PHY6604: MACHINE LEARNING IN PHYSICS

Effective Term
Semester B 2025/26

Part I Course Overview

Course Title
Machine Learning in Physics

Subject Code
PHY - Physics

Course Number
6604

Academic Unit
Physics (PHY)

College/School
College of Science (SI)

Course Duration
One Semester

Credit Units
3

Level
P5, P6 - Postgraduate Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Student should learn Python programming before taking the course. One way to achieve this is to take PHY5504 Data Acquisition and Processing Skills for Physicists I.

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
PHY8604 Machine Learning in Physics

Part II Course Details

Abstract

The course consists of two parts. The first part of the course will enable the student to learn the theory and gain hands-on experiences on a variety of machine-learning techniques. We will explain these techniques from physicists' point of view, for example, we will use physics terminology when applicable, and explain conceptual links between machine learning and physics. In the second part, several faculty members of the Department of Physics will teach real-life examples of how to apply machine learning in their research.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Understand the important machine-learning algorithms covered in the lectures. Understand how they work, and what are their strengths and weaknesses.	40	x	x	
2	Being able to implements these algorithms in programs.	30		x	x
3	Understand how to solve real-life machine-learning problems in physics research.	30	x	x	

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

	LTAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Presentation of course material	1, 2, 3	3

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Programming Assignments	1, 2, 3	60	-	Yes

Continuous Assessment (%)

60

Examination (%)

40

Examination Duration (Hours)

2

Assessment Rubrics (AR)

Assessment Task
Programming Assignments (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
The program the student writes.

Excellent
(A+, A, A-) The program produces near-optimal results.

Good
(B+, B, B-) The program runs correctly but does not produce near-optimal results.

Fair
(C+, C, C-) The program is buggy but demonstrates that the student understands many basic concepts.

Marginal
(D) The program is buggy and demonstrates that the student understands very few basic concepts.

Failure
(F) The program fails to demonstrate that the student understands any basic concept.

Assessment Task
Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
The student demonstrates comprehensive understanding of the algorithms and their applications.

Excellent
(A+, A, A-) High (excellent, detailed understanding with creativity)

Good
(B+, B, B-) Significant (good understanding with occasional errors)

Fair
(C+, C, C-) Satisfied (fair understanding with some errors)

Marginal
(D) Basic (basic understanding with many errors)

Failure
(F) Not reaching marginal level

Assessment Task
Programming Assignments (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
The program the student writes.

Excellent
(A+, A, A-) The program produces near-optimal results.

Good

(B+, B) The program runs correctly but does not produce near-optimal results.

Marginal
(B-, C+, C) The program is buggy but demonstrates that the student understands some basic concepts.

Failure
(F) The program fails to demonstrate that the student understands any basic concept.

Assessment Task
Examination (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
The student demonstrates comprehensive understanding of the algorithms and their applications.

Excellent
(A+, A, A-) High (excellent, detailed understanding with creativity)

Good
(B+, B) Significant (good understanding with occasional errors)

Marginal
(B-, C+, C) Basic (basic understanding with many errors)

Failure
(F) Not reaching marginal level

Part III Other Information

Keyword Syllabus

software for machine learning: scikit-learn, Pytorch, and Google Colab.

general concepts in machine learning: training, validation, and testing datasets; overfitting and underfitting; regularization; data augmentation; gradient descent and stochastic gradient descent.

linear regression, polynomial regression, logistic regression, and softmax regression.

artificial neural networks: activation functions, the vanishing/exploding gradient problem, the loss-function landscape, convolutional neural networks, graph neural networks.

physics-informed neural networks.

unsupervised learning: principal-component analysis, variational autoencoders, generative adversarial networks, diffusion models.

Bayesian machine learning: probability theory and Bayesian statistics, Bayesian neural networks, Hamiltonian Monte Carlo sampling, ensemble learning.

Reading List

Compulsory Readings

	Title
1	Lecture slides.

Additional Readings

	Title
1	Machine Learning with PyTorch and Scikit-Learn, by Sebastian Raschka et. al.
2	Physics-informed machine learning, by George Em Karniadakis et. al.
3	Bayesian Learning via Stochastic Dynamics, by Radford M. Neal
4	Weight Uncertainty in Neural Networks, by Charles Blundell et. al.