Anekant Education Society's

Tuljaram Chaturchand College

of Arts, Science and Commerce, Baramati

(Autonomous)

M.Sc. Degree Program in Physics

(Faculty of Science & Technology)

CBCS Syllabus

M.Sc. Part – II (Physics) Semester – IV

For Department of Physics

Tuljaram Chaturchand College of Arts, Science and Commerce, Baramati

Choice Based Credit System Syllabus (2023 Pattern)

(As Per NEP 2020)

To be implemented from Academic Year 2024-2025

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.

Programme Outcomes (POs)

PO1	**Comprehensive Knowledge and Understanding:** Postgraduates will possess a profound understanding of their field, encompassing foundational theories, methodologies, and key concepts within a multidisciplinary context.
PO2	**Practical, Professional, and Procedural Knowledge:** Postgraduates will acquire practical skills and expertise necessary for professional tasks, including industry standards, regulations, and ethical considerations, with effective application in real-world scenarios**.**
PO3	**Entrepreneurial Mindset, Innovation, and Business Understanding:** Postgraduates will cultivate an entrepreneurial mindset, identify opportunities, foster innovation, and understand business principles, market dynamics, and risk management strategies.
PO4	**Specialized Skills, Critical Thinking, and Problem-Solving:** Postgraduates will demonstrate proficiency in technical skills, analytical abilities, effective communication, and leadership, adapting and innovating in response to changing circumstances.
PO5	**Research, Analytical Reasoning, and Ethical Conduct:** Postgraduates will exhibit observational and inquiry skills, formulate research questions, utilize appropriate methodologies for data analysis, and adhere to research ethics while effectively reporting findings.
PO6	**Communication, Collaboration, and Leadership:** Postgraduates will effectively communicate complex information, collaborate in diverse teams, demonstrate leadership qualities, and facilitate cooperative efforts toward common goals.
PO7	**Digital Proficiency and Technological Skills:** Postgraduates will demonstrate proficiency in using ICT, accessing information sources, analyzing data using appropriate software, and adapting to technological advancements.
PO8	**Multicultural Competence, Inclusive Spirit, and Empathy:** Postgraduates will engage effectively in multicultural settings, respect diverse perspectives, lead diverse teams, and demonstrate empathy and understanding of others' perspectives and emotions.
PO9	**Value Inculcation, Environmental Awareness, and Ethical Practices:** Postgraduates will embrace ethical and moral values, practice responsible citizenship, recognize and address ethical issues, and promote sustainability and environmental conservation.
PO10	**Autonomy, Responsibility, and Accountability:** Postgraduates will apply knowledge and skills independently, manage projects effectively, and demonstrate responsibility and accountability in work and learning contexts, contributing to societal well-being.

Credit Distribution Structure for M.Sc. Part-II (Physics)

Sem. (2 Yr.)	Major		RM	OJT/ FP	RP	Cum. Cr.	Degree
	Mandatory	Electives					
Sem-III	PHY-601-MJM: Statistical Physics (Credit 04) PHY-602-MJM: Solid State Physics (Credit 04) PHY-603-MJM: Physics Laboratory-V (Credit 02) PHY-604-MJM: Physics Laboratory-VI (Credit 02)	PHY-611-MJE: A. Experimental Techniques in Physics-I B. Laser C. Energy Studies-I (Credit 02) PHY-612-MJE: Practicals (Credit 02)		--	PHY-621: Research Project (Credit 04)	20	
Sem- IV	PHY-651-MJM: Nuclear and Particle Physics (Credit 04) PHY-652-MJM: Material Science (Credit 04) PHY-653-MJM: Physics Laboratory-VII (Credit 02)	PHY-661-MJE: A. Experimental Techniques in Physics-II B. Nanotechnology C. Energy Studies-II (Credit 02) PHY-662-MJE: Practicals (Credit 02)	--	-	PHY-681: Research Project (Credit 06)	20	

Course Structure for M.Sc. Part-II (Physics) (2023 Pattern)

Sem	Course Type	Course Code	Course Name	Theory/ Practical	No. of Credits
III	Major (Mandatory)	PHY-601-MJM	Statistical Physics	Theory	4
	Major (Mandatory)	PHY-602-MJM	Solid State Physics	Theory	4
	Major (Mandatory)	PHY-603- MJM	Practical Laboratory-V	Practical	2
	Major (Mandatory)	PHY-604-MJM	Practical Laboratory-VI	Practical	2
	Major (Elective)	PHY-611-MJE (A)	Experimental Techniques in Physics-I	Theory	2
		PHY-612-MJE (A)	ETP-I Practicals	Practical	2
		PHY-611-MJE (B)	Laser	Theory	2
		PHY-612-MJE (B)	Laser Practicals	Practical	2
		PHY-611-MJE (C)	Energy Studies-I	Theory	2
		PHY-612-MJE (C)	Energy Studies-I Practicals	Practical	2
	Research Project	PHY-621-RP	Research Project		4
Total Credit Semester-III					**20**
IV	Major (Mandatory)	PHY-651-MJM	Nuclear and Particle Physics	Theory	4
	Major (Mandatory)	PHY-652-MJM	Material Science	Theory	4
	Major (Mandatory)	PHY-653- MJM	Physics Laboratory-VII	Practical	2
	Major (Elective)	PHY-661-MJE (A)	Experimental Techniques in Physics-II	Theory	2
		PHY-662-MJE (A)	ETP-II Practicals	Practical	2
		PHY-661-MJE (B)	Nanotechnology	Theory	2
		PHY-662-MJE (B)	Nanotechnology Practicals	Practical	2
		PHY-661-MJE (C)	Energy Studies-II	Theory	2
		PHY-662-MJE (C)	Energy Studies-II Practicals	Practical	2
	Research Project	PHY-681-RP	Research Project	Project	6
Total Credit Semester-IV					**20**
Cumulative Credits Semester III and IV					**40**

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Mandatory Theory
Course Name	: **NUCLEAR & PARTICLE PHYSICS**
Course Code	: **PHY-651-MJM**
No. of Credits	: **4**
No. of Lectures	: **60**

PHY-651-MJM: NUCLEAR AND PARTICLE PHYSICS

Course Objectives:

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

1. To describe the structure of the atom.
2. To describe the constituents of the nucleus, and different types of radiation.
3. To give definitions of some basic terms related to nuclear physics.
4. Use a periodic table and chart of the nuclides to identify specific isotopes and elements and their properties.
5. Explanation about 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 processes in the subatomic world.
8. Describe the basic models of the atomic nucleus.
9. Learn the concepts of the radiation detectors and accelerators.
10. Describe the applications of nuclear physics in various fields such as in medicine, defence agriculture etc.

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

CO1: The students would be able to understand the basic concepts of nuclear physics.

CO2: The students should be able to tell a chronology of some of the major events in nuclear physics.

CO3: To understand the different types of radioactive decays.

CO4: The students should be able to understand some of the basic terms in decay processes such as half-life, mean life and decay constant etc.

CO5: Students should be able to list the types of decay such as alpha decay, beta decay and gamma decay.

CO6: Can express reaction equation and Q values and Energy of alpha particles.

CO7: Students should be able to know types of elementary particles and their interactions.

Topics and Learning Points

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, Collective Model, Semi-Empirical mass formula, Detectors: Gas filled detectors, Ionization chamber, Geiger-Mueller counter, Scintillation counter, Bubble Chamber, Cloud Chamber, Linear Accelerator, 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, General Properties and Concepts of Nuclear Reactors, Reactor Materials, Types of Reactors, List of Different Types of Reactors, Accelerators: Van de Graff generator, Electron & Proton Synchrotron, Cyclotron, Problems.

Unit 4: Elementary Particle Physics [15L]

Classification of Elementary Particles and their Quantum Numbers (Charge, Spin, Parity, Isospin, 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. Nuclear Physics- D.C. Tayal, Himalaya Publishing House
2. Concepts of Nuclear Physics - B.L. Cohen, Tata McGraw Hill
3. Nuclear Physics - I. Kaplan, 2nd Edition, Narosa, New Delhi, 1989
4. Atomic and Nuclear Physics - S.N. Ghoshal, S. Chand
5. Nuclear Physics: An Introduction - S.B. Patel, New Age International, 1991
6. Nuclear Radiation Detectors - S.S. Kapoor and V.S. Ramamurthy, Wiley Eastern Limited.

Mapping of Program Outcomes with Course Outcomes
Justification

Course Outcomes	Programme Outcomes									
	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO8**	**PO9**	**PO10**
CO 1	3								2	
CO 2		2							2	
CO 3		3				2			2	
CO 4		3							2	
CO 5				2					2	
CO 6									2	
CO7				3					2	

PO1: Disciplinary Knowledge

CO1: Can express the basic concepts of nuclear physics. Weightage: 3

This CO directly aligns with the objective of developing disciplinary knowledge in nuclear physics.

PO2: Critical Thinking and Problem Solving

CO2: Can tell a chronology of some of the major events in nuclear physics. Weightage: 2

Understanding the chronological sequence in nuclear physics requires critical thinking skills to analyze and interpret historical events.

CO3: Can express the radioactive decays. Weightage: 3

Expressing radioactive decays involves critical thinking and problem-solving skills related to understanding complex processes.

CO4: Can state some quantities characterizing the decay, such as half-life, decay constant. Weightage: 3

Calculating quantities like half-life and decay constant involves critical thinking and problem-solving skills.

PO4: Research-related Skills and Scientific Temper

CO5: Can list the types of decay. Weightage: 2

Listing types of decay requires knowledge of research findings and contributes to scientific temper.

CO7: Can express reaction equation and Q values and Energy of alpha particles. Weightage: 3

Expressing reaction equations and understanding Q values involve research-related skills and scientific temper.

PO6: Personal and Professional Competence

CO3: Can express the radioactive decays. Weightage: 2

Expressing radioactive decays contributes to personal and professional competence by building a foundational understanding of nuclear physics.

PO9: Self-directed and Life-long Learning

All COs can be related to this PO to some extent, as they contribute to building a foundation for continuous learning. Weightage: 2

Each CO requires a level of self-directed learning, and the knowledge gained contributes to lifelong learning.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Mandatory Theory
Course Name	: **MATERIAL SCIENCE**
Course Code	: **PHY-652-MJM**
No. of Credits	: **4**
No. of Lectures	: **60**

PHY-652-MJM: MATERIAL SCIENCE

Course 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.

Course 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 thermodynamic origin of phase diagrams, draw phase diagrams.

Topics and Learning Points

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, 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 behavior – 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

Mapping of Program Outcomes with Course Outcomes
Justification

Course Outcomes	Programme Outcomes									
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO8	PO9	PO10
CO 1	3									
CO 2		3								
CO 3				2						
CO 4				2						
CO 5					2					
CO 6					2					
CO7						2				

PO1: Disciplinary Knowledge

CO1: Qualitatively describe the bonding scheme and its general physical properties, as well as possible applications. Weightage: 3

This directly aligns with acquiring disciplinary knowledge in materials science and bonding schemes.

PO2: Critical Thinking and Problem Solving

CO2: Describe the physical origin of defects and its effects on various mechanical, electrical, thermal, and other properties of materials. Weightage: 3

Critical thinking is required to understand the complex relationship between defects and material properties.

PO4: Research-related Skills and Scientific Temper

CO3: Describe resultant elastic properties in terms of its 1D and 2D defects.

CO4: Understand diffusion mechanisms and solve problems related to diffusion processes.

Weightage: 2

Justification: While these outcomes involve research-related skills, they might not directly align with the entire spectrum of scientific temper.

PO5: Trans-disciplinary Knowledge

CO5: Derive various metallurgical thermodynamics equations and functions.

CO6: Understand and apply Gibb's phase rule to various systems of materials.

Weightage: 2

These outcomes involve knowledge that spans multiple disciplines within materials science.

PO6: Personal and Professional Competence

CO7: Understand alloy systems, families of engineering alloys.

Weightage: 2

Understanding alloy systems contributes to professional competence in materials engineering.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Mandatory Practical
Course Name	: **Practical Laboratory-VII**
Course Code	: **PHY-653-MJM**
No. of Credits	: **2**
No. of Lectures	: **60**

PHY-653-MJM: Practical Laboratory-VII

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

1. Understand the depth knowledge of various subjects of Physics.
2. Demonstrate skills and competencies to conduct wide range of scientific experiments.
3. Identify their area of interest in academic and R&D. Perform job in various fields'
4. To provide structured curricula, this supports academic development of students.
5. To provide and prepare the students for employment and higher studies in Physics.
6. To provide a good learning environment for Physics.

Course Outcomes: After completion of the course, the student should be able to:

CO1: The students would be able to have strong foundation knowledge and comprehend the basic concepts and principles in Physics.

CO2: The students would be able to experience a well-resourced environment for learning physics

CO3: To motivate and inspire the students to create deep interest in physics, to develop broad and balanced knowledge and understanding of physical concepts, principles and theories of Physics.

CO4: Learn, design and perform experiments in the labs to demonstrate the concepts, principles and theories learned in the classrooms.

CO5: Develop the ability to apply the knowledge acquired in the classroom and laboratories to specific problems in theoretical and experimental Physics.

CO6: Emphasize the discipline of Physics to be the most important branch of science for pursuing the interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas.

CO7: Problem solving ability

CO8: Critical Analysis

List of Experiments

(Students must perform Any 8 Experiments)

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. Study of optical absorption of thin film (UV-visible spectroscopy) and determination of band gap energy of thin film
6. Determination of particle size of thin film from X-ray diffraction.
7. Determination of grain size of thin film from SEM
8. Resistivity measurement of thin film by two probe method
9. Deposition of thin films by chemical bath deposition method

Mapping of Programme Outcomes with Course Outcomes

Course Outcomes	Programme Outcomes (POs)									
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10
CO 1	3									
CO 2	2									
CO 3										
CO 4		3								
CO 5		3								
CO 6			2							
CO7				3						
CO8				3						

Justification

PO1: Comprehensive Knowledge and Understanding

CO1: The students would be able to have strong foundation knowledge and comprehend the basic concepts and principles in Physics. Weightage: 3

Justification: This directly relates to the goal of acquiring comprehensive knowledge and understanding. A strong foundation in basic concepts and principles is fundamental to developing a deep understanding of Physics.

CO2: The students would be able to experience a well-resourced environment for learning physics. Weightage: 2

Justification: While a well-resourced environment can enhance understanding, it is not directly tied to comprehensive knowledge. However, it does support the practical, professional, and procedural knowledge (PO2) aspect.

PO2: Practical, Professional, and Procedural Knowledge

CO4: Learn, design and perform experiments in the labs to demonstrate the concepts, principles and theories learned in the classrooms. Weightage: 3

Justification: This directly aligns with the practical, professional, and procedural knowledge aspect. Hands-on experience in labs helps students apply theoretical knowledge and develop practical skills.

CO5: Develop the ability to apply the knowledge acquired in the classroom and laboratories to specific problems in theoretical and experimental Physics. Weightage: 3

Justification: Application of knowledge to solve problems is a key component of practical, professional, and procedural knowledge.

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding

CO6: Emphasize the discipline of Physics to be the most important branch of science for pursuing interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas. Weightage: 2

Justification: While this does emphasize the importance of Physics in interdisciplinary fields, it is not directly linked to entrepreneurial mindset or business understanding.

PO4: Specialized Skills, Critical Thinking, and Problem-Solving

CO7: Problem-solving ability. Weightage: 3

Justification: Problem-solving is a critical aspect of specialized skills, critical thinking, and problem-solving.

CO8: Critical Analysis. Weightage: 3

Justification: Critical analysis is directly related to developing specialized skills and critical thinking.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Elective Theory
Course Name	: **Experimental Techniques in Physics- II**
Course Code	: **PHY-661-MJE (A)**
No. of Credits	: **2**
No. of Lectures	: **30**

PHY-661-MJE (A): EXPERIMENTAL TECHNIQUES IN PHYSICS- II

Course 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.

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

CO1: Students will be able to describe the electromagnetic spectrum and identify various types of electromagnetic radiation (γ-rays, X-rays, UV-VIS, IR, microwaves).

CO2: They will also gain knowledge about different radiation sources and their applications in scientific research and industry.

CO3: Students will be able to use optical and electron microscopy techniques (SEM, FESEM) to analyse the morphology of materials.

CO4: Use appropriate spectroscopic technique to measure vibrational / electronic transitions to estimate parameters like energy band gap, elemental concentration, etc.

CO5: Apply thermal analysis techniques to determine thermal stability of and thermodynamic transitions of the specimen.

CO6: Students will develop an understanding of magnetic characterization techniques, particularly using Vibrating Sample Magnetometer (VSM). They will be able to analyze hysteresis loops and other magnetic properties of materials.

CO7: Students will be able to apply the knowledge and skills gained from the course in real-world research scenarios, especially in the characterization of materials and understanding their properties.

Topics and Learning Points

Unit 1: Radiation Sources and Detectors [05L]

Electromagnetic Spectrum: Overview of the electromagnetic spectrum. **Sources of Electromagnetic Radiation**: Detailed study of γ-rays, X-rays, UV-VIS, IR, microwaves, and their sources. **Detectors:** Detection methods for γ-rays, X-rays, UV-VIS, IR, and microwaves.

Unit 2: Structural Characterization and Thermal Analysis [10L]

X-ray Diffraction (XRD): Production of X-rays, types, Bragg's law, and different XRD techniques (e.g., Powder method). **Scherrer Formula**: Derivation for particle size determination. **Thermal Analysis**: Principles and instrumentation of Thermo-Gravimetric Analysis (TGA).

Unit 3: Morphological and Magnetic Characterization [10L]

Optical Microscopy: Principles and operation of optical microscopes. **Electron Microscopy**: Detailed study of Scanning Electron Microscopy (SEM) and Field Emission SEM (FESEM). **Magnetic Characterization**: Principles, instrumentation, and analysis using Vibrating Sample Magnetometer (VSM), including hysteresis loop analysis.

Unit 4: Spectroscopic Analysis [5L]

Spectroscopy: Principles, instrumentation, and applications of Infra-Red (IR), Fourier Transform Infra-Red (FTIR), and Ultraviolet-Visible (UV-VIS) spectroscopy.

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 Program Outcomes with Course Outcomes

Justification

Course Outcomes	Programme Outcomes									
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO8	PO9	PO10
CO 1	3									
CO 2	3									
CO 3	3									
CO 4		3								
CO 5		3								
CO 6		3								
CO7			3							
CO8				3						

PO1: Comprehensive Knowledge and Understanding:

CO1: Understand the importance and various fields of applications of vacuum physics.

Justification: Vacuum physics forms the foundation of understanding various fields like material science, semiconductor manufacturing, space technology, and more. Therefore, a comprehensive knowledge and understanding of vacuum physics are crucial.

CO2: Demonstrate knowledge of the kinetic theory of gases and its relevance to vacuum physics.

Justification: The kinetic theory of gases is fundamental to understanding the behavior of gases in vacuum conditions. Mastery of this theory is essential for a comprehensive understanding of vacuum physics.

CO3: Analyze gas transport properties including thermal conductivity, viscosity, and diffusion in vacuum environments.
Justification: Gas transport properties are directly relevant to understanding vacuum physics, as they determine how gases behave under vacuum conditions.

PO2: Practical, Professional, and Procedural Knowledge:
CO4: Classify different ranges of vacuum and explain their significance, Evaluate gas conductance and impedance in vacuum lines.
Justification: This directly relates to practical knowledge required in handling vacuum systems, understanding different vacuum levels, and assessing the performance of vacuum lines.
CO5: Calculate pumping speed and determine pump down times for various systems, Apply low-temperature techniques in vacuum systems.
Justification: These skills are essential for practical operation and maintenance of vacuum systems, ensuring efficient functioning and performance.
CO6: Analyze the flow of gases through different components such as apertures, elbows, and tubes considering both viscous and molecular flow regimes.
Justification: Understanding gas flow through components is crucial for designing and optimizing vacuum systems, demonstrating practical knowledge and skills.

PO3: Entrepreneurial Mindset, Innovation, and Business Understanding:
CO7: Understand the principles and operational characteristics of different types of vacuum pumps including Rotary, Molecular drag, Diffusion, Cryogenic, Getter, Titanium sublimation, Sputter ion, and Orbiton pumps.
Justification: Understanding different types of vacuum pumps enables innovation in system design and selection, aligning with entrepreneurial and innovative mindsets.

PO4: Specialized Skills, Critical Thinking, and Problem-Solving:
CO8: Understand various vacuum measurement techniques including McLeod gauge, Thermocouple (Pirani) gauge, Penning gauge, and Hot cathode ionization gauge.
Justification: Mastery of vacuum measurement techniques is crucial for problem-solving and critical thinking in diagnosing and optimizing vacuum systems.
CO9: Perform leak detection using Bayard-Alpert leak detection methods and understand simple methods of leak detection using palladium barriers and halogen leak detectors.
Justification: Leak detection skills are vital for ensuring the integrity and performance of vacuum systems, requiring specialized knowledge and problem-solving abilities.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme : M.Sc. Physics

Program Code : **PSPH**

Class : **M.Sc. II**

Semester : **IV**

Course Type : Major Elective Practicals

Course Name : **Experimental Techniques in Physics- II**

Course Code : **PHY-662-MJE (A)**

No. of Credits : **2**

No. of Lectures : 30

PHY-662-MJE (A): EXPERIMENTAL TECHNIQUES IN PHYSICS- II [P]

Course Objectives

1. Gain practical knowledge of different types of vacuum pumps and their operating principles.
2. Understand the working principles of various vacuum gauges and leak detection techniques.
3. Learn how to set up and calibrate vacuum instruments for accurate pressure measurements.
4. Explore the applications and limitations of different vacuum technologies.
5. Develop skills in troubleshooting and maintaining vacuum systems.
6. Understand the importance of vacuum technology in various scientific and industrial applications.

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

CO1: Understand the principles of various vacuum pumps and their applications in different contexts.

CO2: Gain practical experience in setting up and operating different types of vacuum pumps.

CO3: Learn about the working principles of different vacuum gauges and their applications in measuring vacuum levels.

CO4: Acquire skills in conducting experiments related to vacuum technology, including

leak detection and pressure measurement.

CO5: Enhance understanding of the importance of vacuum technology in various scientific and industrial processes.

CO6: Explore the practical applications of vacuum technology in research, manufacturing, and other fields.

CO7: Develop proficiency in using specialized equipment and techniques related to vacuum technology.

CO8: Learn about safety protocols and best practices for working with vacuum systems and associated equipment.

CO9: Improve critical thinking skills through analyzing and interpreting experimental results related to vacuum technology.

List of Experiments

(Students must perform Any 8 Experiments)

1. Study radiation detection principles and detector response.
2. Record diffraction pattern and identify crystal structure.
3. Use known crystal and X-ray source to confirm diffraction angles.
4. Particle Size Estimation using Scherrer's Formula.
5. Use transmission/reflection mode to observe microstructure.
6. Analyze surface morphology and grain size.
7. UV-VIS Absorption Spectra of a Dye or Semiconductor.
8. Smoothing of FTIR (Fourier Transform Infrared Spectroscopy) Spectrum Using Origin Software.
9. Identify functional groups via characteristic peaks.
10. UV-Visible Spectroscopy Machine Operating.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Elective Theory
Course Name	: **NANOTECHNOLOGY**
Course Code	: **PHY-661-MJE (B)**
No. of Credits	: **2**
No. of Lectures	: 30

PHY-661-MJE (B): NANOTECHNOLOGY

Course Objectives: This course aims to;

1. To equip the students for pursuing higher studies and employment in Physics and related areas.
2. Imagines developing thorough and in-depth knowledge in Physics of nanomaterials.
3. Understand the influence of dimensionality of the object at nanoscale on their properties
4. Size and shape controlled synthesis of nanomaterials and their future applications in industry
5. The program also acts as a bond between theoretical knowledge and its implementation in experimental scenario.
6. The program also introduces the students to the scientific research approach in defining problems, execution through analytical methods, systematic presentation of results keeping in mark with the research ethics through M. Sc dissertation

Course Outcomes: Upon completion of the course, the student will be able to;

1. Define and explain fundamental ideas of size effect in materials science and explain the effects of quantum confinement on the electronic structure and corresponding physical and chemical properties of materials at nanoscale.
2. Choose appropriate synthesis technique to synthesize quantum nanostructures of desired size, shape and surface properties.

3. Correlate properties of nanostructures with their size, shape and surface characteristics.
4. Elaborate which properties can be used to application in solving problem of present and future community.
5. Study various applications of nanomaterials.
6. Focus on the design and development of efficient innovative nanostructured materials prepared by various methodologies and physicochemical characterization for technological applications.
7. Propose new applications of nanoscience and nanotechnology.
8. To define a research problem, translate ideas into working models, interpret the data collected draw the conclusions and report scientific data in the form of dissertation.
9. To disseminate scientific knowledge and scientific temper in the society to contribute towards greater human cause

Topics and Learning Points

Module-1 Introductory Concepts for Nanomaterials and its Synthesis [15L]

Introduction to Nanomaterials & Structures, Effect of Reduction of Dimension, Quantum size effect, Surface Effect and Interface Effect; Nucleation and Growth Phenomenon.

Synthesis Methods: Top-down and bottom-up approach, Physical Vapour Deposition, Sputtering, Chemical vapor deposition, chemical bath deposition with capping techniques, mechanical milling, Sol-gel method, hydrothermal method and biological methods.

Module-2 Properties and applications of Nanomaterials [15L]

Size and shape dependency of electronic, optical, photonic, mechanical, magnetic, catalytic properties.

Applications of nanomaterials: Biomedical, Optoelectronic, Mechanical, Energy generation and storage, Nano coatings and Nanocomposites Graphene, Carbon nanotubes and their applications.

Reference Book:

1. Nanotechnology: Principal and Practices; by Sulbha Kulkarni; Capital Publication
2. Nanostructures and Nanomaterials: Synthesis, Properties and Application; by Guozhong Cao; Imperical College Press, Londen
3. Nanomaterials: Synthesis, Properties and Application; by A. S. Edstein and R.C. Commorta; Institute of Physics publishing Bristol and Philadephia
4. Introduction to Nanotechnology: by C. P. Poole, Jr. Frank J. Owens: Willey student Edition
5. Semiconductor Material and Device Characterization by D. K. Schroder
6. C. N. R. Rao, A. Muller, A. K. Cheetham (Eds), The chemistry of nanomaterials: Synthesis, properties and applications, Wiley VCH Verlag Gmbh & Co, Weinheim, 2004.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Elective Practical
Course Name	: **NANOTECHNOLOGY Practicals**
Course Code	: **PHY-662-MJE (B)**
No. of Credits	: **2**
No. of Lectures	: 30

PHY-662-MJE (B): NANOTECHNOLOGY [P]

Course Objectives

1. Understand the depth knowledge of various subjects of Physics.
2. Demonstrate skills and competencies to conduct wide range of scientific experiments.
3. Identify their area of interest in academic and R&D. Perform job in various fields' viz.
4. To provide students a strong foundation education in Physics.
5. To provide structured curricula, this supports academic development of students.
6. To provide and prepare the students for employment and higher studies in Physics.
7. To provide a good learning environment for Physics.

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

CO1: The students would be able to have strong foundation knowledge and comprehend the basic concepts and principles in lasers.

CO2: The students would be able to experience a well-resourced environment for learning laser.

CO3: To motivate and inspire the students to create deep interest in Physics, to develop broad and balanced knowledge and understanding of basic concepts, principles and theories of lasers.

CO4: Learn, design and perform experiments in the labs to demonstrate the concepts, principles and theories learned in the classrooms.

CO5: Develop the ability to apply the knowledge acquired in the classroom and laboratories to specific problems in theoretical and experimental Physics.

CO6: Emphasize the discipline of Physics to be the most important branch of science for pursuing the interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas.

CO7: The students would be able to experience a well-resourced environment for learning

CO8: Problem solving ability.

CO9: Critical Analysis

List of Experiments

(Students must perform Any 8 Experiments)

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. Data plotting using Origin 8 software
7. Photoluminescence study of nano materials
8. Thickness measurement of thin film by weight difference method
9. Electro-deposition of Cu nano particle
10. Deposition of thin films by CBD method
11. Synthesis of ferrites by Co-precipitation method
12. Resistivity measurement of thin film by two probe method
13. Contact angle measurement of thin films
14. Structural properties of nano materials by XRD
15. Analysis of surface morphology by TEM
16. Morphological study by SE

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Elective Theory
Course Name	: **ENERGY STUDIES-II**
Course Code	: **PHY-661-MJE (C)**
No. of Credits	: **2**
No. of Lectures	: 30

PHY-661-MJE (C): ENERGY STUDIES-II

Course Objectives:

1. To create awareness about use of renewable energy sources.
2. To develop the technologies, have low cost.
3. To foster scientific attitude, provide in-depth knowledge of scientific and technological concepts of Physics.
4. To familiarize with recent scientific and technological developments.
5. To create foundation for research and development in Physics.
2. To help students to build-up a progressive and successful career in Physics.

Course Outcomes:

After completion of the course, the student should be able to:

CO1: The course providing a basic understanding of theory and practice of various photovoltaic technologies and design concepts.

CO2: To understand the physical principles of the photovoltaic (PV) solar cell.

CO3: Discuss the positive and negative aspects of solar energy in relation to natural and human aspects of the environment.

CO4: Gain knowledge about working principle of various solar energy systems.

CO5: Understand the challenges and solutions for integrating renewable energy sources into existing energy grids.

CO6: Explore the role of energy storage and grid management in facilitating renewable energy integration.

CO7: Explore methods for promoting energy literacy and awareness.

Topics and Learning Points

Unit-1: Photovoltaic converters [10L]

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, problems.

Unit-2: Materials and Solar cell Technology [10L]

Fabrication technology of solar cell, Single, poly and amorphous silicon, GaAs, CdS, Cu_2S, $CuInSe_2$, CdTe etc. technologies for fabrication of single and polycrystalline silicon solar cells and tandem cells, solar cell modules, photovoltaic systems, space quality solar cells, perovskite solar cell, Different materials used in solar cells, problems.

Unit-3: Photochemical Converters [10L]

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, concept of photocatalysis and photo electrocatalysis process, problems.

Reference Books:

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

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: Major Elective Practical
Course Name	: **Energy Studies-II Practicals**
Course Code	: **PHY-662-MJE (C)**
No. of Credits	: **2**
No. of Lectures	: 30

PHY-662-MJE (C): Energy Studies-II [P]

Course Outcomes:

After completion of the course, the student should be able to:

CO1: Describe environmental impacts of renewable sources of energy.

CO2: Describe hydrogen as clean sources of energy.

CO3: Understand the concept of superconductors and fuel cell energy resources.

CO4: Understand the batteries and super capacitors.

CO5: Understand the challenges and solutions for integrating renewable energy sources into existing energy grids.

CO6: Explore the role of energy storage and grid management in facilitating renewable energy integration.

CO7: Explore methods for promoting energy literacy and awareness.

List of Experiments

(Students must perform Any 8 Experiments)

1. PV-IV Characteristics of Solar Module at Different Light Intensities
2. PV-IV Characteristics of series connected Solar Module
3. PV-IV Characteristics of parallel connected Solar Module
4. Sunshine Recorder
5. Solar Dryer
6. Solar Cooker
7. I-V Characteristics of a Solar Cell (Dark and Illuminated)
8. Determination of Voc, Isc, Pm, Fill Factor (FF), and Efficiency
9. Effect of Load Resistance on Solar Cell Output
10. Temperature Dependence of Solar Cell Performance
11. Compare performance under sunlight and artificial light.
12. Calculate conversion efficiency from input light and generated current.

SYLLABUS (CBCS as per NEP 2020) FOR M.Sc. II Physics

Name of the Programme	: M.Sc. Physics
Program Code	: **PSPH**
Class	: **M.Sc. II**
Semester	: **IV**
Course Type	: RESEARCH PROJECT
Course Name	: **Research Project**
Course Code	: **PHY-681-RP**
No. of Credits	: **6**
No. of Lectures	: 180

PHY-681- Research Project

Course Objectives

1. To teach students how to define a research topic, understand its scope, and formulate relevant research questions or hypotheses.
2. To guide students in identifying research gaps and understanding the significance of addressing these gaps within their research.
3. To enable students to search for relevant literature, evaluate and select credible sources, analyze and synthesize information, and write a structured literature review.
4. To instruct students on the components of a research project proposal, including introduction, literature review, study area, objectives, hypothesis, methodology, significance, expected outcomes, chapter scheme, and timeline.
5. To provide students with knowledge on developing a clear and effective research methodology that aligns with their research objectives and hypotheses.
6. To improve students' academic writing skills through structured writing of research proposals and literature reviews.
7. To teach students how to effectively present their research proposals in both written and oral formats, focusing on clarity, coherence, and academic rigor.

Course Outcome:

By the end of the course, students will be able to:

CO1. Clearly define a research topic, articulate its scope, and formulate appropriate research questions or hypotheses.

CO2. Identify gaps in existing research and understand the importance of addressing these gaps in their studies.

CO3. Conduct a comprehensive literature review, including searching for relevant sources, evaluating their credibility, and synthesizing information into a coherent review.

CO4. Prepare a detailed research project proposal, demonstrating understanding of its various components, such as objectives, methodology, and expected outcomes.

CO5. Develop a clear and effective research methodology that aligns with their research objectives and is appropriate for their study.

CO6. Enhance their academic writing skills, enabling them to produce well-structured and coherent research proposals and literature reviews.

CO7. To present their research proposals effectively, both in written format and oral presentations, demonstrating clarity, coherence, and academic rigor.

Standard Operating Procedure (SOP) and Guidelines for Research Project:

1. The research project spans across Semester III (4 credits) and Semester IV (6 credits), comprising a total of 10 credits. This is a single, continuous research project divided into two parts over the two semesters of the PG program.
2. The research project must be completed under the supervision and guidance of an in-house research mentor.
3. In Semester III, students are required to present their plan of work and conduct a literature review related to their project.
4. The actual research work will be conducted during Semester IV.
5. The department may organize necessary lectures, workshops, and laboratory training exercises as part of the research project.
6. Students may undertake the research project individually or in groups of up to three members, selecting relevant research topics in consultation with their dissertation supervisor.
7. Supervisors will assist students in reading research articles relevant to selected research topic and guide them in selecting a topic for their dissertation project.

8. With the guidance of their supervisors, students will discuss the research objectives, approach, methodology, data collection methods, and other critical aspects of their project.
9. Students are expected to prepare a comprehensive proposal in a scientific format for their dissertation project.
10. A printed copy of the project proposal must be submitted for internal assessment.
11. Students must also prepare a PowerPoint presentation of their project proposal for the final evaluation.
12. Building on the project proposal from the previous semester, students will plan and engage in an independent and thorough investigation of their chosen research topic.
13. Students may engage in activities such as surveys, interviews, field observations, or experiments to achieve their research objectives.
14. Midway through the semester, students will present their preliminary findings to an internal examiner. Feedback from this session should be incorporated into the final analysis and report.
15. At the conclusion of the dissertation project, students will write a thesis that includes the aim, methodology, results, discussion, and future implications of their research.
16. Students must adhere to ethical principles and standards throughout all stages of their research.
17. A printed and hardbound copy of the dissertation thesis must be submitted for internal assessment.
18. Additionally, students will prepare a PowerPoint presentation of their dissertation thesis for the oral presentation during the Viva-voce, as part of the external evaluation.
19. For the external assessment, students must submit the final report and participate in a viva-voce.
20. The Project Report must be duly signed by the supervisor and the Head of the Department before being submitted to the concerned department.

The final Research Project thesis shall be presented in accordance with the following specifications whenever necessary:

(a) The paper used for printing shall be of A4 size.

(b) Printing shall be in a standardized form on both sides of the paper and in 1.5 line spacing.

(c) A margin of 1.5 inches shall be on the left-hand side.

(d) The card for cover shall not be more than 330 GSM.

(e) The title of the thesis/dissertation, name of the candidate, degree, name of the Research Supervisor, place of research and the month and year of submission shall be printed on the title page and the front cover. The name of the Co-supervisor, if any, may be mentioned on the title page and the front cover.

(f) Use the standard referencing style for bibliography/references as per the discipline.

(g) The hard-bound cover of the thesis/dissertation shall be of black color.

Note: In addition, BoS will follow guidelines given by Institution for smooth execution of Research Project (RP) course.

Topics and Learning Points	
UNIT 1: Planning of fieldwork for data collection	**Teaching Hours**
1.1 Planning of fieldwork/survey	**[30]**
1.2 Preparation of questionnaire/field sheet/field book	
1.3 Carrying out fieldwork/survey for primary data collection	
1.4 Filling up questionnaires/collection of samples	
1.5 Secondary data collection	
UNIT 2: Laboratory analysis/data analysis	**[70]**
2.1 Sample analysis/questionnaire analysis to obtain data	
2.2 Data entry and data rectification	
2.3 Statistical analysis of the data	
2.4 Representation of the data	
2.5 Interpretation of the data	
UNIT 3: Research project writing	**[60]**
3.1 Introduction	
3.2 Literature Review	
3.3 Study area	
3.4 Objectives	
3.5 Hypothesis	
3.6 Methodology	
3.10 Chapter Scheme (Main text of the project)	
3.11 References	

UNIT 4: Submission of research project and viva-voce [20]

4.1 Submission of print copy of research project in prescribed format

4.2 Research project viva-voce

References:

1. Gomez, B., & Jones III, J. P. (Eds.). (2010). Research methods in geography: A critical introduction (Vol. 6). John Wiley & Sons.

2. Gomez, B., & Jones, J. P. III (2010). Research Methods in Geography: A Critical Introduction. John Wiley and Sons.

3. Goudie, A. (Ed) (2004): Encyclopaedia of Geomorphology, Routledge, London.

4. Gregory, D., Johnston, R., Pratt, G., Watts, M. & Whatmore, S. (2009). The Dictionary of Human Geography. Singapore: Wiley-Blackwell.

5. Hay, I. (2000). Qualitative research methods in Human Geography.

6. Montello, D. and Sutton, P. (2013). An Introduction to Scientific Research Methods in Geography and Environmental Studies. SAGE Publications.

7. Warf, B. (Ed)(2006). Encyclopaedia of Human Geography. London: SAGE Publications.

8.Kothari, C.R. (2004): Research Methodology: Methods and Techniques, New Age International (P) Ltd., New Delhi – 110002.

9.Kothari, C.R., (1984): Quantitative Techniques, 2nd ed., New Delhi: Vikas Publishing House Pvt. Ltd.

10. Mishra Shanti Bhushan and Shashi A. (2011): Handbook of Research Methodology, Educreation Publishing, New Delhi – 110075

11. Pandey, P. and Pandey, M.M. (2015): Research Methodology: Tools and Techniques, Romania, European Union.