City University of Hong Kong
Course Syllabus

offered by College/School/Department of Physics
with effect from Semester A 2025/26

Part I Course Overview

Course Title:	**Machine Learning in Physics**
Course Code:	**PHY6604**
Course Duration:	**One semester**
Credit Units:	**3**
Level:	**P6**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**Student should learn Python programming before taking the course. One way to achieve this is to take *PHY 5504 Data Acquisition and Processing Skills for Physicists I.***
Precursors: *(Course Code and Title)*	**NA**
Equivalent Courses: *(Course Code and Title)*	**NA**
Exclusive Courses: *(Course Code and Title)*	**NA**

Part II Course Details

1. Abstract

(A 150-word description about the course)

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.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Understand the important machine-learning algorithms covered in the lectures. Understand how they work, and what are their strengths and weaknesses.	40	✓	✓	
2.	Being able to implements these algorithms in programs.	30		✓	✓
3.	Understand how to solve real-life machine-learning problems in physics research.	30	✓	✓	
	** If weighting is assigned to CILOs, they should add up to 100%.*	100%			

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 self-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.

3. Learning and Teaching Activities (LTAs)

(LTAs designed to facilitate students' achievement of the CILOs.)

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

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.			Weighting*	Remarks
	1	2	3		
Continuous Assessment: _60_%					
Programming Assignments	✓	✓	✓	60	
Examination: _40_% (duration: 2 hours, if applicable)					
** The weightings should add up to 100%.*				100%	

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Programming Assignments	The program the student writes.	The program produces near-optimal results.	The program runs correctly but does not produce near-optimal results.	The program is buggy but demonstrates that the student understands many basic concepts.	The program is buggy and demonstrates that the student understands very few basic concepts.	The program fails to demonstrate that the student understands any basic concept.
2. Examination	The student demonstrates comprehensive understanding of the algorithms and their applications.	High (excellent, detailed understanding with creativity)	Significant (good understanding with occasional errors)	Satisfied (fair understanding with some errors)	Basic (basic understanding with many errors)	Not reaching marginal level

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Programming Assignments	The program the student writes.	The program produces near-optimal results.	The program runs correctly but does not produce near-optimal results.	The program is buggy but demonstrates that the student understands some basic concepts.	The program fails to demonstrate that the student understands any basic concept.
2. Examination	The student demonstrates comprehensive understanding of the algorithms and their applications.	High (excellent, detailed understanding with creativity)	Significant (good understanding with occasional errors)	Basic (basic understanding with many errors)	Not reaching marginal level.

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

(An indication of the key topics of the course.)

software for machine learning: scikit-learn, tensorflow, 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.

2. Reading List

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

1.	Lecture slides.

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

1.	Hands-on Machine Learning with Scikit-Learn, Keras & Tensorflow, by Aurelien Geron
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.