गोंय विद्यापीठ
ताळगांव पठार,
गोंय - ४०३ २०६
फोन : + ९१ - ८६६९६०९०४८

(Accredited by NAAC with Grade A+)

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GU/Acad –PG/BoS -NEP/2026-27/399 Date: 09.09.2026

CIRCULAR

Ref. No.: GU/Acad –PG/BoS -NEP/2025-26/174 dated 26.06.2025

In supersession to the above referred Circular, the structure and syllabus of Semester III and IV of the **Master of Science in Physics** Programme, approved by the Academic Council in its meeting held on 24th April, 12th & 13th May 2026 is attached.

The Syllabus of Semester I and II approved earlier by the Academic Council in its meeting held on 13th & 14th June 2025 is also attached.

The Dean & Vice-Dean (Academic) of the School of Physical and Applied Sciences are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN V LAWANDE Digitally signed by ASHWIN V LAWANDE Date: 2026.09.09 11:56:55 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,

1. The Dean, School of Physical and Applied Sciences, Goa University.
2. The Vice-Dean (Academic), School of Physical and Applied Sciences, Goa University.
3. The Principals of Affiliated Colleges offering the Master of Science in Physics Programme.

Copy to:

1. Chairperson, BoS in Physics, Goa University.
2. Programme Director, M.Sc. Physics, Goa University.
3. Controller of Examinations, Goa University.
4. Assistant Registrar Examinations (PG), Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

GOA UNIVERSITY

MASTER OF SCIENCE IN PHYSICS

(Effective from the Academic Year 2025-26)

ABOUT THE PROGRAMME
The School of Physical and Applied Sciences (SPAS) offers a two-year (4-semester) Master's program, with an annual intake of 50 students. It continuously reinvents its teaching orientation and syllabi contents, taking into account contemporary requirements to introduce courses, particularly in applied, vocational and interdisciplinary areas. M. Sc. programme comes with three specializations; Solid State Physics, Computational Physics and Biophysics which students are required to select in the third semester. Advanced papers have been designed to acquaint students and provide them with a broader perspective.

OBJECTIVES OF THE PROGRAMME
To provide students with advanced knowledge in fundamental and advanced physics concepts, develop strong analytical and problem-solving skills, enhance practical skills through laboratory experience, and equip students with computer-aided investigation skills. Additionally, the program aims to foster an understanding of interdisciplinary science and prepare students for professional development or further research.

PROGRAMME SPECIFIC OUTCOMES (PSO)	
PSO 1.	**Gain knowledge** of classical and quantum mechanical approaches, their realm and applicability to nuclear, atomic and condensed systems or astronomical systems.
PSO 2.	**Demonstrate** proficiency in mathematics and the mathematical concepts needed for a proper understanding of physics
PSO 3.	**Understand** the theorems and circuits in electronics and use them in various applications
PSO 4.	**Gain hands on experience** in designing, constructing experiments, experimental circuits and setups and measurement of physical quantities and estimating associated errors.
PSO 5.	**Understand and analyse** the structural, electrical, thermal, magnetic and optical properties of solids
PSO 6.	**Apply** advanced numerical techniques and computer programming to solve complex problems in physics.
PSO 7.	**Apply** concepts of physics in understanding biological processes and various methods in Biophysical analysis.
PSO 8.	**Develop** an appreciation of experimental and theoretical techniques used to infer the nature of different physical systems
PSO 9.	Use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanations

PROGRAMME STRUCTURE

Master of Science in Physics

Effective from Academic Year 2025-26

Bridge Course			
Sr. No.	**Course Code**	**Title of the Course**	**Credits (Theory + Practical)**
1	**PHY-1000**	Bridge Course in Mathematical Methods	2+0=2
2	**PHY-1001**	Bridge Course in Thermal Physics	2+0=2
3	**PHY-1002**	Bridge Course in Optics	2+0=2
4	**PHY-1003**	Bridge Course in Quantum Mechanics	2+0=2
5	**PHY-1004**	Bridge Course in Electrostatics and Magnetostatics	2+0=2
6	**PHY-1005**	Introduction to Biology and Biophysics	2+0=2

SEMESTER I				
Discipline Specific Core (DSC) Courses (16 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
1	**PHY-5000**	Mathematical Methods of Physics	4+0=4	400
2	**PHY-5001**	Classical Mechanics	4+0=4	400
3	**PHY-5008**	Electromagnetic Theory	4+0=4	400
4	**PHY-5003**	Electronics	4+0=4	400
Total Credits for DSC Courses in Semester I			**16**	
Discipline Specific Elective (DSE) Course (4 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
1	**PHY-5201**	Electronics and Computer Programming in Fortran/C/Python Practical	0+4=4	400
2	**PHY-5202**	Design and Fabrication Practical - I	0+4=4	400
Total Credits for DSE Courses in Semester I			**4**	
Total Credits in Semester I			**20**	

SEMESTER II				
Discipline Specific Core (DSC) Courses				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
1	**PHY-5004**	Quantum Mechanics	4+0=4	500
2	**PHY-5005**	Statistical Mechanics	4+0=4	500
3	**PHY-5006**	Nuclear and Elementary Particle Physics	4+0=4	500
4	**PHY-5007**	Atomic Physics	4+0=4	500
Total Credits for DSC Courses in Semester II			**16**	
Discipline Specific Elective (DSE) Courses (4 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
1	**PHY-5203**	General Physics Practical	0+4=4	400
2	**PHY-5204**	Design and Fabrication Practical - II	0+4=4	400
Total Credits for DSE Courses in Semester II			**4**	
Total Credits in Semester II			**20**	

SEMESTER III				
Research Specific Elective (RSE) Courses (12 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
Solid State Physics Specialization				
1	**PHS-6000**	Solid State Physics I	4+0=4	500
2	**PHS-6001**	Solid State Physics II	4+0=4	500
3	**PHS-6002**	Solid State Physics Practical	0+4=4	500
4	**PHS-6003**	Research Methodology for Solid State Physics	3	500
5	**PHS-6004**	Research Methodology Lab for Solid State Physics	1	500
6	**PHS-6005**	Advanced Research Methodology	4	500
7	SWAYAM-I		4+0=4	500
8	SWAYAM-II		4+0=4	500
Computational Physics Specialization				
9	**PHC-6000**	Advanced Quantum Mechanics	4+0=4	500
10	**PHC-6001**	Advanced Statistical Mechanics	4+0=4	500
11	**PHC-6002**	Numerical Techniques Practical	0+4=4	500
12	**PHC-6003**	Research Methodology for Computational Physics	3	500
13	**PHC-6004**	Research Methodology Lab for Computational Physics	1	500
14	**PHC-6005**	Advanced Research Methodology	4	500
15	SWAYAM-III		4+0=4	500
16	SWAYAM-IV		4+0=4	500
Total Credits for RSE Courses in Semester III			**12**	
Discipline Specific Vocational Elective (DSVE) Courses (8 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
1	**PHY-6401**	Academic Writing and Documentation using Latex	0+4=4	500
3	**PHC-6401**	Parallel Programming and Numerical Methods	2+2=4	500
4	**PHS-6401**	Experimental Techniques in Physics	2+2=4	500
5	**PHS-6402**	Advanced Experimental Methods in Condensed Matter Physics	2+2=4	500
Total Credits for DSVE Courses in Semester III			**8**	
Total Credits in Semester III			**20**	

OR

Discipline Specific Dissertation (DSD) (40 Credit Dissertation)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits**	**Level**
Solid State Physics Specialization				
1	**PHS-6501**	**Dissertation**	**40**	**500**
Computational Physics Specialization				
2	**PHC-6501**	**Dissertation**	**40**	500

SEMESTER IV				
Generic Elective (GE) Courses (20 credits)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
1	**PHY-6201**	Nuclear Reactor Physics	2+0=2	500
2	**PHY-6202**	Physics of Glasses and Thin Films	4+0=4	500
3	**PHY-6203**	Laser Physics and Advanced Optics	4+0=4	500
4	**PHY-6204**	Physics of Energy and Ferroic Materials	4+0=4	500
5	**PHY-6205**	Astronomy and Astrophysics	4+0=4	500
6	**PHY-6206**	Superconductivity, BEC and Superfluidity	4+0=4	500
7	**PHC-6207**	Simulation Techniques	2+2=4	500
Courses for Advanced Learners				
8	**PHS-6201**	Physics of Magnetic and Quantum Materials	4+0=4	500
9	**PHS-6202**	Introduction to Crystallography and X-ray Spectroscopy	4+0=4	500
10	**PHS-6203**	Optical and Nuclear Spectroscopy for Condensed Matter	4+0=4	500
11	**PHC-6201**	Introduction to Quantum information and computing	4+0=4	500
Total Credits for GE Courses in Semester IV			**20**	

OR

Discipline Specific Dissertation (DSD)/ Internship (20 Credit Dissertation)				
Sr. No.	**Course Code**	**Title of the Course**	**Credits (T+P)**	**Level**
Solid State Physics Specialization				
1	**PHS-6502**	Dissertation	20	500
Computational Physics Specialization				
2	**PHC-6502**	Dissertation	20	500
Total Credits in Semester IV			**20**	

Blooms Taxonomy Cognitive Levels	
Cognitive Level	**Notations**
K1	Remembering
K2	Understanding
K3	Applying
K4	Analyzing
K5	Evaluating
K6	Create

BRIDGE COURSES

Title of the Course	Bridge Course in Mathematical Methods
Course Code	PHY-1000
Number of Credits	2
Theory/Practical	Theory
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course develops problem solving capabilities of students. It also helps to revise and understand the concepts based on Integration, differentiation and such other basic topics of mathematics, which are useful in solving problems based on Physics.	
Course Outcomes:	Students able to	**Mapped to PSO**
	CO 1. Understand differentiation, partial differentiation, integration and Ordinary differential equations	PSO2
	CO 2. Apply the above techniques to solve the problems in physics.	PSO2
	CO 3. Understand concepts of vector algebra, limits and series.	PSO2
	CO 4. Apply these techniques for solving the problems in physics and day to day life	PSO2

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Preliminary Calculus** Differentiation from first principles; products; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz' theorem; special points of a function; theorems of differentiation, Integration from first principles; the inverse of differentiation; integration by inspection; sinusoidal functions; logarithmic integration; integration using partial fractions; substitution method; integration by parts; reduction formulae; infinite improper integrals; plane polar coordinates; integral inequalities; applications of integration.	**10**	CO1, CO2	K2, K3
Module 2:	**Partial Differentiation** Definition of partial derivative; the total differential and total derivative; Exact and inexact differentials; Useful theorems of partial differentiation; the chain rule; Change of variables; Taylor's theorem for many variable functions; Stationary values of many variable functions; Stationary variables under constraints; Thermodynamic relations; Differentiation of integrals.	**5**	CO1, CO2	K2, K3
Module 3:	**Series and Limits** Series; Summation of series (arithmetic, geometric); convergence of infinite series; Operations with series; Power series; Taylor series; Evaluation of limits.	**5**	CO1, CO2	K2, K3
Module 4:	**Vector Algebra** Scalars and vectors; Addition and subtraction of vectors; Multiplication by a scalar; Basis vectors and components; Magnitude of a vector; Multiplication of vectors; Equation of lines and planes; Using vectors to find distances; Reciprocal vectors.	**5**	CO3, CO4	K2, K3
Module 5:	**Ordinary differential equations** Linear equations with constant coefficients; Linear equations with variable coefficients; General ordinary differential equations.	**5**	CO3, CO4,	K2, K3
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.			

Texts:	1. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and engineering, Cambridge University Press, Cambridge UK (Reprint 2002). 2. George B. Arfken and Hans J. Weber, Mathematical methods for Physicists, 7/e Elsevier Inc., 2012. 3. Mathematics text books of XI and XII Science prescribed by NTSE/CBSE/Goa Board.

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Title of the Course	Bridge Course in Thermal Physics
Course Code	PHY-1001
Number of Credits	2
Theory/Practical	Theory
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course aims to introduce basic concepts of thermodynamics, laws of thermodynamics, entropy its applications.	
Course Outcomes:	Students able to	**Mapped to PSO**
	CO 1. Describe basic concepts of thermodynamics	PSO1
	CO 2. Understand thermodynamic properties of pure substances	PSO1
	CO 3. Formulate and apply the first and second laws of thermodynamics	PSO1
	CO 4. Understand concepts of entropy and the third law of thermodynamics.	PSO1
	CO 5. Understand thermodynamic potentials and their relations.	PSO1

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Zeroth and First Law of Thermodynamics: Extensive and intensive** Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.	**6**	CO1, CO2	K1, K2
Module 2:	**Second Law of Thermodynamics:** Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.	**8**	CO1, CO3	K1, K2, K3
Module 3:	**Entropy:** Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. The entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. The unattainability of Absolute Zero.	**6**	CO1, CO4	K1, K2
Module 4:	**Thermodynamic Potentials:** Extensive and Intensive Thermodynamic Variables. Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy. Their Definitions, Properties, and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization,	**5**	CO1, CO5	K1, K2

	First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations..			
Module 5:	**Maxwell's Thermodynamic Relations:** Derivations and applications of Maxwell's Relations, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) TdS Equations, (4) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (5) Energy equations, (6) Change of Temperature during Adiabatic Process	**5**	CO1, CO5	K1, K2
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. M.W. Zemansky, Richard Dittman, Heat and Thermodynamics, McGraw-Hill, (1981). 2. Meghnad Saha, and B.N.Srivastava, A Treatise on Heat, Indian Press (1958) 3. S. Garg, R. Bansal and Ghosh, Thermal Physics, 2nd Edition, Tata McGraw-Hill (1993). 4. Carl S. Helrich, Modern Thermodynamics with Statistical Mechanics, Springer (2009). 5. Sears & Salinger, Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Narosa. (1988) 6. S.J. Blundell and K.M. Blundell, Concepts in Thermal Physics, 2nd Ed., Oxford University Press (2012).			

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Title of the Course	Bridge Course in Optics
Course Code	PHY-1002
Number of Credits	2
Theory/Practical	Theory
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	Nil			
Course Objectives:	This course aims to understand the various concepts of geometric and wave optics			
Course Outcomes:	Students able to		**Mapped to PSO**	
	CO 1. Understand geometrical and wave optics		PSO1	
	CO 2. Understand phenomena of interference and diffraction		PSO1	
	CO 3. Apply these phenomena to problems in Physics		PSO1	
	CO 4. Understand concept of polarization of light.		PSO1	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**

Module 1:	**Geometric Optics** Brief history, Propagation of light, Scattering, Reflection and Refraction of light, Fermat's principle, Ray equations, Refraction and reflection by spherical surfaces, Paraxial optics, lenses, mirrors, prisms, optical systems, Total internal reflection, thick lenses, Aberrations. Introduction to eyepieces, Ramsden and Huygens eyepieces.	**6**	CO1	K2
Module 2:	**Wave Optics** Simple harmonic motion, vibrations, origin of refractive index, sinusoidal waves, one-dimensional wave equation, transverse and longitudinal vibrations, Huygen's principle, plane waves, spherical and cylindrical waves.	**6**	CO1	K2
Module 3:	**Interference** Superposition of Waves, Division of wavefront & division of amplitude, Formation of colors in thin film- reflected system, transmitted system, wedge shaped film, Newton's Rings and its application to determine refractive index of liquid (Normal Incidence only), Interferometry: Michelson interferometer-its principle, working and its application to determine wavelength and difference between two wavelengths, Coherence.	**6**	CO2, CO3	K2, K3
Module 4:	**Diffraction** Fraunhofer diffraction, Single slit and Double slit patterns, Limit of resolution, Diffraction grating, Fresnel diffraction, zone-plates, Diffraction by circular discs and apertures, Holography.	**6**	CO2, CO3	K2, K3
Module 5:	**Polarization of light** Nature of polarized light, Dichroism, Birefringence, Scattering and Polarization, Polarization by reflection, Brewster angle, Circular polarizers, Wave plates.	**6**	CO3, CO4	K2, K3
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. Ajoy Ghatak, Optics, 7th Edition, Tata-McGraw-Hill (2020). 2. Eugene Hecht, Optics, Pearson, 5th Edition, (2019).			

	3. Brij Lal, M N Avadhanulu & N Subrahmanyam, A Textbook of Optics, 25th edition, S. Chand & Company (2012). 4. F.A. Jenkins and H.E. White, Fundamental of Optics, Tata McGraw-Hill (1981).

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Title of the Course	Bridge Course in Quantum Mechanics
Course Code	PHY-1003
Number of Credits	2
Theory/Practical	Theory
Level	
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course aims to understand the various phenomena of early quantum physics and develop the essential ideas of the old quantum theory.	
Course Outcomes:	Students able to	**Mapped to PSO**
	CO 1. Understand the concept of the wave-particle duality of radiation and particles.	PSO1
	CO 2. Understand energy quantization.	PSO1
	CO 3. Understand quantization of angular momentum.	PSO1
	CO 4. Describe the structure of the hydrogen atom.	PSO1
	CO 5. Apply wave mechanics to one dimension problems	PSO1

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Thermal Radiation and Planck's Postulate** Thermal Radiation, Classical Theory of Cavity Radiation, Planck's Theory of Cavity Radiation, Planck's Postulate and Its Implications.	**3**	CO1	K2
Module 2:	**Photons—Particle-like Properties of Radiation** Introduction, The Photoelectric Effect, Einstein's Quantum Theory of the Photoelectric Effect, The Compton Effect, The Dual Nature of Electromagnetic Radiation.	**2**	CO1	K2
Module 3:	**de Droglie's Postulate—Wave-like Properties of Particles** Matter Waves, The Wave-Particle Duality, The Uncertainty Principle, Properties of Matter Waves, Some Consequences of the Uncertainty Principle, The Philosophy of Quantum Theory	**2**	CO1	K2
Module 4:	**Bohr's Model of the Atom** Thomson's Model, Rutherford's Model, The Stability of the Nuclear Atom, Atomic Spectra, Bohr's Postulates, Bohr's Model, Atomic Energy States.	**3**	CO1, CO2, CO3, CO4	K1, K2
Module 5:	**Schroedinger's Theory of Quantum Mechanics** Introduction, Plausibility Argument Leading to Schrödinger's Equation, Born's Interpretation of Wave Functions, Expectation Values, the time-independent Schrödinger Equation, Required Properties of Eigen functions, Energy Quantization in the Schrodinger Theory.	**5**	CO2, CO3, CO5	K1, K2
Module 6:	**Solutions of Time-Independent Schrodinger Equations** Introduction, The Zero Potential, The Step Potential (Energy Less Than Step Height), The Step Potential (Energy Greater Than Step Height), The Barrier Potential, Examples of Barrier Penetration by Particles, The Square Well Potential, The Infinite Square Well Potential, The Simple Harmonic Oscillator Potential	**15**	CO5	K3

Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.
Texts:	1. Robert Eisberg and Robert Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, John Wiley & Sons (2006) 2. A. Ghatak and S. Lokanathan, Quantum Mechanics, Theory and Applications, Mc Millan (2004). 3. P. M. Mathews, and K. Venkatesan, A Textbook of Quantum Mechanics, 2nd Ed., McGraw Hill (2010) 4. Leonard I. Schiff, Quantum Mechanics, 3rd Edn. Tata McGraw Hill, (2010)

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Title of the Course	Bridge Course in Electrostatics and Magnetostatics
Course Code	PHY-1004
Number of Credits	2
Theory/Practical	Theory
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

<table>
<tr><td>Pre-requisites for the Course:</td><td colspan="4">Nil</td></tr>
<tr><td>Course Objectives:</td><td colspan="4">This course is aimed at revising the electrostatics and magnetostatics</td></tr>
<tr><td rowspan="5">Course Outcomes:</td><td colspan="2">Students able to</td><td colspan="2">Mapped to PSO</td></tr>
<tr><td colspan="2">CO 1. Understand concepts like electric field, potential, electrostatic energy, dielectrics.</td><td colspan="2">PSO1</td></tr>
<tr><td colspan="2">CO 2. Apply Gauss Law to simple problems</td><td colspan="2">PSO1</td></tr>
<tr><td colspan="2">CO 3. Understand generation of magnetic field</td><td colspan="2">PSO1</td></tr>
<tr><td colspan="2">CO 4. Apply Maxwell equations</td><td colspan="2">PSO1</td></tr>
<tr><td>Content:</td><td></td><td>No of hours</td><td>Mapped to CO</td><td>Cognitive Level</td></tr>
</table>

Module 1:	**Electrostatics** Coulomb's law, Electric field and potential, Gauss's law, Application of Gauss's law, the electric field in various circumstances, Electrostatic energy, dielectrics.	**15**	CO1, CO2	K2, K3
Module 2:	**Magnetostatics** Electric current, the magnetic field, the magnetic force of a current, Ampere's law, magnetic field of a straight wire and of a solenoid, atomic currents, the relativity of magnetic and electric fields, the magnetic field in various situations, the vector potential, induced currents, the Maxwell equations.	**15**	CO3, CO4	K2, K3
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. The Feynman lectures on Physics, Vol-2, Pearson (2013) 2. Young and Freedman, University Physics with modern Physics, Pearson (2016) 3. H. C. Verma, Concepts of Physics, vol-2, Bharati Bhawan Publishers & Distributors (2019).			

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Title of the Course	Introduction to Biology and Biophysics
Course Code	PHY-1005
Number of Credits	3
Theory/Practical	Theory
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	Yes
Course for advanced learners	No

Pre-requisites for the Course:	Nil			
Course Objectives:	This is a bridge course for the students for introducing them to the concepts in biology and biophysics.			
Course Outcomes:	Students will be able to	**Mapped to PSO**		
	CO 1. Learn about biology and biochemistry	PSO1		
	CO 2. Understand the basic concepts of molecular biophysics	PSO1		
	CO 3. Gain knowledge in the structure and functioning of molecular processes	PSO1		
	CO 4. Get exposed to the recent developments in biomechanics and molecular motion.	PSO1		
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**

Module 1:	**Introduction to Biology** Origin and evolution of life, prokaryotic cells, photosynthesis, eukaryotic cells, elementary building blocks of life	**5**	CO1, CO2, CO3, CO4	K2
Module 2:	**Biochemistry I** Chemical components of the cell, energy, catalysis and biosynthesis, cellular membranes, transport across membranes, energy generation in cells, cytoskeletons, cell division	**15**	CO1, CO2, CO3, CO4	K2
Module 3:	**Biochemistry II** Proteins-structure and function, DNA, RNA and chromosomes, Genes, genetics, carbohydrates, lipids and enzymes	**15**	CO1, CO2, CO3, CO4	K2
Module 4:	**Biophysics** Biological motion, free energy transduction, chemochemical machines, pumps and motors as chemochemcial machines, flux force dependence, molecular motors, mechanochemistry of molecular motors, biomolecular forces, biomechanics of muscle contraction and cardiovascular system.	**10**	CO1, CO2, CO3, CO4	K2
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. Geoffrey M. Cooper and Robert E. Hausman, The Cell: A Molecular Approach, Seventh Edition, Oxford University Press (2018). 2. Dennis Bray, Karen Hopkin, Alexander D. Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter, Essential Cell Biology, Bruce Alberts, Fourth Edition Garland Science (2013). 3. David Clark Nanette Pazdernik Michelle McGehee, Molecular Biology, Third Edition, Elsevier (2019). 4. Jack A Tuszynski and Michal Kurzynski, Introduction to Molecular Biophysics, First Edition, CRC Press, (2003). 5. Rodney Cotterill, Biophysics: An Introduction, Wiley (2002). 6. Thomas A Weigh, Applied Biophysics, A Molecular Approach for Physical Scientist, First Edition, Wiley, (2007). 7. Mayer & Jackson, Molecular & Cellular Biophysics, Cambridge Press (2006).			

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SEMESTER I

Discipline Specific Core Courses

Title of the Course	Mathematical Methods of Physics
Course Code	PHY-5000
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	Prepare the students with necessary mathematical skills that are essential to understand different phenomena in physics. The course also helps students to understand the theoretical background of other core courses in physics.	
Course Outcomes:	Students able to	**Mapped to PSO**
	CO 1. Solve ordinary differential equations using different methods.	PSO2
	CO 2. Understand basics of complex variables, vector space and integral transforms.	PSO2

	CO 3. Solve wave equation and heart conduction problems		PSO2	
	CO 4. Demonstrate proficiency in mathematical skills required for a master's in Physics.		PSO2	
	CO 5. Apply the mathematical skills in other courses of Physics.		PSO2	
	CO 6. Evaluate the mathematical background of various concepts in physics.		PSO2	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Ordinary Differential Equations** Second order homogeneous and inhomogeneous equation, Wronskian, General Solutions, Ordinary and Singular points, Series Solutions. Polynomial solutions, Legendre's equation, Bessel's equation, Gamma function	**14**	CO1, CO4, CO5, CO6	K2, K3, K4,K5
Module 2:	**Functions of Complex Variable** Limits, Continuity, Analyticity of Functions of a Complex Variable, Taylor and Laurent Series, Isolated and Essential Singularities, Branch Cuts, Cauchy Formula, Contour Integration, Application of Residue Theorem.	**14**	CO2, CO4, CO5, CO6	K2, K3, K4,K5
Module 3:	**Linear Vector Spaces** Linear Operators, Matrices, Coordinate Transformations, Eigenvalue Problems, Diagonalization of Matrices, Infinite Dimensional Spaces, Elements of Group Theory.	**10**	CO2, CO4, CO5, CO6	K2, K3, K4,K5
Module 4:	**Integral Transforms** Fourier Series, Fourier Transforms, Laplace Transforms, Applications of Integral Transforms.	**12**	CO2, CO4, CO5, CO6	K2, K3, K4,K5
Module 5:	**Boundary Value and Initial Value Problems** Vibrating String in one Dimension, Heat Conduction, and Wave Equation.	**10**	CO3, CO4, CO5, CO6	K2, K3, K4,K5
Pedagogy:	Lectures/ tutorials or a combination of these. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. George B. Arfken and Hans J. Weber, Mathematical methods for Physicists, 7/e Elsevier Inc., (2012).			

	2. K.F. Riley, M.P. Hobson and S.J. Bence, Mathematical Methods for Physics and engineering, Cambridge University Press, Cambridge UK (Reprint 2002) 3. J. Mathew and R. L. Walker, Mathematical Methods for Physics, Benjamin Publishers (1973). 4. James W. Brown and R. V. Churchill Complex Variables and Applications, 6th Edition (international), McGraw - Hill (1996**).** 5. L. A. Pipes, Applied Mathematics for Engineers and Physicists, 3rd Edition, McGraw-Hill (1971). 6. W. W. Bell, Special Functions for Scientists and Engineers, D. Van Nostrand Company Ltd (2004). 7. Charlie Harper, Introduction to Mathematical Physics, PHI. 8. Murray R. Spiegel, Theory and problems in Complex Variables by (Schaum' series) (2009). 9. Murray R. Spiegel, Theory and problems of advanced Mathematics for Engineers and Scientists by (Schaum's series) (1980).
Web Resources:	1. https://nptel.ac.in/courses/115103036 2. https://archive.nptel.ac.in/courses/115/105/115105097/ 3. https://nptel.ac.in/courses/115106086

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Title of the Course	Classical Mechanics
Course Code	PHY-5001
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course is aimed at understanding intermediate to advanced classical mechanics and to build the necessary framework for other topics that requires classical mechanics such as quantum mechanics, statistical mechanics and electromagnetism.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand and apply the principles of Lagrange-Hamilton formalism to classify and explain the motion of a mechanical system.	PSO 1
	CO 2. Analyze equations of motion for complex mechanical systems in classical mechanics by applying the formalism of Lagrangian and Hamiltonian.	PSO 1
	CO 3. Analyze the differential equations of orbit and determine the stability of the orbit under	PSO 1

	central force.			
	CO 4. Evaluate and contrast the differences between Lagrangian and Hamiltonian formalism, Galilean and Lorentz transformation, and various reference frames.		PSO 1	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Newton's Laws of Motion:** Mechanics of a single particle, Mechanics of a system particles, Constraints and their classification, Principle of virtual work, D'Alembert's principle.	**6**	CO1	K2, K3
Module 2:	**Lagrangian Formulation:** Degrees of Freedom, Generalized Coordinates, Calculus of variations, Hamilton's principle, Euler-Lagrange's equations of motion, Application to non-holonomic systems, Advantages of a variational principle formulation, Conservation theorems and symmetry properties.	**10**	CO1, CO2	K2, K3, K4
Module 3:	**Rigid Body Dynamics:** Eulerian angles, Inertia tensor, Angular momentum of rigid body. Free motion of rigid body, Motion of symmetric top.	**8**	CO1, CO2	K2, K3, K4
Module 4:	**Hamilton's equation of motion:** Legendre transformation and the Hamilton equations of motion, cyclic coordinates and conservation theorems, Routh's procedure and oscillation about steady motion, Derivation of Hamilton's equations from a variational principle, Principle of least action.	**10**	CO1, CO2, CO4	K2, K3, K4, K5
Module 5:	**Canonical Transformations:** Equations of canonical transformations, Examples of canonical transformations, Poisson brackets and other canonical invariants, Equations of motion, Infinitesimal canonical transformation theorems in Poisson bracket formulation, Angular momentum, Poisson brackets relations, Lagrange brackets.	**8**	CO1, CO2, CO4	K2, K3, K5
Module 6:	**Hamilton - Jacobi Theory:** H-J equation for Hamilton's principal function, Harmonic oscillator problems, H -J equation for characteristic function, Action angle, Kepler's problem.	**6**	CO1, CO2, CO3	K2, K3, K4
Module 7:	**Two-body Central Force Problem:** Equations of motion and first integrals, Classification of orbits, virial theorem, Differential equation and integrable power	**7**	CO1, CO3	K2, K3, K4

	law potentials, Kepler's problem.			
Module 8:	**Small Oscillations:** Simple Harmonic Oscillations, Damped Oscillations, Forced Oscillations without and with damping, Coupled Oscillations.	**5**	CO1, CO2	K2, K3, K4
Pedagogy:	Lectures/ tutorials/ assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. H. Goldstein, Classical Mechanics. McMillan, Bombay, (1998). 2. J. C. Upadhyaya, Classical Mechanics. Himalaya, Publishing House, Mumbai, (1991). 3. M. G. Calkin, Lagrangian and Hamiltonian Mechanics. World Scientific, (1996). 4. N. C. Rana, and P. S. Joag, Classical Mechanics. Tata McGraw-Hill, (1991). 5. P. V. Panat, Classical Mechanics. Alpha Science International Ltd, (2004).			

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Title of the Course	Electromagnetic Theory
Course Code	PHY-5008
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	Academic year 2026-2027
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	The aim of this course is to develop an understanding of fundamental concepts in electromagnetism, propagation of electromagnetic waves in free space and in waveguides, electromagnetic radiation, charges in electromagnetic fields, and relativistic electrodynamics.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand the concepts in electromagnetism and develop Maxwell's equations	**PSO1**
	CO 2. Interpret the properties of plane waves in unbounded space and in waveguides	**PSO1, PSO2**
	CO 3. Analyse the properties of electromagnetic radiation	**PSO1, PSO2**
	CO 4. Understand the principles of relativistic electrodynamics	**PSO1, PSO2**

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Electrostatics, Magnetostatics, and Maxwell's Equations** Review of concepts in electrostatics and magnetostatics, Displacement current, Maxwell's equations, Vector and Scalar potentials, Gauge transformation, Lorentz and Coulomb gauge, Poynting's theorem, Conservation of energy and momentum for charged particles and fields	**15**	CO 1	K2
Module 2:	**Electromagnetic Waves** Plane electromagnetic waves and their propagation in non-conducting and conducting media, Frequency dispersion in conductors, Wave guides, Propagation of Waves between conduction planes, Wave guides in arbitrary cross-section, Wave guides in Rectangular Cross-section, Coaxial Wave guide, Resonant Cavities, Dielectric wave guides.	**15**	CO 1, CO 2	K2, K3
Module 3:	**Electromagnetic Radiation** Retarded Potentials, Fields, and radiation by localized dipole, Lienard Weichert potentials, Power radiated by an accelerated charge, scattering of radiation	**15**	CO 2 CO 3,	K3, K4
Module 4:	**Relativistic Electrodynamics** Lorentz transformation as a four-dimensional orthogonal transformation, Lorentz, four vectors in mechanics and electrodynamics, Lorentz covariance of Maxwell equations, field tensor, transformation of fields, field due to a point charge in uniform motion, charged particles in electromagnetic fields magnetohydrodynamics, pinch effect	**15**	CO 3, CO 4	K3, K4
Pedagogy:	Lectures/ tutorials/ assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. David J. Griffiths, Introduction to Electrodynamics, Prentice-Hall of India Pvt. Ltd., New Delhi (2015), (Fourth Edition). 2. J. D. Jackson, Classical Electrodynamics, Wiley, New York (1995). (Third Edition 3. B. B. Laud, Electromagnetics, Wiley Eastern Ltd., New Delhi (1983). (Third Edition) J. B. Marion, Classical Electromagnetic Radiation, Academic Press, New York (1980). (Second edition) 4. J. R. Reitz and F. J. Milford, Foundations of Electromagnetic theory, Addison – Welsey, Reading (1960). (Third			

	Edition)
References/ Readings:	1. The Feynman Lectures On Physics: Vol II: The New Millennium Edition: Mainly Electromagnetism and Matter, Pearson Education India; First Edition (1 January 2012); Pearson India 2. Melvin Schwartz, Principles of Electrodynamics, Dover Publications Inc.; New edition (2003)
Web Resources:	Electromagnetic Theory: https://nptel.ac.in/courses/108104087

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Title of the Course	Electronics
Course Code	PHY-5003
Number of Credits	4
Theory/Practical	Theory
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	The objective of the course is to • Introduce students to wide range of electronic circuits and their applications in solving different problems of day to day to life and physics. For Ex. Using OP-AMPs. • To give basic understanding of opto-electronic devices, modulation, signals, microprocessor and memories.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Understand the principles and circuits in electronics and use them in various applications.	PSO3
	CO 2. Acquire knowledge about working principles of opto-electronic devices and communication electronics.	PSO3
	CO 3. Get exposure to microprocessor and memory devices.	PSO3

	CO 4. Be able to analyze process of AM and FM communication.		PSO3	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**OP-AMP Applications** 1.1. OP-AMPS with negative feedback, 1.2. Voltage controlled voltage source (VCVS), Current controlled voltage source (ICVS), Voltage controlled current source (VCIS), Current controlled current source (ICIS), 1.3. Inverting and noninverting amplifier circuits, 1.4. Open-loop frequency and phase response, Closed-loop frequency response, 1.5. Differential amplifier, Instrumentation amplifier, DC and AC amplifiers, 1.6. Summing, scaling and averaging amplifier, 1.7. Voltage to current converter, Current to voltage converter.	**15**	CO1	K2
Module 2:	**Opto-electronic devices** 2.1. Radiative and non-radiative transitions, Characteristics of LED, Photoconductor, 2.2. Photo diode, Photo transistor, Photo detector, 2.3. Solar cell, 2.4. Semiconductor laser; 2.5. Optical fiber, Optical fiber waveguides, 2.6. Fundamentals of optical communication	**15**	CO1, CO2	K2, K3
Module 3:	**Communication Electronics** 3.1. Analog and digital signals, 3.2. Modulation, Types of modulation, Basic principles of amplitude, frequency and phase modulation, 3.3. Simple circuits for amplitude modulation and demodulation, 3.4. Digital modulation and demodulation, 3.5. Microwave Oscillators, 3.6. Cavity resonators, 3.7. Standing wave detector.	**15**	CO2, CO4	K2, K4

Approved by: Academic Council on 13th & 14th June 2025

Module 4:	**Digital Electronics** 4.1. Types of signals, A/D and D/A conversion methods; 4.2. Digital signal processing (DSP) basics, DSP applications; 4.3. Introduction to Microprocessors, Elements of 8-bit Microprocessors (INTEL \ 8085) 4.4. Memory and storage, RAM, ROM, PROM and EPROM, Flash memories, 4.5. Magnetic and optical storage.	**15**	CO1, CO3	K2, K3
Pedagogy:	Lectures/tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. Millman, J., Halkias, C., Parikh C., Integrated Electronics, Analog and Digital Circuits and Systems, McGraw – Hill Education, 2nd Edition (2018) 2. Kennedy, G., Electronics Communication Systems, IV Edn, Tata McGraw-Hill Book Co. New Delhi (2003). 3. Chen, Chin-Lin, Elements of Optoelectronics and Fiber Optics, McGraw-Hill Book Co. New Delhi (2014).			
References/ Readings:	1. Boylestad, R. L. and Nashelsky L., Electronic Devices & Circuit Theory, XI Edn. Prentice-Hall of India (2015). 2. Floyd, T. L., Electronic Devices, V Edn. Pearson Education Asia (2001). 3. Gayakwad, R, A., Op-Amps and Linear Integrated Circuits, IV Edn. Prentice-Hall of India (2002). 4. Shrader, R., Electronic Communication, Glencoe Division of MacMillan (1993).			

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Discipline Specific Elective Courses

Title of the Course	Electronics and Computer Programming in Fortran/C/Python Practical
Course Code	PHY-5201
Number of Credits	4
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course offers laboratory training • in the design and construction of electronic circuits commonly used in physics experiments, • in computer programming using one of the three languages (Fortran / C /Python), with an emphasis on solving simple scientific problems	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Design and construct electronic circuits by identifying and fetching different components.	PSO4
	CO 2. Record observations from different measuring instruments, plot graphs and analyze the	PSO4

	results.			
	CO 3. Demonstrate the ability to maintain a laboratory notebook.		PSO4	
	CO 4. Understand fundamental programming concepts such as variables, data types, control structures, functions, and arrays		PSO6	
	CO 5. Write and debug simple programs using a high-level programming language such as Fortran/C/Python		PSO6	
	CO 6. Apply logical thinking and problem-solving techniques to develop algorithms for basic computational problems		PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	Experiments are to be performed on following topics (minimum 8) with emphasis on designing and constructing the circuit on a bread board. 1. Operational Amplifier parameters 2. Design and Construction of Wien Bridge Oscillator 3. Design and Construction of phase shift oscillator 4. Design and Construction of Astable Multivibrator 5. Design and Construction of Monostable Multivibrator 6. Schmitt Trigger circuit and its use as a zero crossing detector and squaring circuit 7. Voltage Regulator 8. Constant Current Source 9. Design and Construction of DC differential amplifier using op-amps 10. Design and Construction of Function generator 11. Design and construction of Negative nonlinear resistor 12. J. K. flip-flop counter: Scale of 16 and 10 using IC 13. Adder and Subtractor Circuits	**60**	CO1, C02, CO3	K3, K4, K5, K6
Module 2:	**Fundamentals of Computer Programming**	**15**	CO4,	K2, K3

	Introduction to computers, Introduction to programming languages, Writing, compiling/interpreting, and executing programs, Error diagnostics, Variables, constants, and data types, Input and output operations, Operators and expression evaluation, Practical exercise		CO5	
Module 3:	**Logical Operations and Control Constructs** Logical expressions and operators, conditional operators, Branching statements, Looping statements, Nested control statements, Practical exercise	**15**	CO4, CO5, CO6	K2, K3, K5
Module 4:	**Procedures** Program Units, Introduction to Procedures, Intrinsic Procedures, User defined procedures, accessing procedures, passing arguments to procedures, Practical Exercise	**15**	CO4, CO5, CO6	K2, K3, K5
Module 5:	**Arrays and Data Handling** Defining an array, processing an array, passing arrays to procedures, multidimensional arrays, file handling, Practical Exercise	**15**	CO4, CO5, CO6	K2, K3, K5
Pedagogy:	Laboratory Experiments, Lectures and self-study			
References/ Readings:	1. D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications. Tata Mc Graw Hill 7e, (2011). 2. J. Millman and C. C. Halkias, Integrated Electronics: Analog and Digital Circuits and Systems. McGraw Hill International Student Ed., (1972). 3. LM317 – 3 Terminal Adjustable Voltage regulator datasheet Rev. X, Texas Instruments 4. V. Rajaraman, Computer Programming in FORTRAN 90 and 95, Prentice-Hall of India, New Delhi (1999). 5. Martin Counihan, Fortran 95, UCL Press Limited University College London (1996). 6. Stephen Chapman, Fortran 95/2003: for Scientists and Engineers, McGraw-Hill (2007). 7. Byron Gottfried, Programming with C, Tata McGraw- Hill (1996). 8. David Beazley and Brian K. Jone, Python Cookbook: Recipes for Mastering Python 3, O'Reilly Media (2013) 9. Martin C. Brown, Python: The Complete Reference, McGraw Hill (2018)			

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Title of the Course	Design and Fabrication Practical - I
Course Code	PHY-5202
Number of Credits	4
Theory/Practical	Practical
Level	400
Effective from AY	2025-2026
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To develop interest and skill for designing and building laboratory equipment commonly used in Physics Laboratory	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Understand the working of simple electronic equipment used in a Physics Laboratory.	PSO3, PSO4
	CO 2. Design and build simple electronic equipment used in Physics Laboratory.	PSO3, PSO4
	CO 3. Evaluate and rectify faults in simple electronic equipment used in Physics Laboratory.	PSO3, PSO4

	CO 4. Compare and contrast the performance of a commercial and their built equipment.		PSO3, PSO4	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	Design and construct a Constant current source (100 µA – 100 mA), evaluate its performance and make it work and pack it in a box. Compare its performance with a commercial product.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Module 2:	Design and construct a DC Differential Amplifier (with three switchable inputs and amplification of 10 and 100), evaluate its performance, make it work and pack it in a box. Compare its performance with a commercial product.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Module 3:	Design and construct a Signal Generator producing sine, square and triangle waves over 4 decades of frequency from 10 Hz – 100 KHz, evaluate its performance, make it work. Compare its performance with a commercial product.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Module 4:	Design and construct an analog Lock-in Amplifier, evaluate its performance, make it work. Compare its performance with a commercial product.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Pedagogy:	Laboratory work and Self Study			
Texts:	1. R. Srinivasan, K. R. Priolkar and T. G. Ramesh Experiments in Physics - Laboratory Manual, Indian Academy of Sciences 2017. 2. J. Millman and C. C. Halkias, Integrated Electronics: Analog and Digital Circuits and Systems, Mc Graw Hill International Student Ed. (1972).			

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SEMESTER II

Discipline Specific Core Courses

Title of the Course	Quantum Mechanics
Course Code	PHY-5004
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

<table>
<tr><td>Pre-requisites for the Course:</td><td colspan="2">Credited PHY-5000, PHY-5001</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">To develop foundational Concepts and Formalism of non-relativistic Quantum Mechanics.
To develop Mathematical Framework of Quantum Mechanics
To understand Schrodinger’s and Heisenberg’s formalism in Quantum Mechanics
To illustrate the concepts by analysing simple quantum mechanical systems</td></tr>
<tr><td>Course Outcomes:</td><td>Student will be able to</td><td>Mapped to PSO</td></tr>
</table>

	CO 1. Understand core concepts of Quantum Mechanics		PSO1, PSO 2	
	CO 2. Apply the Schrodinger equation to different systems, solve them and analyse the properties of eigenfunctions and energies		PSO1, PSO 2	
	CO 3. Explain the structure of the hydrogen atom.		PSO1, PSO 2	
	CO 4. Understand the concepts of quantization of angular momentum, spin and apply and anlyze how the addition of these quantities results.		PSO1, PSO 2	
	CO 5. Understand the concepts of approximation methods for solving Schrodinger equations and apply these methods to different systems and analyse their results.		PSO1, PSO 2	
	CO 6. Understand the fundamental scattering of quantum particles and apply it to simple systems.		PSO1, PSO 2	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Schrodinger's Equation and Hermitian operators** 1.1. Time-dependent Schrodinger equation, continuity equation, expectation values, Ehrenfest's theorems, time independent Schrodinger equation and stationary states. 1.2. Hermitian operators, eigenvalues and eigenstates of Hermitian operators, momentum eigenfunctions, orthogonality and completeness of wave functions, Computability and compatibility of observables, parity operation.	**8**	CO1, CO2	K2, K3, K4
Module 2:	**The Schrodinger equation in three dimensions** Separation of the Schrodinger equation in Cartesian coordinates, Central potential, separation of the Schrodinger equation in spherical polar coordinates, The free particle, The three-dimensional square well potential, The hydrogen atom, The three-dimensional isotropic oscillator.	**12**	CO1, CO2, CO3	K2, K3, K4
Module 3:	**Vector space formulation of quantum mechanics** Dirac Notation, representation of states and observables, bra and ket vectors, linear operators, relation with wave mechanics, algebra of Hermitian operators,	**5**	CO1, CO2	K2, K3, K4

	matrix representation, unitary operators, Schrodinger and Heisenberg representations, linear harmonic oscillator problem by operator method.			
Module 4:	**Angular Momentum theory** Angular Rotations in Classical and Quantum Mechanics, Rotational Symmetry and conservation of angular momentum, Treatment of general angular momentum by operator method, eigenvalues and eigenvectors, Eigenvalues and Eigen functions of L^2 and L_z operators, ladder operators L^+ and L^-, spin angular momentum, algebra of Pauli matrices, Pauli representation of angular momentum operators. Addition of two angular momenta, spin-orbit interaction, Clebsch Gordon coefficients.	**10**	CO1, CO2, CO3, CO4	K2, K3, K4
Module 5:	**Approximation methods for stationary problems** Time-independent perturbation theory for a nondegenerate energy level, Time-independent perturbation theory for a degenerate energy level, The variational method, The WKB approximation.	**8**	CO1, CO2, CO3, CO5	K2, K3, K4
Module 6:	**Approximation methods for time-dependent problems** Time-dependent perturbation theory, General features, Time-independent perturbation, periodic perturbation, The adiabatic approximation, The sudden approximation	**7**	CO1, CO2, CO3, CO5	K2, K3, K4
Module 7:	**Quantum Collision Theory** Scattering experiments and cross-sections, potential scattering and general features, the method of partial waves, Application of the partial-wave method, the integral equation of potential scattering, The Born approximation, Collision between identical particles, Collision involving composite systems.	**10**	CO1, CO2, CO3, CO6	K2, K3, K4
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2004) 2. P. M. Mathew and K. Venkatesan, A Text Book of Quantum Mechanics, 2/e, Tata McGraw Hill (2017) 3. L. I. Schiff and Jayendra Bandhyopadhyay, Quantum Mechanics, 4/e, McGraw-Hill (2017).			

	4. V. K. Thankappan, New Age International Publishers (2012)). 5. V. Devanathan, Quantum Mechanics, 2/e Narosa Publishing House (2015). 6. David J. Griffiths, Introduction to Quantum Mechanics 2/e, Cambridge India, (2016). 7. J. J. Sakurai Modern Quantum mechanics, Addition-Wesley Publishing Company, (1994). 8. R. Eisberg and R. Resnick, Quantum Physics of atoms, molecules, solids, nuclear and particles, 2/e, John Wiley and Sons, (1985). 9. W. Greiner, Introductory Quantum mechanics, Springer Publication, (2001). 10. R. L. Liboff, Introductory Quantum Mechanics, 4e, Pearson Education Ltd (2003). 11. Nouredine Zettili, Quantum Mechanics: Concepts and Applications 2/e, Wiley India (2016)

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Title of the Course	Statistical Mechanics
Course Code	PHY-5005
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	PHY-5000, PHY-5001	
Course Objectives:	This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, statistical interpretation of thermodynamics, microcanonical, canonical and grand canonical ensembles; the methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and photon gases.	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Understand the connection between statistics and thermodynamics.	PSO1
	CO 2. Analyze different ensemble theories used to explain the behaviour of statistical systems.	PSO
	CO 3. Compare classical and quantum statistics.	PSO1

	CO 4. Explain the statistical behaviour of ideal Bose and Fermi systems.		PSO1	
	CO 5. Apply techniques from statistical mechanics to a range of situations.		PSO1	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Kinetic Theory and Equilibrium state of Dilute Gas** Formulation of problem, binary collisions, Boltzmann transport equation, Boltzmann's H theorem, Maxwell- Boltzmann distribution, Method of the most probable distribution, analysis of the H theorem, recurrence and reversal paradoxes, Validity of the Boltzmann transport equation.	**12**	CO1	K2
Module 2:	**Classical Statistical Mechanics** Review of laws of thermodynamics, Entropy, Thermodynamic Potentials, Postulate of Classical Statistical Mechanics, Microcanonical ensemble, derivation of thermodynamics, equipartition theorem, Classical ideal gas, Gibbs paradox.	**12**	CO2	K4
Module 3:	**Canonical and Grand Canonical Ensembles** Canonical ensemble, energy fluctuations in canonical ensemble, grand canonical ensemble, density fluctuations in grand canonical ensembles, equivalence of canonical and grand canonical ensembles, behaviour of W(N), meaning of Maxwell construction.	**12**	CO2	K4
Module 4:	**Quantum Statistical Mechanics** Postulates of quantum statistical mechanics, density matrix, ensembles in quantum mechanics, third law of thermodynamics, ideal gases in microcanonical and grand canonical ensembles, foundations of statistical mechanics.	**8**	CO3	K2
Module 5:	**Ideal Fermi Gas** Equation of state of Ideal Fermi Gas, theory of white dwarfs, Landau diamagnetism, de Hass-Van Alphen effect, Pauli paramagnetism.	**8**	CO4, CO5	K2, K3
Module 6:	**Ideal Bose Gas** Photons, phonons, Bose-Einstein condensation.	**8**	CO4, CO5	K2, K3

Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.
Texts:	1. Kerson Huang, Statistical Mechanics, 2/e, Wiley India (2008). 2. B. B. Laud, Fundamentals of Statistical Mechanics, New Age International Ltd. New Delhi (1998). 3. F. Reif, Fundamentals of Statistical and Thermal Physics, Waveland Press (2009). 4. L. D. Landau and E. M. Lifshitz, Statistical Mechanics, Pergamon Press (1969). 5. R. P. Feynmann, Statistical Physics, The Benjamin Cummings Publishing Co (1981). 6. S. K. Sinha, Introduction to Statistical Physics, Narosa Publishing House, New Delhi (2007). 7. Tony Guenault, Statistical Physics, New Age International Ltd. New Delhi (2007). 8. Francis W. Sears and Gerhard Salinger, Thermodynamics, Kinetic Theory, and Statistical Thermodynamics, Addison- Wesley Principles of Physics Series, (1975).

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Title of the Course	Nuclear and Elementary Particle Physics
Course Code	PHY-5006
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	To introduce students to the fundamental principles and concepts governing nuclear and particle physics and have a working knowledge of their application to real-life problems.	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Understand and apply the models describing the basic nucleon and nuclear properties.	PSO1
	CO 2. Interpret the properties of strong and weak interaction.	PSO1
	CO 3. Relate the different forms of nuclear disintegration – natural and artificial, and fusion and account for their occurrence.	PSO1
	CO 4. Categorize elementary particles and nuclear states in terms of their quantum numbers.	PSO1
	CO 5. Understand elementary particle production and their detection	PSO1

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Basic Properties of Nuclei:** a. Nuclear mass, charge, radius, binding energy, nuclear spin, and parity. b. Magnetic moments and electric quadrupole moments.	**8**	CO1	K2, K3
Module 2:	**Two-Body Problem:** a. Brief review of quantum mechanics tools, properties of deuteron, theory of the ground state of deuteron, magnetic moment, and electric quadrupole moment of deuteron. b. Theory of nucleon-nucleon scattering at low energy, phase shift and scattering length, effective range theory, experimental determination of low energy parameters. c. Nature of nuclear forces and Meson theory of nuclear force.	**12**	CO2	K2
Module 3:	**Nuclear Models:** a. Liquid drop model, Weizsacker's mass formula, stable and unstable nuclei, mass parabolas. b. Nuclear shell model, energy levels in a three-dimensional harmonic oscillator well potential, spin orbit interaction, prediction of magic numbers, ground state spins and parities. c. Magnetic moments, Schmidt lines, nuclear quadrupole moments, and collective model.	**10**	CO1	K2, K3
Module 4:	**Nuclear Transformations:** a. Alpha decay, barrier penetration problem, Gamow's theory of alpha decay, Geiger-Nuttal law, alpha spectra and nuclear energy levels. b. Beta decay, experiments in beta spectra, neutrino hypothesis, Fermi's theory of beta decay, Kurie plots, ft values, allowed and forbidden transitions, selection rules, electron capture, parity violation in beta decay, experimental verification, measurement of neutrino helicity.	**10**	CO3	K3

	c. Gamma transitions, multipole radiations, quantum theory of the transition probability, selection rules, angular correlation, calculations of transition rates and comparison with experiments, internal conversion.			
Module 5:	**Nuclear Reactions:** a. Rutherford scattering, cross-sections, decay rates, resonances, Breit-Wigner formula, nuclear fission and fusion processes.	**4**	CO3	K3
Module 6:	**Elementary Particles:** a. Classification of elementary particles; properties of quarks and leptons, properties of mesons and baryons. Classification of fundamental forces; Strong, Weak and Electromagnetic interactions. b. Introduction to Feynman diagrams, relativistic kinematics, quark model and eightfold way. c. Particle quantum numbers; charge, isospin, strangeness and parity, Gell-Mann Nishijima formula, conservation laws and symmetries	**10**	CO4	K4
Module 7:	**Particle accelerators and detectors:** a. Introduction to modern accelerators, event rates and luminosity. Large detector systems at electron-positron, electron-proton and hadron colliders. b. Interaction of particles with matter, principle of gas chambers, silicon detectors, scintillators, time-of-flight detectors, and calorimetry.	**6**	CO5	K2
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. H. Enge, Introduction to Nuclear Physics, Addison- Wesley (1974). 2. E. Segre, Experimental Nuclear Physics, John Wiley (1960). 3. V. Devanathan, Nuclear Physics, Alpha Science International Ltd, (2011). 4. S. N. Ghoshal, Nuclear Physics, S. Chand and Co. (2019).			
Web Resources:	https://nptel.ac.in/courses/115104043			

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Title of the Course	Atomic Physics
Course Code	PHY-5007
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course is aimed at understanding the atomic structure and analyzing atomic spectra.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand atomic structure	PSO1
	CO 2. Analyze optical and X-ray spectra of atoms	PSO1
	CO 3. Apply the knowledge of atomic structure to understand the effect of the interaction of atoms with electric and magnetic fields.	PSO1
	CO 4. Evaluate the spin-orbit interaction, exchange interaction, and electron-electron interaction in atoms with different atomic numbers.	PSO1

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Early Atomic Physics** Atomic spectra of hydrogen, The Bohr's theory, Relativistic effects, Moseley and atomic number, Radiative decay, Einstein A and B coefficients, The Zeeman effect.	**6**	CO1, CO2	K2, K4
Module 2:	**One-electron atoms**: The Schrödinger equation for one-electron atoms, energy levels, the eigenfunctions of the bound states, expectation values. Transitions, selection rules, parity, spin of the electron, the spin-orbit interaction, Fine structure of hydrogenic atoms, The Lamb shift, transitions between fine-structure levels.	**12**	CO1, CO2	K2, K4
Module 3:	**Two-electron atoms:** The Schrödinger equation for two-electron atoms, The ground state of two-electron atoms, Excited states of two-electron atoms. Doubly excited states of two electron atoms.	**12**	CO1, CO2	K2, K4
Module 4:	**Many-electron atoms**: Shell structure and the periodic table, The central field approximation, The Hartree-Fock method and the self-consistent field, Corrections to the central field approximation. Correction effects, *L-S* coupling and *j-j* coupling. Fine structure in the alkalis.	**15**	CO1, CO2	K2, K4
Module 5:	**Interaction of atoms with electromagnetic radiation and with static and magnetic field:** Many electron atoms in an electromagnetic field, selection rules for electric dipole transitions, Oscillator and line strengths, Retardation effects, Magnetic dipole and electric quadrupole transitions, The spectra of the alkalis, Helium and the alkaline earths, Atoms with several optically active electrons, Multiplet structure, X-ray spectra, The stark effect, The Zeeman effect.	**15**	CO3, CO4	K3, K5
Pedagogy:	Lectures/tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning			

Texts:	Physics of Atoms and Molecules, B. H. Bransden, C. J. Joachain, Pearson (2004), Second Edition
References/ Readings:	1. Atomic Physics, C. J. Foot, Oxford Master Series in Physics (2005) 2. Atomic Physics, D. C. Jones, CRC Press/Sarat Book House. (2018) 3. Atomic Physics, S. N. Ghoshal, S. Chand Publishing (2007)

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Discipline Specific Elective Courses

Title of the Course	General Physics Practical
Course Code	PHY-5203
Number of Credits	4
Theory/Practical	Practical
Level	400
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course provides laboratory training in performing experiments that verify important physical laws and using modern and novel techniques of measurements.	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Estimate and translate errors and report quantities up to last significant digit.	PSO4
	CO 2. Demonstrate the ability to use selected pieces of measuring devices including the multimeter, oscilloscope, and AC and DC power supplies, Lock-in Amplifier.	PSO4
	CO 3. Apply the appropriate physics to the physical situation presented.	PSO4

	CO 4. Employ proper techniques when making scientific measurements.		PSO4	
	CO 5. Formulate and report scientific conclusions based on data analysis.		PSO4	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	Short Lecture Course on – Theory of errors, Treatment of Errors of observation, linear least squares fitting and Data analysis. The experiments on the following topics (any 12) are to be performed with emphasis on the estimation and calculation of errors. 1. Types of Statistical Distributions 2. Analysis of Sodium Spectrum – Quantum defect and Effective quantum number 3. Michelson Interferometer/Fabry-Perot Interferometer 4. Diffraction experiments using laser– single slit, double slit, grating 5. Polarization experiments using laser–linearly and elliptically polarized light 6. Statistical Distribution of radioactive decay 7. Verification of Inverse Square Law using GM counter 8. Linear Absorption Coefficient of Aluminum using GM counter 9. Verification of Debye Relaxation Law and measurement of thermal relaxation of serial light bulb 10. Thermal diffusivity of Brass 11. Thermometry – measurement of thermoemf of Iron- Copper (Fe-Cu) thermocouple as a function of temperature and verification of law of intermediate metals 12. Calibration of Lock-in Amplifier 13. Measurement of mutual inductance of a coil using lock-in amplifier 14. Measurement of low resistance using lock-in amplifier 15. X-ray Emission – characteristics lines of a W target 16. Experiments using Strain Gauge	**120**	CO1, CO2, CO3, CO4, CO5	K2, K3, K5

	17. Ultrasonic Interferometer 18. Nonlinear dynamics – Feigenbaum circuit 19. Nonlinear dynamics – Chua's circuit 20. Verification of Percolation phenomena 21. Measurement of electrical resistance of Ni wire to verify para to ferromagnetic phase transition 22. Measurement of electrical resistance of NiTi based shape memory alloy 23. Measurement of Young's modulus of Brass by Flexural vibrations 24. Measurement of Rigidity modulus of Brass			
Pedagogy:	Lectures and Laboratory Experiments.			
References/ Readings:	1. P. R. Bevington and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences. McGraw Hill (Indian Edition), 2015. 2. R. Srinivasan, K. R. Priolkar, and T. G. Ramesh, A Manual on Experiments in Physics. Indian Academy of Sciences, 2018.			

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Title of the Course	Design and Fabrication Practical – II
Course Code	PHY-5204
Number of Credits	4
Theory/Practical	Practical
Level	400
Effective from AY	2025-2026
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	PHY-5202			
Course Objectives:	To develop interest and skill for designing and building Physics experiments and experimental setups			
Course Outcomes:	Student will be able to		**Mapped to PSO**	
	CO 1. Understand the principle of working of experiments.		PSO4	
	CO 2. Design Physics experiments and experimental setups.		PSO4	
	CO 3. Construct Physics experiments and test them.		PSO4	
	CO 4. Evaluate the performance and systematic errors in their setups.		PSO4	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**

Module 1:	Design and construct a Stephan's Constant setup, evaluate its performance and test it for measuring Stephan's Constant.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Module 2:	Design and construct a thermal and electrical conductivity setup for measuring thermal and electrical conductivity of a metal and measure thermal and electrical conductivity of copper.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Module 3:	Design and construct a thermal diffusivity setup and use it to measure thermal diffusivity of brass.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Module 4:	Design and construct setup for measuring dielectric constant of a liquid and use it to measure dielectric constants of polar and non-polar liquids.	**30**	CO1, CO2, CO3, CO4	K2, K4, K5, K6
Pedagogy:	Laboratory work and Self Study			
Texts:	R. Srinivasan, K. R. Priolkar and T. G. Ramesh Experiments in Physics - Laboratory Manual, Indian Academy of Sciences 2017.			

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SEMESTER III

Research Specific Elective Courses

Solid State Physics Specialization

Title of the Course	Solid State Physics I
Course Code	PHS-6000
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Should have basic knowledge of Quantum Mechanics and Statistical Mechanics
Course Objectives:	1. To introduce fundamental concepts of solids like crystalline order, symmetry in solids, simple crystal structures and their properties. 2. To acquaint with the concept of reciprocal lattice and its importance in structure determination using X-rays. 3. To introduce different types of crystal bindings and elastic properties of solids. 4. To familiarize the concept of lattice vibration and their role in thermal and optical properties of solids

Course Outcomes:	Student will be able to		**Mapped to PSO**	
	CO 1. Apply the fundamental aspects related to symmetry and X-ray diffraction to evaluate different crystal structures		PSO 1, PSO 5	
	CO 2. Differentiate between different types of crystal binding and estimate the elastic properties of solids		PSO 1, PSO 5	
	CO 3. Understand the concept of lattice vibrations and judge their role in thermal conductivity		PSO 1, PSO 5	
	CO 4. Understand and evaluate optical and dielectric properties of solids		PSO 1, PSO 5	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Crystal Structure** Crystals - Lattice, Bravais lattice, primitive unit cell, symmetry of molecules and crystals, symmetry operations and symmetry elements, Lattices in one, two and three dimensions, Space groups, definitions of directions, coordinates and planes. Simple crystal structures: NaCl, CsCl, diamond, hexagonal close-packed structure, cubic ZnS structure and their properties, Non ideal crystal structures – random stacking and polytypism Reciprocal Lattice - Diffraction of waves by crystals, Bragg law, Scattered wave amplitude - Fourier analysis, reciprocal lattice vectors, diffraction conditions, Laue equations, Brillouin zones, Geometric structure factor, Atomic Structure factor Point Defects General Thermodynamic Features, Color centres, Line Defects: Dislocations	**20**	CO1	K1, K2, K3, K4, K5
Module 2:	**Crystal Binding and Elastic Constants** Crystals of inert gases - Van der Waals - London interaction, repulsive interaction, equilibrium lattice constants, cohesive energy, Ionic Crystals - Electrostatic or Madelung Energy, evaluation of Madelung constant, covalent crystals, bonding in metals and Hydrogen bonds, Atomic Radii, Analysis of elastic strains, elastic compliance and stiffness constants, elastic waves in cubic crystals	**13**	CO2	K1, K2, K3, K4
Module 3:	**Thermal Properties** Vibrations of a one -dimensional monatomic lattice, first Brillouin zone, group	**15**	CO3	K1, K2, K3, K4,

	velocity, long wavelength limit, 20 hours 13 hours 15 hours derivation of force constant from experiment. Vibrations of a one-dimensional diatomic lattice. Quantization of elastic waves, phonon momentum, Inelastic scattering by Phonons, Phonon Heat capacity, Planck distribution, normal mode enumeration, density of states in one dimension, density of states in three dimensions Debye model for density of states, Debye T3 law, Einstein model of the density of states, Thermal conductivity - Thermal resistivity of phonon gas, Umklapp process			K5
Module 4:	**Optical and Dielectric Properties** Macroscopic electric field, local electric field at atom, dielectric constant and polarizability, Complex dielectric constant, Classical theory of electronic polarization and optical absorption, Structural Phase transitions, Ferroelectric Crystals and Displacive transitions Optical reflectance, Excitons, Raman effect in crystals. Luminescence and Luminescence centres	**12**	CO4	K1, K2, K3, K4, K5
Pedagogy:	Lectures/ tutorials/ assignments. Sessions will be interactive in nature to enable peer group learning.			
Texts:	1. C. Kittel, Introduction to Solid State Physics, Wiley India (2019) 2. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001) 3. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 4. H. Ibach and H. Luth, Solid-State Physics, An Introduction to Principles of Materials Science, Springer (1995). 5. J. Singleton, Band theory and Electronic Properties of Solids, Oxford University Press, (2014) 6. G. Bums, Solid State Physics, Academic press, Inc. London (1985) 7. A. J. Dekker, Solid State Physics, McMillan, India (1985) 8. J. S. Blakemore, W. B. Sauders, Solid State Physics, Philadelphia (1969)			
Web Resources:	1. Solid state physics: https://nptel.ac.in/courses/115105099 2. Introduction to Solid State Physics: https://nptel.ac.in/courses/115104109 3. Solid State Physics: https://nptel.ac.in/courses/115106127 4. Electronic Theory of Solids: https://nptel.ac.in/courses/115105122			

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Title of the Course	Solid State Physics II
Course Code	PHS-6001
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Should have basic knowledge of Quantum Mechanics and Statistical Mechanics	
Course Objectives:	1. To introduce electronic properties of solids 2. To introduce the concept of formation of bands in solids. 3. To acquaint with techniques associated with measurement of band structure and transport phenomena in solids. 4. To introduce students to different types of magnetic order and superconductivity in solids	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Explain about electronic properties of solids	PSO1, PSO5
	CO 2. Understand formation of bands, their importance in classification of solids.	PSO1, PSO5
	CO 3. Compare diverse types of magnetic orders in solids	PSO1, PSO5
	CO 4. Understand the phenomenon of superconductivity	PSO1, PSO5

Approved by: Academic Council on 24th April, 12th & 13th May 2026

Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Metals: Drude and Sommerfeld models:** Free electron theory – Drude model - assumptions, failures of Drude model, Sommerfeld model, Successes and failures of the Sommerfeld model, Electrical conductivity, Experimental electrical resistivity of metals, Heat capacity of electron gas, Experimental heat capacity.	**7**	CO1	K2, K3
Module 2:	**Nearly Free electron model:** Periodic potential, born – von Karman boundary conditions, Schrodinger equation in a periodic potential, Bloch's theorem, electronic band structure, single electron energy state, degenerate electron levels, Consequences of the nearly free electron model, Fermi surface.	**7**	CO1, CO2	K2, K3
Module 3:	**Tight binding model:** Band arising from a single electronic level, electronic wavefunctions, General points about the formation of tight binding bands, Group I and II metals, Group IV elements, transition metals, comparison of tight binding and nearly free electron band structure, crystal momentum, effective mass, holes.	**7**	CO1, CO2	K2, K3
Module 4:	**Semiconductors and Insulators:** Band structure of Si and Ge, Band structure of direct gap III-V and II-VI semiconductors, Optical absorption and excitons, Thermal population of bands in semiconductors, Intrinsic carrier density, Impurities and extrinsic carrier density, degenerate semiconductors.	**7**	CO1, CO2	K2, K3
Module 5:	**Transport Properties:** Thermal and electrical conductivity of metals, electronelectron scattering – Fermi liquid behaviour, Electrical conductivity of semiconductors, Disordered systems and hopping conduction, Hall effect, magnetoresistance in metals, magnetophonon effect, magnetoresistance in two dimensional systems, quantum Hall effect, fractional quantum Hall effect.	**7**	CO1, CO2	K2, K3, K4, K4, K5
Module 6:	**Magnetic Properties:** Magnetic moments, Quantum mechanics of spin, Atom in mangetic field, Magnetic susceptibility, Diamagnetism, Paramagnetism, Semiclassical treatment, Quantum Theory of Paramagnetism, Hund's Rules, Crystal field, Paramagnetic Susceptibility of Conduction electrons, Van Vleck paramagnetism, Adiabatic demagnetization Ferromagnetism, The Weiss model of a ferromagnet, Origin of molecular field, Magnons, Domains, Antiferromagnetism,	**12**	CO3	K2, K3, K4

	Neel's theory, Ferrimagnetism			
Module 7:	**Superconductivity**: Experimental survey- Occurrence of Superconductivity, Destruction of superconductivity by magnetic fields, Meissner effect, Heat capacity, Energy gap, microwave and infrared properties, Isotope Effect Theoretical Survey - Thermodynamics of the transition, London equation, Coherence length, BCS theory, Flux quantization, Type II superconductors, Tunnelling, Josephson effects, High Tc superconductivity (introduction)	**6**	CO4	K2
Pedagogy:	Lectures/ tutorials /assignments. Sessions will be interactive in nature to enable peer group learning.			
Texts:	1. C. Kittel, Introduction to Solid State Physics, Wiley India (2019) 2. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001) 3. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 4. H. Ibach and H. Luth, Solid-State Physics, An Introduction to Principles of Materials Science, Springer (1995). 5. J. Singleton, Band theory and Electronic Properties of Solids, Oxford University Press, (2014) 6. G. Bums, Solid State Physics, Academic press, Inc. London (1985) 7. A. J. Dekker, Solid State Physics, McMillan, India (1985) 8. J. S. Blakemore, W. B. Sauders, Solid State Physics, Philadelphia (1969)			
Web Resources:	1. Solid state physics: https://nptel.ac.in/courses/115105099 2. Introduction to Solid State Physics: https://nptel.ac.in/courses/115104109 3. Solid State Physics: https://nptel.ac.in/courses/115106127 4. Electronic Theory of Solids: https://nptel.ac.in/courses/115105122			

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Title of the Course	Solid State Physics Practical
Course Code	PHS-6002
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course provides laboratory training in performing experiments that verify important physical laws and using modern and novel techniques of measurements.	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Perform quantitative measurements and evaluation of various properties and constants introduced in the theory courses of Physics	PSO 1, PSO 4, PSO 8
	CO 2. Verify different laws and concepts learned in the theory courses of Physics	PSO 1, PSO 4, PSO 8
	CO 3. Develop fine and intensive experimental skills.	PSO 1, PSO 4, PSO 8
	CO 4. Interpret results, perform error analysis, analyze data and write reports.	PSO 1, PSO 4, PSO 8

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	The experiments on the following topics (any 12) are to be performed with emphasis on the estimation and calculation of errors. 1. X-ray diffraction: Analysis of diffraction patterns of cubic crystal structures to determine their lattice constant, intensity ratios, and lattice type 2. Measurement of dispersion relation of monoatomic and diatomic lattices using electrical equivalent circuits. 3. Measurement of Resistivity of a metal and energy band gap of a Semiconductor 4. Measurement of Thermoelectric Power of a metal 5. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Material by Gouy's Method. 6. Determination of Magnetic Susceptibility and Magnetic Moment of a Paramagnetic Liquid by Quinke's Method. 7. Study of Hysteresis loop of magnetic materials. 8. Determination of Lande's Splitting Factor, ‘g’ in an organic radical. 9. Study of elastic behaviour of solids using a composite piezoelectric oscillator and determine the ultrasonic velocity in liquids using ultrasonic interferometer 10. Measurement as well as determination of Transition Temperature of a Ferroelectric Material Dielectric Constant and understanding failure of mean field theory 11. Measurement of Activation Energy of F-Centres in Alkali Halide Crystals Thermoluminescence 12. Determination of a Hall Coefficient and Nature of a Semiconductor and Mobility of Charge Carriers 13. Analysis of frequency dependence of Dielectric constant of a material. 14. Study of optical properties of a material - absorption, excitation and emission spectra. 15. Measurement of thermal conductivity of a good and poor thermal conductor. 16. Study of magneto-resistance of a semiconductor	**120**	CO1 CO2 CO3 CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Laboratory experiments, self-study			

Texts:	1. Experimental Manuals assigned to each experiment. 2. C. Kittel, Introduction to Solid State Physics, 7th Edition, John Wiley & Son, Inc. New York (1997). 3. B.L. Worsnop & H.T. Flint, Advanced Practical Physics for Students, (1927). 4. A. J. Dekker, Solid State Physics, McMillan, India (1985). 5. Jerry D. Wilson, Physics Lab. Experiments 7/e, D. C. Heath and Company (2009).

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Title of the Course	Research methodology for Solid State Physics
Course Code	PHS-6003
Number of Credits	3
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course seeks to 1. Introduce students to the fundamental concepts, principles, and methods of scientific research. 2. Develop skills in research problem formulation, experimental design, data analysis, and scientific interpretation. 3. Familiarize students with commonly used material synthesis and sample preparation techniques. 4. Provide an understanding of advanced characterization techniques and their applications. 5. Develop competence in scientific and technical writing, research proposal preparation, and presentation of research findings.	
Course Outcomes:	Students able to	**Mapped to PSO**
	CO 1. Understand research concepts, methods, and apply critical thinking in scientific inquiry.	PSO9

	CO 2. Identify research problems, apply methodologies, hypotheses, and prepare research proposals.		PSO9	
	CO 3. Learn Scientific and technical writing techniques and apply to in the preparation of research documents using LaTeX.		PSO9	
	CO 4. Study various sample preparation and Characterization techniques and analyse data		PSO4, PSO5, PSO8, PSO9	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Research and Scientific Inquiry** Meaning of research; types of research, objectives and motivation in research, significance of research, scientific inquiry and the scientific method; Criteria of good research, interdisciplinary approaches to research and their implications in various research areas. **Research Methodology** Selection of a topic; hypothesis; identification and formulation of a research problem; literature review; Designing experiment; data collection and analysis; presentation and interpretation of results; scientific models. **Critical Thinking in Science** Role of critical thinking in scientific research; strategies for critical analysis and reasoning; identification of common logical and scientific fallacies. **Development of a Research Proposal** Meaning and purpose of a research proposal; essential elements of a research proposal; formulation of the research problem; development of research objectives, research questions, and hypotheses; preparation of a research plan and methodology. **Technical and Scientific Writing**	**12**	CO1 CO2 CO3	K2, K3, K4, K6

	Structure and organization of a thesis or dissertation; writing research papers and research reports; preparation of effective scientific posters; graphical representation and plotting of scientific data; preparation of scientific documents, reports, and research papers using LaTeX			
Module 2	**Methods of Sample Preparation** Principles, experimental procedures, advantages, limitations, and applications of sample preparation and synthesis techniques: Solid-state reaction method, Melt-quenching method, Sol-gel method, Hydrothermal method, Co-precipitation method, Chemical vapour deposition (CVD) method, Thin film deposition techniques: Thermal evaporation, Pulsed laser deposition (PLD), Electrochemical methods (electrodeposition, anodization and electrophoretic deposition)	**15**	CO4	K3
Module 3	**Sample Characterization and Data Analysis** Principles, instrumentation, data acquisition, and applications of the following characterization techniques: **Structural Characterization:** X-ray diffraction (XRD): principles, instrumentation, phase identification, and basic interpretation of diffraction patterns. **Spectroscopic Techniques:** UV-Visible spectroscopy; infrared (IR/FTIR) spectroscopy; Raman spectroscopy; X-ray absorption spectroscopy (XAS); X-ray fluorescence spectroscopy (XRF); X-ray photoelectron spectroscopy (XPS) **Surface and Morphological Characterization:** Techniques for the study of surface morphology, microstructure, surface area, pore size, pore volume, and porosity.	**18**	CO4	K4

	Thermal Characterization: Principles and applications of calorimetric and thermal analysis techniques. **Data Analysis** Introduction to statistical tools for scientific data analysis; analysis of quantitative data; error and uncertainty analysis; graphical representation of experimental data; presentation of data using tables, graphs, and figures; fitting and interpretation of experimental data; drawing scientifically valid conclusions from experimental results			
Pedagogy:	Lectures and Laboratory Experiments			
Texts:	1. C R Kothari, Gaurav Garg, Research Methodology, Methods and Techniques, New Age International Publishers, (2019) 2. R. Srinivasan, T. G. Ramesh, G. Umesh and C. S. Sunder, Experimental, Techniques in Physics and Materials Science, World Scientific,(2024) 3. C. Kittel, Introduction to Solid State Physics, Wiley India (2019) 4. Thin film deposition techniques, Joy George, CRC Press (1992) 5. Handbook of semiconductor electrodeposition, R K Pandey, CRC Press (2017) 6. Electrochemical methods: Fundamentals and Applications, A.J Bard and Faulkner, John Wiley and sons, (2022)			
References/ Readings:	1. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 2. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001) 3. Anthony R. West, Solid State Chemistry and its applications, Wiley (2014) 4. Research Methodology: The Aims, Practices and Ethics of Science, P. Pruzan, Springer, (2016)			

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Title of the Course	Research Methodology Lab for Solid State Physics
Course Code	PHS-6004
Number of Credits	1
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course seeks to 1. Develop practical skills in sample preparation, handling, and processing techniques 2. Acquire knowledge of various characterization techniques for synthesized materials. 3. Analyze and interpret experimental data obtained from different characterization methods 4. Develop scientific research skills through project-based learning, including literature review, experimental planning, data analysis, and scientific reporting.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Apply suitable synthesis and sample preparation techniques for material development.	PSO4, PSO5
	CO 2. Select and use appropriate characterization techniques for synthesized materials.	PSO4, PSO5

	CO 3. Analyze and interpret experimental data to understand material properties.		PSO2, PSO4, PSO5, PSO6	
	CO 4. Develop research skills through project work, scientific reporting, and presentations.		PSO4, PSO5, PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1: Practical	**Experimental Work and Characterization** **(Perform minimum four characterizations for the sample)** 1. Sample Preparation and Synthesis: Preparation of material samples using suitable synthesis methods and optimization of experimental conditions for targeted applications. 2. Structural Characterization: Study of structure and phase identification using X-ray Diffraction (XRD) techniques. 3. Functional Group Analysis: Identification of chemical bonding and functional groups through Fourier Transform Infrared (FTIR) and Raman spectroscopy. 4. Optical Characterization: Investigation of optical properties of synthesized samples using appropriate techniques such as UV–Visible and Photoluminescence spectroscopy. 5. Magnetic Characterization: Study of magnetic behavior and properties of materials using suitable magnetic measurement techniques. 6. Thermal Characterization: Analysis of thermal stability and phase transitions using techniques such as Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). 7. Surface Morphology Analysis:	**30**	CO1 CO2 CO3 CO4	K3, K4, K5

	Examination of surface morphology, particle size, and microstructural features using Scanning Electron Microscopy (SEM) and related techniques. 8. Porosity Characterization: Investigation of surface area, pore size distribution, and porosity characteristics using BET surface area analysis and related techniques. 9. Data Analysis and Interpretation: Processing, analysis, and interpretation of experimental data to evaluate structural, morphological, optical, thermal, magnetic, and physical properties of the synthesized materials**.**			
Pedagogy:	Lectures and Laboratory Experiments			
Texts:	1. R. Srinivasan, T. G. Ramesh, G. Umesh and C. S. Sunder, Experimental Techniques in Physics and Materials Science, World Scientific, 2024 2. CNR Rao and J. Gopalakrishnan, new Directions in Solid State Chemistry. Cambridge university Press, 1997 3. C. Kittel, Introduction to Solid State Physics, Wiley India (2019)			
References/ Readings:	1. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 2. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001) 3. Anthony R. West, Solid State Chemistry and its applications, Wiley (2014)			

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Title of the Course	Advanced Research Methodology
Course Code	PHS-6005
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Basic knowledge of Solid-State Physics / Solid State Chemistry	
Course Objectives:	1. To provide students with a foundational background of crystal structure, thermal, and electrical properties of solids 2. To familiarize students with methods of physical property measurements.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand the basics of crystal structure and bonding mechanisms in solids.	PSO5
	CO 2. Develop a broad understanding of the electrical, thermal, and optical properties of solids.	PSO5
	CO 3. Gain knowledge of magnetic order in solid materials.	PSO5
	CO 4. Gain knowledge of experimental methods of electrical, thermal, optical, dielectric, and magnetic property measurement.	PSO5

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Crystal structure and Crystal Binding:** Crystals - Lattice, Bravais lattice, primitive unit cell, seven crystal systems, fourteen Bravais lattices, definitions of directions, coordinates and planes, Simple crystal structures: NaCl, CsCl, diamond, hexagonal close-packed structure, cubic ZnS structure, Reciprocal Lattice - Diffraction of waves by crystals, Bragg law, Scattered wave amplitude - Fourier analysis, reciprocal lattice vectors, diffraction conditions, Laue equations, Brillouin zones, Geometric structure factor, Atomic Structure factor Point Defects General Thermodynamic Features, Color centres, Line Defects: Dislocations Crystals of inert gases - Van der Waals - London interaction, repulsive interaction, equilibrium lattice constants, cohesive energy, Ionic Crystals - Electrostatic or Madelung Energy, evaluation of Madelung constant, covalent crystals, bonding in metals, and Hydrogen bonds.	**10**	CO1	K2
Module 2:	**Free Electron Theory and Energy Bands in solids:** Free electron theory - Sommerfield model, Electrical conductivity, Experimental electrical resistivity of metals, Heat capacity of electron gas, Experimental heat capacity, Thermal conductivity of metals, motion in magnetic fields Cyclotron frequency, Hall effect, AC conductivity, Energy Spectra in atoms, molecules and solids, Energy Bands in Solids; the Bloch Theorem, Band symmetry in k-space; Brillouin Zones, Number of states in the band, The nearly free electron model, The energy gap and the Bragg reflection, Tight binding model, Metals, insulators and semiconductors, density of states, The Fermi surface, Velocity of Bloch electron, Electron dynamics in an electric field, The dynamical effective mass, Physical origin of effective mass, The hole, Electrical conductivity, Electron dynamics in a magnetic field; cyclotron resonance and Hall effect, Experimental methods of determination of band structure, Limit of band theory; metal-insulator transition	**10**	CO2	K2
Module 3:	**Thermal Properties of Solids:** Vibrations of a one -dimensional monatomic lattice, first Brillouin zone, group velocity, long wavelength limit, derivation of force constant from experiment. Vibrations of a one-dimensional diatomic lattice. Quantization of elastic waves, phonon momentum, Inelastic scattering by Phonons Phonon Heat capacity, Planck distribution, normal mode enumeration, density of states in one	**8**	CO2	K2

	dimension, density of states in three dimensions Debye model for density of states, Debye T' law, Einstein model of the density of states, Thermal conductivity - Thermal resistivity of phonon gas, Umklapp process Optical and			
Module 4:	**Dielectric Properties:** Optical reflectance, Excitons, Raman effect in crystals, Macroscopic electric field, local electric field at atom, dielectric constant and polarizability, Structural Phase transitions, Ferroelectric Crystals and Displacive transitions	**10**	CO2	K2
Module 5:	**Magnetic Properties:** Langevin Diamagnetism Equation, Quantum Theory of Diamagnetism, Paramagnetism, Quantum Theory of Paramagnetism, Paramagnetic Susceptibility of Conduction electrons, Ferromagnetic Order, Magnon, Ferrimagnetic Order, Antiferromagnetism, Ferromagnetic Domains.	**12**	CO3	K2
Module 6:	**Methods:** X-ray diffraction, High and low temperature measurements, thermocouples, photoresistors, optical measurements, photon counting techniques, UV-vis, FTIR, Raman, low and high magnetic field measurements, High and low resistivity measurements, lock-in-amplifier. DC and AC resistance measurement methods, Thermal property measurements, DSC, and TGA. Heat capacity measurements, Magnetic property measurement, Faraday balance, VSM, SQUID,	**10**	CO4	K3, K4, K5
Pedagogy:	Lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.			
Texts:	1. C. Kittel, Introduction to Solid State Physics, Wiley India (2019) 2. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 3. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001) 4. G. Bums, Solid State Physics, Academic press, Inc. London (1985) 5. A. J. Dekker, Solid State Physics, McMillan, India (1985) 6. J. S. Blakemore, W. B. Sauders, Solid State Physics, Philadelphia (1969) 2815. 7. Solid State Physics An Introduction to Principles of Materials Science, Springer, (2009) 4th Edition 8. A. R. West, Solid State Chemistry and its Applications, Wiley (2014) 2nd Edition			

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Computational Physics Specialization

Title of the Course	Advanced Quantum Mechanics
Course Code	PHC-6000
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Should have basic knowledge of Quantum Mechanics and Statistical Mechanics	
Course Objectives:	To introduce advanced topics in the field of quantum mechanics such as many-body systems, relativistic wave equations and relativistic fields	
Course Outcomes:		**Mapped to PSO**
	CO 1. **Interpret** and **develop** the second quantization formalism for many-body fermionic and bosonic systems.	PSO1, PSO2, PSO8, PSO9
	CO 2. **Apply** second quantization and **analyse** the physical properties of the non-interacting and weakly interacting quantum systems, such as the Fermi gas and dilute Bose gas, including ground state energy, excitation spectra, and correlation functions.	PSO1, PSO2, PSO8, PSO9

	CO 3. **Develop** and **analyse** relativistic wave equations such as the Klein-Gordon and Dirac equations and their physical interpretations.		PSO1, PSO2, PSO8, PSO9	
	CO 4. **Develop** the fundamental concepts of quantum field theory, including field quantization and particle creation/annihilation effects and **examine** the different radiation fields such as scalar, complex fields, electromagnetic fields.		PSO1, PSO2, PSO8, PSO9	
	CO 5. **Examine** the radiation–matter interaction and related scattering processes.		PSO1, PSO2, PSO8, PSO9	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Second Quantization Identical Particles** Many-Particle States, and Permutation Symmetry, Completely Symmetric and Antisymmetric States, Bosons: States, Fock Space, Creation and Annihilation Operators, The Particle-Number Operator, General Single- and Many-Particle Operators, Fermions: States, Fock Space, Creation and Annihilation Operators, Single- and Many-Particle Operators, Field Operators: Transformations Between Different Basis Systems, Field Operators, Field Equations, Momentum Representation: Momentum Eigen functions and the Hamiltonian, Fourier Transformation of the Density, The Inclusion of Spin..	**12**	CO1	K2, K3
Module 2:	**Spin-1/2 Fermions** Non-interacting Fermions, The Fermi Sphere, Excitations, Single-Particle Correlation Function, Pair Distribution Function, Density Correlation Functions, and Structure Factor, Ground State Energy and Elementary Theory of the Electron Gas, Hamiltonian, Ground State Energy, in the Hartree–Fock Approximation, Modification of Electron Energy Levels due to the Coulomb Interaction, Hartree Fock Equations for Atoms	**10**	CO2	K3, K4
Module 3:	**Bosons** Free Bosons, Pair Distribution Function for Free Bosons, Two-Particle States of Bosons, Weakly Interacting, Dilute Bose Gas, Quantum Fluids and Bose–Einstein Condensation, Bogoliubov Theory of the Weakly Interacting Bose Gas, Superfluidity.	**10**	CO2	K3, K4

Module 4:	**Relativistic Wave Equations** Klein-Gordon equation, Plane wave solution, charge and current densities, hydrogen atom. Dirac equation, algebra of Dirac matrices, covariance of Dirac equation, plane wave solutions, equation in an electromagnetic field. Properties of Dirac electron. The spin of the Dirac particle, Magnetic dipole moment of electron, Velocity operator, Expectation value of the velocity. Parity, Charge conjugation and time reversal operations, Parity operation, Charge conjugation, and Time reversal operation. Dirac's hole theory, Feynman's theory of Positrons	**14**	CO3	K3, K4
Module 5:	**Quantization of Fields and Radiation Theory** Wave equation for a field, Conjugate field momentum, Hamiltonian, density conservation laws, quantum condition and quantization of scalar field, quantization of complex scalar and Schrodinger fields, Quantization of electromagnetic fields, Interaction of radiation with matter spontaneous and induced emission, Thomson scattering, cross-section for photoelectric effect, Heisenberg-Kramer formula, Rayleigh and Raman scattering. Quantization of Schrodinger field by anti-commutator, Atomic level shift, Lamb shift.	**14**	CO4, CO5	K3, K4
Pedagogy:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.			
Texts:	1. Franz Schwabl, Advanced Quantum mechanics, Springer (2005) 2. J. J. Sakurai, Advanced Quantum mechanics, Addison Wesley (1967). 3. B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson (2004) 4. S. N. Biswas, Quantum Mechanics, Books and Allied Pvt. Ltd. (2015) 5. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2004) 6. P. Coleman, Introduction to Many Body Physics, Cambridge University Press (2015)			
Web Resources:	1. Advance Quantum Mechanics with Applications: http://www.digimat.in/nptel/courses/video/115103104/L04.html 2. Relativistic Quantum Mechanics: https://nptel.ac.in/courses/115108074 3. Quantum Mechanics in the Relativistic Regime: https://nptel.ac.in/courses/115108791			

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Title of the Course	Advanced Statistical Mechanics
Course Code	PHC-6001
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-2026
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Should have basic knowledge of Quantum Mechanics and Statistical Mechanics	
Course Objectives:	To introduce advanced statistical methods to study phase transition and critical phenomena.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. **Understand and characterize** types of phase transitions.	PSO1, PSO6, PSO8
	CO 2. **Apply** and **Analyse** different models to describe these phase transitions.	PSO1, PSO6, PSO8
	CO 3. **Solve** different models and **examine** phase transitions theoretically using analytical and numerical methods.	PSO1, PSO6, PSO8
	CO 4. **Explain** scaling laws in phase transition.	PSO1, PSO6, PSO8
	CO 5. **Develop** the scaling behavior using renormalization group theory.	PSO1, PSO6, PSO8

Content:		No of Hours	Mapped to CO	Cognitive level
Module 1:	**Phase Transition and Critical Phenomena** First and second-order transitions, critical phenomena, morphology, fluctuation and correlation and response, Critical exponents, scaling inequalities, how to study critical phenomena.	**8**	CO1	K2
Module 2:	**Models and Universality** Ising models and its ground state, Ising models and its applications, other models and their ground states, Universality in different models.	**6**	CO1, CO2	K2, K3, K4
Module 3:	**Mean Field theory** Mean field theory for fluids, critical exponent of a fluid system, Mean field theory for magnetic systems, Mean field equation of state and its solution, Mean field critical exponents, correlation length and correlation function, Bethe approximation, Bethe approximation for 2D Ising model, Landau theory of Phase transition, Critical exponents from Landau theory.	**12**	CO3	K3, K4
Module 4:	**Transfer Matrix method** Transfer matrix and 1D Ising model, Determination of magnetization, susceptibility, specific heat, and correlation length. Spin-1 Ising model and potts model, 2D Ising model.	**6**	CO3	K3, K4
Module 5:	**Series expansion method (Perturbation method)** High-temperature expansion and 1-D Ising model, High and low-temperature expansions for 2D Ising model, Duality and critical temperature, approximation techniques	**6**	CO3	K3, K4
Module 6:	**Monte Carlo method (Numerical method)** Ensemble average in Monte Carlo method, Ergodicity, Detailed balance, and Metropolis algorithm, Monte Carlo Simulation for 2D Ising model, Measurements and errors.	**8**	CO3	K3, K4

Module 7:	**Scaling and renormalization** Homogeneous function, Homogeneity of free energy and scaling, Renormalization group, Renormalization Group, Renormalization operation, Free energy function, correlation length, Critical exponents, fixed point, and universality.	**14**	CO4, CO5	K3, K6
Pedagogy:	Lectures/ tutorials/assignments. Sessions will be interactive in nature to enable peer group learning.			
Texts:	1. R. K. Pathria and P. D. Beale, Statistical Mechanics, Elsevier, London, 2011. 2. L. D. Landau and E. M. Lifshitz, Statistical Physics, Third Edition, Part 1: Volume 5 (Course of Theoretical Physics, Volume 5), Butterworth-Heinemann, 1980. 3. J. M. Yeomans, Statistical Mechanics of Phase Transitions, Oxford University Press, New York, 1994. 4. H. E. Stanley, Introduction to Phase Transitions and Critical Phenomena, Oxford University Press, New York, 1987. 5. P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics, Cambridge University Press, Cambridge 2013. 6. S. B. Santra and P. Ray, Statistical Mechanics and Critical Phenomena: A brief overview, in Computational Statistical Physics, edited by S. B. Santra and P. Ray, Hindustan Book Agency, New Delhi, 2011.			
Web Resources:	1. Advanced Statistical Mechanics: nptel.ac.in/courses/115103028 2. Statistical Physics of Non-Interacting and Interacting Systems: https://nptel.ac.in/courses/115103538			

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Title of the Course	Numerical Techniques Practical
Course Code	PHC-6002
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

<table>
<tr><td>Pre-requisites
For the Course:</td><td colspan="4">Knowledge in Computer Programming in Fortran/C/Python/Matlab.</td></tr>
<tr><td>Course Objectives:</td><td colspan="4">To equip students with numerical methods and computational techniques for solving mathematical problems in physics.</td></tr>
<tr><td rowspan="5">Course Outcomes:</td><td colspan="2"></td><td colspan="2">Mapped to PSO</td></tr>
<tr><td colspan="2">CO 1. Understand and describe and efficient numerical techniques.</td><td colspan="2">PSO 2, PSO 8</td></tr>
<tr><td colspan="2">CO 2. Design and implement algorithms for numerical techniques using computer programming.</td><td colspan="2">PSO 6</td></tr>
<tr><td colspan="2">CO 3. Apply the algorithms to solve physical problems.</td><td colspan="2">PSO 2, PSO 6, PSO 8</td></tr>
<tr><td colspan="2">CO 4. Analyze the accuracy and stability of the numerical techniques</td><td colspan="2">PSO 2, PSO 6, PSO 8</td></tr>
<tr><td>Content:</td><td></td><td>No. of hours</td><td>Mapped to COS</td><td>Cognitive level</td></tr>
</table>

Module 1:	1. Error Analysis: Errors in numerical computation, sources, propagation, analysis 2. Root of Equations: Bracketing & Open Methods, Polynomial Roots a) Bisection method b) Regula Falsi method c) Fixed-point iteration method d) Newton Raphson method e) Secant Method, etc 3. Curve Fitting a) Least Square Regression for linear and nonlinear functions b) Interpolation & Extrapolation using Newton’s divided difference and Lagrange method 4. Numerical Differentiation & Integration a) Differentiation and Richardsons Extrapolation b) Trapezoidal integration c) Simpsons Rule integration 5. Solving Linear Algebraic Equations a) Gauss Elimination method b) Gauss Sidel method c) LU decomposition 6. Solving Ordinary Differential Equations a) Runge Kutta methods b) Predictor corrector methods c) Adaptive step size methods 7. Solving Partial Differential Equations a) Solving heat equations	**120**	CO1, CO2, CO3, CO4	K1, K2, K3,K4,K5

	b) Schrodinger equation c) Wave equation, etc 8. Eigen values & Eigenvectors of Matrices using QR decomposition and Schur factorization			
Pedagogy:	Lectures/Laboratory practicals. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery, Numerical Recipes: The Art of Scientific Computing, Cambridge University Press, 1986. 2. W. Cheney and D. Kincaid, Numerical Mathematics and Computing. Thomson Higher Education, USA, 2012 3. L. Gercia, Numerical methods for Physics, Create Space Independent Publishing, 2015. 4. S. E. Koonin, and D. C. Meredith, Computational Physics, Westview Press, 1998. 5. S. Chapra, R. Canale, Numerical Methods for Engineers, McGraw Hill Education, 7th edition, 2016.			
Web Resources:	1. Numerical Methods for Engineers, https://nptel.ac.in/courses/127106019 2. Numerical Methods Guy: https://autarkaw.wordpress.com/			

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Title of the Course	Research Methodology for Computational Physics
Course Code	PHC-6003
Number of Credits	3
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:		
Course Objectives:	The aim of course is to orient students towards research by introducing them to research methodology and basic principles of different simulation techniques solve many body physics.	
Course Outcomes:		**Mapped to PSO**
	CO 1. Understand research concepts, methods, and apply critical thinking in scientific inquiry.	PSO1, PSO2
	CO 2. Understand simulation techniques for studying complex physical systems.	PSO1, PSO2, PSO8
	CO 3. Learn algorithms to study properties of interacting quantum and classical systems.	PSO1, PSO2, PSO8
	CO 4. Identify the advantages and limitations of different simulation techniques.	PSO1, PSO2, PSO8

Approved by: Academic Council on 24th April, 12th & 13th May 2026

Content:		No. of hours	Mapped COS	Cognitive level
Module 1:	**Research and Scientific Inquiry** Meaning of research; types of research, objectives and motivation in research, significance of research, scientific inquiry and the scientific method; Criteria of good research, interdisciplinary approaches to research and their implications in various research areas. **Research Methodology** Selection of a topic; hypothesis; identification and formulation of a research problem; literature review; Designing experiment; data collection and analysis; presentation and interpretation of results; scientific models. **Critical Thinking in Science** Role of critical thinking in scientific research; strategies for critical analysis and reasoning; identification of common logical and scientific fallacies. **Development of a Research Proposal** Meaning and purpose of a research proposal; essential elements of a research proposal; formulation of the research problem; development of research objectives, research questions, and hypotheses; preparation of a research plan and methodology. **Technical and Scientific Writing** Structure and organization of a thesis or dissertation; writing research papers and research reports; preparation of effective scientific posters; graphical representation and plotting of scientific data; preparation of scientific documents, reports, and research papers using LaTeX	**12**	CO1	K1, K2, K3
Module 2	**Exact Diagonalization and Density-matrix renormalization group** Exact Diagonalization technique to solve Hamiltonians: Basis set generation, Hamiltonian Matrix construction and storing, Diagonalization, Calculating observables and understanding system properties. Advantages and limitations. Mean Field Theory, Truncated iterative diagonalization, formulation DMRG for Infinite and finite systems. DMRG using Tensor Networks and Matrix Product State. Advantages and limitations	**33**	CO2,CO3,CO4	K1, K2, K3, K4, K5

	Or **Density Functional Theory** Early First principle calculations, Hatree and Hatree fock method, Honberg Kohn Theorems, Khon Sham Equations, Different Exchange correlation fuctionals, solving Khon Sham Equations, DFT extensions and limitations, Obtaining the band structure.			
Pedagogy:	Lectures/Tutorials and Practical. Sessions shall be interactive in nature to enable peer group learning.			
References/ Readings:	1. C R Kothari, Gaurav Garg, Research Methodology, Methods and Techniques, New Age International Publishers, (2019) 2. Research Methodology: The Aims, Practices and Ethics of Science, P. Pruzan, Springer, (2016) 3. J. Thijssen, Computational Physics, Second Edition, Cambridge University Press, (2012) 4. Tao Pang, An Introduction to Computational Physics, Second Edition, Cambridge University Press, (2006) 5. U. Schollwock, The density-matrix renormalization group in the age of matrix product states, Annals of Physics 326, 96192 (2011) 6. J M Zhang and R X Dong , Exact diagonalization: the Bose–Hubbard model as an example, European Journal of Physics 31 591,(2010) 7. Sholl, D. S., & Steckel, J. A. Density functional theory: A practical introduction. John Wiley & Sons, (2009) 8. Lee, J. G. *Computational Materials Science: An Introduction*. CRC Press, (2011)			
Web Resources:	1. https://tensornetwork.org/ 2. https://pennylane.ai/qml/demos/tutorial_mps 3. https://archive.nptel.ac.in/content/storage2/courses/103103036/module5/lec21/1.html			

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Title of the Course	Research Methodology Lab for Computational Physics
Course Code	PHC-6004
Number of Credits	1
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites For the Course:		
Course Objectives:	The aim of the course is to orient students towards research by giving them hands-on training on different simulation techniques used in physics to study many body systems.	
Course Outcomes:	The student will be able to	**Mapped to PSO**
	CO 1. Apply computational and simulation techniques to solve physical problems techniques in physics.	PSO1, PSO2, PSO8
	CO 2. Perform numerical simulations using appropriate computational tools and software.	PSO1, PSO2, PSO8
	CO 3. Interpret and compare results obtained from different simulation methods.	PSO1, PSO2, PSO8
	CO 4. Explain the strengths and limitations of different computational techniques.	PSO1, PSO2, PSO8

Content:		No. of hours	Mapped COS	Cognitive level
Module 1	**Practical: (Any two of the following)** 1) Exact Diagonalizaion of Hubbard like Hamiltonians: • Basis set generation, • Hamiltonian matrix construction, • Diagonalization, • Analysis, 2) Truncated Iterative Diagonalization • Construction of sparse Hamiltonian matrices • Truncation • Growing the system size. • Convergence analysis • Calculation of physical observables 3) DMRG studies. • Construction of sparse Hamiltonian matrices • Truncation using Density matrix • Growing the system size. • Convergence analysis • Calculation of physical observables 4) Mean Field Theory • Construction of the mean-field Hamiltonian using the decoupling approximation. • Self-consistent determination of the order parameter. • Evaluation of physical observables • Analysis	**30**	CO1,CO2,CO3,CO4	K1, K2, K3,K4,K5

	5) Study of Material Properties Using Density Functional Theory (DFT) • Perform a self-consistent field (SCF) calculation. • Compute and visualize the electron density distribution of the system. • Determine and analyze the electronic band structure of the material.			
Pedagogy:	Practical sessions shall be interactive in nature to enable peer group learning.			
References/ Readings:	1. J. Thijssen, Computational Physics, Second Edition, Cambridge University Press, 2012. 2. Tao Pang, An Introduction to Computational Physics, Second Edition, Cambridge University Press, 2006 3. U. Schollwock, The density-matrix renormalization group in the age of matrix product states, Annals of Physics 326, 96192 (2011) 4. J M Zhang and R X Dong , Exact diagonalization: the Bose–Hubbard model as an example, European Journal of Physics 31 591,(2010) 5. Lee, J. G. *Computational Materials Science: An Introduction*. CRC Press, (2011)			

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Title of the Course	Advanced Research Methodology
Course Code	PHC-6005
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Basic knowledge of Quantum Mechanics and Statistical Mechanics.	
Course Objectives:	1. To introduce advanced topics in quantum mechanics, with emphasis on many-body systems, second quantization, and the quantization of relativistic fields. 2. To develop a comprehensive understanding of phase transitions and critical phenomena through symmetry principles, mean-field and Landau theories, and scaling concepts.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Apply the principles of **second quantization** to describe many-body quantum systems, including the construction and manipulation of bosonic and fermionic Fock spaces.	PSO2 , PSO6
	CO 2. Analyze **noninteracting and interacting fermionic and bosonic systems**, and compute physical quantities such as ground-state energy, excitation spectra, and correlation functions using standard many-body techniques.	PSO2 , PSO6
	CO 3. Formulate and interpret **quantized field theories**, including scalar, Schrödinger, and	PSO2 , PSO6

	electromagnetic fields			
	CO 4. **Understand and explain** phase transitions in terms of symmetry, order parameters, and thermodynamics, and **analyze the** order transitions in systems such as magnetic and ferroelectric materials..		PSO2 , PSO6	
	CO 5. **Apply** mean-field and Landau theories, along with basic scaling ideas, to **describe** critical phenomena, critical exponents, and model systems such as the Ising model		PSO2 , PSO6	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Second Quantization** Identical Particles, Many-Particle States, and Permutation Symmetry, Completely Symmetric and Antisymmetric States, Bosons: States, Fock Space, Creation and Annihilation Operators, The Particle-Number Operator, General Single- and Many-Particle Operators, Fermions: States, Fock Space, Creation and Annihilation Operators, Single- and Many-Particle Operators, Field Operators: Transformations Between Different Basis Systems, Field Operators, Field Equations, Momentum Representation: Momentum Eigen functions and the Hamiltonian, Fourier Transformation of the Density, The Inclusion of Spin.	**10**	CO1	K1,K2,K3
Module 2:	**Fermions and Bosons** Noninteracting Fermions, The Fermi Sphere, Excitations, Single-Particle Correlation Function, Pair Distribution Function, Density Correlation Functions, and Structure Factor, Ground State Energy and Elementary Theory of the Electron Gas, Hamiltonian, Ground State Energy, in the Hartree–Fock Approximation, Modification of Electron Energy Levels due to the Coulomb Interaction, Hartree–Fock Equations for Atoms. Free Bosons, Pair Distribution Function for Free Bosons, Two-Particle States of Bosons, Weakly Interacting, Dilute Bose Gas, Quantum Fluids and Bose–Einstein Condensation, Bogoliubov Theory of the Weakly Interacting Bose Gas, Superfluidity.	**14**	CO2	K1,K2,K3,K4
Module 3:	**Quantization of Fields**	**8**	CO3	K1,K2,K

	Wave equation for a field, Conjugate field momentum, Hamiltonian, density conservation laws, quantum condition and quantization of scalar field, quantization of complex scalar and Schrodinger fields, Quantization of electromagnetic fields,			3
Module 4:	**Phase transitions** The role of symmetry and the onset of order, switching of the degree of order, Example of atomic site ordering, Ferroelectric phase transitions, how to observe a phase transition, Order of a phase transition, General aspects of the thermodynamics of a phase transition, Seeds of a theoretical model, Examples Magnetic phase transitions- Macroscopic and microscopic views of magnetism, Non-interacting atoms in a magnetic field: paramagnetism, interacting atoms in a magnetic field: ferromagnetism, Critical exponents revisited, Successes and failures of the mean-field model Landau theory -Introduction, Quantification of the free energy, Results for second-order phase transitions, Field-dependence of the order parameter at the transition temperature, Taking account of spatial variations, Validity of Landau theory, Ferromagnetism, the mean-field approximation, and Landau theory, First-order phase transitions, The case when the free energy is allowed to have odd-order terms, Tricritical phase transitions. Examples like phase transitions and elastic strain, ferroelectric phase transition, superfluid Mott insulator phase transition.	**20**	CO4	K1,K2,K3,K4
Module 5:	**Critical Phenomena** The Widom scaling hypothesis: relationships between critical exponents, Introduction to the renormalisation group, Deriving the Widom scaling hypothesis, A sketched example: the 1D Ising mode	**8**	CO5	K1,K2,K3,K4
Pedagogy:	Lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.			
Texts:	1. Franz Schwabl, Advanced Quantum mechanics, Springer (2005) 2. J. J. Sakurai, Advanced Quantum mechanics, Addison-Wesley (1967).			

	3. B. H. Bransden and C. J. Joachain, Quantum Mechanics, Pearson (2004) 4. S. N. Biswas, Quantum Mechanics, Books and Allied Pvt. Ltd. (2015) 5. A. K. Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer (2004) 6. P. Coleman, Introduction to Many Body Physics, Cambridge University Press (2015) 7. Binney, J. J., N. J. Dowrick, A. J. Fisher, and M. E. J. Newman, The theory of critical phenomena: An introduction to the renormalisation group. Oxford: Clarendon Press, (1992).
References/ Readings:	1. Blundell, S., Magnetism in condensed matter. Oxford: Oxford University Press, (2001). 2. Burns, G. and A. M. Glazer, Space groups for solid state scientists, third edition. Waltham: Academic Press, (2013). 3. Dove, M. T. Structure and dynamics. Oxford: Oxford University Press, (2003). 4. Goldenfeld, N., Lectures on phase transitions and the renormalisation group. Reading, MA: Addison-Wesley, (1992). 5. Muller, U. Symmetry relationships between crystal structures. Oxford: Oxford University Press, (2013). 6. Nishimori, H. and G. Ortiz, Elements of phase transitions and critical phenomena. Oxford: Oxford University Press, (2011). 7. Salje, E. K. H., Phase transitions in ferroelastic and co-elastic crystals, Student Edition, Cambridge University Press, (1993). 8. Tol´edano, J.-C. and P. Tol´edano, The Landau theory of phase transitions. Singapore: World Scientific, (1987). 9. Yeomans, J. M. Statistical mechanics of phase transitions. Oxford: Clarendon Press, (1992).

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Discipline Specific Vocational Elective (DSVE) Courses

Title of the Course	Academic Writing and Documentation using Latex
Course Code	PHY-6401
Number of Credits	4
Theory/Practical	Practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites For the Course:	Nil	
Course Objectives:	To equip students with academic writing, communication and documentation using Latex.	
Course Out comes:		**Mapped to PSO**
	CO 1. Understand the basic structure of academic and research writing.	PSO 2, PSO 9
	CO 2. Apply standard practices in formatting an academic and research document.	PSO 2, PSO 9
	CO 3. Create well-structured academic documents.	PSO 9
	CO 4. Learn to create professional slide presentations	PSO 9

Content:		No. of hours	Mapped COS	Cognitive level
Module 1:	• Understand the basic structure of academic and research writing. • Understand basics of LaTeX syntax, document structure, and formatting. • Design and create Articles, Letters, Question papers, Reports, Book/Thesis, Presentation, Poster, flowcharts, etc using Latex.	**120**	CO 1, CO 2, CO 3, CO 4	K1, K2, K3, K6
Texts:	1. Ajay Semalty, Academic Writing, BS Publications, Hyderabad, India, 2021 (ISBN: 9789390211739). 2. Anne Whitaker, A Step-by-Step Guide to Writing Academic Papers, City University Seattle, 2009 3. C P Ravikumar, On Writing a Thesis, IETE Journal of Education, Vol. 41, pp 45-52, 2000 4. Leslie Lamport, LaTeX: A document preparation system, User's guide and reference manual, Addison Wesley, 1994. 5. Frank Mittelbach, Michel Goossens, Johannes Braams, David Carlisle, Chris Rowley, The LaTeX Companion,			
Web Resources:	1. https://www.overleaf.com/learn 2. https://www.latex-project.org/ 3. https://www.unigoa.ac.in/a/documentation-using-latex.html			

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Title of the Course	Parallel Programming and Numerical Methods
Course Code	PHC-6401
Number of Credits	2+2=4
Theory/Practical	T+P
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

<table>
<tr><td>Pre-requisites
For the Course:</td><td colspan="4">Knowledge in Computer Programming in Fortran/C/Python/Matlab.</td></tr>
<tr><td>Course Objectives:</td><td colspan="4">To equip students with parallel computing skills for solving mathematical problems in physics.</td></tr>
<tr><td rowspan="5">Course Outcomes:</td><td colspan="2"></td><td colspan="2">Mapped to PSO</td></tr>
<tr><td colspan="2">CO 1. Understand the basics of parallel computing.</td><td colspan="2">PSO 2, PSO 8,</td></tr>
<tr><td colspan="2">CO 2. Apply principles of parallel algorithm design to numerical computation problems.</td><td colspan="2">PSO 2, PSO 6, PSO 8</td></tr>
<tr><td colspan="2">CO 3. Analyze performance metrics of parallel programs.</td><td colspan="2">PSO 6</td></tr>
<tr><td colspan="2">CO 4. Create and Implement parallel programs using Fortran/C/Python/Matlab.</td><td colspan="2">PSO 2, PSO 6, PSO 8</td></tr>
<tr><td>Content:</td><td></td><td>No. of hours</td><td>Mapped COS</td><td>Cognitive level</td></tr>
<tr><td>Module 1:</td><td>Introduction to Parallel Computing:</td><td>30</td><td>CO 1,</td><td>K1, K2,</td></tr>
</table>

	Need for high-performance computing in physics, parallelism vs concurrency, types of parallelism. Parallel Programming Platforms, Principles of Parallel Algorithm: Task decomposition, data decomposition, load balancing, scalability, Performance Metrics & Analytical Modelling: Speedup, efficiency, scalability, Amdahl's law, Gustafson's law Shared memory, distributed memory, GPUs, clusters, supercomputers,		CO 2,	K3, K4
Module 2:	Parallel Programming using Fortran/C/Python/Matlab: Basic constructs, libraries (OpenMP, MPI, NumPy, MATLAB parallel toolbox). Shared Memory Programming: Multithreading, OpenMP, synchronization, race conditions. Distributed Memory Programming: MPI concepts, communication models, point-to-point, collective communication	**30**	CO 1, CO 2, CO 3, CO 4	K1, K2, K3, K4
Module 3:	Algorithms : Dense matrix operations, linear system solvers, sorting, FFT, Monte Carlo simulations, and other Numerical methods in Physics.	**30**	CO 1, CO 2, CO 3, CO 4	K1, K2, K3, K4
Texts:	1. Ananth Grama, Anshul Gupta, George Karypis, Vipin Kumar, Introduction to Parallel Computing, Second Edition, Addison Wesley, (2003). 2. Jan Palach, Parallel Programming with Python, Packt Publishing,(2014) 3. Alyasseri Zaid, Introduction to Parallel Computing using Matlab, LAP Lambert Academic Publishing, (2015).			
Web Resources:	1. https://www.cs.purdue.edu/homes/ayg/book/Slides 2. https://hpc.llnl.gov/documentation/tutorials/introduction-parallel-computing-tutorial 3. OpenMP Tutorial from LLNL https://computing.llnl.gov/tutorials/openMP			

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Title of the Course	Experimental Techniques in Physics
Course Code	PHS-6401
Number of Credits	2+2
Theory/Practical	Theory and practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Nil	
Course Objectives:	This course seeks to 1. Develop understanding of principles behind the measurement of various fundamental quantities 2. Apply these measurement techniques to evaluate different properties in a Physics laboratory.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand working principle of different scientific measurements and devices	PSO4, PSO8
	CO 2. Understand the advantages and disadvantages of using a technique or probe for making scientific measurements.	PSO4, PSO8
	CO 3. Estimate and translate errors and report quantities up to last significant digit	PSO4, PSO8
	CO 4. Demonstrate the ability to use selected measuring devices.	PSO4, PSO8

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Measurement of temperature** Thermocouple, diode and semiconductor sensors, RTD, pyrometer, Langmuir probes **Measurement of resistance** Two probe measurement and four probe measurement using constant current source and constant voltage source, Lock-in amp, discharge of capacitance **Measurement of capacitance** RC circuit, DC bridges, AC Bridges **Measurement of radiation** GM counter, ionization chambers, scintillation detector, solid state detectors, CCD detectors **Measurement of Pressure** Manometers, Piezometer, Different pressure gauges **Measurement of magnetic flux** Force methods, induction methods (including SQUID), Hall probe, indirect methods (MOKE), microscopic methods (MFM) **Estimation of errors in measurement.** Precision and accuracy, estimation of errors, propagation of errors, general formula, least square fitting, non-linear least square fitting, error distribution functions	**3** **3** **3** **3** **3** **5** **10**	CO1 CO2 CO3	K1, K2, K3, K4, K5
Module 2:	The experiments on the following topics (any 6) are to be performed with emphasis on the estimation and calculation of errors. 1. Propagation of error from measured quantities to derived quantities 2. Linear least square fitting, polynomial fitting and curve fitting 3. Calibration of temperature sensors (Si-diode, and thermocouples with RTD as standard)	**60**	CO1 CO2 CO3 CO4	K1, K2, K3, K4, K5, K6

	4. Choosing appropriate method for measurement of resistance (ultra-low value (< 1 Ohm), low value (1Ohm – 100 Ohm), high value (K Ohms), ultra-high value (M Ohms) 5. Construction of an appropriate bridge circuit to measure the value of an unknown capacitance. 6. Estimating value of unknown capacitance using series and parallel resonance 7. Calibration of a Scintillation counter 8. Calibrating a Hall probe to measure magnetic field 9. Measuring magnetic moment using SQUID magnetometer			
Pedagogy:	Lectures and Laboratory Experiments.			
Texts:	1. P. R. Bevington and D. K. Robinson, Data Reduction and Error Analysis for the Physical Sciences, McGraw Hill (Indian Edition) 2015. 2. R. Srinivasan, T. G. Ramesh, G. Umesh and C. S. Sunder, Experimental Techniques in Physics and Materials Science, World Scientific, 2024 3. C. Kittel, Introduction to Solid State Physics, Wiley India (2019) 4. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 5. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001)			

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Title of the Course	Advanced Experimental Methods in Condensed Matter Physics
Course Code	PHS-6402
Number of Credits	2+2
Theory/Practical	Theory and practical
Level	500
Effective from AY	2026-27
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Nil	
Course Objectives:	This course seeks to 1. Develop skills required to synthesis and characterize samples using different method 2. Evaluation of data and interpretation of physical properties of synthesized samples	
Course Outcomes:	Students able to	**Mapped to PSO**
	CO 1. Understand different sample preparation methods for solids	PSO4, PSO8
	CO 2. Understand different characterization methods for solids	PSO4, PSO8
	CO 3. Estimate and translate errors and report quantities up to last significant digit	PSO4, PSO8
	CO 4. Demonstrate the ability to use selected measuring devices.	PSO4, PSO8

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Overview of sample preparation methods** Solid state reaction, solution methods, melts, thin films, glasses, nano materials, quantum dots, the strengths and limitations of various methods **Sample characterizations** Diffraction methods, Spectroscopic techniques: UV-Vis, IR, Raman, XAS, XRF, XPS, NMR; Surface morphology and porosity, Calorimetry **Material Properties** Optical, electrical, mechanical and magnetic properties	**10** **10** **10**	CO1 CO2 CO3	K1, K2, K3, K4, K5
Module 2:	Samples need to be prepared using one of the synthesis methods and then characterized. The data collection, analysis and interpretation will be used to understand the different properties exhibited by synthesized samples.	**60**	CO1 CO2 CO3 CO4	K1, K2, K3, K4, K5, K6
Pedagogy:	Lectures and Laboratory Experiments			
Texts:	1. R. Srinivasan, T. G. Ramesh, G. Umesh and C. S. Sunder, Experimental Techniques in Physics and Materials Science, World Scientific, 2024 2. CNR Rao and J. Gopalakrishnan, new Directions in Solid State Chemistry. Cambridge university Press, 1997 3. C. Kittel, Introduction to Solid State Physics, Wiley India (2019) 4. M. A. Omar, Elementary Solid State Physics; Principles and Applications, Addison Wesley (2000) 5. Niel W. Ashcroft, N. David Mermin, Solid State Physics, Harcourt Asia Pte Ltd. (2001) 6. Anthony R. West, Solid State Chemistry and its applications, Wiley (2014)			

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SEMESTER IV

Generic Elective (GE) Courses

Title of the Course	Nuclear Reactor Physics	
Course Code	PHY-6201	
Number of Credits	2	
Theory/Practical	Theory	
Level	500	
Effective from AY	2026-27	
New Course	No	
Bridge Course/ Value added Course	No	
Course for advanced learners	No	
Pre-requisites for the Course:	Should have basic knowledge of nuclear physics, thermodynamics, quantum mechanics, and solid state physics	
Course Objectives:	1. To introduce students to the fundamental principles of neutrons, its interaction with the matter and its importance in nuclear reactors. 2. To understand the phenomenon of diffusion and slowing down of neutron in nuclear reactors and the waste disposal	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand neutron interaction with matter	PSO 1
	CO 2. Familiarise with the main feature of a nuclear reactor and conditions	PSO 1

	CO 3. Understand neutron diffraction and slowing down			PSO 1
	CO 4. Gain insight on the management of nuclear waste			PSO 1
Content:		**No of hours**	**Mapped to CO**	**Cognitive level**
Module 1:	**Introduction**: Discovery of neutron, Fundamental properties of neutron, decay of neutron, moment of the neutron, Classification of neutron energy: slow neutrons, thermal neutrons, Epithermal neutrons, Resonance neutron, Intermediate neutrons, Fast neutrons.	**2**	CO 2	K1, K2
Module 2:	**Interaction of Neutrons with Matter**: Interaction of neutrons with matter, cross-section, variation of cross section with neutron energy. Neutron flux, Maxwellian distribution, Fissile and fertile materials, Neutron life cycle, Fermi four factor formula k_{eff}.	**4**	CO 1	K1, K2
Module 3:	**Neutron Diffusion**: Diffusion theory approximation, neutron leakage, diffusion equation. Thermal diffusion length, One group critical equation for bare reactor. Boundary conditions and extrapolation distance, measurement of diffusion length	**5**	CO 2	K1, K2
Module 4:	**Slowing down of Neutrons**: Slowing down length, lethargy, slowing down in a mixture. Moderations.	**5**	CO 3	K1, K2, K3
Module 5:	**Calculation of Critical Size of Reactors**: Critical equation, One group model, four factor formula and calculation of parameters. Critical size of sphere. Effect of reflector.	**5**	CO3	K4
Module 6:	**Power Operation**: Reactor kinetics, prompt neutron lifetime, stable reactor period, the Inhour equation, Fission product poisoning. Fuel burn-up. Measurement or reactor power and period.	**5**	CO3	K2, K3, K4
Module 7:	**Radiological Protection**:	**2**	CO 4	K1, K2, K4

	Units of radiation and radioactivity, Radiation protection standards, Radiation monitoring instruments			
Module 8:	**Reactor Fuels and Materials:** Uranium resources and requirements. Isotope separation. (one method), reprocessing of spent fuel, Nuclear fuel management	**2**	CO 4	K1, K2, K3, K4
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. S. Glasstone and A. Sesonske, Nuclear Reactor Engineering, Van Nostrand Reinhold Co., (1963). 2. P. Mohanakrishnan, Om Pal Singh and K. Umasankari, Physics of Nuclear Reactors, Academic Press (2021)			
References/ Readings:	1. Weston M. Stacey, Nuclear Reactor Physics, Wiley- VCH (2018) 2. A. Klimov, Nuclear Physics and Nuclear Reactors, Argon Press (2018) 3. E. E. Lewis, Fundamentals of Nuclear Reactor Physics, Elsevier (2008). 4. L.F. Curtiss, Introduction to neutron Physics, D. Van Nostrand Co., (1969). 5. G. L. Squires, Introduction to the theory of Thermal Neutron scattering, Dover Publication, Inc. (1996).			
Web Resources:	1. https://ocw.mit.edu/courses/22-312-engineering-of-nuclear-reactors-fall-2015 2. Fundamentals of Nuclear Power Generation https://onlinecourses.nptel.ac.in/noc21_me54/preview			

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Title of the Course	Physics of Glasses and Thin Films
Course Code	PHY-6202
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

<table>
<tr><td>Pre-requisites for the Course:</td><td colspan="2">Should have basic knowledge of Solid-state Physics, Thermodynamic and statistical mechanics</td></tr>
<tr><td>Course Objectives:</td><td colspan="2">1. To introduce students to the Physics governing amorphous materials. The course includes the preparation of amorphous materials, kinetics and their characterization methods.
2. To introduce various types of thin films techniques, growth mechanisms and their applications</td></tr>
<tr><td rowspan="4">Course Outcomes:</td><td>Students will be able to</td><td>Mapped to PSO</td></tr>
<tr><td>CO 1. Understand the differences between crystalline and amorphous materials, and acquire knowledge of the history, structure, and key properties of glass. Learn about different techniques and growth mechanism of thin films</td><td>PSO 1</td></tr>
<tr><td>CO 2. Understand the glass transition, thermodynamic and kinetic aspects of glass. Gain knowledge about characteristics of thin film materials.</td><td>PSO 1, PSO 2</td></tr>
<tr><td>CO 3. Apply the basic rules of glass formation and understand structure of glass. Understand structural and mechanical properties of thin films</td><td>PSO 1, PSO 4</td></tr>
</table>

	CO 4. Understand the different methods for characterization of glasses. Comprehend applications of thin film in various fields		PSO 1, PSO 4	
Content:		**No of Hours**	**Mapped to CO**	**Cognitive level**
Module 1:	**Amorphous materials** Introduction, Definition, difference between crystalline and amorphous materials, properties of amorphous materials, Examples of amorphous materials, Methods of preparation of amorphous materials. Historical perspective of glass, Types of glasses. Refractive index, color, density, porosity, transparency, viscosity	**6**	CO 1	K1
Module 2:	**The Glass transition** The glass transition-change in volume with temperature, glass formation vs crystallization, Thermodynamic phase transition, Entropy, Relaxation, Factors determining glass transition temperature, Theory of glass transition, kinetics of glass formation	**10**	CO 2	K1, K2
Module 3:	**Structure of glass** Network former, network modifier, Intermediates, Structure and topology, Zachariasen random Network theory, coordination number, radial distribution function, structural modelling	**9**	CO 3	K2, K3
Module 4:	**Experimental techniques** Microscopy, X-ray diffraction, small angle scattering, vibrational spectroscopy, Raman spectroscopy, Thermal analysis.	**5**	CO 4	K1, K2, K3
Module 5:	**Introduction to Thin Films:** Definition of thin films, Comparison of thin and thick films, Theory of growth of thin films: Nucleation, condensation, Capillarity model, Atomistic model, comparison of models, various stages of film growth.	**4**	CO1	K1, K2
Module 6:	**Physical, Electrochemical, Chemical Deposition**: Techniques Overview of vacuum techniques, physical vapour deposition, chemical vapour deposition, molecular beam epitaxy, sputtering, electron –beam deposition, pulsed laser ablation. Electrodeposition: deposition mechanism and preparation of compound thin film,	**8**	CO2	K1,K2

	anodization, chemical bath deposition, successive ionic layer adsorption reaction method (SILAR) method Spray pyrolysis: deposition mechanism and preparation of compound thin films, sol-gel method, hydrothermal method			
Module 7:	**Characterization of Thin Films**: Thickness measurement - Tolansky technique, Talystep (styles) method, Quartz crystal microbalance, Stress measurement by optical method, Gravimetric method. Influence of thickness on the resistivity of thin films, Hall Effect & Magneto-resistance in thin films, FuchSondhemir theory, TCR and its effects. Mechanical properties: Contact angle (hydrophobicity and hydrophilicity), Adhesion and its measurement with mechanical and nucleation methods, stress measurement by using optical method. Structural characterization: X-ray diffraction (GI-XRD)	**10**	CO3	K1, K2,K3
Module 8:	**Emerging Thin Film Materials and Applications**: Patterning techniques (Photolithography), Diamond Films, Thin film resistors, capacitors, Junction devices (Diodes, Transistors, Solar cells), ICs, Thin film sensors (gas and humidity), Thin films for information storage (Magnetic and optical recording), Metallurgical applications, Photo thermal converters, Optical coatings, Electro acoustics and telecommunication	**8**	CO4	K1,K2,K3
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. S R Elliott, Physics of Amorphous materials, Longman, Harlow, 1990 2. Richard Zallen, The Physics of Amorphous materials, Wiley VCH, 2004. 3. Maissel and Glang, Hand book of Thin Film Technology, Mc Graw Hill 1970. 4. K. L. Chopra Thin Film Phenomena, Mc Graw Hill, 1969			
Web Resources:	Thin Film Technology https://onlinecourses.nptel.ac.in/noc24_ge56/preview			

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Title of the Course	Laser Physics and Advanced Optics
Course Code	PHY-6203
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Student should have basic knowledge of Atomic Physics.	
Course Objectives:	1. To develop understanding of construction and operation of different Laser systems. 2. To understand advances in laser physics and its applications. 3. To gain knowledge on different properties of light 4. To study advanced concepts in the modulation of light, nonlinear and quantum optics	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand the basic principles and operation of different types of Lasers.	PSO1, PSO3,PSO4, PSO5,PSO8
	CO 2. Get exposure to Lasers-amplifiers, resonators, and pulsing techniques.	PSO1, PSO8
	CO 3. Gain insights of intricacies involved in laser construction, design and their application in different fields.	PSO1, PSO3, PSO4, PSO8

	CO 4. Understand the basic properties of light through geometric, Galilean and Hamiltonian formulation	PSO1, PSO2, PSO8, PSO9		
	CO 5. Demonstrate their knowledge in using mathematical tools in understanding Optics	PSO1, PSO2, PSO8, PSO9		
	CO 6. Comprehend and appreciate concepts in optical modulation methods, nonlinear and quantum optics	PSO1, PSO2, PSO8, PSO9		
Content:		**No of hours**	**Mapped to CO**	**Cognitive level**
Module 1:	**Introduction to lasers:** Definition, brief history of Lasers, unique Properties of lasers, coherence, fundamental wave and quantum properties of light, Laser Safety: Various hazards due to laser radiation-eye, skin, chemical etc., safety measures and standard ANSI	**6**	CO1	K1, K2, K4
Module 2:	**Laser Amplifiers and Resonators:** Conditions for producing a laser – population inversions, Gain and gain saturation, Development and growth of laser beam, Requirements for obtaining population inversion, laser pumping requirements and techniques. laser cavity modes: longitudinal and Transverse, Q switching, mode-locking, pulse shortening techniques.	**8**	CO3, CO4	K2, K3, K5
Module 3:	**Laser systems and their applications:** He -Ne laser, Ar ion laser, Molecular Gas lasers: CO2 laser, Excimer lasers, Laser systems involving high-density gain media: Organic dye lasers, solid state lasers: Ruby laser, Nd-YAG and glass lasers. Applications of lasers in materials engineering (cutting, welding, cladding, peening, surface engineering), communication, LIDAR, Medical Applications (dentistry, LASIK, laser lithotripsy, dermatology), Laser Cooling and Trapping of Atoms, Spectroscopic applications (Raman scattering, LIBS).	**16**	CO1, CO2, CO3	K2, K3, K5
Module 4:	**Light Waves** Eikonal equations, laws of reflection and refraction, guided optics, Lagrange and Hamiltonian formulation of optics, ABCD matrix, thin lens formula, Gaussian optics, and Aberrations.	**12**	CO4, CO5,	K2, K3

	Coherence of light and Fourier Optics Fourier transforms in one and two dimensions, convolution operations, spatial frequency filtering, phase contrast microscopy, Correlation function, The Wiener–Khinchin Theorem, Linewidth, Spatial coherence, Interference spectroscopy, Temporal coherence, Stellar interferometers, Fourier transform properties of lenses.			
Module 5:	**Optical Modulation and Nonlinear Optics** Electro-optical effects, acousto-optical effect, Raman-Nath diffraction, and Magneto-optics. Nonlinear optical media, second-order and third-order optical effects, Kerr optical effect, self-focusing, optical bistability, second and third harmonic generation, coupled mode equations, Ultrafast optics.	**10**	CO6	K2, K3
Module 6	**Introduction to Quantum Optics** Quantum states of electromagnetic fields, coherent and squeezed states, Operators, ordering procedures and star products, Q, P, and Wigner functions of a density operator, Correlation functions and quantum coherence, Nonclassical light, Quantum entanglement, Bell's inequalities, Cavity QED, Quantum cryptography.	**8**	CO6	K2, K3
Pedagogy:	Lectures/ tutorials /viva/ seminars/ term papers/assignments/ presentations			
Texts:	1. William T. Silfvast, Laser Fundamentals, second edition, Cambridge University Press, 2004. 2. Joseph T. Verdeyen, Laser Electronics, third edition, Prentice Hall series, 1994. 3. K. Thyagarajan, Ajoy Ghatak, Lasers: Fundamentals and Applications (Graduate Texts in Physics), second edition, Springer publication, 2012. 4. B. D. Guenther, Modern Optics, Oxford University Press, 2015. 5. Ajoy Ghatak and K. Thyagarajan, Optical Electronics, Cambridge University Press, 2017. 6. Yariv and Yeh, Photonics-Optical Electronics in Modern Communications, Oxford University Press, 2007. 7. B.E.A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley and Sons, 2019. 8. Marc Fox, Quantum optics: an introduction, Oxford University Press, 2009.			
References/ Readings:	1. Karl F. Renk, Basics of laser physics, second edition, Springer, 2012. 2. Tarasov. L, Laser Physics and Application, Mir Publication, 1987.			

	3. Bakefi, George, Principles of Laser Plasmas, John Wiley & Sons Inc., 1977. 4. Ross Monte, Laser application, Academic Press, New York, 1974. 5. J. Goodman, Introduction to Fourier Optics, Roberts and Company Publishers, 3rd edition, 2004. 6. Sharma K. K., Optics- Principles and Applications, Academic Press, Elsevier, 2006. 7. R. W. Boyd, Nonlinear Optics, Elsevier 4th Edition, 2020.
Web Resources:	1. Laser: Fundamentals and Applications https://onlinecourses.nptel.ac.in/noc20_cy17/preview 2. Introduction to Laser http://elearn.psgcas.ac.in/nptel/courses/video/115102124/115102124.html

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Title of the Course	Physics of Energy and Ferroic Materials
Course Code	PHY-6204
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Student should have basic understanding of thermodynamics, electrodynamics and solid-state physics.	
Course Objectives:	1. Identify and analyze different energy materials, their properties, and evaluate their potential for energy extraction. 2. Explain the basic principles underlying various energy extraction phenomena. 3. Describe and classify various types of ferroic materials and illustrate their applications.	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Understand properties and basic principles of energy materials and devices.	PSO5
	CO 2. Understand the physics of thermoelectric and magnetocaloric effects.	PSO5
	CO 3. Learn about different ferroic phase transitions and characteristics of ferroic materials.	PSO5
	CO 4. Apply the understanding for different applications of ferroelectric, ferromagnetic and ferroelastic materials, and understand concepts of multiferroicity and glassy behaviour in different ferroic materials.	PSO5

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Photovoltaic Energy materials** Sources of energy: renewable and non-renewable sources, solar power and photovoltaic materials, photovoltaic devices	**7**	CO1	K2, K3
Module 2:	**Energy Storage materials** Electrochemical energy conversion and storage, Battery materials, fuel cells, supercapacitors, metal-organic framework for hydrogen storage, materials for water splitting.	**8**	CO2	K2, K3
Module 3:	**Thermoelectric Materials** Introduction, The Seebeck and Peltier effects, thermoelectric figure of merit, Measuring the thermoelectric properties, Heat conduction by the crystal lattice, Materials for Peltier cooling, Generator materials, Thermoelectric refrigerators and generators.	**8**	CO2	K2, K3
Module 4:	**Magnetocaloric materials** Magnetocaloric effect in the phase transition region, Methods of investigation of magnetocaloric properties, Magnetocaloric effect in different types of materials, Magnetocaloric effect in nanosized materials, Magnetic refrigeration	**7**	CO2	K2, K3
Module 5:	**Phase Transition** Landau Theory of phase transition – first order and second order.	**4**	CO3	K2, K3
Module 6:	**Ferroelectrics** *P*–*E* Loop, Relationships Between Dielectric, Piezoelectric, Pyroelectric, and Ferroelectric, Origin of Ferroelectrics, Structure-Induced Phase Change from Paraelectric to Ferroelectric, Soft Phonon Mode, Ferroelectric Domains and Domain Switching, Domain Structure, Ferroelectric Switching, Ferroelectric Materials – $BaTiO_3$, $PbTiO_3$, Antiferroelectric $PbZrO_3$, $Pb(Zr_xTi_{1-x})O_3$ (PZT), Relaxor Ferroelectrics.	**9**	CO3	K2, K3
Module 7:	**Ferromagnetics**	**9**	CO3, CO4	K2, K3, K4

	General Introduction to Ferromagnetics, Domain and Domain Wall, Magnetoresistance Effect and Device, Anisotropic Magnetoresistance (AMR), Giant Magnetoresistance (GMR), Colossal Magnetoresistance (CMR), Tunnelling Magnetoresistance (TMR), Spin-Transfer Torque Random-Access Memory (STT-RAM), Magnetostrictive Effect and Device Applications, Magnetostrictive Properties of Terfenol-D, Magnetostrictive Ultrasonic Transducer, Magnetoelastic Effect, Magnetomechanical Strain Gauge, Multiferroics, Magnetoelectric Effect, Why Are There so Few Magnetic Ferroelectrics? Single Phase Multiferroic Materials, ME Composite Materials, Multilayered Heterostructures.			
Module 8:	**Ferroelastics** Shape Memory Alloy, SMA Phase Change Mechanism, Nonlinearity in SMA, One-Way and Two-Way Shape Memory Effect, Superelastic Effect (SE), Application Examples of SMAs, Ferromagnetic Shape Memory Alloys, Formation of Twin Variants, Challenges for Ni–Mn–Ga SMA, Device Application of MSMA.	**8**	CO4	K2, K3, K4
Pedagogy:	Lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.			
References/ Readings:	1. Ram Gupta Eds, Handbook of Energy Materials, Springer Singapore, 2022 2. Duncan W. Bruce, Dermot O'Hare, Richard I. Walton, Energy Materials, Wiley, 2011 3. Stephen J Fonash, Solar Cell Device Physics, 2nd Edition, Academy Press, 2010. 4. R. Rajasekar, C. Moganapriya, A. Mohankumar, Eds, Materials for Solar Energy Conversion: Materials, Methods and Applications, Wiley, 2022. 5. H Julian Goldsmid, The Physics of Thermoelectric Energy Conversion, Morgan & Claypool Publishers, 2017. 6. A.M. Tishin, Y.I. Spichkin, The Magnetocaloric Effect and its Applications, CRC press (Taylor and Francis group), 2016. 7. Jian Dai, Ferroic Materials for Smart Systems: From fundamentals to device applications, Wiley VCH (2020) 8. V. K. Wadhavan, Introduction to Ferroic Materials, Taylor & Francis (2000) 9. Jörg Schröder, Doru C. Lupascu, Ferroic Functional Materials: Experiment, Modeling and Simulation, Springer (2018)			

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Title of the Course	Astronomy and Astrophysics
Course Code	PHY-6205
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Should have basic knowledge of electromagnetic theory, classical mechanics, thermodynamics	
Course Objectives:	The objective of this course is to develop an understanding of basic physical principles governing celestial objects, constituents, radiative process, stellar astronomy and compact objects. A descriptive course includes concepts of general relativity and cosmology to describe the structure and dynamics of the universe.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Explain the content of Universe, measurement methods and celestial coordinate systems.	PSO 1
	CO 2. Describe stellar evolution, and death of stars	PSO 1
	CO 3. Analyze morphology, structure and classification of galaxies and Milky way	PSO 1
	CO 4. Apply principles of general relativity and cosmology to interpret the expansion of the universe and black hole physics.	PSO 1
	CO 5. Explain radiative processes and energy transport mechanisms in astrophysical systems.	PSO 1

	CO 6. Analyze compact objects and high-energy astrophysical phenomena such as pulsars, X-ray sources, and accretion disks.		PSO 1	
Content:		**No of hours**	**Mapped to CO**	**Cognitive level**
Module 1:	**Fundamentals of Astrophysics** Major contents of universe, Black body radiation, specific intensity, flux density, luminosity, Apparent Magnitude and Luminosity, Color index. Units of measurement, celestial coordinates, precession, Mass, length and time scales in Astrophysics. Measurement techniques: Parallax method. Standard Candle method**.** Cepheid variable method**,** RedShift, Motions of Celestial Bodies: Diurnal and Annual Motion, Seasons, Eclipses, and Phases of Moon, Spherical Astronomy: Right Ascension and Declination, Introduction to Space Missions.	**10**	CO 1	K1
Module 2:	**Stellar structure: Birth and Death of stars** Formation of Stars: Molecular Clouds and Protostars, The Hydrostatic Equilibrium, Energy Generation in Stars: Nuclear Fusion. Birth of star, Protostar, The Main Sequence stars, Giant and supergiant stars, White Dwarf, Chandrashekhar limit. Neutron Stars and Black Holes, Hertzsprung-Russel (HR Diagrams). Stellar Nucleosynthesis: Production of Elements. Variable Stars and Pulsars, Supernova. Star Clusters: Open and Globular, Stellar Remnants and End States	**10**	CO 2	K2, K3, K4
Module 3:	**Galaxies and Milky Way** Morphology of galaxy, Galaxy formation and Evolution. Radio galaxies. Seyfert galaxies. Hubble classification of galaxy. Types of galaxies: Elliptical galaxies, Spiral galaxy, Lenticular galaxies, Irregular galaxies. Distance, luminosity, size and mass of galaxies. Mass and size of the Milky way Galaxy. Interstellar Medium and its composition. Distribution of stars in the solar neighbour.	**10**	CO 3	K1, K3, K4
Module 4:	**Cosmology and General Relativity** Expansion of the Universe, Interpretation of the Red Shift, CMBR, Fundamentals of cosmology, Friedmann equations, big bang and steady state models of universe.	**8**	CO 4	K2, K3, K4

	General Relativity: The equivalence principle, the principle of general covariance, the stress-energy tensor, Einstein equations, the equation of geodesic deviation, linearized gravity and idea of gravitational waves, Schwarzschild solution and Black holes, Bending of light, Black holes: event horizon and singularity			
Module 5:	**Radiative Processes** Radiative flux, radiative transfer: emission and absorption, Basic theory of radiation field, maxwell's equation, radiation transfer equation, thermal radiation, radiative diffusion, basics of radiative transfer, elementary stellar atmospheres, relativistic electrodynamics, emission of electromagnetic radiation, scattering, Brehmstrahlung, synchrotron radiation, Compton scattering, inverse-Compton process, plasma effects.	**10**	CO 5	K2, K3
Module 6:	**Physics of Compact Objects** Star death and formation of compact objects, Black holes, white dwarfs, and neutron stars, equilibrium configurations, equations of state, stability criteria, and mass limits, the influence of rotation and magnetic fields, pulsar phenomena, black hole spacetimes, Hawking radiation, mass flow in binary systems, spherical and disk accretion, high-temperature radiation processes, pulsar spin-up, compact X-ray sources and X-ray bursts, supermassive black holes in star clusters and galactic nuclei, Accretion on to black hole, gravitational radiation and neutrino radiation, stellar collapse and supernova explosion.	**12**	CO 5	K2, K4, K5
Pedagogy:	Lectures / tutorials/assignments. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. Mohit Kumar sharma and Suresh Chandra, A text book of Astronomy and Astrophysics, TechSar Pvt. Ltd (2019) 2. S L Shapiro & S A Teukolsky, Black Holes, White Dwarfs, and Neutron Stars: The Physics of Compact Objects, Wiley-VCH, 1983.			
References/ Readings:	1. Bradley W. Carroll and Dale A. Ostlie, An Introduction to Modern Astrophysics, Cambridge University Press (2017) 2. G. B. Rybicki & A. P. Lightman, Radiative Processes in Astrophysics, John Wiley, 1985. 3. S. Dhurandhar and S Mitra, General Relativity and Gravitational waves, Springer Nature, 2022. 4. E. Roy and D. Clarke, Astronomy Principles and Practice, 4th ed., Institute of Physics, 2003. 5. A R Choudhuri, Astrophysics for Physicist, Cambridge press,2010			

	6. K D Abhyankar, Astrophysics Stars and Galaxies, University Press (2001)
Web Resources:	1. Astrophysics & Cosmology https://nptel.ac.in/courses/115105046 2. Introduction to Astronomy https://ocw.mit.edu/courses/8-282j-introduction-to-astronomy-spring-2006/ 3. Introduction to General Relativity https://onlinecourses.nptel.ac.in/noc25_ph55/preview

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Title of the Course	Superconductivity, BEC, and Superfluidity
Course Code	PHY-6206
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-2027
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	No

Pre-requisites for the Course:	Should have basic knowledge of electrodynamics, thermodynamics, quantum mechanics, and solid-state physics	
Course Objectives:	To introduce up-to-date experimental and theoretical progress in superconductivity, BEC, and superfluidity	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Understand the basics of superfluidity and BEC	PSO1, PSO5
	CO 2: Explain the processes of laser cooling and trapping techniques	PSO1, PSO5
	CO 3: Compare BEC and superfluid state	PSO1, PSO5
	CO 4: Understand the phenomenon of superconductivity	PSO1, PSO5
	CO 5: Understand theories of conventional superconductors	PSO1, PSO5
	CO 6: Compare families of superconducting materials	PSO1, PSO5

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Superfluid Helium-4:** Introduction, Classical and quantum fluids, the macroscopic wave function, Superfluid properties of He II, Flow quantization and vortices, the momentum distribution, quasiparticle excitations.	**8**	CO1	K2, K3
Module 2:	**Superfluid Helium-3:** Introduction, The Fermi liquid normal state of He-3, the pairing interaction in liquid He-3, Superfluid phases of He3.	**5**	CO1	K2, K3
Module 3:	**Bose-Einstein Condensates-Theory:** Ultracold atomic gases. Bose-Einstein condensation in an ideal gas. Interacting Bose-Einstein condensates. Dynamics of Bose-Einstein condensates. Elementary excitations. Bose-Einstein condensates at finite temperatures. Two-dimensional Bose gases. Quantum vortices in Bose condensed gases. True and quasi condensates in one-dimensional trapped gases. Solitons in 1D Bose-condensed gases. Strongly interacting 1D Bose gases. Rapidly rotating Bose gases.	**10**	CO1	K2, K3
Module 4:	**Bose-Einstein Condensate-Experiment:** Ultracold quantum gases: What? Why? How? Atom-laser interaction, Bloch sphere Dressed state picture, Optical Bloch equations Light forces, Molasses cooling, Sisyphus cooling Atomic beam oven, Zeeman slower, Magneto-optical trap Optical dipole trap, Magnetic trap, Technology, Evaporative cooling, Characterizing a BEC.	**7**	CO1, CO2, CO3	K2, K3, K4, K5
Module 5:	**Basic Experimental Aspects** Introduction, Conduction in metals, Zero-resistivity, Meissner- Ochsenfeld effect, Perfect diamagnetism, Type-I and type-II superconductors, Application of low and high temperature superconductors.	**2**	CO4	K2, K3,
Module 6:	**Superconducting Materials**: Classical Superconductors: Elemental superconductors, superconducting compounds and alloys, A15 compounds, Chevrel phase compounds and their crystal structure, experimental studies on these materials, Phase diagrams. High-temperature Superconductors: La-Ba/Sr-Cu-O systems, Y-Ba-Cu-O systems, Bi-Sr-Ca-Cu-O systems, Ti-Sr-Ca-Cu-O systems, superconductivity in rare-earth and actinide compounds, organic superconductors, MgB2 and Iron Arsenide systems, their crystal structure, phase diagrams, experimental studies on	**10**	CO6	K2, K3, K4

	these materials, Phase diagrams.			
Module 7:	**Theory of Superconductivity**: Phenomenological theories- Thermodynamics of superconducting transition, expressions for critical temperature TC, critical field HC, London's theory, Pippard non-local theory, Ginzburg-Landau Theory. Microscopic theory: BCS theory, the electron-phonon interaction, the Cooper pair formation, BCS ground state, Consequences of the BCS theory and comparison with experimental results, Coherence of the BCS ground state and the Meissner-Ochsenfeld effect. Possible Mechanisms of High T_C Superconductors	**18**	CO5	K2, K3
Pedagogy:	lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.			
Texts:	1. James F. Annett, Superconductivity, Superfluids and Condensates Oxford Series in Condensed Matter Physics (2004). 2. R.P. Feynman, Statistical Mechanics, Westview Press, (1972). 3. K. Huang, Statistical Mechanics, Wiley Eastern Limited, (1988). 4. Ph. Nozieres and D. Pines, Theory of quantum liquids, Vol II, CRC. (2019). 5. J. Singleton, Band theory and Electronic Properties of Solids, Oxford University Press, (2014) 6. J. B. Ketterson and S.N. Song, Superconductivity, Cambridge Univ. Press (1999). 7. M. Tinkham, Introduction to Superconductivity, McGraw Hill (1996).			
References/ Readings:	1. S. Stringari and L. Pitaevskii, Bose-Einstein condensation, Clarendon Press, (2003). 2. C.J. Pethick and H. Smith, Bose-Einstein condensation in dilute gases, Cambridge University Press, (2011). 3. H. J. Metcalf and P. van der Straten, Laser Cooling and Trapping, Springer (1999).			
Web Resources:	D. Jervis and J. H. Thywissen, Making an ultracold gas, arXiv:1401.7659, (2014).			

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Title of the Course	Simulation Techniques
Course Code	PHC-6207
Number of Credits	2+2=4
Theory/Practical	T+P
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Basic knowledge of numerical programming and numerical techniques	
Course Objectives	To equip students with numerical methods and computational techniques for solving mathematical problems in physics.	
Course Outcomes:		**Mapped to PSO**
	CO 1. **Understand** simulation techniques for studying complex physical systems.	PSO 1, PSO 5
	CO 2. **Design** algorithms to model interacting quantum and classical systems.	PSO 6, PSO 8
	CO 3. **Apply** computational methods to solve problems in physics.	PSO 6, PSO 8
	CO 4. **Analyze** results to evaluate the advantages and limitations of different simulation techniques.	PSO 5, PSO 6

Content:		No. of hours	Mapped COS	Cognitive level
Module 1:	**Monte Carlo methods** Random number generation, The Metropolis Monte Carlo Method. **Exact diagonalization method for solving quantum many body systems**. Basis set generation, Setting up the Hamiltonian matrix and storing it, diagonalization of large matrices, calculating correlations and observables. **Density-matrix renormalization group** Truncated iterative diagonalization, formulation DMRG for Infinite and finite systems, Tensor-network basics, Matrix product states and operators, Finite-system DMRG in the language of tensor networks **Density Functional Theory** Early First principle calculations, Hartree and Hartree fock method, Honberg Kohn Theorems, Kohn Sham Equations, Exchange correlation functionals, solving Khon Sham Equations, DFT extensions and limitations.	**30**	CO1, CO2	K1, K2, K3
Module 2:	1. Application of the Monte Carlo Method to study phase transitions in i) 2D Ising model 2. Using Exact Diagonalization Method to study model Hamiltonians i) Bose Hubbard model ii) Hubbard model 3. Using Truncated iterative diagonalization and DMRG to study model Hamiltonians i) Heisenberg Spin Chains ii) Bose Hubbard Models 4. Study of Material Properties Using Density Functional Theory (DFT) Objectives: i) Perform a self-consistent field (SCF) calculation using DFT. ii) Compute and visualize the electron density distribution of the system.	**60**	CO 1, CO 2, CO 3, CO 4	K1, K2, K3, K4

	iii) Determine and analyze the electronic band structure of the material.			
Pedagogy:	Lectures/Laboratory practicals. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. J. Thijssen, Computational Physics, Second Edition, Cambridge University Press, 2012. 2. Tao Pang, An Introduction to Computational Physics, Second Edition, Cambridge University Press, 2006 3. David S. Sholl and Janice A. Steckel, Density Functional Theory: A Practical Introduction, Second Edition, Wiley Publishers, 2009			
References/ Readings:	1. U. Schollwock, The density-matrix renormalization group in the age of matrix product states, Annals of Physics 326, 96192 (2011) 2. J M Zhang and R X Dong , Exact diagonalization: the Bose–Hubbard model as an example, European Journal of Physics 31 591,(2010) 3. Catarina, G., Murta, B. Density-matrix renormalization group: a pedagogical introduction. Eur. Phys. J. B 96, 111 (2023).			
Web Resources:	1. https://tensornetwork.org/ 2. https://pennylane.ai/qml/demos/tutorial_mps 3. https://archive.nptel.ac.in/content/storage2/curses/103103036/module5/lec21/1.html			

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Courses for Advanced Learners

Title of the Course	Physics of Magnetic and Quantum Materials
Course Code	PHS-6201
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Basic knowledge of Solid-State Physics / Solid State Chemistry	
Course Objectives:	1. To provide students with a foundational background relevant to research in the physics of topological materials, low-dimensional structures, and quantum devices. 2. To familiarize students with both general and specific aspects of magnetic interaction in condensed matter, along with methods of magnetic measurements.	
Course Outcomes:	Students will be able to	**Mapped to PSO**
	CO 1. Understand magnetism, magnetic interactions in solids, and various types of magnetic order, including frustrated magnetic states.	PSO5
	CO 2. Gain knowledge of experimental techniques for measuring magnetization at bulk, domain, and atomic scales.	PSO5

	CO 3. Develop a broad understanding of low-dimensional physics, including magnetic order and emerging low-dimensional materials.		PSO5	
	CO 4. Understand topological interactions and their influence on material properties, and recognize key applications in quantum technologies.		PSO5	
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**Magnetic structures and interactions** Diamagnetism, Paramagnetism, Ferromagnetism, Antiferromagnetism, Effect of magnetic field, Ferrimagnetism, Dipolar interactions, Exchange interactions – origin, direct and indirect exchange, Indirect exchange in ionic solids, indirect exchange in metals, Double exchange, Anisotropic exchange	**11**	CO1	K2
Module 2:	**Measurement of magnetic order** Magnetic fields, Atomic scale magnetism, Domain scale measurements, Bulk magnetism measurements – magnetization and magnetic susceptibility, Neutron scattering, other techniques	**6**	CO2	K2
Module 3:	**Order and broken symmetry** Broken symmetry, Landau theory of ferromagnetism, Heisenberg and Ising models (1D and 2D), Consequences of broken symmetry, Phase transitions, Rigidity, Excitations – magnons, Domains, Domain walls, Magnetocrystalline anisotropy, Domain wall width, Magnetization process, Observation of domain wall, small magnetic particles, Stoner-Wohlfarth model, Soft and hard materials	**8**	CO1	K2
Module 4:	**Magnetism in metals** Pauli paramagnetism, spontaneously spin-split bands, spin-density functional theory, Landau levels, Landau diamagnetism	**5**	CO1	K2
Module 5:	**Competing interactions and low dimensionality** Frustration, Spin glasses, Superparamagnetism, One dimensional and two-dimensional magnets – spin chains, Spinons Haldane chains, Spin-Peierls transitions, spin ladders, Kagome and honeycomb lattices, Magnetoresistance, Magneto-optics	**8**	CO3	K3
Module 6:	**Physics of topological materials:**	**11**	CO4	K2

	Berry phase, Dirac fermions, Hall conductance and its link to topology, and the Hofstadter problem of lattice electrons in a magnetic field, Linear response theory, Topological phases of matter such as Chern insulators and two- and three-dimensional topological insulators. Angle, Spin, and Depth Resolved Photoelectron Spectroscopy on Quantum Materials, Results of topological insulators, HgTe, Bi_2Se_3 family (Bi_2Te_3, Sbi_2Te_3), topological semimetal Na_3Bi, quantum spin Hall insulator WTe_2			
Module 7:	**Physics of low-dimensional systems:** Concepts about heterostructures and resulting low-dimensional systems such as quantum wells, nanowires, and quantum dots. Quantum physics applied to such systems. Optical properties of low-dimensional systems (transition rules, polarisation, etc.). Electron transport properties of 2D and 1D systems. Quantised conductance with Landauer formalism. Scattering phenomena in 1D. Devices based on quantum phenomena and the Coulomb blockade.	**11**	CO3	K2, K3
Pedagogy:	Lectures/ tutorials/ seminars/ assignments/ presentations/ etc. or a combination of some of these.			
Texts:	1. D. C. Mattis, Theory of Magnetism. Springer Verlag, 1981. 2. J. M. D. Coey, Magnetism and magnetic materials. Cambridge University Press, 2010. 3. Stephen Blundell, Magnetism in Condensed Matter. Oxford University Press, 2001. 4. N. W. Ashcroft and N. D. Mermin, Solid State Physics, Cengage Learning Publishers, 1976 1st Edition. 5. John Singleton, Band Theory and Electronic Properties of Solids, Oxford University Press, (2012) 6. B. Yan and S-C. Zhang, Topological Materials, Rep.Prog. Phys. **75** (2012) 096501			
References/ Readings:	1. N. Kumar, S. N. Guin, K. Manna, C. Shekhar, C. Felser, Topological Quantum Materials from the viewpoint of Chemistry, Chemical Reviews **Vol. 121** (2021) 2780-2815. 2. P. D. C. King et al., Angle, Spin and Depth resolved photoelectron spectroscopy on Quantum Materials, Chemical Reviews **Vol. 121** (2021) 2816-2856. 3. A. Vasiliev et al, Milestones of low-d quantum magnetism npj Quantum Materials **Vol. 3** (2018) 8368. 4. Kane C L and Mele E J, Quantum Spin Hall Effect in Graphene, *Phys. Rev. Lett.* **95** (2005) 226801 5. B. A. Bernevig and S. C. Zhang, Simple Quantum Spin Hall Effect, 2006 *Phys. Rev. Lett.* **96** 106802.			

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Title of the Course	Introduction to Crystallography and X-ray Spectroscopy
Course Code	PHS-6202
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026-27
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Basic knowledge of Solid State Physics / Solid State Chemistry	
Course Objectives:	This course is designed to familiarize students with 1. the sources of x-rays and various techniques in X-ray spectroscopy 2. general aspects of symmetry, crystal structure and X-ray diffraction and use the basic understanding in the characterization of solid materials	
Course Outcomes:	Student will be able to	**Mapped to PSO**
	CO 1. Gain knowledge about characteristics of different X-ray sources, especially synchrotron radiation sources.	PSO 5
	CO 2. Understand and apply the concepts of crystallography and X-ray diffraction methods.	PSO 5
	CO 3. Use the fundamental concepts to evaluate the structural details of a solid.	PSO 5
	CO 4. Understand and apply the principles, and data analysis methods of X-ray	PSO 5

	photoemission and X-ray absorption spectroscopy.			
Content:		**No of hours**	**Mapped to CO**	**Cognitive Level**
Module 1:	**X-ray Sources and Interaction with matter** X-rays: Waves and photons, Scattering, Absorption, Refraction and Reflection. X-ray tubes, Synchrotron radiation, Bending magnet sources, Undulator radiation, Wiggler radiation. X-ray detection **X-ray Scattering** Scattering from an electron, scattering from an atom, scattering from a molecule, scattering from liquids and glasses, small angle x-ray scattering	**15**	CO1	K1, K2, K3
Module 2:	**Introduction to Symmetry and Crystal Structures** Symmetry, Bravais lattice, Point groups and space groups and their stereographic representations, Herrmann-Mauguin and Schoenflies notations, Group-subgroup-supergroup relationships, Wyckoff notations and site symmetry, Asymmetric unit, Concept of Z and Z′, Metric matrix, Deriving bond length and bond angles **Structure Factors** Form factor, Structure factor, Fourier transform, Laue's equations, Bragg's law, Ewald's sphere, Phase problem in crystallography, Solution to the phase problem, Direct method, Patterson method, ∇F synthesis, L-P corrections, Temperature factors, Absorption and extinction of X-rays, Friedel's law and Absolute configuration determination, Anomalous scattering, Laue method, X-ray detectors	**15**	CO2, CO3	K1, K2, K3, K4, K5
Module 3:	**Single Crystal X-ray Diffraction (SCXRD)** Pros and cons of single crystal and powder X-ray diffraction, Single crystal growth, Data collection and structure determination, Parameters/constraints/restraints, Anisotropic displacement parameters (ADPs), Reliable (R) factor, Twining, Treatment of disordered structures **Powder X-ray Diffraction (PXRD)** Importance of PXRD method, Background of methodology, Geometrical basis of	**15**	CO2, CO3	K1, K2, K3, K4, K5

	PXRD, Sample preparation, Background noise determination, Indexing powder pattern, Profile fitting and Rietveld refinement, Phase identification and quantification, Crystallite size and strain determination **Total X-ray Scattering and Pair Distribution Function (PDF)** Short- and long-range order, Bragg and diffuse scattering concepts, Atomic scattering amplitude, Total scattering structure function, Atomic PDF and refinement			
Module 4:	**X-ray Absorption** Absorption coefficient, absorption edge, Definition: x- ray absorption fine structure (XAFS), x-ray absorption near edge structure (XANES), extended x-ray absorption fine structure (EXAFS), History, Theory of XAFS, XAFS Experiment, Beamline and optics, Data acquisition, treatment and modelling, XANES as fingerprint technique, x-ray magnetic circular dichroism. **X-ray Photoelectron Spectroscopy** Photoelectric Effect, history of x-ray photoelectron spectroscopy (XPS), theoretical model – three step model, instrumentation, the electron mean free path, Auger electrons, core level binding energies in atoms, molecules and solids, final state effects, valence band in solids, band structure, angle resolved photoelectron spectroscopy (ARPES).	**15**	CO4	K1, K2, K3, K4, K5
Pedagogy:	Lectures/tutorials/term papers/assignments/presentations/self-study			
Texts:	1. C. Giacovazzo, Fundamentals of Crystallography, Oxford Science Publications, 2011. 2. G. H. Stout and L. H. Jensen, X-ray Structure Determination: A Practical Guide, John Wiley and Sons, New York, 1989. 3. B. D. Cullity and S. R. Stock, Elements of X-ray Diffraction, 3rd edition, Pearson Education, 2014. 4. Jens Als-Nielsen and Des Mc Morrow, Elements of Modern X-ray Physics, 2nd Edition, Wiley 2011. 5. W. Massa, Crystal Structure Determination, Springer, 2000. 6. R. A. Young, The Rietveld Method, Oxford University Press, 1993. 7. T. Egami and S. J. L. Billinge, Underneath the Bragg Peaks: Structural Analysis of Complex Materials, Pergamon Materials Series, Volume 16, 2012			

Approved by: Academic Council on 24th April, 12th & 13th May 2026

	8. Grant Bunker, Introduction to XAFS, Cambridge University Press, 2010. 9. Stefan Hufner, Photoelectron Spectroscopy, Principles and Applications, Springer 2003.
Web Resources:	1. https://nptel.ac.in/courses/104106093: NOC: Chemical Crystallography 2. https://nptel.ac.in/courses/104108098: NOC: Symmetry and Structure in the Solid State 3. https://nptel.ac.in/courses/112106227:NOC:X-ray Crystallography & Diffraction 4. https://nptel.ac.in/courses/113104634: NOC: Crystal Symmetry, X-Ray Diffraction and Physical Properties,

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Title of the Course	Optical and Nuclear Spectroscopy for Condensed Matter
Course Code	PHS-6203
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2026
New Course	Yes
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites for the Course:	Basic understanding of Classical Mechanics, Electromagnetism, Atomic and Nuclear Physics, elementary Quantum Mechanics, and Solid State Physics	
Course Objectives:	This course aims to introduce concepts in optical and nuclear spectroscopic techniques that can be used for characterizing materials, especially in condensed matter. This course includes fundamental electronic, molecular, and nuclear spectroscopy	
Course Outcomes:	The students will be able to	**Mapped to PSO**
	CO 1. Understand the basic concepts in atomic and molecular physics	PSO1
	CO 2. Demonstrate their knowledge of optical spectroscopic techniques	PSO1, PSO2
	CO 3. Develop a deep understanding of the properties of the nucleus and magnetic resonance	PSO5, PSO8
	CO 4. Comprehend and appreciate concepts in nuclear spectroscopic techniques	PSO8

Content:		No of hours	Mapped to CO	Cognitive Level
Module 1:	**Review of atomic physics** One-electron and two-electron atoms: spectrum of hydrogen, helium and alkali atoms; Many electron atoms: Hund's rule, L-S and j-j coupling, Spectroscopic terms, Lande interval rule; Interaction with Electromagnetic fields: Zeeman, Paschen Back and Stark effects, electron spin resonance spectroscopy, Hyperfine structure and isotope shift, selection rules; Lamb shift, Absorption and Emission of radiation, Line width and its broadening mechanisms, Spontaneous and stimulated emissions, Einstein coefficients, Introduction to lasers and laser spectroscopy	**10**	CO 1	K2
Module 2:	**Molecular Spectroscopy** Microwave spectroscopy, Infrared spectroscopy, the vibrating diatomic molecule – simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator, Interaction of rotation and vibrations, the vibrations of polyatomic molecules, Raman spectroscopy– Electronic spectra of diatomic molecules – Born-Oppenheimer approximation, vibrational coarse structure – progressions. Intensity of vibrational transitions – the Franck-Condon principle. Optical absorption: Free carrier absorption-optical transition between bands-direct, direct and indirect-excitons, Luminescence in crystal - excitation and emission - decay mechanism, Fluorescence, Phosphorescence, Crystal Field Theory, Spectroscopy of transition metal complexes, Fluorescence spectroscopy, Introduction to time-resolved spectroscopy	**20**	CO 1, CO 2	K2, K3
Module 3:	**Properties of the Nucleus and Nuclear Magnetic Resonance Spectroscopy** Nuclear magnetic dipole moment, nuclear electric dipole moment, nuclear decays, magnetic and electric hyperfine interactions, Principles, classical treatment of NMR (Bloch equations), quantum theory of NMR, experimental methods, Chemical shift, Knight shift in metals, spin-lattice relaxation, spin-spin relaxation, applications.	**10**	CO 3, CO 4	K3, K6
Module 4:	**Mössbauer Spectroscopy,** Principles, The Debye-Waller Factor, Mossbauer Sources and Experimental Apparatus, Isomer Shifts, Electric quadrupole interaction, Magnetic Dipole Interaction,	**6**	CO 3, CO 4	K3, K6

	Quadratic Doppler effect, Results from Mossbauer spectroscopy, Neutrons and Neutron Sources, neutron spectrometer and detectors, the process of neutron scattering, response function and correlation function for inelastic neutron scattering, results from neutron scattering.			
Module 5:	**Neutron Scattering:** Neutrons and Neutron Sources, neutron spectrometer and detectors, the process of neutron scattering, response function and correlation function for inelastic neutron scattering, results from neutron scattering.	**6**	CO 3, CO 4	K3, K6
Module 6:	**muon spin rotation (μSR) and Positron annihilation spectroscopy (PAS)** Muons and muon spin rotation, influence of internal fields, results from μSR, Positrons in solids, positron sources and spectrometers, results from PAS	**8**	CO 3, CO 4	K3, K6
Pedagogy:	Lectures/ tutorials/ term papers/assignments/. Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules, 2nd Edition, Pearson; 2008. 2. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th Edition, Tata McGraw, 2004 3. H. E. White, Introduction to Atomic Spectra, Tata McGraw Hill, 1934. 4. K. Thayagarajan and A.K Ghatak, Lasers Theory and Applications, Macmillan (Tata McGraw Hill) 1995. 5. D. Satyanarayana Handbook of Molecular Spectroscopy, International Publishing House, 2015, 1st edition 6. Mark Fox, Optical Properties of Solids, Second Edition, Oxford University Press, 2010. 7. D. R. Vij, Eds, Luminescence of Solids, Plenum Press, New York, 1998. 8. G. Schatz and A. Weidinger, Nuclear condensed matter physics: nuclear methods and applications, John Wiley; 1997. 9. H. Kuzmany, Solid-state spectroscopy, Springer, 1998. 10. Arthur Beiser, Concepts of Modern Physics, McGraw Hill Education, 6th Edition, 2003 11. R. Schafer and P. C. Schmidt, Methods in Physical Chemistry, Wiley-VCH Verlag GmbH & Co. 2012.			
Web Resources:	1. https://nptel.ac.in/courses/102108082: NOC: Optical Spectroscopy and Microscopy : Fundamentals of optical measurements and instrumentation 2. https://onlinecourses.nptel.ac.in/noc22_ph33/preview: Neutron Scattering for Condensed Matter Studies 3. https://onlinecourses.nptel.ac.in/noc21_cy09/preview: Fundamentals of Spectroscopy			

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Title of the Course	Introduction to Quantum information and computing.
Course Code	PHC-6201
Number of Credits	4
Theory/Practical	Theory
Level	500
Effective from AY	2025-26
New Course	No
Bridge Course/ Value added Course	No
Course for advanced learners	Yes

Pre-requisites For the Course:	Basic knowledge of Quantum mechanics.	
Course Objectives:	To introduce the fundamental concepts and algorithms of quantum computing and the principles of quantum information theory.	
Course Outcomes:		**Mapped to PSO**
	CO 1. **Understand** the key quantum mechanical properties as computational resource.	PSO1, PSO2
	CO 2. **Analyze** given quantum circuits.	PSO2, PSO8
	CO 3. **Apply** quantum algorithms to simple computational problems.	PSO2, PSO8
	CO 4. **Evaluate** quantum information measures.	PSO2, PSO8
	CO 5. **Discuss** the basic principles of quantum error correction.	PSO1, PSO2, PSO8

Content:		No. of hours	Mapped COS	Cognitive level
Module 1:	**Introduction and Quantum model of computation**. Need for quantum computation; Postulates of quantum Mechanics, Overview of Quantum Mechanics. Qubits and Bloch sphere representation; Multi-qubit states, Quantum gates and circuits, No-cloning theorem, Quantum Teleportation and Super dense coding.	**20**	CO1, CO2	K1, K2, K3, K4, K5,K6
Module 2:	**Quantum Algorithms** Deutsch algorithm, Simon's problem, Grover's search algorithm, Quantum Fourier Transform (QFT), Shor's factorization algorithm.	**20**	CO1, CO2, CO3	K1, K2, K3,K4
Module 3	**Quantum Information** Pure and mixed states, entanglement, EPR paradox; Bell's inequalities; Density matrices; Entropy and information, Distance measures of Quantum Information, Quantum Error Correction	**20**	CO1, CO2, CO3, CO4, CO5	K1, K2, K3, K4, K5,K6
Pedagogy:	Lectures/ Sessions shall be interactive in nature to enable peer group learning.			
Texts:	1. Michael A. Nielsen and Issac L. Chuang, "Quantum Computation and Information", Cambridge (2002). 2. Riley Tipton Perry, "Quantum Computing from the Ground Up", World Scientific Publishing Ltd (2012). 3. Scott Aaronson, "Quantum Computing since Democritus", Cambridge (2013). 4. P. Kok, B. Lovett, "Introduction to Optical Quantum Information Processing", Cambridge (2010)			
References/ Readings:	1. M Hassan Mahmud, Daniel Goldsmith; A Minimal Introduction to Quantum Computing, arXiv:2504.00995v2, (2025) 2. John Watrous,Understanding Quantum Information and Computation, arXiv:2507.11536, (2025)			
Web Resources:	What is quantum computing? https://www.ibm.com/think/topics/quantum-computing			

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