Syllabus

Course Description

Course Title	Physics Informed Neural Networks
Course Code	71082
Course Title Additional	
Scientific-Disciplinary Sector	IINF-05/A
Language	English
Degree Course	PhD Programme in Computer Science
Other Degree Courses (Loaned)	
Lecturers	Dottore di ricerca Alessandro Bombini, Alessandro.Bombini@unibz.it https://www.unibz.it/en/faculties/engineering/academic-staff/person/53352
Teaching Assistant	
Semester	All semesters
Course Year/s	2025-2026
CP	2
Teaching Hours	20
Lab Hours	0
Individual Study Hours	50
Planned Office Hours	0
Contents Summary	The course introduces the concept of Physics Informed Deep Neural Networks (PINN), discuss its implementation from scratch in PyTorch and using advanced ad-hoc developed open-source libraries such as Nvidia PhysicsNemo for addressing real-world problems in various fields (engineering, physics, petroleum reservoir). We discuss recent topics such as Mixture-of-Models, Neural Operators, Physics-Informed Kolmogorov-Arnold Networks and Physics-Informed Computer Vision.
Course Topics	• General Introduction to the course: Motivation, Recaps of Mathematical Analysis, Functional Analysis, Montecarlo Integration

	• Brief Introduction on Deep Learning: Motivation, Learning as optimization problem, architectures • Intro to numerical resolution of Differential Equations • Physics Informed Neural Networks – Part I: forward problems • Physics Informed Neural Networks – Part II: inverse problems and parametric PINNs • PINN with Nvidia PhysicsNemo – Part I: Introduction & custom PDE • PINN with Nvidia PhysicsNemo – Part II custom geometry & different NN architectures
Keywords	Deep Learning; Physics-Informed Neural Networks
Recommended Prerequisites	Basics of Python; Real Analysis; Numerical Methods; Machine Learning
Propaedeutic Courses	Basics of Python; Real Analysis; Numerical Methods; Machine Learning
Teaching Format	Each lecture will consist of a frontal lecture (using presentation materials) and an hands-on section (using Google Colab, Jupyter Lab)
Mandatory Attendance	Attendance is not compulsory, but non-attending students have to contact the lecturers at the start of the course to agree on the modalities of the independent study.
Specific Educational Objectives and Learning Outcomes	The goal of the course is to introduce the concept of Physics Informed Deep Neural Networks (PINN), discuss its implementation from scratch in PyTorch and using advanced ad-hoc developed open-source libraries such as nvidia-modulus for addressing real-world problems in various fields (engineering, physics, petroleum reservoir). We discuss recent topics such as Mixture-of-Models, Neural Operators, Physics-Informed Kolmogorov-Arnold Networks and Physics-Informed Computer Vision. Knowledge and understanding • D1.x – Ability to analyse and solve complex problems in computational science by integrating physics-informed neural networks with advanced numerical methods. • D1.x – Ability to read, understand, and critically evaluate state-of-the-art scientific literature on PINNs, Neural Operators, and Physics-Informed Computer Vision.

	Applying knowledge and understanding • D2.x – Ability to design and implement PINNs from scratch, demonstrating mastery of both theoretical and practical aspects. • D2.x – Ability to apply innovative architectures (e.g. Mixture-of-Models, Kolmogorov-Arnold Networks) to extract knowledge from complex, high-dimensional physical systems. Making judgements • D3.x – Ability to autonomously select and integrate specialist documentation, libraries, and datasets to advance research in physics-informed AI. • D3.x – Ability to work with broad autonomy in multidisciplinary projects, taking responsibility for the design and validation of computational experiments. Communication skills • D4.x – Ability to present PINN-based research results clearly and effectively to both specialist and non-specialist audiences, including through scientific publications. Learning skills • D5.x – Ability to independently extend knowledge in emerging areas of physics-informed machine learning, keeping pace with rapid developments in AI and computational science.
Specific Educational Objectives and Learning Outcomes (additional info.)	
Assessment	Option a: Discussion of a research work on the topic, selected by the student and accepted by the instructor; it must be presented orally with a presentation and with a Git repo offering the students implementation of the code Option b: Resolution of a small research problem discussed jointly with the instructor; presented either orally with a brief presentation or a written essay, and a git repo.
Evaluation Criteria	The exam is pass/fail and no marks are awarded. Relevant for the assessment are the following: clarity of exposition, ability to summarize, evaluate, and establish relationships between topics, ability to present scientific notions, ability to evaluate research results by others.

Required Readings	All the required reading material will be provided during the course and will be available in electronic format. Copy of the slides will be available as well. Subject Librarian: David Gebhardi, David.Gebhardi@unibz.it and Ilaria Miceli, Ilaria.Miceli@unibz.it
Supplementary Readings	Maziar Raissi, Paris Perdikaris, George Em Karniadakis. Physics Informed Deep Learning (Part I): Data-driven Solutions of Nonlinear Partial Differential Equations. arXiv 1711.10561 Maziar Raissi, Paris Perdikaris, George Em Karniadakis. Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. J. Comp. Phys. 378 pp. 686-707 DOI: 10.1016/j.jcp.2018.10.045 Toscano, Juan Diego et al. “From PINNs to PIKANs: Recent Advances in Physics-Informed Machine Learning.” (2024). arXiv:2410.13228 Chayan B., Kien N., Clinton F., and Karniadakis G.. 2024. Physics-Informed Computer Vision: A Review and Perspectives. ACM Comput. Surv. (August 2024). https://doi.org/10.1145/3689037 Cuomo, S., Cola, V.S., Giampaolo, F., Rozza, G., Raissi, M., & Piccialli, F. (2022). Scientific Machine Learning Through Physics–Informed Neural Networks: Where we are and What’s Next. Journal of Scientific Computing, 92. ArXiV 2201.05624
Further Information	Python, PyTorch, Nvidia PhysicsNemo 2504, JupyterLab/Hub
Sustainable Development Goals (SDGs)	Quality education