ST. XAVIER'S COLLEGE (AUTONOMOUS), AHMEDABAD-9
FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS & ELECTRONICS

SEMESTER – V

SYLLABUS

OF

BSc PHYSICS (HONOURS)

BASED ON UNDERGRADUATE CURRICULUM FRAMEWORK
(NEP – 2020)

(Effective from Academic Year 2023)

Curriculum Framework for Semester – V

Course	Title	Content		Credit
DSC-8 (Theory)	PHMC551C Mathematical Methods and Quantum Mechanics	U1	Partial Differential Equations	4
		U2	2^{nd} Order Ordinary Differential Equations	
		U3	Foundation of Quantum Mechanics	
		U4	3D problem in QM	
DSC-9 (Theory)	PHMC552C Electrodynamics and Nuclear Physics	U1	Specia Techniques in Electrodynamics	4
		U2	Electromagnetic waves	
		U3	Nuclear Emissions	
		U4	Nuclear Structure	
DSC-10 (Laboratory)	PHMC553L Physics and Experiential Lab-V	14 Physics Experiments		4
		Experiential Lab: Hands on experiment.		
Minor-1 (Sub. Specific)	PHMN551C Digital Circuit (Hybrid Mode) SWAYAM	U1	Combinational Circuit	4
		U2	Sequential Circuit	
		U3	Microprocessor 8085	
		U4	Laboratory	
Minor-2 (Theory + Lab)	ELMN551C Basic Electronics-IV	U1	Network Analysis by Laplace Transformation	2
		U2	Multivibrators, Clock and Timer	
		U3 U4	9 experiments and 3 Projects	2
SEC	PHSE551C Statistica Methods in Physics	U1	Basics of Statistical Methods in Physics	2
		U2	Lab: Statistical Data Analysis and Simulation	
Total Credits				**22**

* DSC: Discipline Specific Core

St. Xavier’s College (Autonomous), Ahmedabad

Syllabus of Semester–V to be implemented from the Academic Year **2025-26.**

DEPARTMENT OF PHYSICS & ELECTRONICS

Major Course: Mathematical Methods and Quantum Physics

Course Code & Title	Credit Distribution of The Course				Eligibility Criteria	Prerequisite(s) of the Course (if any)
	Cr	Lecture hrs	Tutorial hrs	Activity/Case study analysis		
PHMC551C: Mathematical Methods and Quantum Physics	4	12x4	3x4		10 + 2 from a recognized board	Science Stream Math-Group

Learning Objectives:

LO1	Learn to solve partial differential equations using the method of separation of variables in various coordinate systems
LO2	Develop techniques for solving second-order linear differential equations using series methods. Understand the behavior of solutions near ordinary and singular points and study special functions like Bessel functions.
LO3	Understand the formulation and interpretation of the Schrödinger equation and fundamental postulates of quantum mechanics.
LO4	Study the mathematical structure and physical interpretation of angular momentum and spin in quantum mechanics.
LO5	Apply quantum mechanical principles to three-dimensional systems and analyze the hydrogen atom and magnetic field effects.

Course Outcomes:

CO1	Students will demonstrate the ability to apply separation of variables to solve Laplace's and Helmholtz equations in different coordinate systems.
CO2	Students will be able to derive and interpret series solutions for ODEs near regular and singular points using the Frobenius method.
CO3	Students will solve physical problems modeled by second-order ODEs and systems of first-order ODEs, including those involving Bessel functions.
CO4	Students will formulate and solve the time-independent Schrödinger equation for simple systems and interpret the solutions physically.
CO5	Students will derive and interpret angular momentum operators, eigenvalues, and commutation relations, and apply them to systems involving spin and coupled angular momenta.
CO6	Students will solve the Schrödinger equation for central potentials, understand the structure of hydrogen atom wavefunctions, and analyze Zeeman splitting.

Unit 1: Partial Differential equations

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

Partial derivative, Jacobian, Imperfect and perfect differentials. Some partial differential equations in physics, the method of Separation of variables, separation of Helmholtz equation in Cartesian coordinates, in spherical polar and cylindrical Coordinates, Laplace's equation in various coordinates, Choice of coordinate system and separability of a partial differential equation.

Text Book:

- Mathematical Methods in the Physical Sciences by **Mary L. Boas:** Chapters 13.1–13.7 (PDEs), 6.2 (Jacobian), 2.5 (Perfect/Imperfect Differentials)
- Quantum Mechanics: Concept and Applications by **Nouredine Zettili**: Appendix B (Mathematical Tools for Quantum Mechanics, overview of PDEs – optional reading)

Unit 2: Second Order Ordinary Differential Equations

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

Ordinary and Singular points, Series solution around an ordinary point, Series solution around a regular singular point: the method of Frobenius, Getting a second solution, Alternative method of getting the second solution, System of linear first order differential equations, Non-linear differential equations, related examples. Bessel functions.
Unit 1: Electrostatics

Text Book

- Mathematical Methods in the Physical Sciences by **Mary L. Boas:** Chapters 12.1–12.11 (Series solutions of ODEs), 7.1–7.4 (Bessel Functions)
- Quantum Mechanics: Concept and Applications by **Nouredine Zettili**: Appendix C (Special Functions), Section 2.3 (Differential Equations in QM – optional reading)

Unit 3: Foundations of Quantum Mechanics

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

[A] **Origins and Principles***:* Need for Quantum Theory – Ultraviolet catastrophe, atomic stability, and specific heat anomaly. Recap of historical experiments with no derivations (Photoelectric effect & Compton scattering, Davisson-Germer, Stern Gerlach). Numerical problems on de Broglie wavelength. Superposition Principle in Quantum Mechanics – Concept of wavefunction, linear combination of states, and introduction to quantum probability interpretation.

[B] **Mathematical Framework**: Schrödinger equation: Time-dependent and time-independent forms. Operators, eigenvalues, expectation values, and commutators.
Exact Solutions to Schrödinger Equation: One-dimensional infinite potential wells. One-dimensional harmonic oscillator. Quantum Tunneling and Potential Barriers. Reflection and transmission at a step potential. Tunneling through a potential barrier (application to alpha decay).

Text Book

- Introduction to Quantum Mechanics by **David J. Griffith:** Chapters 1 and 2
- Quantum Mechanics: Concept and Applications by **Nouredine Zettili**: Chapters 1 (Historical Introduction), 2.1–2.6 (Postulates of Quantum Mechanics)

Unit 4: Three-Dimensional Problems in Quantum Mechanics

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

[A] **Angular Momentum in Quantum Mechanics***:* Formalism of angular momentum: Commutation relations, ladder operators. Orbital angular momentum: Eigenvalues and eigenfunctions. Matrix representation of angular momentum. Geometrical interpretation: Uncertainty in angular momentum components.

[B] **Spin and Total Angular Momentum***:* Experimental evidence for spin: Stern-Gerlach experiment. Spin- 1/2 particles: Pauli matrices and their properties. Addition of angular momentum: Clebsch-Gordan coefficients. L-S and j-j coupling in many-electron atoms.

[C] **Quantum Mechanics in Three Dimensions***:* Schrödinger equation in Cartesian and spherical coordinates. Separation of variables: General treatment. Central potential and angular momentum quantization

[D] **Solutions to Common 3D Problems***:* Free particle and box potential in three dimensions. Hydrogen atom: Energy levels, wavefunctions, degeneracy. Effect of magnetic fields on central potentials (Zeeman effect)

Text Book:

- Introduction to Quantum Mechanics by **David J. Griffith:** Chapters 4 (Angular Momentum), 5 (Hydrogen Atom), 6.3 (Zeeman Effect)
- Quantum Mechanics: Concept and Applications by **Nouredine Zettili**:**:** Chapters 4.1–4.5 (Angular Momentum), 5 (Spin), 6 (Addition of Angular Momentum), 7.1–7.4 (3D QM), 9.1–9.3 (Hydrogen Atom)

St. Xavier's College (Autonomous), Ahmedabad

Syllabus of Semester–V to be implemented from the Academic Year **2025-26.**

DEPARTMENT OF PHYSICS & ELECTRONICS

Major Course: Electrodynamics and Nuclear Physics

Course Code & Title	Credit Distribution of The Course				Eligibility Criteria	Prerequisite(s) of the Course (if any)
	Cr	Lecture hrs	Tutorial hrs	Activity/Case study analysis		
PHMC552C: Electrodynamics and Nuclear Physics	4	12x4	3x4		10 + 2 from a recognized board	Science Stream Math-Group

Learning Objectives:

LO1	**Understand and apply Laplace's equation** with appropriate boundary conditions in various coordinate systems using techniques such as separation of variables and the method of images.
LO2	**Explain and utilize the Uniqueness Theorem** in electrostatic problem-solving.
LO3	**Derive and interpret Maxwell's equations** in free space and matter, and apply them to obtain and solve the electromagnetic wave equation.
LO4	**Analyze the properties of electromagnetic waves**, including polarization, reflection, transmission, and energy transport using the Poynting vector and Fresnel equations.
LO5	**Study nuclear decay processes**, specifically alpha and beta decay, and understand the theoretical frameworks behind them
LO6	**Apply the liquid drop model** to analyze nuclear stability, spontaneous fission, and isobar predictions. **Strengthen conceptual understanding through practical experiments** related to the theoretical aspects of electromagnetism and nuclear physics.

Course Outcomes:

CO1	**Apply electrostatic principles** to solve Laplace's equation in various coordinate systems using boundary conditions, uniqueness theorems, and the method of images
CO2	**Analyze electric potentials and fields** using multipole expansion techniques, interpreting monopole and dipole contributions in charge distributions.
CO3	**Explain and derive Maxwell's equations**, including the displacement current, and use them to formulate and solve the electromagnetic wave equation in free space and media.
CO4	**Evaluate the behavior of electromagnetic waves**, including reflection, transmission, polarization, and energy flow through concepts like the Poynting vector.

	The student shall be able to apply the theory of quantum Mechanics to understand Alpha and Beta decay processes
CO5	A clear understanding of comparing the Liquid Drop model of the nucleus with a liquid drop to explain various nuclear phenomenon
CO6	A very sound theoretical basis for solving problems related to Alpha decay, Beta decay and the Liquid drop model of the Nucleus.

Unit 1: Special Techniques in Electrodynamics

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

[A] **Laplace's Equation**: Introduction, Laplace's equation in one dimension, Laplace's equation in two-dimensions, Laplace's equation in three-dimension, Boundary conditions and Uniqueness Theorem, Conductors and second Uniqueness Theorem.
The Method of Images: The Classic Image Problem, Induced surface charge, Force and Energy, Other Image Problems,

[B] **Separations of variables**: Cartesian coordinates, Spherical coordinates

[C] **Multipole Expansion:** Approximate potential at large distances, The monopole and dipole terms, Origin of Coordinates in Multipole Expansions, The Electric field of a Dipole.

Text Book:

[A] Introduction to Electrodynamics by **David J. Griffiths** (4TH Edition): 3.1, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.1.6, 3.2.1, 3.2.2, 3.2.3, 3.2.4

[B] Introduction to Electrodynamics by **David J. Griffiths** (4TH Edition): 3.3, 3.3.1, 3.3.2

[C] Introduction to Electrodynamics by **David J. Griffiths** (4TH Edition): 3.4.1, 3.4.2, 3.4.3, 3.4.4

Reference Books:

- Classical Electrodynamics by J.D Jackson's
- Electricity and Magnetism by Purcell
- Classical Electrodynamics by H C Verma

Unit 2: Electromagnetic Waves

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

[A] **Maxwell's Equations**: Electrodynamics before Maxwell, How Maxwell Fixed Ampere's law, Maxwell's Equations, Magnetic Charge, Maxwell's Equations in matter, Boundary Conditions

[B] **Waves in One Dimension**: The wave Equation, Sinusoidal Equation, Boundary Conditions: Reflection and Transmission, Polarization.
Electromagnetic waves in Vacuum: The wave equation for E and B, Monochromatic Plane waves, Energy and momentum in Electromagnetic waves

[C] **Electromagnetic waves in matter**: Propagation in Linear Media, Reflection and Transmission at normal incidence, Reflection and transmission at Oblique incidence

[D] Electromagnetic waves in matter: Propagation in Linear Media, Reflection and Transmission at normal incidence, Reflection and transmission at Oblique incidence

Text Book:

[A] Introduction to Electrodynamics by **David J. Griffiths** (4^{TH} Edition): 7.3.1, 7.3.2, 7.3.3, 7.3.4, 7.3.5, 7.3.6

[B] Introduction to Electrodynamics by **David J. Griffiths** (4^{TH} Edition): 9.1.1, 9.1.2, 9.1.3, 9.1.4

[C] Introduction to Electrodynamics by **David J. Griffiths** (4^{TH} Edition): 9.2, 9.2.1, 9.2.2, 9.2.3

[D] Introduction to Electrodynamics by **David J. Griffiths** (4^{TH} Edition): 9.3, 9.3.1, 9.3.2, 9.3.3

Reference Books:

- Classical Electrodynamics by J.D Jackson's
- Electricity and Magnetism by Purcell
- Classical Electrodynamics by H C Verma

Unit 3: Nuclear Emissions

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

[A] **Alpha and Beta Decay**: Alpha Rays: Range of alpha particles, Disintegration energy of the spontaneous alpha decay, Alpha decay paradox - barrier penetration.

[B] **Beta Rays**: Introduction, Continuous Beta ray spectrum - difficulties encountered to understand it, Pauli's Neutrino Hypothesis, Fermi's theory of Beta decay, the detection of neutrino, Parity non-conservation in Beta decay.

[C] **Gamma Rays**: Introduction, Gamma-ray emission – selection rules, Internal conversion, nuclear isomerism

Text Book:

[A] Nuclear Physics, An Introduction-**S B Patel:** 4.2.1, 4.2.2, 4.2.3

[B] and[C] Nuclear Physics, An Introduction-**S B Patel:** 4.3.1, 4.3.2, 4.3.3, 4.3.4,4.3.5

Unit 4: Nuclear Structure

Credit of Course: 1 Cr **Lecture 12 Hrs** **Tutorial 3Hrs**

The liquid drop model of the nucleus: Introduction, Binding energies of nuclei : plot of B/A against A., Weizsacher's semi empirical mass formula Mass parabolas: prediction of stability against Beta decay for members of an isobaric family, Stability limits against spontaneous fission, Barrier penetration - decay probabilities for spontaneous fission, Nucleon emission.

Text Book:

Nuclear Physics, An Introduction-**S B Patel:** 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7

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Syllabus of Semester–V to be implemented from the Academic Year **2025-26.**

DEPARTMENT OF PHYSICS & ELECTRONICS

Major Course: Physics Lab and Experiential Lab-V

Course Code & Title	Credit Distribution of The Course			Eligibility Criteria	Prerequisite(s) of the Course (if any)
	Cr	Laboratory Hrs per week	Activity/Case study analysis		
PHMC552C: **Physics Lab and Experiential Lab-V**	4	8		10 + 2 from a recognized board	Science Stream Math-Group

LEARNING OBJECTIVES (LO)
(Physics Laboratory)

LO1	To understand the principle of a reversible pendulum. To analyse and minimize errors in time period measurement.
LO2	To use the Callender-Griffiths bridge for precise temperature measurements.
LO3	To understand the working principle and structure of a G.M. tube and to explore its application in radiation detection.
LO4	To understand the concept of magnetic susceptibility in magnetic fluids.
LO5	To study the Seebeck effect and thermoelectric emf generation and to understand the concept of neutral and inversion temperatures.
LO6	To use the Gauss eyepiece for accurate angle measurements.
LO7	To study multiple-beam interference using a Fabry-Perot interferometer. Also to understand the principles of amplitude division interference and wavefront division and how to operate a Michelson interferometer for fringe pattern observation.
LO8	To understand electronic transitions and vibrational transitions in molecules and to analyse the fine structure and estimate energy differences.
LO9	To understand the concept of mutual inductance and induced emf and use bridge circuits for determination of same.

(Experiential Lab.)

LO1	Independently identify the aim of a basic experiment with a creative or modified twist.
LO2	Collaboratively understand the problem and set up the complete experiment through self-learning in a team of 2–3 students
LO3	Analyse potential sources of error and assess their impact on the results.

Course Outcomes (CO)
(Physics Laboratory)

CO 1	Differentiate between various types of pendulums and report the main sources of error in the determination of acceleration due to gravity (g) using Kater's pendulum.
CO 2	Determine the temperature of the unknown substance by studying the variation of resistance of platinum wire and demonstrate the working of a Callendar Griffith Bridge.
CO 3	Operate Gieger Muller Tube (GM Tube) and demonstrate its characteristic
CO 4	Analyze the behavior of a thermocouple.
CO 5	Study and analyse interference through understanding of the operation of instruments like Michelson Interferometer, Fabry-Perot etalon and Bi prism.
CO 6	Understand the use of Gauss eye piece for calibrating the spectrometer and investigate the phenomena of Total internal reflection.
CO 7	Evaluate the disassociation energy and force constant from study of fine structure of the vibrational spectrum of Iodine molecule.

(Experiential Lab.)

CO 1	Set up and demonstrate new experiments to verify assigned physics principles and measure physical quantities.
CO 2	Independently calculate errors in measured results.
CO 3	Present and submit the experiment in the form of a scientific report.

B.Sc. (PHYSICS) SEMESTER -V PH-PHMC5513L (Practical)

01	Acceleration due to gravity by Kater’s pendulum (fixed knife edges.)
02	To determine melting point of a substance by platinum resistance thermometer using Callender-Griffiths bridge.
03	Characteristics of G.M. Tube and Dead Time of the G.M tube
04	Susceptibility of ferromagnetic substance by Quink's method (Magnetic fluid)
05	Study of thermocouple and determination of neutral temperature.
06	Refractive index by total internal reflection using Gauss eye piece.
07	Fabry-Perot etalon. Determination of the thickness of air film and wavelength of light using spectrometer.
08	Michelson interferometer. To determine the wavelength of monochromatic light.
09	Absorption spectrum of iodine molecule.
10	Biprism.
11	Mutual Inductance by Ballistic Galvanometer.
12	Heaviside mutual inductance bridge.
13	Determination of Curie temperature of ferroelectric ceramic.
14	An optical method of determining dielectric constant, dipole moment and polarizability of a polar liquid using Hollow prism