Course unit English denomination	Atomic Force Microscopy
SS	PHYS-03/A
Teacher in charge (if defined)	Enrico Di Russo (responsabile) Francesco Sgarbossa
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	February 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (minimum attendance of 75 %) ☐ No
Course unit contents	The course is structured in two parts: I) theoretical lessons held in the classroom: the principles of the theory behind atomic force microscopy (AFM) will be explained, and some advanced electrical modes will be discussed; II) practical lesson: how to set up a morphology measurement using AFM will be demonstrated, as well as how to use some advanced electrical modes on selected test samples. The topics covered in the course are as follows: • Physical principle of operation, structure, and basic functions of an AFM: laser detection system, piezoelectric scanner, feedback loop. • Basic operating modes and surface imaging techniques: contact (static) mode, semi-contact (tapping) mode. • Image analysis and common causes of scanning artifacts: non-linearity of piezoelectric scanners, tip mapping, incorrect feedback loop settings, incorrect image processing, external interferences (mechanical, acoustic, electrical), thermal drift. • Imaging of various types of samples: crystals, polymers, biological samples. • Advanced electrical modes: current AFM (c-AFM), piezo-force microscopy (PFM), Kelvin probe force microscopy (KPFM), scanning microwave microscopy (SMM).
Learning goals	i) Understanding the physical principles underlying the operating modes of the atomic force microscope, including advanced electrical modes. ii) Ability to identify the most suitable imaging mode for studying the properties of different classes of materials.

Teaching methods	The course includes two lectures of 3 hours each, plus 2 hours of laboratory work to be carried out in small groups.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Knowledge of General Physics 1 and 2: harmonic oscillator, elastic forces, basic electrical circuits.
Examination methods (in applicable)	A test will be conducted using the Moodle platform.
Suggested readings	V. L. Mironov, Fundamentals of Scanning Probe Microscopy, 2004. https://www.labtrek.it/Mironov_SPM.pdf On overview of AFM modes: https://www.nanosurf.com/en/support/afm-modes-overview Free video-tutorals and webinars: https://www.nanosurf.com/en/nanosurf-afm-masterclass-on-demand
Additional information	

Course unit English denomination	Electrochemical Methods for the ex-situ Characterization of Energy Storage Materials
SS	CHEM-06/A
Teacher in charge	Di Noto Vito Pagot Gioele
Teaching Hours	8 h
Number of ECTS credits allocated	1 ECTS
Course period	July - August 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The proposed course will provide a comprehensive overview of the most important aspects of electrochemistry, with a strong focus on its application to materials for reversible energy storage. The objective is to equip students with a solid understanding of the fundamentals of electrode reactions and the principles underlying key electrochemical methods. A significant portion of the course will focus on voltammetric techniques, used to analyze insertion/de-insertion and deposition/stripping processes that occur during the redox reactions of active materials in electrochemical cells. Special attention will be given to how these methods can evaluate the reversibility, efficiency, overpotential, and kinetics of such reactions through various ex-situ electrochemical techniques. Additionally, the course will introduce key alternating current (AC) techniques, such as electrochemical impedance spectroscopy (EIS), with an emphasis on how these methods reveal changes in cell properties during cycling. In particular, EIS will be discussed in the context of its ability to provide detailed insights into the evolution of electrode-electrolyte interfaces. The course will also address device testing protocols for various active materials, highlighting specific procedures that offer a deeper understanding of the unique characteristics of these compounds. Case studies on electrochemical devices for reversible energy storage will be examined to contextualize the discussed techniques. In summary, the lectures and discussions will offer an in-depth exploration of the application of various electrochemical methodologies. These theoretical sessions will be complemented by laboratory exhibitions, providing students with an experience in conducting real-world electrochemical experiments.

Learning goals	• Understand the fundamental principles of electrochemistry and their application to electrochemical energy storage materials. • Master the theoretical background and practical application of voltammetric techniques for analyzing redox reactions in electrochemical cells. • Analyze the insertion/de-insertion and deposition/stripping processes of active materials using electrochemical methods. • Evaluate key performance metrics of electrochemical reactions, such as reversibility, efficiency, overpotential, and kinetics, through ex-situ characterization techniques. • Gain proficiency in AC electrochemical techniques, particularly electrochemical impedance spectroscopy (EIS), and understand its role in monitoring cell behavior and electrode-electrolyte interfaces. • Design and interpret experiments for the characterization of electrochemical energy storage materials and assess their performance in device configurations. • Explore real-world applications of electrochemical techniques in the testing and evaluation of materials for reversible energy storage devices. • Critically assess the limitations and advantages of various electrochemical methods in relation to material performance and device operation.
Teaching methods	The course will consist of dynamic lectures, fostering active two-way discussions between the teacher and students. These interactive sessions will be complemented by case studies in the field, exploring how theoretical electrochemical techniques are applied to investigate the chemical and physical properties of energy storage materials. A particular focus will be on the electrochemical characterization of these systems and the design of experiments to evaluate their performance in devices. Additionally, students will have the opportunity to visit laboratories where innovative materials for electrochemical energy storage and conversion systems are developed. These labs also provide hands-on demonstrations of the electrochemical methods discussed in class, showing their practical application in real-world research settings.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☐ Yes ☒ No
Prerequisites	Students enrolling in this course should have a general knowledge in basic electrochemistry, including concepts such as redox reactions, electrode potentials, and the Nernst equation. A solid understanding of physical chemistry principles is also essential, particularly in relation to thermodynamics, kinetics, and surface chemistry. Familiarity with energy storage systems, such as batteries and supercapacitors, is highly recommended.

Examination methods	Short report on a case study
Suggested readings	• Electrochemical Methods: Fundamentals and Applications, Allen J. Bard, Larry R. Faulkner, John Wiley & Sons • Electrochemical Systems, John Newman, Karen E. Thomas-Alyea, John Wiley & Sons • Instrumental Methods in Electrochemistry, D. Pletcher, R. Greff, R. Peat, L.M. Peter, J. Robinson, Woodhead Publishing • Electrocatalysis for Membrane Fuel Cells: Methods, Modeling and Applications, Nicolas Alonso-Vante, Vito Di Noto, Wiley-VCH GmbH
Additional information	No additional information

Course unit English denomination	Ellipsometry
SS	IMAT-01/A
Teacher in charge (if defined)	E. Colusso
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	september 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The course will present the basic principle of spectroscopic ellipsometry. The first part will include a theoretical background on the technique (polarization of light, interaction of light and materials, optical constants) and the fundamentals of ellipsometry data analysis, with examples of applications to different types of thin films. In the second part, the students will participate in a practical activity where they will perform measurement and data analysis with the instrument installed at the Department of Industrial Engineering.
Learning goals	1. Understanding the basic principles of ellipsometry 2. Ability to choose the most suitable model for analyzing a few types of thin films (glass, semiconductor, metal).
Teaching methods	Lectures, laboratories, case studies
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No Open to all, with priority given to PhD students from Materials Science and Technology course; therefore, a waiting list will be created and external PhD students will be contacted if there are vacancies
Prerequisites (not mandatory)	

Examination methods (if applicable)	Multiple choice test
Suggested readings	Lecture notes
Additional information	

Course unit English denomination	Methods and instrumentation for the study of density and surface area of solids
SS	CHEM-06/A
Teacher in charge (if defined)	Keti Vezzù Begum Yarar Kaplan
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	July 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75 % minimum of presence) ☐ No
Course unit contents	This course presents the principles of density, surface area and porosity measurements by gas techniques such as pycnometer and BET (Brunauer, Emmett and Teller). These methods are becoming increasingly popular and important for the characterization of nanostructured materials. The knowledge of the values of density, surface area and the pore size distribution are very important to understand the behavior of new synthetized materials such as catalysts (porosity, …), active carbon (porosity, …), membranes (porosity, …), thermal insulator (open and close cells, …), drugs (bioavailability, …), etc… and also in the evaluation of product performance and manufacturing consistency as quality control method. In the first part of the course a general description of techniques will be present. In the case of density measurements, different methods will be illustrated with their strengths the main applications and the different meanings. The Brunauer–Emmett–Teller (BET) theory will present together with the basis of methodology (principles, selection of adsorbent, etc…), experimental procedure and the evaluation of adsorption data in terms of hysteresis loops, surface area, micro- and mesopore volume and distribution. The second part is instead devoted to practical activity: in small groups, the participants will be able to see how BET and the gas pycnometer work.
Learning goals	Principles of BET and gas pycnometer Methods of preparation of samples

	Understanding the BET and physical adsorption data
Teaching methods	Lecture, laboratory
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	N/A
Examination methods (in applicable)	Discussion
Suggested readings	Articles
Additional information	

Course unit English denomination	Nuclear Magnetic Resonance and Mass Spectrometry
SS	CHEM-05/A
Teacher in charge (if defined)	Andrea Sartorel
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	September 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75 % minimum of presence) ☐ No
Course unit contents	The basic principles and applications of Nuclear Magnetic resonance and Mass Spectrometry will be presented.
Learning goals	1. Understanding of the principles of NMR and mass spec techniques 2. Interpretation of NMR and mass spec for molecules and materials characterization
Teaching methods	Frontal lessons and case studies
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	No
Examination methods (in applicable)	Written test
Suggested readings	Lecture notes
Additional information	None

Course unit English denomination	STM: Scanning Tunneling Microscopy
SS	CHEM-03/A
Teacher in charge (if defined)	Silvia Carlotto, Francesco Sedona.
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The principles and applications of scanning tunneling microscopy (STM) will be presented and then applied to a case study: the deposition of organic molecules on metal surfaces. The course is divided into two parts: i) a practical part in which the surfaces will be prepared and characterized in a UHV system and ii) a part in which DFT modeling will be used to interpret the experimental results. Prof. Sedona and Prof. Carlotto co-teaching ✔ Scanning Tunneling Microscopy (STM) and Tunneling Spectroscopy (TS): a brief overview of operational principles and technical aspects. (2h) Prof. Sedona ✔ Experimental practice: deposition of organic molecules on a metal substrate under UHV conditions and STM characterization. (3h max 4 students) Prof. Carlotto ✔ Connection between periodic calculations and STM measurements (1h) ✔ Description of an input file for periodic calculations in QuantumEspresso (1h) ✔ Analysis of optimized structures for metal (iron) phthalocyanines on metal surfaces before and after oxygen dosing: geometrical parameters, DOS, PDOS, and charge density, STM simulations at different bias of the optimized structures (1h)
Learning goals	Knowledge of the basic operating principles of the STM technique, understanding the difference between morphological contrast and electronic contrast, understanding the technical issues related to STM measurements, development of a critical ability to assess the

	reliability of the measurements reported in the literature. Ability to write an input and understand an output in a program that performs periodic calculations and to calculate absorption energies of molecules on surfaces and simulate STM images.
Teaching methods	Laboratory activity in which students will be able to perform operations in UHV systems, deposit molecules, and conduct STM measurements. All of this will take place under the supervision of Prof. Sedona, who will explain step by step the meaning and implications of the various experimental procedures. Lectures in the classroom in which parts of the input files and the output files of programs that perform periodic calculations will be presented and discussed.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (in applicable)	Multiple-choice test
Suggested readings	Power point presentations and notes
Additional information	

Course unit English denomination	X-ray Photoelectron Spectroscopy
SS	CHEM-03/A
Teacher in charge (if defined)	Mattia Cattelan
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	January 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	This course provides a comprehensive introduction to X-ray Photoelectron Spectroscopy (XPS), a key technique for surface chemical analysis. Students will gain an understanding of the physics behind the photoelectric effect and learn to extract compositional and structural information from the analysis of an X-ray photoemission spectrum. The course covers surface sensitivity, energy scales (kinetic and binding energy), and photoelectron peak intensity analysis. It also includes topics such as chemical shifts, spin-orbit coupling, and Auger electron spectroscopy, with emphasis on the practical application of XPS in material science to investigate surface layers (<10 nm).
Learning goals	Understanding the physics behind the photoelectric effect Ability to extract compositional and structural information from the analysis of an X-ray photoemission spectrum
Teaching methods	Lessons (4 hours), laboratory (4 hours)
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No The course is open to all PhD students in MST and Molecular Sciences
Prerequisites	

(not mandatory)	
Examination methods (in applicable)	Multiple-choice test on the Moodle platform of the course
Suggested readings	Course slides available on Moodle.
Additional information	

Course unit English denomination	Microfabrication and Microfluidics
SS	PHYS-03/A
Teacher in charge (if defined)	Davide Ferraro
Teaching Hours	8 h
Number of ECTS credits allocated	1 CFU
Course period	June-July 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	- Microfabrication strategies, including soft-lithography, photo-lithography, etching, 3D printing, micro-milling. - Microfluidics concepts, including the presentation of its properties and applications in chemical and biological field. - Hands-on activity will be considered, and a visit to the facilities presented at the within the Department of Physics and Astronomy.
Learning goals	- Acquire competences in microfabrication and microfluidics.
Teaching methods	Frontal lesson and hands-on activities.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	

Examination methods (in applicable)	
Suggested readings	- Slides from the lessons - Suggested book: Introduction to Microfluidics, Oxford University Press, 2010, Patrick Tabeling
Additional information	None

Course unit English denomination	Ion Beam Analysis in materials science
SS	PHYS-03/A
Teacher in charge (if defined)	Francesco Sgarbossa (course coordinator, DFA-UNIPD) Enrico Di Russo (DFA-UNIPD)
Teaching Hours	8
Number of ECTS credits allocated	1 CFU
Course period	July 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	The topic covered by the course are the following: - Fundamentals of ion-matter interaction. • MeV ion energy range: - Coulomb interaction between one ion and one nucleus, Rutherford Backscattering Spectrometry - Non-Coulomb interaction techniques and Channeling phenomena - Experimental setup for MeV ion beam analysis and examples of applications in material science • keV ion energy range: -Secondary Ion Mass Spectrometry and examples of applications in material science -Atom Probe Tomography and Focused Ion Beam sample preparation
Learning goals	• Understanding the physical principles underlying the ion – matter interaction and the information that can be derived from the obtained data. • Ability to identify the most suitable ion beam technique for studying the properties of various material classes.
Teaching methods	The course is structured in two parts:

	• Theoretical lessons, covering the basics of ion-matter interaction and the fundamentals of Rutherford Backscattering Spectrometry, Secondary Ion Mass Spectrometry and Atom Probe Tomography. • Practical lessons, aimed at becoming familiar with ion beam setups. A visit at the Ion Beam Analysis facility at Legnaro National Laboratory or the Secondary Ion Beam Analysis laboratory at DFA will be planned. During the course, there will be moments of critical reflection in the classroom, and some case studies of particular interest in materials science will be discussed.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	General Physics 2, structure of solids and/or solid-state physics courses are strongly recommended. This knowledge is generally guaranteed by master's degrees in Material Science, Physics and Materials Engineering.
Examination methods (in applicable)	A final online test will be conducted using the Moodle platform.
Suggested readings	During the course, slide and lecture notes will be available to students. Optional book: L.C. Feldman, J.W. Mayer, Fundamentals of Surface and Thin Film Analysis. New York: North-Holland: --, 1986.
Additional information	

Course unit English denomination	Electrochemical energy conversion and storage devices: reuse and recycling of CRMs
SS	CHEM-06/A
Teacher in charge (if defined)	Di Noto Gioele Pagot Begum Yarar Kaplan
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	September 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75 % minimum of presence) ☐ No
Course unit contents	The importance of secondary battery recycling will be explained based on the type, raw material costs, and recycling systems. Various recovery processes for separators, current collectors, carbon, polymeric ionomers, and metals will be shown, and their different uses will be highlighted. Additionally, the different types of mechanical and chemical pretreatments, component separation through sieving, the use of magnetic and electric fields, thermal treatments, flotation, and chemical processes will be described. Finally, hydrothermal and chemical processes will be discussed. Future perspectives will also be illustrated.
Learning goals	Principles of lithium extraction technology Principles of battery recycling Methods for recovering strategic materials (carbon, separators, ionomers, lithium, cobalt, etc.)
Teaching methods	Lecture, discussion on lithium secondary battery recycling mechanisms, laboratory
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No

Prerequisites (not mandatory)	N/A
Examination methods (in applicable)	Discussion
Suggested readings	Articles, reviews
Additional information	

Course unit English denomination	**Applications of vibrational spectroscopies in materials characterization**
SS	CHEM-06/A
Teacher in charge (if defined)	Stefano Rossetti / Enrico Negro
Teaching Hours	8 hours
Number of ECTS credits allocated	1
Course period	Second semester
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	*Introduction* ● Fundamentals of infrared spectroscopy; ● Fundamentals of Raman spectroscopy. *Techniques and Instrumentations for vibrational spectroscopy* ● Infrared spectroscopies: MIR, FIR, FT-MIR, FT-FIR; ● Raman spectroscopies: FT-Raman, confocal micro-Raman; ● Main accessories and experimental approaches for materials characterization. *Sample preparation and spectra collection* *Interpretation of the experimental results* ● Processing of vibrational spectra; ● Qualitative and quantitative analysis of vibrational spectra; ● Case studies: vibrational analysis of macromolecules and graphene.
Learning goals	To provide an introduction to the applications of the various types of vibrational spectroscopies in materials characterization.
Teaching methods	Frontal lectures, with simple demonstrations in the lab.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	NONE
Examination methods (in applicable)	Drafting of a brief written essay.
Suggested readings	• K. Nakamoto, *"Infrared Spectra of Inorganic and Coordination Compounds"*, John Wiley and Sons (1963). • J. G. Grasselli, B. J. Bulkin, eds., "Analytical Raman Spectroscopy", John Wiley and Sons (1991).
Additional information	NONE

Course unit English denomination	**Principles and Applications of Rheology**
SS	PHYS-03/A
Teacher in charge (if defined)	Matteo Pierno
Teaching Hours	8
Number of ECTS credits allocated	1
Course period	November-December 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minima di presenza) ☐ No
Course unit contents	Constitutive Relations. Elastic solids. Viscous Liquids. Viscolesticity. Rheometry. Operating principles of rheometers. Drag and pressure-driven flows. Surface and interfacial rheology. Shear Cells. Rheo-Optics. Acoustic rheometers. Rheo-NMR. Flow, Slip, Yield. Applications. Emulsion rheology. Polymers, Gels, Surfactants. Particulate Suspensions.
Learning goals	Understand the fundamentals of rheology and get its relevance in materials science and engineering. Have an updated overview of measurement methodologies.
Teaching methods	Classroom lectures (4 h). Lab experiences (4 h).
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	MSc in STEM disciplines
Examination methods (in applicable)	Homeworks + Project presentation + discussion

Suggested readings	Ronald G. Larson, ‘The Structure and Rheology of Complex Fluids’, Oxford University Press Christopher W. Macosko, ‘Rheology: Principles, Measurements, and Applications’ Wiley-VCH
Additional information	

Course unit English denomination	**Applications of inductively-coupled plasma spectrometry in materials characterization**
SS	CHEM-06/A
Teacher in charge (if defined)	Begum Yarar Kaplan / Enrico Negro
Teaching Hours	8 hours
Number of ECTS credits allocated	1
Course period	Second semester
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	*Introduction* ● The relevance of inductively coupled plasma spectrometry in materials science; ● Strengths and weaknesses of the technique. *Fundamental principles of inductively coupled plasmas* ● Plasma generation; ● Line intensities; ● Line profiles; ● Multiline diagnostics. *Basic Concepts and Instruments for Plasma Spectrometry* ● Detection limits and sensitivity; ● Accuracy and precision; ● Instrumental overview. *Sample preparation and sample analysis* ● Approaches for the dissolution of samples; ● Case studies: determination of the chemical composition of solid samples.
Learning goals	To provide an introduction to the fundamentals of inductively-coupled plasma spectrometry and its applications in the determination in the chemical composition of materials.

Teaching methods	Frontal lectures, with simple demonstrations in the lab.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	NONE
Examination methods (in applicable)	Drafting of a brief written essay.
Suggested readings	● Steve J. Hill, ed. *"Inductively Coupled Plasma Spectrometry and it Applications"*, 2nd Edition, Blackwell Publishing (2006)
Additional information	NONE

Course unit English denomination	Basic Concepts of Machine Learning
SS	PHYS-06/A
Teacher in charge (if defined)	Marco Baiesi
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	To be defined
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	This course introduces students to modern tools for data classification and machine learning techniques, equipping them to apply these methods in computer-based lab experiences. It deals with: -- Machine learning: vocabulary and basic concepts -- Deep learning: vocabulary and basic concepts -- Data heterogeneity -- Convolutional neural networks -- Clustering -- Data visualization -- Combination of models, XGBoost
Learning goals	By the end of the course, students are expected to: 1) Define and differentiate between the machine learning methods covered. 2) Select and apply the most suitable method for a given problem. 3) Identify and analyze key aspects of each procedure, combining methods as needed to enhance solutions. 4) Evaluate results, explaining and justifying the chosen approaches and methods.
Teaching methods	The course focuses on learning foundational principles through practical applications. Theoretical explanations of key data analysis techniques and algorithms are followed by exercises that allow students to apply these concepts on computers. Numerical analysis tasks involve adapting and modifying pre-built software or designing simple algorithms from scratch.

Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Basic knowledge of python
Examination methods (in applicable)	Evaluation of exercises and an oral discussion on the applied methods or a developed project.
Suggested readings	Review: “A high-bias, low-variance introduction to Machine Learning for physicists” by Mehta et al., Physics Reports, 810, 1-124 (2019).
Additional information	

Course unit English denomination	An introduction to Python for chemical sciences: from fundamentals to data and HPC
SS	CHEM-02/A
Teacher in charge (if defined)	Nicola Spallanzani (CNR Institute of Nanoscience, Modena)
Teaching Hours	24
Number of ECTS credits allocated	3
Course period	Settembre 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (85% minimum of presence) ☐ No
Course unit contents	The course, interspersed with practical exercises, is an introduction to using the non-assuming Python language previous programming skills. It will come to illustrate the use of some scientific Python libraries (e.g.numpy,matplotlib)
Learning goals	Knowledge: basics of Python languages and main scientific libraries Skills: Writing Python scripts/Jupyter notebooks useful for own research activity Competencies: Use and design of python to enhance research activity
Teaching methods	Frontal teaching intermixed with coding exercises
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No Students external to the PhD Course admitted upon evaluation of the CV by the teachers, provided the maximum number of allowed participants (30) has not been reached
Prerequisites (not mandatory)	
Examination methods	Software project assigned by the teacher

Study material	Slides and Jupyter notebooks provided by the teacher
Additional information (not mandatory)	Max. number of participants: 30 Using of own laptop is strongly encouraged

Course unit English denomination	*Information Literacy for Materials Scientists*
Teacher in charge (if defined)	Dr. Filippo Vomiero, Dr. Marina Zannoni, Dr. Michela Zorzi,
SSD	
Teaching Hours	12
Number of ECTS credits allocated	1.5
Course period	1st year in February
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (75% minimum of presence) ☐ No
Course unit contents	Citation databases and bibliographic databases Search by topic: building a search string and filters Publishing a scientific article: • Choosing the journal (STEM market, indexes) • The peer review process • Author facilitations Institutional repositories: PRA-Iris and Research Data Unipd Copyright Zotero AdisInsight
Learning goals	Autonomy in bibliographic research using the main scientific databases Knowledge of the publication process in a scientific journal Principles of Open Science, practices and tools in use at the university
Teaching methods	Lectures; exercises, innovative teaching tools for classroom interaction, with the aim of: • teaching interactively • using the critical incident technique • promoting effective feedback • establishing authentic relationships in the classroom • developing collaborative and supportive peer relationships
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No

	The course is open only to PhD students of the following courses: Molecular Sciences, Material Science and Technology and Pharmacological Sciences
Prerequisites (not mandatory)	
Examination methods (if applicable)	Not applicable.
Suggested readings	Course Moodle, module slides
Additional information	Soft Skills Course