi, 1989

4. S.N. Ghoshal, Atomic and Nuclear Physics, S. Chand

5. S.B. Patel Nuclear Physics: An Introduction, New Age International, 1991

6. D.C. Tayal, Nuclear Physics, Himalaya Publishing House

7. R.D. Evans, The Atomic Nucleus, Tata McGraw Hill

8. G.F. Knoll, Radiation Detection and Measurement, 3rd Edition, Wiley India

9. S.S. Kapoor and V.S. Ramamurthy, Nuclear Radiation Detectors, Wiley Eastern Limited

10. R.R. Roy, B.P. Nigam, Nuclear Physics-Theory and Experiment, Wiley Eastern Limited

11. Blatt and Weisskopf, Theoretical Nuclear Physics, New York, Wiley

12. S. Sharma, Atomic and Nuclear Physics, Pearson Education 2008

Mapping of PSPH 241: (Nuclear & Particle Physics)

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	1					
CO2	1						
CO3	1	1		1			1
CO4			1	1	1		1
CO5	1	1		1			
CO6	1	1			1	1	
CO7					1	1	
CO8	1	1	1	1	1		
CO9	1	1			1		

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)

Academic Year 2023-2024

M. Sc-II (Physics) Semester-IV

PSPH 242: MATERIAL SCIENCE

Credit: 04 **Total No. of Lectures: 60**

Learning Objectives:

On successful completion of this course students will be able to:

1. To understand and distinguish between variety of materials based on their structure and properties
2. Use the fundamental science principles relevant to materials that include the relationships between nano/microstructure, characterization, properties, processing, performance and design of materials.
3. To apply knowledge of mathematics, science and materials engineering to solve complex engineering problems.
4. To analyse complex materials engineering problems reaching substantiated conclusions.

Learning Outcomes: On successful completion of this course students will be able to do the following:

1. Qualitatively describe the bonding scheme and its general physical properties, as well as possible applications.
2. Describe physical origin of defects and its effects on various mechanical, electrical, thermal and other properties of the materials.
3. Describe resultant elastic properties in terms of its 1D and 2D defects.
4. Understand diffusion mechanisms and solve problems related to diffusion processes.
5. Derive various metallurgical thermodynamics equations and functions.
6. Understand and apply Gibb's phase rule to various systems of materials.
7. Understand alloy systems, families of engineering alloys.
8. Understand thermodynamic origin of phase diagrams, draw phase diagrams.
9. Understand phase diagrams and apply their knowledge of phase diagrams for various applications.
10. Understand Phase transformation mechanisms.

Unit 1: Properties of Materials and Defects in Solids **(15L)**

Structure, property-processing relationship, Mechanical, electrical, magnetic, thermal, and structural properties

Point defects - Vacancies, interstitials, non-stoichiometry, substitution, Schottky and Frenkel defects with proofs.

Line defects - Edge and screw dislocations, properties of dislocations – force on dislocation, energy of dislocation, pinned dislocation (These properties with derivation), dislocation density, interaction between dislocations, motion of a dislocation (cross-slip and climb), dislocation generator (Frank Read source).

Surface defects – grain boundaries with explanation of high angle, low angle, tilt and twist boundaries, stacking fault.

Volume defect- twin boundary

Solid Solution - Types of solid solutions (Substitutional and Interstitial), Factors governing solid solubility (Hume - Rothery rule), Atomic size and size factor in solid solutions, Vegard's law.

Unit 2: Diffusion in Solids (15L)

Introduction, types of diffusion, Diffusion mechanism, Fick's first and second laws of diffusion, solution to Fick's second law (without proof, introduction of error function), Factors governing diffusion, Factors affecting diffusion coefficient (D), Experimental determination of D, Diffusion in oxides and ionic crystals, Applications of diffusion: Corrosion resistance of duralumin, Decarburization of steel, Doping of semiconductors.

Unit 3: Metallurgical Thermodynamics (15L)

Revision of laws of thermodynamics, Auxiliary thermodynamic functions, measurement of changes in enthalpy and entropy, Richard's rule, Trouton's rule, Chemical reaction equilibrium, Thermodynamic properties of solutions (mixing processes – Rault's law, activity coefficient; regular solution behaviour – Henry's law), Gibb's phase rule: proof, explanation, and application to single component (H_2O) and binary phase diagram

Unit 4: Phase diagrams and Phase transformations (15L)

Phase diagrams: Thermodynamic origin of phase diagrams, Lever rule, Type I (Cu-Ni) phase diagram, Type II (explanation only) phase diagram, Type III (Pb-Sn) phase diagram, Maxima and minima in two-phase regions, Miscibility gaps, Topology of binary phase diagrams (Explanation in short of eutectic, peritectic, Monotectic, eutectoid, peritectoid, syntactic reaction, extension rule), Applications of phase diagrams.

Phase transformation: Introduction, Mechanism of Phase Transformation, kinetics of Solid-state reaction, Nucleation and Growth, Applications of phase transformations.

Reference books:

1. Elements of Materials Science and Engineering (5th edition) - Lawrence H. Van Vlack, Addison – Wesley Publishing Co.

2. Materials Science and Engineering - V. Raghvan

3. Physical Metallurgy (Part I) R. W. Cahn and P. Hassen, North Holland Physics Publishing, New York

4. Introduction to Materials Science for Engineers (6th edition) - J.F. Shaekelford and M. K. Murlidhara - Pearson Education

5. Materials Science – Kodgire and Kodgire

6. Materials Science – S L Kakani and Amit Kakani

Course Name **: MATERIAL SCIENCE**

Course Code : **PSPH-242**

Program Outcome								
Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3							
CO2	2	2						
CO3				1	1			
CO4			2			1	1	2
CO5		2	1					
CO6	2				1			
CO7	2					1		
CO8	2							

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)

Academic Year 2023-2024

M. Sc-II (Physics) Semester-IV

PSPH 243: EXPERIMENTAL TECHNIQUES IN PHYSICS-II

Credit: 04 **Total No. of Lectures: 60**

Learning Objectives:

1. The course is to provide a broad overview about different techniques available for structural characterization of various materials systems.
2. It is an amalgamation of the science behind these characterization techniques and their application in material systems.
3. Students gain knowledge about the principles of various techniques.
4. Student acquires knowledge of the different existing experimental techniques for the microstructural and physicochemical characterizations of materials.

Learning Outcomes: On successful completion of this course students will be able to do the following:

1. Apply appropriate characterization techniques for microstructure examination at different magnification level and use them to understand the microstructure of various materials.
2. Choose and appropriate electron microscopy techniques to investigate microstructure of materials at high resolution.
3. Determine crystal structure of specimen and estimate its crystallite size and stress.
4. Use appropriate spectroscopic technique to measure vibrational / electronic transitions to estimate parameters like energy band gap, elemental concentration, etc.
5. Apply thermal analysis techniques to determine thermal stability of and thermodynamic transitions of the specimen.

Unit-1: Radiation Sources and Detectors **[15L]**

Electromagnetic spectrum, Sources of Electromagnetic Radiations: Different types of radiations (γ - rays, X-rays, UV-VIS, IR, microwaves) and their sources, Detectors: γ-rays, X-rays, UV-VIS, IR, microwaves

Unit-2: Structural Characterization and Thermal Analysis **[15L]**

X-ray Diffraction – Production of X-rays, Types (continuous and characteristics), Bragg's diffraction condition, principle, instrumentation (with filters) and working, Techniques used for XRD – Powder method, Derivation of Scherrer formula for size determination, Neutron Diffraction: Principle, Instrumentation and Working, Thermal analysis: Principle, Instrumentation and Working: Thermo-gravimetric (TGA), Differential Thermal Analysis (DTA), Problems.

Unit-3: Morphological and Magnetic Characterization **[15L]**

Optical Microscopy: Principle, Instrumentation and Working of optical microscope, Electron Microscopy: Principle, Instrumentation and Working of Scanning Electron Microscope (SEM), Field Emission Scanning Electron Microscope (FESEM) –Advantages over SEM, Transmission Electron Microscope (TEM), Selected Area Electron Diffraction (SAED), Probe Microscopy : Principle, Instrumentation and Working of Scanning Tunnelling Microscope (STM) and Atomic Force Microscope (AFM), Magnetic Characterization: Principle, Instrumentation and Working of Vibrating Sample Magnetometer (VSM), Analysis of Hysteresis loop, SQUID Technique : Principle only, Problems.

Unit 4: Spectroscopic Analysis **[15L]**

Spectroscopic characterization (principle, instrumentation and working): Infra-Red (IR), Fourier Transform Infra-Red (FTIR), Ultraviolet-Visible (UV-VIS), Diffused Reflectance Spectroscopy (DRS), X-ray Absorption (XPS), Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR), Raman Spectroscopy, Problems.

References:

1. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy, (Wiley-Eastern Limited, Bombay)
2. Instrumentation: Devices and Systems, C.S. Rangan, G.R. Sarma and V.S.V. Mani, Tata Mc Graw Hill Publishing Co. Ltd.
3. Characterization of Materials, John B. Wachtman and Zwi. H. Kalman, Pub. Butterworth Heinemann (1992)
4. Instrumental Methods of Chemical analysis, G. Chatwal and S. Anand, Himalaya Publishing House
5. Elements of X-ray Diffraction, B. D. Cullity, S. R. Stock, (Printice Hall)
6. Instrumental Methods of Analysis, H. H. Willard, l. L. Merritt, J. A. Dean, CBS Publishers

Mapping of PSPH 243: EXPERIMENTAL TECHNIQUES IN PHYSICS-II

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	2	1	1		2	
CO2	1		1				
CO3	2	1		1			1
CO4			1	2	1		1
CO5	1	1		1			
CO6	2	1	3		1	1	
CO7					2	1	
CO8	1	2	1	1	1		
CO9	1	3			1		1

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)
Academic Year 2023-2024
M. Sc-II (Physics) Semester-IV
PSPH 244 (A): NANOTECHNOLOGY-II

Credit: 04 **Total No. of Lectures: 60**

Learning Objectives:

The course main objective is to enhance critical, creative, and innovative thinking. The course encourages multicultural group work, constructing international 'thinking tanks' for the creation of new ideas. Throughout the course, you will be asked to reflect upon your learning, think "out of the box", and suggest creative ideas. The course is set to encourage the understanding of:

1. The importance of nanoscale materials for sensing applications.
2. Approaches used for characterizing sensors-based nanomaterials.
3. Approaches used for tailoring nanomaterials for a specific sensing application.
4. Metallic and semiconductor nanoparticles.
5. Organic and inorganic nanotubes and nanowires.
6. Optical, mechanical, and chemical sensors based on nanomaterials.
7. Hybrid nanomaterial-based sensors.

Learning Outcomes:

At the end of the course, the student will be able to

1. To learn basic material science with special, emphasize on nanomaterials.
2. To know about processes in handling polymers and nanostructured materials.
3. To understand various forms of nanomaterials and polymers for special applications.
4. Understand Metal/Ceramic Powder synthesis methods for composite.
5. Understand the environmental impact of nanostructured materials.

Unit 1: Nano sensors **(20)**

Introduction to sensors. Characteristics and terminology - static and dynamic characteristics. Micro and nano-sensors, Fundamentals of sensors, biosensor, micro fluids, Packaging and characterization of sensors, Sensors for aerospace and defence. Organic and inorganic nano sensors.

Unit 2. Nanotechnology enabled devices (20)

Nanomaterials and nanostructured films, Nanoscale electronic and ionic transport. Sensor for bio-medical applications. Bioelectronics, Nanoparticle biomaterial hybrid systems for sensing applications. Gas sensor.

Unit 3: Biosensors: (20)

Principles, DNA and nucleotide-based biosensors, Protein-based biosensors, Materials for biosensor applications, Fabrication of biosensor devices, Detection in Biosensors – fluorescence, absorption, electrochemical methods, Techniques used for microfabrication, Future direction in biosensor research.

References:

1. Chemical Sensors and Biosensors; Brian, R Eggins; Wiley; New York, Chichester, 2002.
2. Biosensors: A Practical Approach, J. Cooper & C. Tass, Oxford University Press, 2004.
3. Nanomaterials for Biosensors, Cs. Kumar, Wiley – VCH, 2007. 4. Smart Biosensor Technology, G.K. Knoff, A.S. Bassi, CRC Press, 2006.

Mapping of CB Group- II: PSPH 244 (A): NANOTECHNOLOGY-II

Programme Outcomes								
Course Outcome	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**1**							
CO2	**1**							**1**
CO3	**1**							**1**
CO4		**1**						
CO5							**1**	

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)

Academic Year 2023-2024

M. Sc-II (Physics) Semester-IV

PSPH 244 (B): ENERGY STUDIES-II

Credit: 04 **Total No. of Lectures: 60**

Learning Objectives:

1. To develop capability to understand the fundamentals of science and energy technology for analysing the engineering problems with futuristic approach.
2. To foster a confident and competent post graduate capable to solve real life practical engineering problems fulfilling the obligation towards society.
3. To nurture and nourish effective communication and interpersonal skill to work in a team with a sense of ethics and moral responsibility for achieving goal.

Course Objectives:

On successful completion of this course students will be able to do the following:

1. The course providing a basic understanding of theory and practice of various photovoltaic technologies and design concepts.
2. To understand the physical principles of the photovoltaic (PV) solar cell.
3. Discuss the positive and negative aspects of solar energy in relation to natural and human aspects of the environment.
4. Gain knowledge about working principle of various solar energy systems.

Unit-1: Photovoltaic converters **[15L]**

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

Unit-2: Materials and Solar cell Technology **[15L]**

Fabrication technology of solar cell, 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, solar cell modules, photovoltaic systems, space quality solar cells, dye synthesized solar cell, perovskite solar cell, Different materials used in solar cells, problems.

Unit-3: Photochemical Converters **[15L]**

Semiconductor – electrolyte interface, Helmholtz double layer, Gouy-Chapman model, Stern model, Principle of photoelectrochemical solar cells, conversion efficiency in relation to different material properties, photo electrolysis cell, driving force of photo electrolysis, alkaline fuel cell, semiconductor- septum storage cell, concept of photocatalysis and photo electrocatalysis process, problems.

Unit 4: Thermoelectric Converters **[15L]**

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, problems.

References:

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

Mapping of PSPH 244 (B): ENERGY STUDIES-II

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	3		1		1	1
CO2	1		1		1		
CO3	1	1		1		1	1
CO4		2	1		1		1
CO5	1	1		3			
CO6	1	1			1	1	
CO7			2		2	1	
CO8	1	2	1	1	1		
CO9	1	1			2	1	1

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)

Academic Year 2023-2024

M. Sc-II (Physics) Semester-IV

PSPH 244 (C): BIOPHYSICS-II

Credit: 04 **Total No. of Lectures: 60**

Course Objectives:

This course aims to introduce Biophysics:

1. To study the basic concepts regarding Cellular and Molecular Biology
2. To impart knowledge about Biophysical Techniques

Course Outcomes:

Upon completion of the course, the student will be able to,

1. Understand Basic Structure of Cell
2. Identify Biophysical Techniques
3. Properties and their significance
4. Working of Nervous System
5. Apply the knowledge of Physics in Living things.

Unit 1: Basics of Biophysics **(15 L)**

Introduction to Biophysics, General organization of prokaryotic and eukaryotic organisms' basic concepts and their detailed structure and functions, Cell, Animal and Plant Cell, Types of Cell and its composition, Prokaryotic cell wall, Eukaryotic cell wall, their functions, ribosomes, Physical and biological properties of protoplasm. Cytoskeleton – basic components, properties, and functions in prokaryotic and eukaryotic cells.

Unit 2: Properties of Lipid Membrane **(15L)**

Cell surface charge, Resting membrane potential, Action potential, properties of action potential, Nernst-Plank equation, Hodgkin- Huxely equation, Hodking-Kartz experiment, Voltage clamp, Na+, K+ conductance, Membrane impedance and capacitance, Transmembrane potential, Zeta, stern and total electrochemical potential, Chemical synapse, post synaptic potential, Historical perspective of lipid model systems lipid monolayer. Liposomes: small and large unilamellar and multilamellar vesicles, planner lipid bilayer, Application of liposomes in biology and medicine.

Unit 3: Molecular Biophysics **(15L)**

Types of Protein structure (Primary, secondary and Tertiary), polypeptide chains, potential energy, hydrogen bonding, hydrophobic interactions, disulfide bonds & ways of pairing, Protein stability, chemical & surface denaturation, primary structure sequencing of polypeptide, α and β-helix, Ramchandran plot, protein folding & misfolding, Types of DNA, properties of DNA & RNA, Nucleotide structure, Base pairing, Genetic code symmetry, Structure& function of water and carbohydrates

Unit 4: Neuro-biophysics **(15 L)**

Neuron –structure and function, excitable membrane, Ion channels, Resting membrane potential, Depolarization, Hyper-polarization, Nernst equation, Goldman equation, Passive electrical prop. of neuron, Nerve conduction, Cell equivalent circuits, Synaptic Integration & transmission, Voltage clamp technique, coding of sensory information, MRI Technique, PET (Positron Emission Tomography) Technique, CT (Computed Tomography).

Reference Books:

1. Biophysics by G. R. Chatwal, Himalaya Publishing House, Mumbai, (2011)
2. Principles of neural science by E. R. Kandel& J. H. Schwatz, Elsevier, North Holland, (1982)
3. Neuron to Brain by S. W. Kuffler and J. G. Nichols, SinacuerAsso. Inc., (1995)
4. Biophysics by Mohan P. Arora, Himalaya Publishing House, (2012)
5. Biophysics An Introduction by Rodney Cotterill, Wiley, (2014)
6. Essentials of Biophysics by P. Narayanan, New Age International Publication, (2005)

Mapping of PSPH 244 (C): BIOPHYSICS-II

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	1	3		1		1	1
CO2	1		1		1		
CO3	1	1		1		1	1
CO4		2	1		1		1
CO5	1	1		3			
CO6	1	1			1	1	
CO7			2		2	1	
CO8	1	2	1	1	1		
CO9	1	1			2	1	1

SYLLABUS (CBCS) FOR M.Sc. PHYSICS (W.E.F. June 2023)

Academic Year 2023-2024

M. Sc-II (Physics) Semester-IV

PSPH 244 (D): PHYSICS OF THIN FILMS-II

Credit: 04 **Total No. of Lectures: 60**

Course Objectives

1.To make the students to understand about the difference between bulk and thin film, the optical, electrical, dielectric, and magnetic properties of thin film, the theories explaining the formation of thin film and the fabrication and advantages of thin film devices.

2.Learn the fundamental atomistic mechanisms

3. Know thin film deposition techniques

4.Acquire knowledge on thin film device

5.Acquaint with thin film

6.Appreciate applications of thin films

7.Narrate various thin film deposition techniques

Course Outcomes:

1. To understand the principle, differences and similarities, advantages, and disadvantages of different thin film deposition Techniques.
2. To understand and evaluate and use models for understanding nucleation and growth of thin films.
3. To understand about different instrumentation techniques and to analyze thin film properties to apply for various applications.
4. To improve problems solving skills related to evaluation of different properties of thin films.
5. Problem solving ability.
6. Critical analysis
7. Discuss the differences and similarities between different vacuum based deposition techniques
8. Evaluate and use models for nucleating and growth of thin films.
9. Asses the relation between deposition technique, film structure, and film properties

Unit 1: Thin Film Characterization Methods **(15 L)**

Monitoring and Analytical Technique, Deposition Rate and Thickness Measurement, X-ray diffraction, Microstructural Analysis- SEM, TEM, AFM, Composition Analysis

Unit 2: Thin Films In Optics **(15 L)**

Optics of Thin Films, Antireflection Coatings- Single-Layer AR Coatings, Double-Layer AR Coatings, Multilayer and Inhomogeneous AR Coatings, Reflection Coatings-Metal Reflectors, All-Dielectric Reflectors, Interference Filters-Edge Filters, Band-Pass Filters, Thin Film Polarizers, Beam Splitters-Polarizing Beam Splitter, Dichroic Beam Splitter, Integrated Optics Waveguides, Thin Film Optical Components, Passive Devices: Couplers, Active Devices.

Unit 3: Optoelectronic Applications **(15 L)**

Introduction, Photon Detectors-Photoconductive Detectors, Photo emissive Detectors, Photovoltaic Devices-Thin Film Solar Cells, Applications in Imaging, Electrophotography (Xerography and Electro fax), Thin Film Displays- Electroluminescent (EL) Displays, Electrochromic Displays

Unit 4: Microelectronic Applications **(15 L)**

Introduction, Thin Film Passive Components, Electrical Behaviour of Metal Films, Dielectric Behaviour of Insulator Films, Resistors, Capacitors, Inductors, Conductors (Interconnections and Contacts), Thin Film Active Components-Thin Film Transistor (TFT), Thin Film Diodes, Thin Film Integrated Circuits, Microwave Integrated Circuits (MICs), Charge-Coupled Devices (CCDs): Introduction, Principle, Applications, Thin Film Strain Gauges, Gas Sensors

References:

1. Handbook of Thin Film Technology: Maissel and Glang, (Mc Graw Hill)
2. Thin Film Device Applications: K. L. Chopra, (Springer)
3. Thin Film Phenomena: K. L. Chopra, (Mc Graw Hill)
4. Material Science of Thin Films: M. Ohring, (Academic Press)
5. Thin Film Process: J. L. Vossen and Kern, (Academic Press)
6. Vacuum Technology (2nd revised edition), A. Roth, (North Hollad)

Course Name : **PHYSICS OF THIN FILMS-II**
Course Code : **PSPH 244 (D):**

Program Outcome								
Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3							
CO2	2	2						
CO3				1	1			
CO4			2			1	1	2
CO5		2	1					
CO6	2							
CO7	2							
CO8	2							

M. Sc-II (Physics) Semester-IV

PSPH 244 (E): ELECTRONIC INSTRUMENTATION-II

Credit: 04 **Total No. of Lectures: 60**

Learning Objectives: The specific learning objectives of this paper are as follows:

1. To understand the fundamental principles and techniques involved in measurement and instrumentation.
2. To learn about various types of sensors and transducers used for measuring physical quantities.
3. To understand the fundamentals of process control and its significance in industrial and engineering applications.
4. Explore the components of control systems, including controllers, actuators, and control valves.
5. To understand the process of signal conditioning to improve the quality of measured signals.
6. To understand various control modes, such as on-off control, PI, PD, PID control.
7. To demonstrate the use of PLCs in process control and automation.
8. To motivate students to work on projects based on process control instrumentation techniques.

Learning Outcomes: On successful completion of this course the students will be able to do the following:

1. Understand the basic ideas and techniques applied in instrumentation and measurement.
2. The students will be able to identify and explain the key components of control systems.
3. Design and implement circuits for signal conditioning for quality control.
4. The students will be able to measure and control a variety of process variables,
5. Students will understand and apply various control modes and techniques.
6. To demonstrate abilities in designing and using data acquisition systems.
7. Process and analyze measurement data and present results effectively.
8. Students can perform experiments and do the projects based on process control systems.

TOPICS/CONTENTS:

Unit 1: Introduction to Process Control (15L)

Introduction, Control systems, Process control block diagram, Control system Evaluation and Control system Objective, Evaluation Criteria, Damped response, Cyclic response, Process Control Drawing and symbols with their meaning, Discrete Process Control: Introduction, definitions of discrete state process control, Characteristics of the systems, relay, controllers, and ladder diagrams, PLC's, interfacing with LAN, SCADA systems, Problems.

Unit 2: Controller Principles (15L)

Introduction of controller, Process Characteristics- Process Load, Transient, Process Lag, Control System Parameters, Error, Variable Range, Control Parameter Range, Control Lag, Dead Time, Cycling, Controller Modes, reverse and direct action, discontinuous controller modes, two position, Neutral Zone, Applications, Multi position controller floating control mode- Continuous controller modes, Proportional Control Mode, Integral Control Mode, Derivative Control Mode, Composite Control, PI Control, PD Control Mode, Three Mode Controller (PID), Problems

Unit 3: Types of Controllers (15L)

Analog Controllers: Electronic controller with design considerations: Proportional (P), Integral (I), Derivatives (D) PI, PD and PID, Digital Control: Introduction two position controls and multivariable alarms.

Unit 4: Modelling, Simulation and Programming (15L)

Introduction to modelling and simulation: Mathematical model, equivalent circuit model, Empirical Model, methodology, concept and need of simulation and its applications, Introduction to MATLAB/SciLab

References Books:

1. Process Control Instrumentation Technology, Curtis D. Johnson, 7th Edition, Prentice Hall India Pvt. Ltd.
2. Computer based industrial controls K. Kant PHI publications.
3. MATLAB an introduction and applications", by Amos Gilat, Wiley Students Edition
4. Instrumentation, measurement, and systems. Nakra and Chaudhary.
5. Electronic Instrumentation and measurement techniques by A. D. Helfrick and W. D. Cooper.
6. Instrumentation, devices, and systems. Rangan, Mani and Sarma Prentice Hall of India.
7. Electronics Instrumentation. Kalsi (Tata McGraw-Hill)
8. Measurement system – applications and design by E.O. Doblin and Manik .

Course Code : **PSPH 244 (E): ELECTRONIC INSTRUMENTATION-II**

Program Outcome								
Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
CO1	3							
CO2	2	2						
CO3				1	1			
CO4			2			1	1	2
CO5		2	1					
CO6	2							
CO7	2							
CO8	2							

M. Sc-II (Physics) Semester-IV

PSPH 244 (F): DENSITY FUNCTION THEORY-II

Credit: 04 **Total No. of Lectures: 60**

Course Objectives:

1. The course is designed for materials scientists, chemists, physicists, and applied mathematicians who are seeking to know both the basic concept and certain advanced topics in density functional theory.
2. Density functional theory (DFT) is widely used nowadays in both industry and academia to simulate various properties of materials and molecules, such as electronic properties, crystal structures, and chemical reactions.
3. In this course, you will learn both the theoretical and numerical aspects of DFT.
4. We will also learn how to perform DFT calculations on simple molecules and solids using DFT programs such as NWChem and ABINIT.

. **Course Outcome**s:

1. Learn theoretical concepts of different computational techniques in materials science.
2. Simulate and compute material properties using density functional theory, molecular dynamics and Monte Carlo methods.
3. Understand SCF and convergence test.
4. Ability to understand interpretation of data for physical properties of materials.
5. Ability to understand interpretation of data for magnetic properties of materials.
6. Ability to understand interpretation of data for optical properties of materials

Unit 1: Basic concepts in DFT **(05)**

Hohenberg-Kohn theorem, Levy-Lieb constrained-search formulation of DFT, Kohn-Sham equation, and spin-polarized DFT.

Unit 2: Exchange correlation functionals **(15)**

Local density approximation, hybrid exchange-correlation functional, self-interaction correction, etc. Orbital-dependent exchange correlation functionals: optimized effective potential, exact exchange, and random phase approximation.

Unit 3: Basics of solids state physics **(15)**

Bravais lattice, reciprocal space, Bloch theorem, and Brillouin zone. Pseudopotentials: norm-conserving pseudopotential, nonlinear core correction, and project augmented wave technique.

Unit 4: Numerical aspects of Kohn-Sham DFT **(15)**

Smearing, k-point sampling, Gaussian basis set, and plane-wave basis set. Geometry optimization: Hellmann-Feynman force, Pulay force, and stress. Ab initio molecular dynamics. Physical meaning of Kohn-Sham eigenvalues, and fractional number of electrons.

Unit 5: Applications **(10)**

Vibrational frequencies, enthalpy, and Gibbs free energy of molecules. Bulk modulus, shear modulus, phase transition pressure, reaction barrier, vacancy formation energy, surface adsorption energy, surface energies, and charge analysis.

References:

1. “Density-Functional Theory of Atoms and Molecules” by Parr and Yang.
2. “The ABC of DFT”, by Kieron Burke, http://dft.uci.edu/doc/g1.pdf
3. Supplementary References • “Modern Quantum Chemistry, Introduction to Advanced Electronic Structure Theory”, Szabo and Ostlund.
4. “A bird’s-eye view of density-functional theory” by K Capelle, Brazilian Journal of Physics 36, pp 1318 (2006).
5. “Challenges for Density Functional Theory”, Cohen et al., Chemical Review 112, pp 289 (2012).
6. “Iterative minimization techniques for ab initio total-energy calculations: molecular dynamics and conjugate gradients”, Payne et al., Review of Modern Physics 64, pp 1045 (1992).
7. “Orbital-dependent density functionals: theory and applications” K¨ummel and Kronik, Review of Modern Physics, 80, pp 3 (2008)
8. “Random-phase approximation and its applications in computational chemistry and materials science”, Ren et al., Journal of Materials Science 47, pp 7447 (2012). Grading Policy

Mapping of CB Group- II: PSPH 244 (F): Density function theory-II

Programme Outcomes								
Course Outcome	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**1**	**1**						
CO2			**1**					
CO3			**1**					
CO4					**1**			**1**
CO5								**1**
CO6						**1**	**1**	**1**

M. Sc-II (Physics) Semester-III & IV

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Credit: 04 **No of Practicals: 10**

List of Experiments:

(Students must perform Any 8 Experiments)

(CB Group –I: PSPH 234 (A): NANO TECHNOLOGY-I & CB Group –II: PSPH 244 (A): NANO TECHNOLOGY-II):

1	Synthesis of Fe_2O_3 by sol-gel method
2	Preparation of Mn_3O_4 thin film by SILAR method
3	Synthesis of metal oxides by spray pyrolysis method
4	Synthesis of metal nanoparticles using green route
5	Band gap energy Measurement of thin films by UV-Visible spectrophotometer
6	Use of FT-IR for functional group identification (in CNT, graphene etc.)
7	Data plotting using Origin 8 software
8	Photoluminescence study of nano materials
9	Thickness measurement of thin film by weight difference method
10	Electro-deposition of Cu nano particle
11	Deposition of thin films by CBD method
12	Synthesis of ferrites by Co-precipitation method
13	Preparation of film by Doctor Blade method
14	Resistivity measurement of thin film by two probe method
15	Contact angle measurement of thin films
16	Structural properties of nano materials by XRD
17	Analysis of surface morphology by TEM
18	Morphological study by SEM
19	Temperature measurement
20	Ph measurement
21	Humidity Measurement
22	Blood pressure measurement
23	Blood sugar Measurement
24	UV- Vis Absorption, reflection and transmittance
25	Gas sensor.
26	Water flow meter

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Programme Outcomes								
Course Outcome	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**1**	**1**						
CO2			**1**					
CO3			**1**					
CO4					**1**			**1**
CO5								**1**
CO6						**1**	**1**	**1**

M. Sc-II (Physics) Semester-III & IV

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Credit: 04 **No of Practicals: 10**

List of Experiments:

(Students must perform Any 8 Experiments)

(CB Group –I: PSPH 234 (B): ENERGY STUDIES-I & CB Group –II: PSPH 244 (B): ENERGY STUDIES-II):

1	Recording the amount of sunlight receives throughout a day using Sunshine Recorder
2	Bio-gas Production from Kitchen waste.
3	Energy Content in Wind.
4	Utilizing the latent heat released by the condensing water steam using Solar Still
5	Performance evaluation of box type and concentrating type solar cooker
6	Find out the kinetics of photocatalytic reaction
7	Measure the solar radiation flux density using Pyrometer
8	Determining efficiency of lighting system/loads

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Programme Outcomes								
Course Outcome	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**1**	**1**						
CO2			**1**					
CO3			**1**					
CO4					**1**			**1**
CO5								**1**
CO6						**1**	**1**	**1**

M. Sc-II (Physics) Semester-III & IV

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Credit: 04 **No of Practicals: 10**

Learning objectives:

1) Understand the principle in measuring the thickness of thin films and to find a suitable method for measuring the thickness of thin films.

2) Understand, analyze and treating the Structural defects in thin films.

3) Understanding the mechanical behavior of thin films.

Learning Outcomes:

1) Students will have acquired necessary skills for working in research institutes.

2) Students will have acquired necessary skills and expertise to work in industry related to materials processing and quality control

List of Experiments:

(CB Group –I: PSPH 234 (D): PHYSICS OF THIN FILM-I & CB Group –II: PSPH 244 (D): PHYSICS OF THIN FILM-II):

1	Deposition of metallic thin films by vacuum evaporation method
2	Deposition of thin films by spray pyrolysis method and thickness measurement by gravimetric method
3	Thin film formation by Electro-chemical deposition technique.
4	Deposition of thin films by spin coating method and resistance measurement.
5	Deposition of thin film by Dip Coating method and thickness measurement.
6	Thickness measurement of thin film by Tolansky method.
7	Study of optical absorption of thin film (UV-visible spectroscopy) and determination of particle size
8	Determination of particle size of thin film from X-ray diffraction.
9	Determination of grain size of thin film from SEM
10	Resistivity measurement of thin film by two probe method
11	Band gap energy of thin film
12	Crystal structure of thin film
13	Electron Spin Resonance (ESR)

14	Development of microstructures by photolithography.

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Programme Outcomes								
Course Outcome	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**1**	**1**						
CO2			**1**					
CO3			**1**					
CO4					**1**			**1**
CO5								**1**
CO6						**1**	**1**	**1**

M. Sc-II (Physics) Semester-III & IV

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Credit: 04 **No of Practicals: 10**

Learning Objectives:

1. To develop analytical abilities toward real life problems
2. To familiarize with recent scientific and technological developments
3. To enrich knowledge through problem-solving, hands-on training, study visits, projects etc

Learning Outcomes:

After successfully completing this laboratory course, the students will be able to do the following:

1. Demonstrate an ability to collect data through observation and/or experimentation and interpreting data.
2. Demonstrate a deeper understanding of abstract concepts and theories gained by experiencing and visualizing them as authentic phenomena.

3. Acquire the complementary skills of collaborative learning and teamwork in laboratory settings.

(CB Group –II: PSPH 234 (E): ELECTRONIC INSTRUMENTATION-I&

CB Group –IV: PSPH 244 (E): ELECTRONIC INSTRUMENTATION-II):

1	Application of ultrasonic pressure transducer.
2	Temperature Characteristic of Thermistor
3	D to A converter circuit (R-2R & binary weighted).
4	V to F, converter as basic concept of ADC.
5	Op-amp as Instrumentation amplifier.
6	Characteristics and applications of photoelectric devices, LED, Photodiode
7	Study of Sample and Hold Circuits
8	F to V Converter using OP-AMP
9	Study of Data Acquisition System
	Measurement of temperature by thermocouple
11	Measurement of displacement using LVDT
12	Temperature Characteristic of strain gauges and its application
13	Logarithmic amplifier using op-amp 741
14	Measurement of load using strain gauge-based load cell
15	Measurement of temperature by RTD
16	Study of storage oscilloscope and determination of transient response of RLC Circuit
17	Determination of characteristics of a Fiber-optic sensor
18	Study of data acquisition system using “lab view” software and test all signal points
19	Measurement of water level using strain gauge-based water level transducer
20	Study of P, PI and PID controllers

Additional Activity (Any one Activity equivalent to two experiments)

Students must perform at least one additional activity out of two activities in addition to eight experiments mentioned above. Total Laboratory work with additional activities should be equivalent to ten experiments.

1. **Simulation/Demonstration/Mini Project**

2. **Industrial Visit / Study Tour / Field visit**

M. Sc-II (Physics) Semester-III & IV

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Credit: 04 **No of Practicals: 10**

(CB Group –II: PSPH 234 (F): DENSITY FUNCTION THEORY-I &

CB Group –IV: PSPH 244 (F): DENSITY FUNCTION THEORY-II):

1	Self-Consistent calculation
2	Convergence Test
3	Structure Optimisation
4	DOS Calculations
5	Band structure
6	P dos calculations

PSPH 235: SPECIAL LAB– I / PSPH 245: SPECIAL LAB– III

Programme Outcomes								
Course Outcome	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**
CO1	**1**	**1**						
CO2			**1**					
CO3			**1**					
CO4					**1**			**1**
CO5								**1**
CO6						**1**	**1**	**1**