CURRICULUM & SYLLABUS

Ph.D. COURSE WORK

FOR

DOCTOR OF PHILOSOPHY

IN

PHYSICS

[w. e. f. 2025-26]

FACULTY OF SCIENCE AND HUMANITIES

SRM UNIVERSITY DELHI-NCR, SONEPAT

Plot No.39, Rajiv Gandhi Education City, P.S. Rai, Sonepat

Haryana-131029

Doctor of Philosophy (Ph.D.) Programs

Research plays a vital role in enhancing the quality of higher education and achieving academic excellence. As outlined in its objectives, the University encourages quality in research by introducing Doctor of Philosophy (Ph.D.) programs in all area of engineering, management, sciences, law and Humanities commensurate with the academic resources available. The rules and regulation framed comply with the guidelines of the regulating bodies and ensure that the standard of Ph. D. studies at SRM University Delhi - NCR Sonepat, Haryana shall be comparable to the best in the country.

Categories

There shall be two categories of Ph.D. candidates.

a. Full Time candidates: All candidates who pursue full time research in this University shall belong to this category.

b. Part Time (Internal) candidates: All candidates employed in SRM University who pursue part time research in this University shall belong to this category.

Eligibility

Minimum academic qualification required for admission is that the candidate should possess at least 55% in PG Degree/ PG Diploma recognized by the respective statutory bodies for pursuing research.

Ph.D. Course Work

All candidates shall complete four courses prescribed by the Doctoral Committee and approved by the concerned Boards of Studies.

The courses shall be

a) Research methodology for the subject.

b) Research & Publication Ethics

c) A background subject related to his/her Ph.D. research.

d) An advanced subject in the area of Ph.D. research.

In the case of candidates with M.Phil. degree in the respective area, the course work on Research Methodology may be exempted.

Comprehensive Examination

A research scholar shall take a comprehensive examination after the completion of two semesters of his/her research program but before the completion of four semesters. The comprehensive examination is mandatory. The subjects and their syllabuses for the course work are prescribed in subsequent pages.

COURSE REVISION DETAILS

1. Introduced following courses
   a) Nuclear reaction (25PHPH0113)
   b) Nuclear Electronics (25PHPH0114)

Ph. D. (Physics) Programme Course-work Structure

S. No.	Course Type	No. of Courses	Credits	%
1	Research Methodology	1	1 × 4 = 4	29
2	Research & Publication Ethics	2	1 × 2 = 2	14
3	Discipline Specific Course	2	2 × 4 = 8	57
	Total	4	14	100

SRM UNIVERSITY HARYANA
DEPARTMENT OF PHYSICS
FACULTY OF SCIENCE & HUMANITIES
Pre Ph.D. Course Work in Physics

Scheme of Syllabus and Credits

S.No.	Paper Code	Paper Title	Teaching Scheme			Credit
			L	P	T	
1.	RES701	Research Methodology	4	0	0	4
2.	RPE100	Research & Publication Ethics	2	0	0	2
3.	25PHPH101	Materials characterization and Nanomaterials	3	1	0	4
4	25PHPH102	Solid State Physics	3	1	0	4
5.	25PHPH103	Spectroscopy & Laser Physics	3	1	0	4
6.	25PHPH104	X-Ray Absorption Spectroscopy	3	1	0	4
7.	25PHPH105	Multifunctional Materials	3	1	0	4
8.	25PHPH106	Plasmonics	3	1	0	4
9.	25PHPH107	Advanced Optics	3	1	0	4
10.	25PHPH108	Many Body Physics	3	1	0	4
11.	25PHPH109	Physics of Ultra-Cold Atoms	3	1	0	4
12	25PHPH110	Astronomy & Astrophysics	3	1	0	4
13	25PHPH111	Solar Physics	3	1	0	4
14	25PHPH112	Advances in Spintronics	3	1	0	4
15	25PHPH113	Nuclear reactions	3	1	0	4
16	25PHPH114	Nuclear Electronics	3	1	0	4

Subject Code	Subject Name	L	T	P	C
RES701	**Research Methodology**	4	0	0	4

Learning Objectives:

The primary objective of this course is to develop a research orientation among the scholars and to acquaint them with fundamentals of research methods. Specifically, the course aims at introducing them to the basic concepts used in research and to scientific social research methods and their approach. It includes discussions on sampling techniques, research designs and techniques of analysis.

Learning Outcomes:

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

• understand some basic concepts of research and its methodologies
• identify appropriate research topics
• select and define appropriate research problem and parameters
• prepare a project proposal (to undertake a project)
• organize and conduct research (advanced project) in a more appropriate manner
• write a research report and thesis

Unit – I: Introduction to Research **9**

Introduction, Philosophical Underpinnings, Meaning of Research, Objectives of Research, Motivations in Research, Types of Research, Research Approaches, Significance of Research, Scope of Research, Literature Review, Research Methods vs. Research Methodology, Research Process, Research and Scientific Methods, Criteria of Good Research, Research Questions, Research problem, Selecting the Problem, Necessity and Techniques of Research Problem, Qualitative & Quantitative Research, Research Proposal, Synopsis, Transdisciplinarity, Multidisciplinarity& Interdisciplinarity in Research.

Unit – II: Data Collection & Sampling **9**

Collection of Primary Data/Sources, Secondary Data/Sources, Observation Method, Interview, Libraries, Archives & Repositories, Questionnaire, Schedules, Case Study and other Innovative Methods, Research Procedure. Sampling, Steps and Criteria for selecting a Sample procedure, Characteristics of Good Sampling, Types of Sample Design, Selecting Random Samples, Complex Random Sampling Design.

Unit – III: Data Analysis & Interpretation **9**

Measures of Central Tendency, Dispersion, Correlation & Regression, Chi-Square Test: applications, Steps, Characteristics, Limitations, Analysis of Variance & Co-variance. Hypothesis: Meaning, Basic Concepts, Flow Diagram, Testing, of Means, Testing of Hypothesis testing of Correlation coefficients, Limitations of Tests of Hypothesis Theory & Empirical approaches, Ethnographic, Comparative and Interpretative Research.

Unit – IV: Research Tools & Ethics in Research **9**

Computer Fundamentals, Basics, Data Representation, Word Processing Package, Creating & Editing a Word Document. Ethical issues related to Publishing & Plagiarism, LaTex tool for Detection and Elimination of Plagiarism, Intellectual Property Rights, Copy Rights & Patent Laws.

Unit – V: Research Report & Presentations **9**

Structure & Components of Research Report, Types of Report, Layout of Research Report, Mechanism of Writing a Research Report.

Presentation: Tailoring the presentation to the target audience, Oral Presentation, Poster Presentation, Submission of Research Article, Thesis Writing, Visual & Delivery.

TEXT BOOKS:

1. Adam Pzreworsky and Frank Solomon. On the Art of Writing Proposals, rev. edn, New York, 1995.
2. Blaxter Loraine, Hughes Christina and Tight Malcolm. How to Research, Open University Press, 2006.
3. Gerard Guthrie. Basic Research Methods, Sage, London, 2010.

REFERENCE BOOKS:

1. Kothari, C. R. Research Methodology: Methods and Techniques, New Age Publishers, Delhi, 2018.
2. Rand R. Wilcox, Fundamentals of Modern Statistical Research, Springer, New York, 2010.
3. Ross, Timothy J. Fuzzy Logic with Engineering Applications, 2nd Edn. Wiley Publications, 2005.

Subject Code	Subject Name	L	T	P	C
RPE 100	Research & Publication Ethics	2	0	0	2

Unit – I: Philosophy & Ethics

Unit – II: Scientific Conduct

Unit – III: Publication Ethics

Unit – IV: Open Access Publishing

Unit – V: Publication Misconduct

Unit – VI: Databases & Research Matrices

		L	T	P	C
25PHPH101	**MATERIALS CHARACTERIZATION AND NANOMATERIALS**	3	1	0	4
	Prerequisite				
	Master level course in Solid State Physics				

COURSE OBJECTIVES

1. To understand the imperfections in solids and to understand properties and applications of smart materials.
2. To develop an advanced level of understanding about crystal structure analysis by X-ray diffraction method.
3. To make the students familiar with the characterization techniques such SEM, TEM, AFM, and thermal measurement techniques.
4. To analyze the various properties of nano-materials.
5. To explore the diverse applications of nano-materials in fields such as nanoelectronics, medicine, biology, and the textile industry.

COURSE LEARNING OUTCOMES

The syllabus has been prepared in accordance with National Education Policy (NEP). After completion of course, students would be:

1. Equipped with the knowledge of imperfection in solids and gain understanding of smart materials properties..
2. Fluent with concepts of scattering and absorption of X-ray and application of X-ray diffraction.
3. Able to understand the working of thermal measurements such as differential scanning calorimetry.
4. Explore the quantum confinement effect and its influence on the properties of nano-materials.
5. Analyze the properties and various applications of special nano-materials

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (COs’)	Course Learning Outcomes (CLOs)				
	CLO1	CLO2	CLO3	CLO4	CLO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT 1: MATERIAL PROPERTIES AND SMART MATERIALS 09

Mechanical, Electrical and thermal, Impurities in solids, Solid solutions in metals, Rules of solid solubility, Imperfection in crystals, Defects in solids point, line, surface and volume, single phase and molecular phase metals. Introduction to smartmaterials -Definition of smart materials, Types and structure of smart materials, Properties of smart materials, Applications of smart materials.

UNIT 2 X-RAY DIFFRACTION 09

Diffraction phenomena as applied to Solid State problems, Scattering and Absorption of X-rays, neutrons and electrons, X-ray methods for orienting crystals, applications of XRD, Diffraction from regular and faulted closed packed structures, Broadening of diffraction spots due to defects, Line profile analysis, crystal structure analysis, measurement of intensities of X-ray reflection

UNIT 3 CHARACTERIZATION TECHNIQUES (I) 09

Electron microscopy - SEM, TEM, STEM. Atomic Force Microscopy (AFM), Thermal analysis –Differential Scanning , Calorimetry (DSC)Raman Spectroscopy, Photoluminescence, Scanning Electron Microscopy (SEM), Auger Electron Spectroscopy, X-Ray Photoelectron Spectroscopy, SIMS, Rutherford Backscattering Spectroscopy

UNIT 4 INTRODUCTION TO NANO-MATERIALS AND SYNTHESIS 09

Introduction to nano-sized materials and structures, Brief history of nanomaterials and challenges in nanotechnology, Significance of nano-size and properties, classification of nanostructured materials. Advantages and limitations at the nano level – thermodynamic aspects at the nano level, health and environmental issues. Bottom-up and Top-down approaches, Physical methods: High energy ball milling, Physical vapour deposition, sputter deposition. Chemical methods: colloidal method, co-precipitation and sol-gel method

UNIT 5 PROPERTIES AND APPLICATIONS OF NANO-MATERIALS 09

Quantum confinement, Surface-Area ratio, Mechanical, Electrical, Thermal, Optical, solubility, melting point and Magnetic properties Applications: Nanoelectronics, Medical, Biological, Automobiles, Space, Defence, Sports, Cosmetics, Cloth industry etc. Quantum Dots, Photo luminescence, Carbon nano-tubes (CNTs), Graphene, Quantum dots, Nanocrystalline ZnO and TiO2.

TEXT AND REFERENCE BOOKS:

1. Solid State Physics: S.O.Pillai, 3rdEdition, New Age International (P) Ltd, Publisher, (1999).
2. Solid State Physics : Kakani and Hemrajani, S. Chand Publication.
3. Solid State Physics: Saxena, Gupta and Saxena, Pragati Prakation.
4. Introduction to Solid State Physics :Charles Kittel, John Wiley and Sons, 7Edition.
5. Solid State Physics: A.J.Dekker, Macmillan India Ltd, (1998).
6. Solid State Physics : R.K. Puri, V.K. Babbar, S. Chand Publication.
7. Problems in Solid State Physics: S.O. Pillai, New Age International (P) Ltd.
8. Solid State Physics - Palanyswamy.

REFERENCE BOOKS:

1. Nanotechnology: Principles and Practices by Sulbha Kulkarni, Capital Publishing Co. New Delhi.
2. Introduction to nanotechnology, by C. P. Poole Jr. and F. J. Ownes, Willey Publications.
3. Origin and development of nanotechnology by P. K. Sharma, Vista International publishing house.
4. Nanostructure and nanomaterials synthesis, Properties and applications, by G. Cao, Imperials College Press, London.

		L	T	P	C
25PHPH102	**SOLID STATE PHYSICS**	3	1	0	4
	Prerequisite:				

COURSE OBJECTIVES

1. To understand the crystal structure and different structural parameters.
2. To understand crystal bonding, and defects in solids.
3. To develop an advanced level of understanding about nanomaterial and their preparation methods.
4. To make the students familiar with characterization technique of nanomaterial.
5. To discuss the applications of nanomaterial.

COURSE LEARNING OUTCOMES

The syllabus has been prepared in accordance with National Education Policy (NEP). After completion of course, students would be:

1. Equipped with the knowledge of crystal structure and various structural parameters
2. Gain understanding of crystal bonding, and defects in solids.
3. Fluent with concepts of nanomaterial and their synthesis methods.
4. Able to understand the working of various characterization techniques of nanomaterial.
5. Well versed with the applications of nanomaterial.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (COs)	Course Learning Outcomes (CLOs)				
	CLO1	CLO2	CLO3	CLO4	CLO5
CO1					
CO2					
CO3					
CO4					
CO5					

COURSE CONTENTS

Unit-1: CRYSTAL STRUCTURE

Crystalline solids, Direct lattice, translational vectors, two and three – dimensional Bravais lattices, Miller Indices, Closed packed structures, Interaction of X- Rays with matter, absorption of X-Rays, Elastic scattering from a perfect lattice, Reciprocal lattice, Bragg's Law, Ewald construction, Brillouin zones and applications of reciprocal lattice to diffraction techniques, Experimental method in X-ray Diffraction - Laue method, powder method and rotating crystal method, structure factor, Geometric factors of SC, BCC, FC, Diamond cubic.

Unit-2: CRYSTAL BONDING, DEFECTS AND DIFFUSION IN SOLIDS

Bond classification- types of crystal binding, Covalent, molecular and ionic crystals, Vanderwaal bonding, hydrogen bonding, cohesive and Madelung energy.

Point Defects (Schottky and Frankel) and their thermodynamics, Color Centres F, M, R, V and H, Polarons and Excitons, Edge dislocation and screw dislocation, Mechanism of plastic deformation, Stress and strain fields of screw and edge dislocation, Elastic energy of dislocations.

Unit-3: NANOMATERIALS AND THEIR PREPARATION

Introduction to nanomaterial, Difference between the bulk and nano-sized material. Classification of nanomaterials, Significance of nano-size and properties. Bottom-up and Top-down approaches.

Sol-gel method, Solid state reaction method, Ball milling method, Glancing angle deposition, Sputtering, Chemical vapor deposition, Thermal evaporation method, pulse laser deposition.

Unit 4: CHARACTERIZATION TECHNIQUES OF NANOMATERIAL

X- ray diffraction, Scanning electron microscopy, UV-VIS-NIR spectroscopy, Fourier transform infrared spectroscopy, Field emission scanning electron microscopy, Transmission electron microscopy, High resolution transmission electron microscopy, Raman spectroscopy, photoluminescence spectroscopy, X – ray photoelectron spectroscopy, Electron paramagnetic resonance, Atomic force microscopy.

Unit 5: APPLICATIONS OF NANOMATERIAL

Gas sensing, Water splitting, Dye degradation, Electrocatalysis, Photocatalysis, Photo electrocatalysis, Microplastic degradation.

TEXT BOOKS:

1. Introduction to Solid State Physics, C. Kittel (Wiley, New York).
2. Principles of the Theory of Solids, J.Ziman (Cambridge University Press, Cambridge).
3. Introduction to Solids, Azaroff & Elementary Solid-State Physics,Omar.
4. Solid State Physics, S. O. Pillai (New Age International Publisher) & Soild State Physics,M. A. Wohab.
5. Solid State Physics, N. W. Ashcroft and N. D. Mermin (Ist Ed., Cengage Learning, 2003).

REFERENCE BOOKS:

1. Elementary Excitations in Solids, D. Pines (CRC press, 1999).
2. Solid State Physics A.J. Dekker.
3. Thin film analysis by X-ray scattering, Mario Birkholz, Wiley VCH publisher.
4. Handbook of X-ray data, Gunter Zschornack, Springer.
5. Fundamentals of powder diffraction and structural characterization of materials, Vitalij K Pescharsky, Peter Y Zavali, Springer.
6. Solid State Physics: R. K. Puri, V. K. Babbar, S. Chand Publication.

		L	T	P	C
25PHPH103	**SPECTROSCOPY AND LASER PHYSICS**	3	1	0	4
	Prerequisite				
	Master level course in Atomic & Molecular Physics				

Course Objectives:

1. Explain the principles of atomic and molecular energy levels, electron configurations, and spectroscopic transitions.
2. Apply quantum mechanics to calculate atomic and molecular energy levels and transition probabilities.
3. Analyze complex atomic and molecular spectra to determine electronic, vibrational, and rotational energy levels.
4. Evaluate the advantages and limitations of various spectroscopic techniques for different sample types.
5. Design and conduct spectroscopy experiments, analyzing data and interpreting results.

Course Learning Outcomes:

The syllabus has been prepared in accordance with National Education Policy (NEP). After completion of course, students would:

1. Summarize the behavior of atoms and molecules in external electric and magnetic fields.
2. Demonstrate the ability to predict and interpret atomic and molecular spectra using selection rules and quantum mechanics.
3. Differentiate between different types of molecular bonds and their characteristic vibrations and rotations.
4. Critique the performance of lasers in terms of efficiency, output power, and beam quality for specific applications.
5. Create innovative applications that leverage spectroscopy and lasers in fields such as chemistry, biology, and materials science.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (COs')	Course Learning Outcomes (CLOs)				
	CLO1	CLO2	CLO3	CLO4	CLO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT 1: ATOMIC PHYSICS **9**

Two electron system: Interaction energy in L-S and J-J coupling, atomic states arriving due to different electronic configuration (L-S coupling only), Briet's scheme, Spectrum of He-atom and Heisenberg resonance.Hyperfine structure of spectral line: Isotope effect, nuclear spin and hyperfine multiplet, Determination of nuclear spin using hyperfine structure

UNIT 2: MOLECULAR PHYSICS **9**

Microwave spectroscopy: Diatomic molecule as rigid rotator; its energy level and spectra, Intensity of rotational lines, Diatomic molecule as non rigid rotator. Isotope effect in rotational spectra.

UNIT 3: INFRARED & RAMAN SPECTROSCOPY **9**

Infrared spectroscopy: Diatomic molecules as harmonic and anharmonic oscillator, Diatomic molecule as vibrating rotator, Energy levels and spectrum, thermal distribution of quantum states, Isotope effect in vibration spectra.Raman spectroscopy: Introduction, Pure rotational Raman spectra, Pure Vibrational Raman spectra, Raman rotational vibrational spectra,

UNIT 4: ELECTRONIC BAND SPECTRA **9**

Salient features of electronic band spectra, Born Oppenheimer approximation, Vibrational coarse structure of electronic bands, progression and sequences, Rotational fine structure of electronic bands, The Fortrat parabola.Intensity of electronic bands: Franck Condon principle (absorption and emission), quantum mechanical treatment of Franck Condon principle.

UNIT 5: LASER PHYSICS & FLUORESCENCE SPECTROSCOPY **9**

Laser: Spontaneous and stimulated emission, Einstein A & B coefficient, optical pumping, population inversion, rate equation, modes of resonator and coherence length.
Fluorescence and Phosphorescence, Kasha's rule, quantum yield, nonradioactive transition, Jablonski diagram, Time resolved fluorescence and determination of excited state life time.

TEXT BOOKS:

1. Introduction to Atomic spectra: H.E. White
2. Fundamental of Molecular spectroscopy: C.N. Banwell
3. Atomic spectra & Structure: G. Herzberg
4. Physics of Atoms and Molecule: Bransden and Joachain
5. Molecular spectroscopy: J. M. Brown

REFERENCE BOOKS:

1. Introduction to Molecular spectroscopy : G. M. Barrow
2. Spectra of Atoms and Molecule: P.F. Bemath
3. Laser- Theory and Application: K. Thyagrajan and A. K. Ghatak
4. Principle of Fluorescence spectroscopy : Lacowicz
5. Theory & Interpretation of Fluorescence and Phosphorescence: Ralph S Beck

		L	T	P	C
25PHPH104	**X-RAY ABSORPTION SPECTROSCOPY**	3	1	0	4
	Prerequisite				
	Master course in Solid State Physics				

Course Objectives (CO):

1. To introduce the advanced techniques of X-ray generation and detection.
2. To gain detailed knowledge about the crystal structures and X-ray diffraction.
3. To know the experimental techniques of the Synchrotron source.
4. To introduce the experimental techniques of X-ray absorption spectroscopy.
5. To make familiar about the analysis of X-ray absorption spectroscopy.

Course Learning Outcome (CLO):

1. Familiarity with the advanced techniques of X-ray generation and detection.
2. Knowledge about the crystal structures and X-ray diffraction.
3. Familiarity with experimental techniques of the Synchrotron source.
4. Knowledge of the experimental techniques of X-ray absorption spectroscopy.
5. Well equipped with the analysis of X-ray absorption spectroscopy.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (Cos)	Course Learning Outcome (CLOs)				
	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT 1: BASICS OF X-RAY 9

X-ray tube, continuous X-ray, Characteristic X-ray, X-ray coefficient, Filters, X-ray detection: contrast due to absorption, contrast due to phase (propagation based, analyzer based, coded aperture and interferometer). X-ray scattering by electron, atom and unit cell, Factors effecting X-ray scattering (Structure, multiplicity, Lorentz, absorption and temperature), Particle size effect, De-bye Sherrer's formula,

UNIT 2: CRYSTAL STRUCTURES AND X-RAY DIFFRACTION 9

Latices, Crystal systems, symmetry, primitive and non-primitive cells, lattice directions and planes, crystal structures (perovskite, wurtzite), X-ray diffraction, Bragg law, Laue diffraction pattern, powder diffraction pattern, Preliminary treatment of data, Indexing patterns of cubic crystals, non-cubic crystals (graphical and analytical methods), grazing incident XRD, X-ray reflectivity (XRR)

UNIT 3: SYNCHROTRON LIGHT SOURCE **9**

Basic structure of Synchrotron, radiation from relativistic electron, RF cavity and bunching, photon beam properties (Flux, brilliance, emittance, coherence, polarization), Insertion devices, Wigglers, Future sources of synchrotron light (Free electron laser), Beam line: Front end, filters, X-ray mirrors, monochromators, focusing geometry, microfocus and nanofocus, Beam intensity monitors, Detectors (photographic plates, scintillator detectors, crystal analyzers, CCD, microstrip detector, energy dispersive detectors), time resolved experiments.

UNIT 4: X-RAY ABSORPTION FINE STRUCTURE (I) **9**

Theoretical Description of EXAFS Spectra, Single scattering, multiple scattering, Other corrections to the EXAFS equation, Programs for Calculating and Analyzing EXAFS, Fourier transforms, Curve fitting, XANES, Sensitivity of XANES to Oxidation State, Multiple Scattering and XANES, Bound State Transitions in XANES, Multi-electron Transitions in XANES, Polarization-dependent Measurements

UNIT 5: X-RAY ABSORPTION FINE STRUCTURE (I) **9**

Linearly polarized measurements, X-ray MCD, Natural circular dichroism, High-resolution X-ray Fluorescence, Elimination of lifetime broadening in XANES, Site-selective XAS, Spatially Resolved Measurements, Methods for focusing X-rays.

TEXT BOOKS:

1. Elements of X-ray diffraction, B.D Cullitty
2. Thin film analysis by X-ray scattering, Mario Birkholz, Wiley VCH publisher
3. Handbook of X-ray data, Gunter Zschornack, Springer

REFERENCE BOOKS:

1. Fundamentals of powder diffraction and structural characterization of materials, Vitalij K Pescharsky, Peter Y Zavali, Springer
2. An introduction to synchrotron radiation techniques and applications, Philip Wilmott, John Wiley sons ltd

		L	T	P	C
25PHPH105	**MULTIFUNCTIONAL MATERIALS**	3	1	0	4
	Prerequisite				
	Masters course in solid state Physics				

Course Objectives (CO):

1. To introduce the properties of dielectric, pyroelectric, piezoelectric and ferroelectrics.
2. To gain detailed knowledge about the impedance spectroscopy.
3. To make familiar about the magnetic behavior of material.
4. To introduce multiferroic properties of materials.
5. To make familiar about the electrocaloric and magnetocaloric properties.

Course Learning Outcome (CLO):

1. Students get familiar about the dielectric, pyroelectric, piezoelectric and ferroelectrics.
2. Knowledge about the impedance spectroscopy.
3. Gets Familiar about the magnetic properties of materials.
4. Gains Knowledge of the multiferroic properties of materials.
5. Well equipped with the knowledge of electrocaloric and magnetocaloric properites of materials.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (Cos)	Course Learning Outcome (CLOs)				
	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5
CO1	■				
CO2		■			
CO3			■		
CO4				■	
CO5					■

UNIT 1:

DIELECTRIC AND FERROELECTRIC MATERILS 9

Types of polarization, classical and quantum theory of polarization, dielectric relaxation (Debye and resonance type), Complex dielectric constantsand the loss angle, spontaneous polarization and ferroelectrics, types of ferroelectrics, soft optical phonons, Landau theory of the phase transition, second order transition, aniferroelectricity, Relaxer ferroelectric, diffuse phase transitions, theory of relaxers, Lorentz and Onsagar approximations, Curie-wiess law, Volgel-fulcher relation, methods of dielectric constant measurements, pyro and piezo electric materials.

UNIT 2:

IMPEDANCE SPECTROSCOPY 9

Basics of impedance spectroscopy, physical models for equivalent circuit elements, dielectric relaxation with single time constant, distribution of relaxation times, impedance spectroscopy of electrochemical cell, mass & charge transport, interface & boundary conditions, Grain boundary effect, modeling of electrochemical system, equivalent circuit, impedance measurement techniques, frequency domain, time domain methods, application of impedance spectroscopy.

UNIT 3:

MAGNETISM 9

Langevin theory for diamagnetic susceptibility, derivation of curie's law of paramagnetism, Quantum mechanical treatment, effect of crystalline field, paramagnetic relaxation (spin-lattice & spin-spin type), paramagnetic resonance, classical molecular field theory of ferromagnetism, exchange interactions, Band model theories of ferromagnetism, molecular theory of anti-ferromagnetism advanced theories of antiferromagnetism, domains in antiferromagnetic materials, molecular theory of ferrimagnetism, Spinels, Garnets, soft ferromagnetic materials

UNIT 4:

MULTIFERROICS 9

Magnetoelectric coupling, multiferroic type I and type II, two phase materials, theory and mechanism of multiferroic materials, some multiferroic materials ($BiFeO_3$, $TbMnO_3$etc), possible applications multiferroic materials.

UNIT 5:

ELECTROCALORIC (EC) AND MAGNETOCALORIC (MC) MATERIALS 9

Physics of magnetocaloric effect, methods of MC properties investigation, MC effect in 3d metals, rare-earth metalsand other compounds, thermodynamics of EC effect, measurement of EC effect, EC materials in bulk and thin film, interaction of EC and MC phenomenon, application of EC and MC material in freeing, cooling and heat-pump applications.

TEXT BOOKS:

1. RelaxorBehaviour in Ferroelectric Ceramics, A. Peláiz-Barranco, F. Calderón-Piñar, O. García-Zaldívar and Y. González-Abreu, Intech Publishers
2. Solid state Physics, C Kittle
3. The physical principle of magnetism, Allan H Morish
4. Multiferroics: Theory, Mechanisms, and Materials, Paolo Barone , BiplabSanyal† and Silvia Picozz, Science and Technology of Atomic, Molecular, Condensed Matter & Biological Systems, Volume 2, 2012, Pages 129-161, Elsevier.
5. Electrocaloric materials for future solid-state refrigeration technologies, Matjaz Valant,Progress in Materials Science 57 (2012) 980–1009

REFERENCE BOOKS:

1. A multicaloric material as a linkbetween electrocaloric andmagnetocaloric refrigeration, Hana Ursic1, Vid Bobnar1, Barbara Malic et. al., Scientific Reports | 6:26629
2. A review and new perspectives for the magnetocaloric effect: New materials and local heating and cooling inside the human body, A.M. Tishin, Y.I. Spichkin, et al., international journal of refrigeration 68 (2016) 177–186.
3. The magnetiocaloric effect and its applications, A M Tishin, Y.I. Spichkin
4. Magnetocaloric energy conversion, A Kitanovski, J Tusek et al.

		L	T	P	C
25PHPH106	**PLASMONICS**	3	1	0	4
	Prerequisite				
	Master course in Solid State Physics				

Course Objectives (CO):

1) To understand the electromagnetics in metals and surface plasmons
2) To get well versed with Plasmonic waveguides and their role in guiding and focusing surface plasmon polaritons (SPP) and analyze their propagations
3) To investigate methods for exciting surface plasmon polaritons, including charged particle impact, prism coupling (Kretschmann configuration), and grating coupling and Explore Scanning Near-Field Optical Microscopy (SNOM) and its variations, including aperture-based and tapered fiber tip SNOM.
4) To Grasp the Effective Medium, the Discrete Dipole Approximation (DDA) methods and Finite-Difference Time Domain (FDTD) methods for their application in simulating electromagnetic field confinement in dielectric slabs and plasmonic structures.
5) To study the application of plasmonics and their role in Surface Enhanced Raman Spectroscopy (SERS), Tip Enhanced Raman Scattering (TERS) and evaluate applications of SERS and TERS in advanced technologies.

Course Learning Outcome (CLO):

1. Students get familiar about electromagnetics in metals and surface plasmons
2. Knowledge about Plasmonic waveguides and their role in guiding and focusing surface plasmon polaritons (SPP) and analyze their propagations
3. Gains knowledge about methods for exciting surface plasmon polaritons, including charged particle impact, prism coupling (Kretschmann configuration), and grating coupling and Explore Scanning Near-Field Optical Microscopy (SNOM) and its variations, including aperture-based and tapered fiber tip SNOM.
4. Well equipped with the simulation techniques for plasmon confined simulations.
5. Students get familiar with the application of plasmonics and their role in advanced technologies.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (Cos)	Course Learning Outcome (CLOs)				
	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT 1: ELECTROMAGNETICS OF METALS& SURFACE PLASMONS 10

Free electron theory of metals, optical properties of metals, dielectric constant and skin depth, dispersion and volume plasmons, inter-band transitions, Mie theory, size and shape effect, localized surface plasmons (LSP), LSP of metallic cylinder and spheres,role of dielectric surrounding on the surface plasmon behavior, coupling between localized plasmons, hot spots, void plasmons and metallic nano-shells.

UNIT 2: SURFACE PLASMON POLARITONS PROPAGATION 7

Plasmonic waveguides, Surface plasmon polariton (SPP) propagation, SPP band gap structure, SPP propagation along metal strip- high confinement guiding and focusing, localized modes in gaps and grooves, metal nanoparticles waveguides

UNIT 3: EXCITATION OF SURFACE PLASMON POLARITONS 9

Excitation upon charged particle impact, prism coupling (Kretschmann), grating coupling, excitation using highly focused optical beam, near field excitation, Scanning near field optical microscopy (SNOM), aperture based SNOM, different types of SNOM illuminations, tapered fiber tip SNOM.

UNIT 4: SIMULATION CONCEPTS BY DDA & FDTD 9

Effective medium theory, discrete dipole approximation, Finite-Difference Time domain methods, Maxwell equations, dielectric waveguides, boundary conditions, electromagnetic field confinement in dielectric slabs simulations, plasmonic field confinement simulations.

UNIT 5: APPLICATIONS OF PLASMONICS 10

Optical response of gold metal nanoparticles, Surface Enhanced Raman spectroscopy, theory behind SERS, Polarization SERS, Tip enhanced Raman scattering, applications of SERS and TERS, Chemical and biological sensors, Catalysis enhancement, Surface enhanced fluorescence, enhancement in non-linear optical properties: Tip enhanced CARS, Second and third harmonic generation, Four-wave mixing, Dye-aggregation.

TEXT BOOKS:

1. PLASMONICS: FUNDAMENTALS AND APPLICATIONS, STEFAN A. MAIER, Springer
2. Interparticle Coupling Effect on the Surface Plasmon Resonance of Gold Nanoparticles: From Theory to Applications, Sujit Kumar Ghosh† and Tarasankar Pal, Chem. Rev. 2007, 107, 4797-4862
3. Surface Enhanced Raman spectroscopy, Sebastian Schlucker, Wiley VCH

REFERENCE BOOKS:

1. Theory of surface plasmons and surface-plasmon, Polaritons, J M Pitarke et. al. Rep. Prog. Phys. 70 (2007) 1–87.
2. Plasmons in Strongly Coupled Metallic Nanostructures, Naomi J. Halas et. al. Chem. Rev. 2011, 111, 3913–3961

		L	T	P	C
25PHPH107	**ADVANCED OPTICS**	3	1	0	4
	Prerequisite				
	Master course in Solid State Physics				

Course Objectives (CO):

1. To introduce the properties of wave motion, interference and diffraction.
2. To learn about the photonic crystals and their properties.
3. Too familiar with the various optical techniques to understand the material properties.
4. To introduce nano linear optics.
5. To learn the concept of optical microscopy and imaging technique.

Course Learning Outcome (CLO):

1. Students get familiar with the interference and diffraction phenomena.
2. Knowledge about the photonic crystals and metamaterials.
3. Familiarity with the various optical techniques.
4. Gains Knowledge of nano linear optics and its applications.
5. Well equipped with the knowledge of optical microscopy and imaging techniques and their various techniques.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (Cos)	Course Learning Outcome (CLOs)				
	CLO 1	**CLO 2**	**CLO 3**	**CLO 4**	**CLO 5**
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT 1 PHYSICAL OPTICS 9

Wave motion, superposition of waves, interference, diffraction, basics of coherence theory, temporal and spatial coherence, Michelson and Fabry-Perot interferometer, statistical properties of laser speckle patterns

UNIT 2 PHOTONIC CRYSTALS AND METAMATERIALS 9

Photonics crystals- 2D & 3D, colloidal photonic crystals, light propagation through disordered media, localization of light, photonic glass, optical metamaterials, negative index metamaterials, nonlinear optics with metamaterials.

UNIT 3 APPLICATIONS OF OPTICAL TECHNIQUES 9

Mie scattering technique, static & dynamic light scattering technique, optical tweezers, AFM colloidal probe technique, knife edge scanning to measure laser beam profile

UNIT 4 NON LINEAR OPTICS 8

Non linear optical media, 2^{nd} order optics, 3^{rd} order optics, Wave mixing, High Harmonic Generation, Self Focussing and Phase Modulation.

UNIT 5OPTICAL MICROSCOPY & IMAGING TECHNIQUES 10

Basics of optical microscopy, bright field and dark field microscopy, polarizing microscopy, fluorescence microscopy, fluorescence confocal microscopy, nonlinear optical microscopy, two photon fluorescence microscopy.

TEXT BOOKS:

1. Optical Electronics: A. Ghatak and K.Thyagrajan
2. Principles of Optics: M. Bornand, E. Wolf
3. Optics:A. Ghatak

REFERENCE BOOKS:

4. Optical Metamaterials: Fundamentals & Applications: V. Shalaevand , W. Cai
5. Modern Optical Engineering: W.J. Smith
6. Optics: E. Hecht

		L	T	P	C
25PHPH108	**Many Body Physics**	3	1	0	4
	Prerequisite				
	Master level course in Quantum Mechanics and Statistical Mechanics				

Course Objectives (CO):

1. To introduce the advanced quantum mechanics and its application to Many-body systems.
2. To introduce the second quantization formalism.
3. To introduce Green's function technique and its application to many-body systems.
4. To teach the field theoretical formalism and its application to many-body systems.
5. To review the statistical mechanics for interacting many-particle systems.

Course Learning Outcome (CLO):

1. Familiarity with the concepts of advanced quantum mechanics and its application to Many-body systems.
2. Knowledge of second quantization formalism.
3. Familiarity with Green's function technique and its application to many-body systems.
6. Knowledge of the field theoretical formalism and its application to many-body systems.
4. Understanding the role of underlying rules of the statistical mechanics in the behavior of interacting many-particle systems.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (Cos)	Course Learning Outcome (CLOs)				
	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5
CO1	■				
CO2		■			
CO3			■		
CO4				■	
CO5					■

UNIT 1 SECOND QUANTISATION

Quantum mechanics of a single particle, System of Identical particles, Many-Body Operators, Creation and Annihilation operators, Coherent states – Boson coherent states, Fermion coherent states. Gaussian Integrals.

UNIT 2 REVIEW OF STATISTICAL MECHANICS

Review of Thermodynamics and Statistical Mechanics, Ideal Gas, Bosons, Fermions, Interacting Bose gas.

UNIT 3 GREEN'S FUNCTION & FIELD THEORY AT ZERO TEMPERATURE
Schrödinger picture, Interaction picture, Heisenberg picture, Green's function, Relation to observables, Lehmann representation, Physical interpretation of Green's function, Wick's Theorem, Feynman Diagrams in coordinate space and momentum space.

UNIT 4 LINEAR RESPONSE AND COLLECTIVE MODES
General theory of linear response to an external perturbation, screening in an electron gas, zero sound in an imperfect Fermi gas, Inelastic electron scattering.

UNIT 5 FIELD THEORY AT FINITE TEMPERATURE
Green's function, Perturbation theory and Wick's Theorem for finite temperature, Feynman Diagrams in coordinate space and momentum space.

Text and Reference Books:

1. Quantum Theory of Many-Particle Systems, A. L. Fetter, and J. D. Walecka (McGraw- Hill).
2. Quantum Many Particle Systems, J. W. Negele and H. Orland (Westview Press).

		L	T	P	C
25PHPH109	**Physics of Ultra-Cold Atoms**	3	1	0	4
	Prerequisite				
	Many body Quantum Mechanics				

Course Objectives (CO):

1. To introduce the advanced techniques of trapping and cooling atomic systems.
2. To gain detailed knowledge about the interatomic interactions.
3. To know the theoretical techniques of the description of the degenerate Bose gas.
4. To introduce the theoretical techniques of describing the dynamics of degenerate Bose gas.
5. To know the advanced theoretical techniques of studying the microscopic properties of the ultra-cold bosonic gas.

Course Learning Outcome (CLO):

1. Familiarity with the advanced techniques of trapping and cooling atomic systems.
2. Knowledge about the interatomic interactions.
3. Familiarity with theoretical techniques of the description of the degenerate Bose gas.
4. Knowledge of the theoretical techniques of describing the dynamics of degenerate Bose gas.
5. Understanding the microscopic properties of the ultra-cold bosonic gas.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (Cos)	Course Learning Outcome (CLOs)				
	CLO 1	CLO 2	CLO 3	CLO 4	CLO 5
CO1					
CO2					
CO3					
CO4					
CO5					

COURSE CONTENTS

UNIT 1 COOLING AND TRAPPING OF ATOMS

Magnetic traps - The quadrupole trap, The TOP trap, Magnetic bottles and the Ioffe–Pritchard trap,Microtraps, Influence of laser light on an atom, Forces on an atom in a laser field, Optical traps, Laser cooling: the Doppler process, The magneto-optical trap, Sisyphus cooling, Evaporative cooling, Spin-polarized hydrogen.

UNIT 2 INTERACTIONS BETWEEN ATOMS

Interatomic potentials and the van der Waals interaction, Basic scattering theory, scattering length for a model potential, scattering between different internal states, Determination of scattering lengths, Scattering lengths for alkali atoms and hydrogen.

UNIT 3 THEORY OF THE CONDENSED STATE
The Gross - Pitaevskii equation, The ground state for trapped bosons: A variational calculation and The Thomas–Fermi approximation, Surface structure of clouds, Healing of the condensate wave function, Condensates with dipolar interactions.

UNIT 4 DYNAMICS OF THE CONDENSATE
General formulation, The hydrodynamic equations, Elementary excitations, Collective modes in traps: Traps with spherical symmetry, Anisotropic traps, Collective coordinates and the variational method, Surface modes, Free expansion of the condensate, Solitons.

UNIT 5 MICROSCOPIC THEORY OF THE BOSE GAS
The uniform Bose gas, The Bogoliubov transformation, Elementary excitations, Depletion of the condensate, Ground-state energy, States with definite particle number, Excitations in a trapped gas, Excitations in a trapped gas, Non-zero temperature, The Hartree–Fock approximation, The Popov approximation, Excitations in non-uniform gases, The semi-classical approximation.

TEXT BOOKS:

1. Bose Einstein Condensation in Dilute Gases, C. J. Pethick and H. Smith, Cambridge University Press.
2. Bose Einstein Condensation, L. Pitaevskii, and S. Stringari, Oxford University Press.

REFERENCE BOOKS:

3. Bose Condensed Gases at Finite Temperature, A. Griffin, T. Nikuni, E. Zaremba, Cambridge University Press.
4. Bose Einstein Condensation, Edited by A. Griffin, D. W. Snoke, and S. Stringari, Cambridge University Press.

		L	T	P	C
25PHPH110	**Astronomy & Astrophysics**	3	1	0	4
	Prerequisite				
	Detail knowledge of astronomy and astrophysics				

Learning objectives

1. To discuss the basics of astrophysics and astronomy and the instruments used.
2. To make the students familiar with the formation and evolution of stars.
3. To discuss the various aspects of Sun and its activity.
4. To gain a basic knowledge about the galaxies.
5. To create competency to understanding of solar system and the universe.

Learning outcome

1. Able to understand the basics concepts of astronomy and astrophysics and the measurement tools.
2. Get an understanding of the birth, and life cycle of starts.
3. Fluent with up-to date knowledge of the Sun, its various activity features and space weather.
4. Basic knowledge about the composition, structure and evolution of galaxies.
5. Equipped with the deep understanding of our solar system and the universe.

UNIT I: INTRODUCTION OF ASTRONOMY AND ASTROPHYSICS AND INSTRUMENTS

Mass, length, time, Brightness, Radiant flux and luminosity, and magnitude scales (apparent and absolute), distance modulus. Kepler's Laws, distances, stellar radii, masses of stars, stellar temperatures, color index. celestial sphere and coordinates, geometry of a sphere, astronomical coordinate systems, geographical coordinate systems, equatorial system, diurnal motion of the Stars, Conversion of Coordinates. Electromagnetic radiation and spectrum, radiation from heated objects, emission and absorption spectrum, radiation curves, doppler shift, black body radiation, Wien's Law,
Atmospheric windows, optical telescopes (refracting and reflecting telescopes), telescope mountings, plate scale, light gathering power, magnification, resolution, diffraction limit. radio telescopes, interferometry, astronomical instruments and detectors (photometer, spectroscopes, CCD camera, filters), observations at other wavelengths (infrared, ultraviolet, X-ray and Gamma ray astronomy), Space telescopes (HST, Chandra).

UNIT II: STAR FORMATION AND EVOLUTION

Distance, brightness, size, mass, luminosity, temperature, Spectral types and their temperature dependence, Staller classification (spectral and luminosity), H-R diagram. Basic equation of stellar structure, hydrostatic equilibrium and the virial theorem, radiative and convective energy transport inside stars, nuclear energy production inside the stars. Nebulae, star life cycle, pre-main-sequence stage, Main sequence stage collapse, late evaluation phase of stars, evolution of high-mass and low-mass stars (core and shell hydrogen burning, helium ignition), White dwarf, Neutron stars and black holes. End stages of stars white dwarfs (electron-degeneracy pressure, mass-radius relation), neutron stars (mass limit of neutron stars, Chandrasekhar limit, neutron stars observable as pulsars), black holes as end point of stellar evolution, supernovae.

UNIT III: THE SUN AND SOLAR ACTIVITY

Solar structure, solar interior, core, radiative zone, convective zone, the photosphere, solar atmosphere, chromosphere, corona. Active regions, sunspot, Magnetic field of the Sun. Basics of Solar Magneto-hydrodynamics, solar cycle, butterfly diagram, solar flares, filament eruptions and coronal mass ejections. Helioseismology basics.

UNIT IV: GALAXIES

Galaxies, type of galaxies, classification of galaxies, composition, mass. The Milky Way galaxy (our home galaxy): components, structure, formation, kinematics of the Milky way, the galactic center, spiral arms. Quiet and active galaxies, types of active galaxies, Active Galactic Nuclei (AGN) and Quasars, accretion by supermassive black holes.

UNIT V: SOLAR SYSTEM & COSMOLOGY

Overall composition and structure of solar system, planets, asteroids, meteors, comets, origin of the Solar System: The Nebular Model, Tidal Forces and Planetary Rings, Extra-Solar Planets. Steady state theory, Oscillating Universe theory, expending universe theory. Cosmological redshift, dark matter, dark energy and the accelerating universe, Hubble's law and the expanding Universe, Age of the universe, scale factor and comoving coordinate, big bang theory. Observational evidences of big bang theory (cosmic microwave background, bark matter and bark energy).

TEXT BOOKS:

1. An Invitation to Astrophysics, T. Padmanabhan, World Scientic Publishing Co.
2. An Introduction to Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
3. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
4. Astrophysics in a Nutshell (Basic Astrophysics), Dan Maoz, Princeton University Press.
5. Foundations of Astrophysics, Barbara Ryden and Bradley M. Peterson, Addison Wesley.
6. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press.
7. Astronomy and Astrophysics, A. B. Bhattacharya, S. Joardar, R. Bhattacharya, Overseas Press (India) Pvt.Ltd.

REFERENCE BOOKS:

1. Theoretical Astrophysics, Volume III: Galaxies and Cosmology, T. Padmanabhan, Cambridge University Press.
2. K.S. Krishnasamy, 'Astro Physics a modern perspective,' Reprint, New AgeInternational (p) Ltd, New Delhi,2002.
3. BaidyanathBasu, 'An introduction to Astro physics', Second printing, Prentice - Hall of India Private limited, New Delhi,2001.
4. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication

		L	T	P	C
25PHPH111	**Solar Physics**	**3**	**1**	**0**	**4**
	Prerequisite				
	Detail knowledge of the Sun and space weather				

Learning objectives

1. To discuss the basics about the structure of the Sun.
2. To make the students familiar with the solar activity features.
3. To discuss the various aspects of the Sun's observations.
4. To gain a basic knowledge about the magnetohydrodynamic of the Sun.
5. To create competency to understanding about the Sun-Earth connection.

Learning outcome

1. Able to understand the details about the inner and outer structure of the Sun.
2. Get an understanding of the active Sun and its features.
3. Fluent with up-to date knowledge about the observation of the Sun form ground and from the space.
4. Basic knowledge about the magnetic reconnection and other aspects using magnetohydrodynamics.
5. Equipped with the deep understanding about the relationship between the Sun and the Earth.

UNIT I: STRUCTURE OF THE SUN

The interior: core, radiative zone, convective zone. The atmospheres: photosphere, chromosphere, corona. Inner and outer corona. Chemical composition, density, diameter, temperature, and magnetic field of different layers. Age, mass, rotation, solar radiation. Variation of mass, density, and temperature with height. Energy transport from core to the outer atmosphere. Radiative transfer. Helioseismology.

UNIT II: SOLAR ACTIVITY

Sunspot, theory of sunspot formation, Babcock model of sunspot formation. Chromospheric activity: Faculae, plages, Ellerman bombs. Solar magnetic field. Solar filaments and prominences. Solar Flares. Coronal mass ejection. solar jets. Theories and models of these activity features. Long term of distribution of solar activity. 11-year solar cycle, solar dynamo theory, butterfly diagram.

UNIT III: OBSERVATION OF THE SUN

Solar Optical telescopes. Ground based solar observation and telescope. Space solar observatories. Various instruments to observe the Sun in multiwavelength: solar dynamics observatory (SDO), Helioseismic and Magnetic Imager (HMI), Atmospheric Imaging Assembly (AIA), Solar Probe, LASCO coronagraph, IRIS. etc.

UNIT IV: MAGNETOHYDRODYNAMICS OF THE SUN

Solar Magneto-Hydrodynamics, Magnetohydrodynamic equations, plasma equation, magnetic flux tube, current sheets, magnetic reconnection, current-free fields, force free fields. Alfven's Theorem.

UNIT V: SUN-EARTH CONNECTION AND SPACE WEATHER

Various component of the Sun-Earth connections. Solar Wind, various type of radio bursts. solar energetic particles. Theories and models of these phenomena. Space-weather events and their predictions. Propagation characteristics of solar eruptions from the Sun to the Earth.

TEXT BOOKS:

1. An Invitation to Astrophysics, T. Padmanabhan, World Scientic Publishing Co.
2. An Introduction to Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
3. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
4. Astrophysics in a Nutshell (Basic Astrophysics), Dan Maoz, Princeton University Press.
5. Foundations of Astrophysics, Barbara Ryden and Bradley M. Peterson, Addison Wesley.
6. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press.
7. Astronomy and Astrophysics, A. B. Bhattacharya, S. Joardar, R. Bhattacharya, Overseas Press (India) Pvt.Ltd.

REFERENCE BOOKS:

1. Theoretical Astrophysics, Volume III: Galaxies and Cosmology, T. Padmanabhan, Cambridge University Press.
2. K.S. Krishnasamy, 'Astro Physics a modern perspective,' Reprint, New AgeInternational (p) Ltd, New Delhi,2002.
3. BaidyanathBasu, 'An introduction to Astro physics', Second printing, Prentice - Hall of India Private limited, New Delhi,2001.
4. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.

		L	T	P	C
25PHPH112	**ADVANCES IN SPINTRONICS**	**3**	**1**	**0**	**4**
	Prerequisite				

COURSE OBJECTIVE

1. To acquire the basic knowledge of magnetism and brief idea of spintronics
2. To make student familiar with magnetic tunnel junctions
3. To understand the basics of domain wall dynamics in nanomagnetic system.
4. To illustrate the basics laws of spintronics spin dependent transport processes in spintronics devices.
5. To make student familiar with spin injection phenomena and applications

COURSE LEARNING OUTCOMES

The syllabus has been prepared in accordance with National Education Policy (NEP). After completion of course, students would be:

1. Fluent with good knowledge on the concepts of magnetism and spintronics.
2. Well-versed with knowledge of magnetic tunnel junctions
3. Get an understanding of domain wall dynamics in nanomagnetic systems.
4. Able to understand the spin dependent transport processes in spintronics devices.
5. Well-versed with the spin injection phenomena

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (COs')	Course Learning Outcomes (CLOs')				
	CLO1	CLO2	CLO3	CLO4	CLO5
CO1					
CO2					
CO3					
CO4					
CO5					

Unit I:

SPINTRONICS, ITS NEED AND FUTURE VISION; Basics of magnetic materials, spin orbit interaction, spin polarized current and their injection, accumulation and detection, Magnetoresistance and concepts of spin detection and magnetic memory; Spin valves & GMR, CIP and CPP transport, Semiclassical transport models

Unit II:

MAGNETIC TUNNEL JUNCTIONS: Basics of spin valve and magnetic tunnel junctions, Tunnel magneto resistance, Quantum mechanical model of coherent tunneling and Giant TMR; Magnetic anisotropies and exchange bias, Spin valves with AF and SAF layers, Magnetization switching in AF and SAF layers

Unit III:

MAGNETIC DOMAINS: Magnetic Domains, Elements of Micromagnetism, Magnetism of small particles, Superparamagnetism, Stoner-Wohlfarth Model, Precessional dynamics of magnetization, Ferromagnetic resonance and Landau-Lifshitz-Gilbert equation, Spin waves, Precessional switching of macrospins driven by magnetic field, Precessional motion of domain walls and vortices driven by a magnetic field.

Unit IV:

SPIN DEPENDENT TRANSPORT IN MAGNETIC METALS – Anisotropic Magnetoresistance, Giant Magnetoresistance, Spin dependent tunneling, Tunneling magnetoresistance, Spin-Orbit interaction and Hall effects –Spin Hall Effect and Inverse Spin Hall Effect.

Unit V:

SPIN INJECTION PHENOMENA AND APPLICATIONS - Spin Transfer Torque, Spin injection magnetization reversal; High frequency phenomena; Spin Transfer Torque applications, Dilute magnetic semiconductors, Spintronic properties of ferromagnetic semiconductors, Materials for Spin Electronics, Spintronic devices and their applications.

TEXT BOOKS:

1. Nanomagnetism and spintronics, edited by Teruya Shinjo, Elsevier, 2013.
2. Magnetism and Magnetic Materials, J. M. D. Coey, Cambridge University Press, 2009.
3. Principles of Nanomagnetism, Alberto P. Guimaraes, Springer, 2009.
4. Introduction to Spintronics, SupriyoBandyopadhyay and Marc Cahay, CRC press, 2008.

REFERENCE BOOKS:

1. Spin Waves: Theory and Applications, Daniel D. Stancil, Anil Prabhakar Springer Science, 2009.
2. Relaxation Processes in Micromagnetics, Harry Suhl, Oxford University Press, 2007.
3. Spin Electronics, D. Awschalom, Robert A. Buhrman, James M. Daughton, Stephan von Molnár, Michael L. Roukes (Editors), Springer, 2004.

Nuclear Reactions	
Course Code: 25PHPH113	Continuous Evaluation: Marks
Credits: 4	End Semester Examination: Marks
L T P : 3 1 0	**Course Type:**
Prerequisite: Basic understanding of nuclear structure.	

COURSE OBJECTIVES (CO)

1. To Learn the properties, and structure of the nucleus.
2. To know about the nuclear models.
3. Learning of kinematics of nuclear reactions and reaction cross section.
4. Understanding of Fission and Fusion reactions.
5. Knowledge of different reactors and their use.

COURSE LEARNING OUTCOMES (CLO)

The syllabus has been prepared in accordance with National Education Policy (NEP). After completion of course, students will be able to:

1. explain the basic properties, structures of nucleus.
2. Solve the problems related to states of nucleons using nuclear models.
3. differentiate different nuclear reactions and calculate cross section.
4. Can explain nuclear fission and fusion.
5. Well aware of different reactors available and their use.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (COs')	Course Learning Outcomes (CLOs')				
	CLO1	CLO2	CLO3	CLO4	CLO5
CO1					
CO2					
CO3					
CO4					
CO5					

UNIT I: NUCLEAR STRUCTURE AND GENERAL PROPERTIES OF NUCLEI

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 (N Vs Z Curve), Nature of nuclear force.

UNIT II: NUCLEAR MODELS:
Liquid Drop model. semi-empirical mass formula and binding energy. Nuclear Shell Model. Physical concepts of the unified model (Collective Model).

UNIT III: NUCLEAR REACTIONS I:
Different types of nuclear reactions, Conservation laws in nuclear reactions, Collision between subatomic particles (Elastic and non elastic), Q value of nuclear reactions, Cross section of nuclear reactions, Resonance scattering and Breit-Wigner dispersion relation; Compound nucleus formation and break-up, Statistical theory of nuclear reactions, evaporation probability.

UNIT IV: NUCLEAR REACTIONS II:
Optical model,, Nuclear fission: fission reactions with example, spontaneous fission, liquid drop model, barrier penetration, Nuclear fusion (proton-proton cycle, carbon-nitrogen cycle), thermonuclear reactions, Nucleosynthesis and abundance of elements

UNIT V: NUCLEAR REACTORS:
Basic types of reactors, components of Nuclear Reactor, Light Water Reactor, Gas cooled reactors, Fast Breeder Reactor and its scope in power generation, Basic design of fusion reactor, conditions for a fusion reactor, Lawson criterion, Plasma confinement, peaceful utilization of fusion power.

TEXTBOOKS

1. Concepts of Nuclear Physics, B. L. Cohen (Tata McGraw-Hill).
2. Nuclear Physics, I. Kaplan(Narosa Publishing House).
3. Nuclear Physics,R. R. Roy &B. P. Nigam (New Age International Publisher).
4. Nuclear Physics: Principle and Application by John Lilley (Wiley Pub.).

REFERENCE BOOKS

1. Nuclear Physics, M. K. Pal (Affiliated East West Press Pvt. Ltd.).
2. Nuclear Physics,J. M. Blatt and V. F. Weisskopf (John Wiley & Sons).
3. Nuclear Energy: an introduction to the concepts, systems and application of nuclear proceses, by R. L. Murray and K. E. Holbert.
4. Nuclear Physics, S. N. Ghoshal (S. Chand)

Nuclear Electronics	
Course Code: 25PHPH114	Continuous Evaluation: Marks
Credits: 4	End Semester Examination: Marks
L T P : 3 1 0	**Course Type:**
Prerequisite: Basic understanding of nuclear reactions.	

COURSE OBJECTIVES

1. To develop understanding of how various forms of radiation interact with matter.
2. To provide theoretical knowledge about particle accelerators.
3. To enable students to analyze detector characteristics such as efficiency, energy resolution, dead time, and signal formation.
4. To introduce semiconductor detectors
5. To acquaint students with practical applications and current technologies in particle detection.

COURSE LEARNING OUTCOMES

The syllabus has been prepared in accordance with National Education Policy (NEP). After completion of course, students will be able to:

1. Explain the interaction mechanisms of heavy charged particles, electrons, and gamma rays with matter, including energy loss processes and straggling effects.
2. Describe the principles and applications of various particle accelerators such as Van de Graaff, cyclotron, betatron, and synchrotron.
3. Analyze the operating principles, modes, and characteristics of gas-filled detectors including ionization chambers, proportional counters, and Geiger-Müller tubes.
4. Evaluate the structure, function, and performance of semiconductor detectors like Si, Si(Li), and HPGe, including their response to different radiations.
5. Understand the scintillation process in organic and inorganic materials, and analyze the role of photomultiplier tubes and Cherenkov detectors in light-based radiation detection.

MAPPING MATRIX OF COURSE OBJECTIVES & COURSE LEARNING OUTCOMES

Course Objectives (COs')	Course Learning Outcomes (CLOs')				
	CLO1	CLO2	CLO3	CLO4	CLO5
CO1					
CO2					
CO3					
CO4					
CO5					

COURSE CONTENT

UNIT-I: INTERACTION OF CHARGED PARTICLES

Interaction of heavy charged particles with matter in low, medium and high velocity region. Range-Energy relationship for heavy charged particles, Energy and range straggling. Interaction of fast electrons in matter. Basic idea of gamma ray interaction with matter.

UNIT-II: PARTICLE ACCELERATOR

Introduction to particle Accelerators, Accelerator facility available in India, Different type of accelerators: Van-de Graaff generator, Linear accelerator, Cyclotron, Betatron, Synchrotrons

UNIT-III:

GAS DETECTORS: Features of Gas Ionization detectors, Gas multiplication and modes of operation of gas detectors, Ionization chamber: Mode of operation, integrated type of ion chambers, pulse-mode operated ionization chambers, Proportional counters, Geiger-Muller Counters: Geiger discharge, Counter characteristics: development of pulse and quenching, dead time, Geiger Plateau, Counter efficiency.

UNIT IV:

SEMICONDUTOR DETECTORS: Interaction of heavy charged particles, electrons and photons with semiconductor (silicon and germanium), production of electron-hole pairs. Diode detector, Diffused junction silicon detectors, Surface barrier detectors, Lithium-Drifted silicon detectors, Si (Li),. Lithium-Drifted Germanium detectors, Ge (Li), HPGE detector.

UNIT V:

LIGHT SENSING DETECTORS: Scintillation detectors**:** Scintillation mechanism and classification of scintillation materials, modes of energy transfer, Organic scintillators, Inorganic scintillators, Time characteristics of scintillator output, Photomultiplier tubes**,** Scintillation counter, Cherenkov detector.

TEXTBOOKS

1. Nuclear Radiation Detector by S. S. Kapoor and V. S. Ramamurthy (New Age Int.).
2. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo (Springer-Verlag).

REFERENCE BOOKS

1. Nuclear Radiation Detection, Measurements and Analysis by K. Muraleedhara Varier (Narosa).
2. Nuclear Physics by S. N. Ghoshal (S. Chand).