UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
Dipartimento di Scienze Fisiche, Informatiche e Matematiche

M.Sc. program in Physics – Laurea Magistrale Internazionale – A.Y. 2024/2025

Curriculum **Bio-physics and Applied Physics**

The curriculum provides a broad scientific and methodological background linking fundamental physics to the study of complex systems, biological processes, and technological innovation. It combines solid training in modern experimental, theoretical, and computational physics with interdisciplinary applications to life sciences, soft and active matter, and applied technologies. The program is designed to equip students with flexible and transferable skills, suitable both for advanced academic studies and for innovation-driven professional environments.

Physics at the interface with life and technology

With no mandatory courses, this particularly flexible curriculum allows students to build a personalized study path across a wide range of advanced physics topics, experimental techniques, modeling approaches, and data analysis methods, complemented by laboratory activities. Students learn to investigate biological, soft, and complex systems using the conceptual and quantitative tools of physics, addressing phenomena that span molecular, mesoscopic, and macroscopic scales.

The curriculum fosters a cross-disciplinary mindset, highlighting the unifying role of physical laws in living systems and technologies. At the same time, it emphasizes the transfer of physical principles to applied contexts, where physics naturally interfaces with engineering, mathematics, computer science, medicine, and other applied fields. The broad scope, covering both fundamentals and applications, together with a course in didactical methodologies, makes this curriculum particularly suitable also for students aiming at a career as high-school teachers or for students holding a technological Bachelor degree, e.g. in engineering.

Two complementary specialization tracks and an interdisciplinary path

The broad number of subjects and the flexible rules for elective choices support two main **specialization tracks**, while leaving room for interdisciplinary combinations.

The **Biophysics and Soft Matter** track focuses on the physics of biological systems and soft materials. Students acquire experimental and theoretical methods to study the structure, dynamics, and function of biomolecules, membranes, cells, colloids, and polymers. The track emphasizes quantitative modeling, predictive approaches, and modern experimental techniques such as advanced microscopy, spectroscopy, and simulations. It provides a unified physical perspective on living and soft matter, from molecular interactions to collective and emergent behavior, with applications in medicine, nanobiotechnology, and bio-inspired materials.

The **Applied Physics and Innovation Technologies** track addresses the application of physical principles to technological development and applied research. Students gain expertise in materials characterization, sensors, imaging techniques, flexible and functional materials, and in the modeling and optimization of physical systems relevant for industrial, environmental, and biomedical applications. The track promotes the integration of experimental physics, data-driven analysis, and innovation-oriented methodologies, preparing students for roles in R&D and technology transfer.

By combining fundamental physics courses, applied disciplines across biophysics and technology, and physics education, possibly complemented by courses in mathematical education, students may also build an **interdisciplinary path** particularly suited for teaching and outreach, aimed at transmitting scientific thinking and enthusiasm for physics in high-school environments.

Opportunities and perspectives

The final thesis project is developed within research groups active in biophysics, soft matter, and applied physics and partner laboratories, often in collaboration with interdisciplinary teams and industrial partners.

Graduates are well prepared for doctoral programs in physics, biophysics, materials science, and related interdisciplinary fields, as well as for research and R&D careers in biomedical, environmental, and high-technology sectors. Their ability to bridge fundamental physics, biological complexity, and technological applications positions them at the interface between scientific discovery, education, and innovation.

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Curriculum **Bio-physics and Applied Physics**

Below is a list of the courses available in this curriculum, each with a short description, organized into groups. Please follow the rules indicated for each group when selecting your preferred courses. You also have two free-choice courses, which may be selected from this curriculum, from other curricula, or even from other degree programmes, allowing you to design a highly interdisciplinary personal study plan (subject to approval by the Programme Coordinator). For guidance, you are encouraged to consult the Coordinator or academic tutor.

FIRST YEAR

Title and description of the course	Hours	ECTS	SSD	Term I	Term II	
Distinctive courses [B]		36				
choose two courses among						
Laboratory of nanostructures *Experimental nanotechnology is taught in a self-contained course with lectures, seminars, and hands-on experiments. Topics cover properties of semiconductor nanowires, 2D materials, nanotubes, imaging, nanolithography, and electrical/thermal transport. Students engage in real research at the Nanodevice Fabrication and Transport Lab, an interdisciplinary facility to develop innovative architectures for energy harvesting and quantum technologies.(Prof. F Rossella)*	60	6	FIS/01	I	II	☐
Advanced spectroscopic and imaging methods *X-ray photoemission and absorption spectroscopies are among the most used techniques to characterize properties of materials. Recent technological advances allow to achieve very high spatial (nanometer scale) and temporal (femtosecond scale) resolutions, opening the window to a new universe of phenomena.(Prof. R Biagi)*	48	6	FIS/01		II	☐
Magnetism, spintronics, and quantum technologies *The course deals with quantum and statistical description of magnetic phenomena, with a focus on experimental techniques and advanced applications in spintronics and molecular magnetism. The course also offers an overview on quantum technologies introducing basic concepts on quantum sensing with spin centers, the functioning of superconducting devices/qubits and fundamentals of cryogenics.(Prof. M Affronte)*	48	6	FIS/01	I		☐
choose four courses among						
Fundamentals of condensed matter physics *An introductory course on the quantum theory of condensed phases of matter, focusing on the microscopic principles that govern the behavior of solids. Topics include crystal structures, lattice vibrations, electronic band theory, and transport phenomena. The course provides a solid foundation for understanding a wide range of phenomena and for pursuing further studies in advanced condensed matter physics.(Prof. R Bianco)*	48	6	FIS/03	I		☐
Physics of semiconductors *A course providing all the necessary ingredients to understand the fascinating physical properties of semiconductors, from their electronic structure description to transport and optical phenomena, and how to exploit them in devices such as transistors, LASER, LED and solar cells, or to observe novel states of matter like the quantum Hall liquid.(Prof. S D'Addato)*	48	6	FIS/03		II	☐
Nanoscience and quantum materials *Nanosystems are both quantum worlds with astonishingly new properties and the basis of new nanodevices. The course provides a conceptual and practical framework dealing with the physics and description of a set of prototype nanosystems, from nanotubes and graphene structures to nanocrystals, quantum wells, wires and dots.(Prof. E Molinari)*	48	6	FIS/03		II	☐
Laboratory of quantum simulation of materials *Frontal lectures and hands-on tutorial sessions introduce attendees to theoretical/computational techniques for the electronic structure simulation of condensed matter systems. Special emphasis is given to Density Functional Theory, the present state-of-the-art, parameter-free and atomistic scheme for the predictive description of materials.(Prof. A Ruini)*	60	6	FIS/03	I	II	☐
Lab. of machine learning and advanced computing for physics *A course covering core concepts in machine learning and high-performance computing with a physicist's approach. Foundations and applications of supervised and unsupervised learning — from Bayesian inference to deep and convolutional neural networks — are practiced with Python-based exercises. High-performance and parallel computing are introduced also for students without experience in scientific computing. Fundamental concepts and tools are implemented with MPI and OpenMP on state-of-the-art heterogeneous HPC architectures.(Proff. F Grasselli, P Bonfà)*	60	6	FIS/03	I	II	☐
Related courses [C]		24				
choose four courses among						
Nano-mechanics *An experimental insight on the methods, procedures and apparata used in advanced research to investigate mechanical properties of materials at the nanoscale, with detailed case studies. Experiments on nano-objects are carried out in the lab, aiming at defining their intrinsic tribological properties and their macroscopic effect.(Prof. A Rota)*	48	6	FIS/01	I		☐
Laboratory of electron microscopy and holography *Modern TEMs are powerful instruments, giving access to structural and chemical information at the sub-nanometer scales. This course provides a comprehensive introduction to Transmission Electron Microscopy and to electron holography for the study of electromagnetic fields in magnetic materials and electronic devices.(Prof. M Beleggia)*	48	6	FIS/01		II	☐
Synchrotron radiation: basics and applications	48	6	FIS/01	I		☐

Title and description of the course	Hours	ECTS	SSD	Term I	Term II	
A course on the working principles of synchrotrons and the use of emitted radiation, from description of single ultra-relativistic particles sources to essentials of storage rings, bending magnets, wigglers and undulators, free electron lasers, beam lines. Examples of ensuing popular techniques, as X-ray diffraction, scattering, absorption and X-ray microscopy, are discussed and a visit to to ELETTRA labs in Trieste ends the course.(Prof. S D'Addato)						
Biological physics with laboratory	60	6	FIS/07	I	II	☐
An introduction to the quantitative analysis of biological processes with the methods of physics and mathematics, together with hands-on experiences using the most advanced biophysical techniques. Students learn how to predict the behavior of some biological phenomena and how to analyze in a quantitative way experimental data.(Proff. A Alessandrini, C Cecconi)						
Chemical physics of biomolecules	36	6	FIS/07	I		☐
A unique, multidisciplinary course to acquire advanced theoretical understanding of chemical physics, with emphasis on biomolecules, colloids and their application to nano-biophysics and nano-medicine.(Prof. G Brancolini)						
Medical physics	36	6	FIS/07		II	☐
An advanced introduction to the physical principles and technical applications of diagnostic and therapeutic techniques with ionizing and non-ionizing radiation. Students explore X-rays, CT, MRI, PET scans, and ultrasound imaging, alongside LINAC radiation therapy for cancer treatment. Artificial Intelligence applications and a brief overview of radiation protection for workers, the environment, and patients bridge technology and healthcare, preparing students for innovative roles in medical science.(Prof. G Guidi)						
Physics education: theoretical and experimental methods	48	6	FIS/08		II	☐
How do people actually learn physics? This course examines the theoretical and experimental methods used of physics education research to investigate how student understand physics and design effective instruction. We examine studies on conceptual challenges across classical and modern physics, and critically assess teaching strategies, including laboratories, digital technologies (like AI), and active learning frameworks. Highly interactive, the course engages you with current literature and real-world case studies—ideal for those interested in teaching, educational research, or a research-informed view of the discipline.(Prof. E. Tufino)						
Numerical algorithms for signal and image processing	36	6	MAT/08		II	☐
A course to introduce the basic properties of Fourier transform as a tool for signal analysis, from continuous to discrete settings. Applications to signal and image filtering and compression will be presented also with some laboratory activity in the Matlab environment.(Prof. S Bonettini)						
Elementary particles	48	6	FIS/04	I		☐
A course on the elementary constituents of matter, their properties and their interactions, including the most recent discoveries in this field and an introduction to particle accelerators and particle detectors.(Prof. A Bizzeti)						

SECOND YEAR

Title and description of the course	Hours	ECTS	SSD	Term I	Term II	
Distinctive courses [B]		**6**				
choose one course among						
Advanced quantum mechanics	48	6	FIS/02	I		☐
A course addressing several aspects of quantum mechanics relevant to modern developments of physics, from condensed-matter theory to particle physics and their fundamental interactions. Emphasis will be given to the concept of Berry phase, the path integral formulation, and scattering theory.(Prof. M Gibertini)						
Relativity	48	6	FIS/02	I		☐
Learn the elegant mathematical framework behind Special and General Relativity and apply it to fascinating physical problems, including GR effects on planetary motion, the physics of black holes, gravitational waves and cosmology. The course also provides a first discussion of quantum gravity.(Prof. D Trancanelli)						
Free choice courses [D]		**12**				
Choose at least 12 ECTSs among all courses (of any curriculum), or any other course offered at UNIMORE						
Professional preparation [F]		**6**				
Good practices in research		3		I		☐
Physics and society		3		I		☐
Science-based innovation		6				☐
Attendance of CBI/SUGAR Unimore projects (see https://clab.unimore.it/)						
High-performance computing in sciences		3				☐
Attendance of HPC courses (see e.g. https://eventi.cineca.it/en/hpc/catalogue)						
Thesis project and dissertation [E]		**36**				