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

DEPARTMENT OF PHYSICS & ELECTRONICS

SEMESTER –VII

SYLLABUS

OF

BSc PHYSICS (HONOURS)

BASED ON UNDERGRADUATE CURRICULUM FRAMEWORK (NEP – 2020)

(Effective from Academic Year 2025)

Curriculum Framework for Semester – VII

Course	Title	Content		Credit
DSC-11 (Theory)	PHMC771C AI	U1	Introduction to AI, Evolution, and Subfields	4
		U2	Intuitive Machine Learning	
		U3	Introduction to R Programming and AI-Assisted Coding	
		U4	Domain-Specific Practical Application	
DSC-12 (Theory)	PHMC772C Condensed Matter and Classical Mechanics	U1	Band Theory	4
		U2	Free Electron in Crystal	
		U3	Variational Principle	
		U4	Canonical Transformations, Poisson Brackets and Small Oscillations	
DSC-13 (Laboratory)	PHMC773L Physics and Electronics Lab-VII	A	8-Physics Experiments	2
		B	8-Electronics Experiments	2
Research Project/OJT	PHRP771L/PHOJ771L			6
Minor	PHMN771C Adv. Mathematical Physics & Quantum Mechanics -1	U1	Fourier and Laplace Transforms	3
		U2	Complex variables and Green's function	
		U3	Dirac Formalism and Matrix Mechanics	
		U4	Approximation Methods and Applications	1
Total Credits				**22**

* DSC: Discipline Specific Core

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Syllabus of Semester–VII to be implemented from the Academic Year **2026-27.**

DEPARTMENT OF PHYSICS & ELECTRONICS

Major Course: AI

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		
PHMC771C: AI	4	12x4	3x4		10 + 2 from a recognized board	Science Stream Math-Group

Learning Objectives:

LO1	Develop a foundational understanding of Artificial Intelligence, its evolution, objectives, and major subfields relevant to scientific research.
LO2	Familiarize students with modern AI research tools, multimodal AI systems, and the basic concepts of Large Language Models (LLMs) used in academic workflows
LO3	Introduce the concept of machine learning as a data-driven approach to problem solving and distinguish it from traditional rule-based programming.
LO4	Develop an intuitive understanding of supervised, unsupervised, and reinforcement learning, along with commonly used learning algorithms.
LO5	Introduce the fundamentals of R programming, including syntax, data structures, and script execution.
LO6	Develop the ability to effectively utilize AI-assisted coding tools for code generation, debugging, and program refinement.
LO7	Develop the ability to acquire, prepare, and preprocess physics datasets from laboratory experiments or publicly available scientific sources using AI-assisted tools.
LO8	Interpret and communicate the results of AI-assisted data analysis in the context of physical principles through a mini project.

Course Outcomes:

CO1	Explain the fundamental concepts, evolution, and major applications of Artificial Intelligence across various research domains.
CO2	Identify and appropriately use AI-powered research tools for literature discovery, citation analysis, evidence synthesis, and academic productivity.
CO3	Differentiate among major machine learning paradigms and recognize suitable applications for each.
CO4	Interpret the working principles of basic machine learning algorithms such as Linear Regression, Logistic Regression, Decision Trees, and K-Nearest Neighbours without relying on mathematical formulations.
CO5	Write, execute, and modify basic R programs for simple data analysis tasks.
CO6	Employ AI tools to generate, understand, troubleshoot, and improve R code while demonstrating responsible use of AI assistance.
CO7	Prepare and preprocess physics-specific datasets suitable for machine learning applications.
CO8	Build, interpret, and evaluate basic supervised learning models in R and communicate meaningful, data-driven conclusions relevant to their discipline.

Unit 1: Introduction to AI, Evolution, and Subfields

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

- What is AI? Human intelligence vs. machine intelligence; core goals of Artificial Intelligence.
- Subfields of AI in Research: Computer Vision (medical imaging, satellite data); NLP (literature mining, summarisation, citation analysis); Robotics (lab automation, sample handling).
- AI Research Tools: NotebookLM (AI-powered research notebook & source synthesis), Scite (smart citation analysis & credibility assessment), Consensus (evidence-based paper search), Elicit (automated literature review), Research Rabbit (citation network mapping).
- Modern AI Landscapes: Mono-modal AI vs. Multi-modal AI systems in research contexts.
- Introduction to Large Language Models (LLMs): How they process language; showcase of state-of-the-art AI tools for academic work.

Unit 2: Intuitive Machine Learning

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

The shift from rule-writing to learning from data. Supervised, Unsupervised, and Reinforcement Learning approached intuitively — with classification vs. regression, and visual algorithms such as Linear Regression, Logistic Regression, Decision Trees, and K-Nearest Neighbours — all without mathematics, emphasising conceptual understanding**.**

Unit 3: Introduction to R Programming and AI-Assisted Coding

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

Getting started in with R; foundations of R syntax; using LLMs to generate and translate R code; running AI-generated scripts; and basic troubleshooting with AI assistance.

Unit 4: AI-assisted Analysis of Physics Data using Supervised Learning in R

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

Physics Data Acquisition and Preparation; AI-assisted Data Analysis in R; Supervised Learning for Physics; Model Evaluation and Interpretation; Mini Project using Experimental or Publicly Available Physics Data.

Reference Books

1. The Master Algorithm — Pedro Domingos (Basic Books)
2. Artificial Intelligence: A Guide for Thinking Humans — Melanie Mitchell (Farrar, Straus and Giroux)
3. Data Smart: Using Data Science to Transform Information into Insight — John W. Foreman (Wiley)
4. R for Data Science (R4DS) —Hadley Wickham & Garrett Grolemund (O'Reilly Media)
5. Intuitive Biostatistics: A Nonmathematical Guide to Statistical Thinking — Harvey Motulsky (Oxford University Press)
6. An Introduction to Statistical Learning (ISL) — Gareth James et al. (Springer)

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DEPARTMENT OF PHYSICS & ELECTRONICS

Major Course: Condensed Matter and Classical Mechanics

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		
PHMC772C: **Condensed Matter and Classical Mechanics**	4	12x4	3x4		10 + 2 from a recognized board	Science Stream Math-Group

Learning Objectives:

LO1	• Learning of isolated atomic energy levels to energy bands using the Kronig–Penney model and Bloch theorem. • Analyze electron behavior in periodic potentials using Bloch functions and interpret the concept of crystal momentum • Explain the concept of effective mass from band curvature and distinguish between electron and hole conduction mechanisms. • Free electron model and nearly free electron model to classify materials based on band structure and energy gaps
LO2	• Apply quantum mechanics and Fermi–Dirac statistics to determine quantum states, density of states, and the Fermi energy of a free electron gas. • Analyze electronic properties of metals by evaluating electronic specific heat, electrical conductivity, relaxation time, mean free path, and temperature dependence of resistivity • Interpret transport and emission phenomena in metals, including Ohm's law, Wiedemann–Franz–Lorentz law, Hall effect, and thermionic emission, using free electron theory.
LO3	• Explain electron motion in one- and three-dimensional potential wells, including the concepts of quantum states and degeneracy. • Apply Fermi-Dirac statistics to understand the density of states and the effect of temperature on electron distribution. • Analyze electronic properties of metals such as electrical conductivity, specific heat, relaxation time, mean free path, Hall effect, and thermionic emission.
LO4	• Describe the fundamentals of X-ray diffraction and derive Laue Equations and Bragg's Law. • Demonstrate the equivalence and physical interpretation of Bragg's and Laue equations using Ewald construction. • Apply reciprocal lattice concepts to analyze simple cubic (sc), body-centered cubic (bcc), and face-centered cubic (fcc) crystal structures.
LO5	• The aim of this course is to introduce students with the concept of functional variation and the calculus of variations, derive the Euler–Lagrange equations from Hamilton's principle, connect variational principles to Newtonian and Lagrangian mechanics, develop analytical skills for solving complex dynamical systems using Lagrangian methods, rovide a foundation for advanced topics such as Hamiltonian mechanics, quantum mechanics, and field theory
LO6	• This course aims to develop students' ability to formulate and analyze dynamical systems within the Hamiltonian framework, apply Poisson bracket formalism to derive equations of motion and conservation laws, perform canonical transformations, and systematically solve problems involving small oscillations, including normal modes and forced vibrations.

Course Outcomes:

CO1	• Understand the formation of energy bands in solids and distinguish between metals, insulators, and semiconductors based on band theory. • Apply Bloch theorem and the Kronig–Penney model to describe electron motion in periodic potentials and forbidden energy bands. • Analyze electron dynamics in crystals using concepts of crystal momentum, effective mass, and the nearly free electron model. • The concept of holes and evaluate the transition from isolated atomic states to the free electron limit in solids.
CO2	• Apply quantum free-electron theory and Fermi–Dirac statistics to determine energy states, density of states, Fermi energy, and temperature dependence of electron distribution in metals • Evaluate electrical and thermal transport properties of metals—electrical conductivity, resistivity, relaxation time, mean free path, Hall effect, thermionic emission, and Wiedemann–Franz–Lorentz law—using the free electron gas model.
CO3	• Apply Fermi-Dirac statistics to analyze electron distribution, density of states, and temperature effects in solids. • Analyze electronic properties of metals including specific heat, electrical conductivity, relaxation time, mean free path, and resistivity. • Apply transport laws such as Ohm's Law and Wiedemann–Franz Law, and explain phenomena like Hall Effect and thermionic emission.
CO4	• Explain the principles of X-ray diffraction and apply Bragg's Law and Laue Equations for crystal analysis. • Apply Ewald construction and reciprocal lattice concepts to analyze sc, bcc, and fcc crystal structures.
CO5	• By the end of this course, students will be able to apply the principle of stationary action to derive equations of motion using the Euler–Lagrange formalism, construct appropriate Lagrangians for mechanical systems including those with constraints, and relate symmetries to conservation laws. • They will also be able to use variational methods to solve standard physical problems and appreciate the broader significance of variational principles in advanced physics.
CO6	• By the end of this course, students will be able to apply the Hamiltonian formalism to analyze mechanical systems by formulating small oscillation problems, evaluating Poisson brackets to derive equations of motion and conservation laws, and performing canonical transformations to simplify and interpret dynamical systems in phase space.

Unit 1: Band Theory

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

Developments of energy bands in solids, Electron motion in crystal (one electron approach), Bloch theorem, Kronig-Penny model, Numbers of possible waves functions in a band, Crystal momentum, The concept of effective mass, Concept of holes, Metals, Insulators and semiconductors, From isolated atoms to the free electron limit, Nearly free electron model.

Textbook: Solid State Physics, Ajay Kumar Saxena
Publication: Macmillan India Limited
Article: Chapter 7 Articles: 7.1 to 7.9
Ref. Book: **Solid State Physics by M A Wahab**
Publication: Narosa

Unit 2: Free Electron in Crystal

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

A. Review: (Introduction of Electrons Moving in a One-Dimensional Potential Well, Three-Dimensional Potential Well, Quantum State and Degeneracy, The Density of States), Fermi-Dirac Statistics, Effect of Temperature on Fermi Distribution Function, The Electronic Specific Heat, The Electrical Conductivity of Metals, Relaxation Time and Mean Free Path, Electrical Conductivity and Ohm's Law, Wiedemann-Franz-Lorentz Law, The Electrical Resistivity of Metals, Thermionic Emission, The Hall Effect
B. Introduction and Review of X-ray diffraction, The Laue Equation, Equivalence of Braggs' and Laue Equation, Interpretation of Braggs' Equation, Ewald Construction, Reciprocal lattice to sc, bcc and fcc lattices.

Textbook: Solid State Physics by M A Wahab
Publication: Narosa
Article: For A: Chapter 10 article 10.1 to 10.15
For B: Chapter 8 article 8.1 to 8.12
Ref. Book: **Textbook:** Solid State Physics, Ajay Kumar Saxena
Publication: Macmillan India Limited

Unit 3: Variational Principle

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

Introduction, Configuration space, Some techniques of calculus of variation, the delta-notation, Applications of the Variational principle, Hamilton's principle, Equivalence of Lagrange's equation, Newton's equation and Hamilton's principle, Advantages of the Lagrangian formulation-Electromechanical analogies, Lagrange's undetermined multipliers, Applications of the Lagrangian method of undetermined multipliers, Hamilton's equations of motion, Applications of the Hamiltonian formulation, Phase space, Comments on the Hamiltonian formulation.

Textbook: Introduction to Classical Mechanics by R. G. Takawale and P. S. Puranik.
Publication: Tata McGraw-Hill Publishing Co. Ltd.
Article: Chapter 11: 11.1 - 11.13

Unit 4: Canonical Transformations, Poisson Brackets and Small Oscillations

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

[A] Canonical Transformation: Background and Definition, Generating Functions, properties of Canonical Transformations, Some Examples of Canonical Transformation, Canonical Transformations of the Free particle Hamiltonian, Liouville's Theorem, Area Conservation Property of the Hamiltonian Flows.

[B] Poisson Brackets: Definition, Some useful identities, Elementary PBs, Poisson's Theorem, Jacobi-Poisson's Theorem, Invariance of PB under Canonical Transformations, PBs involving angular momentum.

[C] Small Oscillations: Types of Equilibria and the potential at equilibrium, Study of small oscillations using generalized coordinates.

Textbook:

[A] Classical Mechanics by N.C Rana and P.S. Joag.,
Publication: Tata Mc Graw Hill
Article: Ch 8: 8.0 to 8.7

[B] Classical Mechanics by N.C Rana and P.S. Joag.,
Publication: Tata Mc Graw Hill
Article: Ch 9: 9.0 to 9.7

[C] Classical Mechanics by N.C Rana and P.S. Joag.,
Publication: Tata Mc Graw Hill
Article: Ch 11: 11.0 to 11.2

Reference Books:

1. Classical Mechanics by A. B. Bhatia, Narosa Publication.
2. Classical Mechanics by H. Goldstein, Addison Wesley.
3. Classical Mechanics by J. C. Upadhyaya, Himalaya publications
4. Classical Mechanics by John. R. Taylor Tata Mc Graw Hill

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

DEPARTMENT OF PHYSICS & ELECTRONICS

Major Course: Physics Lab and Electronics Lab-VII

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		
PHMC773L: **Physics Lab and Electronics Lab-VII**	4	8		10 + 2 from a recognized board	Science Stream Math-Group

LEARNING OBJECTIVES (LO)
(Physics & Electronics Laboratory)

LO1	Will be able to determine the specification rotation of sugar solution using Polarimeter
LO2	Will be able to measure dielectric constant of a non-polar liquid
LO3	Will be able to measure the energy band gap, voltage coefficient and diffusion capacitance of the PN junction diode.
LO4	Will be able to measure the resistivity using four probes
LO5	Will be able to measure the speed of the sound wave using CRO
LO6	Will be able to study OPAMP parameters, and as inverting or non-inverting amplifiers.
LO7	Will be able to demonstrate the OPAMP as Voltage to Current and Current to Voltage Converter.
LO8	Will be able to demonstrate the OPAMP as an Integrator and differentiator and as an adder and subtractor circuit.
LO9	Will be able to demonstrate +5 V regulated power supply using three terminal IC

Course Outcomes (CO)
(Physics & Electronics Laboratory)

CO 1	Apply OPAMP and its application concepts, and will be go through OPAMP parameters and its characteristics measurements
CO 2	To prepare the circuit of +5 V regulated power supply and to get the knowledge of regulations.
CO 3	Apply key application of OPAMP such as Integrator and differentiator, and as an adder and subtractor circuits.
CO 4	Apply the concept of four probe measurements and measure the resistivity of the unknown material.
CO 5	Apply the concept of capacitance in a cylinder and measure dielectric constant of a non-polar liquid by using cylindrical structured capacitors.
CO 6	Apply semiconductor P-N Junction knowledge and to study energy band gap, voltage coefficient and diffusion capacitance.
CO 7	Apply and to study the concept of specific rotation of polarization of the light by using sugar solution

B.Sc. (PHYSICS) SEMESTER -VII PHMC773L (Practical)

01	Study of OPAMP parameters
02	OPAMP as Inverting amplifier
03	OPAMP as Non inverting amplifier
04	OPAMP as V to I and I to V converter
05	OPAMP as an integrator
06	OPAMP as a differentiator
07	Voltage regulator using OPAMP
08	OPAMP as an adder and subtractor
09	Frank - Hertz Experiment.
10	Velocity of Liquid using Surface wave
11	To determine specification rotation of sugar solution using Polari meter
12	Dielectric constant of a non-polar liquid
13	Measurement of the energy band gap, voltage coefficient and diffusion capacitance of the PN junction diode
14	Measurement of the resistivity using four probes
15	Time-dependent Schrödinger equation: Evolution of the wave packet in simple potentials.
16	Two-body problem under different potentials: Orbital motion and energy conservation.