FERRARIAE UNIVERSITAS · EX LABORE FRUCTUS · 1391

PHYSICS
UNIVERSITY OF FERRARA

Master’s Degree in Physics

Student’s guide

A.A. 2025-26

Summary

1. Welcome

Welcome to the Master's Degree in Physics at the University of Ferrara. We are delighted that you have chosen to deepen your education in physics with us. This program allows you to explore advanced physics topics and tailor your studies to your interests. Our department takes pride in the wide range of physics courses available, which demonstrate the strength of our research groups working in collaboration with major national (e.g., INFN, INAF, ASI, CNR) and international institutions (e.g., CERN, ESA, NASA, FERMILAB, HIEP).

The structure of the Master's Degree in Physics offers you the flexibility to craft a study plan that aligns closely with your personal and possibly interdisciplinary interests. While this guide outlines six suggested career paths—astrophysics and cosmology, didactics of physics, physics applied to energy, environment and health, physics of condensed matter, physics of fundamental interactions, and theoretical physics—you have ample opportunity to design your own educational journey according to your preferences.

The Master's Degree in Physics is a gateway to both PhD research and high-tech industry careers. You will learn from professors engaged in international research, preparing you for a Master's thesis that propels you toward your future professional goals.

This guide is designed to provide you with a concise overview of the Master's Degree in Physics at the University of Ferrara and to guide you through the various educational and administrative processes. You will find numerous links throughout the guide to further explore and delve into details. We always recommend referring to the official online documents for the most accurate information.

We are committed to supporting your rewarding academic journey in physics, aiding your personal, scientific, and professional growth as you face future challenges.

Coordinator of studies
Prof. Fabio Mantovani
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2. Introduction

The master's degree in physics at the University of Ferrara is designed to be a 2-year program. To graduate, students must achieve a total of 120 credits. These credits are distributed as follows: each credit is equivalent to 9 hours of theoretical lectures or 11 hours of practical exercises.

The curriculum requires students to complete 12 courses, each worth 6 credits, 3 'F credits' allocated for additional educational activities, and a thesis worth 45 credits. The academic year is divided into two semesters (September-December and February-June), with three exam sessions occurring in January-February, June-July, and September → timetable. The specific requirements for all courses and assessments are outlined in the "regolamento degli studi" → regulation.

2.1 Admission

Admission to the master's degree in physics requires compliance with certain criteria and is subject to a verification process. Here's a structured summary of the requirements and procedures:

I. **Basic eligibility:**
   - Bachelor's degree, a three-year university diploma, or an equivalent foreign qualification recognized as appropriate.

II. **Curricular requirements:**
   - Degree in physical sciences and technologies (class L-30 per DM 270/04 or class 25 per DM 509/99).
   - Minimum English language proficiency at level B2.

III. **For other degree holders:**
   - Degrees in other fields or from previous educational systems, with specific credit requirements in:
     - 20 credits in mathematics and/or computer science (MAT/01-MAT/08, INF/01, ING-INF/05).
     - 5 credits in chemistry (CHIM/01-03, CHIM/06).
     - At least 60 credits in physics (FIS/01-FIS/08), including: 9 credits in theoretical physics, models, and mathematical methods (FIS/02).

- 51 credits in various physics disciplines (FIS/01,03,04,05,07).

You can find all the necessary information about the application procedure on the admissions office website → **application for Italian students**.
If you are a non-Italian student interested in applying, please follow this link to find all the necessary application information → **application for non-Italian students**. For international students benefits, such as scholarships, accommodation, tuition fee reductions, regional tax exemptions, see 5.5.

2.2 Verification process

I. **Submission of application:**
Candidates must submit their application for admission, after which the course's admission commission will verify curricular requirements by reviewing submitted documents.

II. **Interview:**
A personal interview will be conducted to assess each candidate's scientific and linguistic preparation.

For a detailed application schedule and colloquia listings, refer to the admissions office's site: → **colloquia**.

2.3 Academic calendar

For the academic year 2025-2026, the schedule for classes is as follows:

- 1st Semester: September 15, 2025 – December 22, 2025
- 2nd Semester: February 23, 2025 – June 5, 2026

For more detailed information and updates regarding the academic calendar, students are encouraged to visit the official website → **timetable**.
Each teaching period is followed by an exam session.
The exam schedule can be accessed on the website studiare.unife.it, under the section “bacheca appelli” → **exam sessions**.

2.4 Course catalogue

In the course catalogue, by clicking on your year of matriculation, (→ catalogue) you can find information about the course content, the lecturer, learning objectives, examinations and any teaching materials.

3. Study programme

The Master's Degree in Physics at the University of Ferrara features a flexible curriculum that encompasses a wide range of fields, including astrophysics and cosmology, didactics of physics, physics applied to energy, environment and health, physics of condensed matter, physics of fundamental interactions, and theoretical physics. Students have the opportunity to engage in practical internships at the Department of Physics and Earth Science towards the end of their studies, gaining firsthand experience in both research and practical applications of physics.

The annual study plan must be submitted by the deadlines listed on page → study plan and can be customized according to the following rules.

1st year:

- 2 exams selected from table B1
- 3 exams selected from table B2
- 1 exam selected from table B3
- 2 exams selected from tables B1, B2, B3
- 2 exams selected from tables B1, B2, B3, C

2nd year:

- 2 exams selected from tables B1, B2, B3, C, D

Tables B1, B2, B3, C and D below detail the corresponding courses.

B1 - Experimental and applied	Semester	Hours	Credits
Artificial intelligence	2	54	6
Environmental radioactivity	2	54	6
High energy physics laboratory	1	60	6
Introduction to particle accelerators and detectors	2	60	6
Laboratory for solid state technologies	1	60	6
Laboratory of medical imaging	1	60	6
Magnetic Materials: from fundamentals to advanced application	1	56	6
Experimental high energy Astrophysics	2	56	6
Observational cosmology	2	54	6
Physics of Medical Imaging	2	54	6
Statistics and modelling	1	54	6

B2 - Theoretical and fundamental physics	Semester	Hours	Credits
Astroparticle cosmology	1	54	6
Astrophysical processes	1	54	6
Classical electrodynamics and beyond	2	54	6
Fundamentals of Particle Physics	1	54	6
General relativity and gravitational waves	2	54	6
Ionizing Radiation Physics	2	54	6
Quantum mechanics	1	54	6
Mathematical methods of physics	1	54	6
Solid state physics	1	54	6
Statistical physics	2	54	6
Surface physics and nanostructures	1	54	6

B3 - Microphysics and matter structure	Semester	Hours	Credits
Electron microscopy for materials science	1	60	6
Experimental particle physics	2	60	6
Nuclear physics	1	54	6
Physics and technology of solar energy	2	54	6
Sensors: physics and technology	2	56	6

C - Related or supplementary educational activities	Semester	Hours	Credits
Advanced cosmology	2	54	6
Advanced Data Analysis in High Energy Physics	1	60	6
Bayesian Inference	1	54	6
Beyond the surface: exploring the physics of 2D and 3D printing technologies	1	66	6
Collider physics phenomenology, gauge theories at work	1	54	6
Computational Methods for Medical Physics	1	54	6
Elements of quantum field theory	2	54	6
Energy and society	1	54	6
From space physics to space economy	2	54	6
Modern physics laboratory	2	60	6
Multimessenger astrophysics	1	54	6
Nuclear and subnuclear geophysics	1	54	6
Physics and Astrophysics of black holes	1	54	6
Quantum computing	2	54	6
Standard model and beyond	1	58	6
Time Domain Astrophysics	1	54	6

D - Elective activities	Semester	Hours	Credits
Economics of innovation and entrepreneurship	1	64	8
Elementi di cosmologia	1	54	6
Energy and resource economics	1	56	7
Environmental economics and policy	1	72	9
Fisica dei beni culturali	2	60	6
Machine learning for quantitative economics	1	56	7
Object-oriented programming for experimental data analysis	1	60	6
Physics of electronic devices	1	54	6

Below is an overview of the six career paths offered by the Master’s Degree in Physics at the University of Ferrara, covering fields such as astrophysics and cosmology, didactics of physics, physics applied to energy, environment and health, physics of condensed matter, physics of fundamental interactions, and theoretical physics. This framework ensures that students can tailor their studies to their career goals while also exploring a wide range of interdisciplinary opportunities.

3.1 Astrophysics and cosmology

- **Topics**

  The astrophysics and cosmology career path is structured to provide a wide ranging education in the fundamental and applied aspects of astrophysics and the broader questions addressed by cosmology. This program is designed to link students with cutting-edge research in cosmology, high-energy astrophysics, and multi-messenger astronomy, leveraging the extensive use of both ground and space-based observatories, as well as advanced computational methods. The career path covers a wide spectrum of topics: astrophysics, as a discipline, focuses on understanding the physics of celestial sources, physical processes, and phenomena beyond the Earth's atmosphere, including stars, planets, galaxies, and black holes. Cosmology complements these studies by exploring the universe on the largest scales, addressing fundamental questions on its origin, structure, evolution, and eventual fate. Key scientific concepts in astrophysics and cosmology include the study of electromagnetic radiation (spectral energy distribution, time variability, polarization) from celestial sources to uncover the universe's history, the investigation of dark matter and dark energy that constitute the majority of the universe's mass-energy content, and the examination of gravitational phenomena that shape the cosmos. Students engage with these concepts through theoretical coursework, observational practices, and hands-on application of technologies in data analysis and interpretation. The program aims to equip students with a robust understanding of the physical processes governing the universe, from the microscale interactions in particle physics to the macroscale structures of cosmology.

- **Research activity**

  Research at the University of Ferrara covers a wide spectrum in cosmology, high-energy astrophysics, and multi-messenger astronomy, in collaboration with major national and international research centres such as INFN, INAF, ASI, ESA, ESO, JAXA, and NASA. The university's contributions are particularly significant in observational astrophysics, especially in the X-ray and gamma-ray domains, as well as in the analysis of the cosmic microwave background (CMB) signals and gravitational waves. Key areas of focus include the study of dark matter, dark energy, and the evolution of the universe. Our researchers engage in detailed analyses through extensive galaxy surveys and observations of the CMB. These studies are crucial for refining cosmological models and are supported by our participation in prominent international projects, including Euclid, Integral, HST, James Webb, LiteBIRD, and LSPE. Moreover, the University of Ferrara excels in the field of multi-messenger astrophysics, which has been revolutionized by the advent of gravitational wave detection and the simultaneous observation of electromagnetic counterparts. This dual approach allows for a comprehensive understanding of the universe's most extreme events. Our efforts are further enhanced by the development of advanced space mission instrumentation, focusing systems for improved imaging, and the use of multi-wavelength survey techniques and gravitational lensing to explore the mysteries of galaxy formation and dark matter.

- **Dive into our research**

  For more information on the research activities of the related groups, please visit the following links.

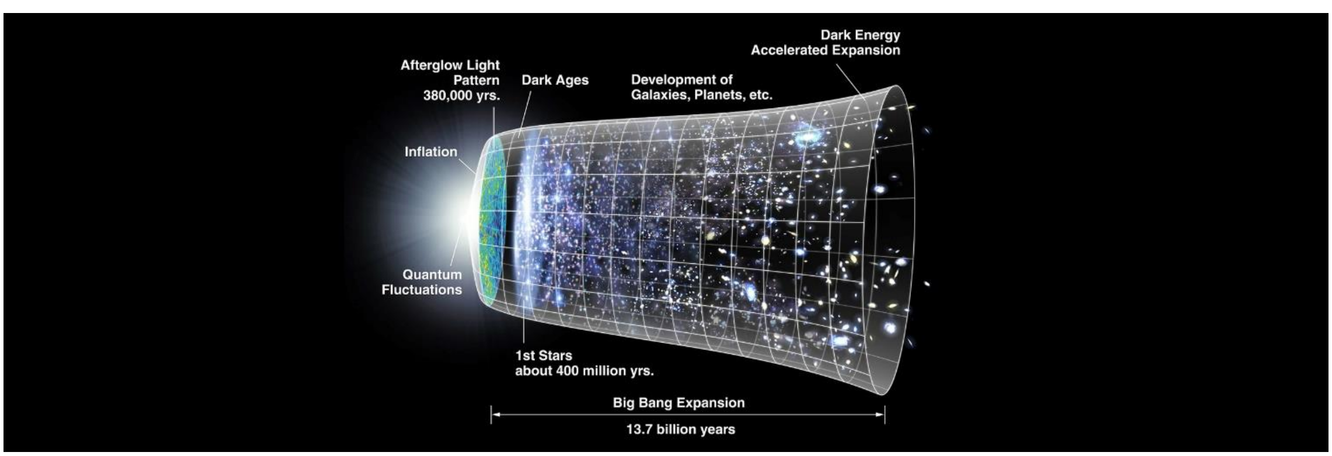
  → **Astrophysics**

  → **Cosmology**

  → **LARIX multi-project facility**

Astrophysics and cosmology: relevant courses

Fundamental			
Course	**Table**	**Hours**	**Semester**
Astroparticle cosmology	B2	54	1
Astrophysical processes	B2	54	1
General relativity and gravitational waves	B2	54	2
Mathematical methods of physics	B2	54	1
Experimental high energy Astrophysics	B1	56	2
Nuclear physics	B3	54	1
Observational cosmology	B1	54	2
Quantum mechanics	B2	54	1
Characterizing			
Course	**Table**	**Hours**	**Semester**
Advanced cosmology	C	54	2
Bayesian inference	C	54	1
From space physics to space economy	C	54	2
Multimessenger astrophysics	C	54	1
Physics and astrophysics of black holes	C	54	1
Time domain astrophysics	C	54	1



3.2 Didactics of physics

- **Topics**

The didactics of physics career path is structured for students with a deep interest in the pedagogy and dissemination of scientific knowledge, fields that are increasingly crucial in educational systems. The curriculum extends beyond foundational physics concepts and laboratory techniques, incorporating selected courses from related disciplines. These additional courses are carefully chosen to enhance the students' academic base, thus preparing them for a variety of teaching roles within secondary education systems. Moreover, the career path is specifically designed to facilitate the entry of graduates into diverse teaching classes at the secondary school level, ensuring they are well-equipped with the necessary expertise and skills for excellence in teaching and effective science communication. By integrating a robust understanding of physics with comprehensive pedagogical training, the program aims to develop educators who are adept at conveying scientific concepts.

- **Research activity**

The career path in Didactics of Physics at the University of Ferrara immerses Master's students in innovative educational projects, linking theoretical knowledge with practical application in real-world settings. In partnership with INFN, the Lab2Go program collaborates with secondary schools to enhance school laboratories and make experimental activities both practical and engaging. This initiative involves upgrading existing equipment and developing new apparatuses through cooperation between students, teachers, and the Physics Department staff. Additionally, the Hands-on Physics (HoP) project, supported by CERN, INFN, and the Agnelli Foundation, introduces an engaging approach to teaching physics in lower secondary schools. Master's students also participate in the Summer Physics Internship @UniFE, which aims to familiarize participants with the physicist's profession and current research activities. Another significant component is the Modern Physics Laboratory, targeted at senior secondary students to expose them to contemporary physics issues. The HoPE initiative, a collaboration with the Liceo "A. Roiti" and the Edgerton Centre at MIT, transforms STEM learning through practical experiments and active learning, fostering independent and cooperative educational experiences. It is also possible to participate in the organising staff of temporary exhibitions (e.g., as guides), meetings for the general public and education projects for primary and secondary schools concerning the Instrumentaria Collection of Physical Sciences, which gathers more than 1,500 historical scientific instruments housed in the Department of Physics. All these activities are synergistic with enabling courses for teaching certifications (classes A20, A27, A28, and A50), equipping students with a robust foundation to foster scientific literacy and passion among future generations. This approach not only enhances their didactic skills but also ensures they are well-prepared for teaching roles in various educational settings.

- **Dive into our activities**

For more information on the educational activities of the related groups, please visit the following links.

→ **Lab2go**

→ **Hands On Physics**

→ **Dissemination activities**

→ **INFN kids**

→ **Art and Science**

→ **Instrumentaria Collection of Physical Sciences**

→ **Science for everybody**

→ **Pint of Science**

→ European Researchers' Night

Didactics of physics: relevant courses

Fundamental			
Course	**Table**	**Hours**	**Semester**
Experimental particle physics	B3	60	2
Fundamentals of Particle Physics	B2	54	1
Introduction to particle accelerators and detectors	B1	60	2
Mathematical methods of physics	B2	54	1
Quantum mechanics	B2	54	1
Solid state physics	B2	54	1
Statistics and modelling	B1	54	1
Characterizing			
Course	**Table**	**Hours**	**Semester**
Energy and society	C	54	1
Modern physics laboratory	C	60	2

3.3 Physics applied to health, energy and environment

- **Topics**

This career path merges rigorous scientific training with practical applications across critical sectors. In the field of Health Physics, the path emphasizes the advancement of medical diagnostics and therapy through the application of physics principles to medical instrumentation, focusing on enhancing imaging techniques, computational methods applied to medicine, and radiation therapy systems. The professional careers accessible to a Medical Physicist range from academic research to employment in bio-medical or health industries, as well as to the important role of the Hospital Medical Physicist (after a post-graduate specialization).

In Environmental Physics, the career path leverages expertise in environmental science and radioactivity, including Naturally Occurring Radioactive Material (NORM). This focus facilitates detailed assessments of natural and artificial radionuclides across diverse environmental settings, including landfills, mining sites, and oil and gas fields. The program develops advanced sensors and data analytics, deploying innovative platforms like drones for in situ monitoring. By integrating AI and Monte Carlo simulations, the curriculum provides comprehensive tools for analysing and interpreting environmental data, thus addressing significant challenges like climate change, precision agriculture and radiation safety in various ecological contexts.

The Energy Physics track addresses the urgent needs of sustainable energy management by educating students on photovoltaic systems, renewable energy sources, and the physics of semiconductors. The interdisciplinary approach combines physics with management and economics, providing students with the tools to innovate in the development and application of energy solutions, including both conventional and renewable energy technologies.

- **Research activity**

  Collaborating with leading institutions, the expertise of our medical physics group covers various aspects of the physics of diagnostic radiology, nuclear medicine and biophysics of blood circulation. This includes developing advanced monochromatic X-ray sources and photon counting detectors with spectroscopic capabilities, significantly advancing the quality of radiographic images. The group is also currently investigating the potential of Artificial Intelligence (AI) techniques in medical applications.

  Environmental researches focus on employing UAV technology and airborne gamma-ray spectrometry to map radioactivity in varied settings like landfills and mining sites. Our research includes developing AI algorithms and geostatistical methods, enhancing data analysis and environmental monitoring. These efforts support precision agriculture and natural resource protection, leveraging strong partnerships with leading companies and institutions.

  In energy physics, our collaboration with many companies has led to the development of high-efficiency photovoltaic systems and semiconductor devices that optimize solar energy conversion and tracking accuracy. These interdisciplinary research endeavours equip our students with the skills to tackle complex environmental and health challenges, contributing to sustainable and innovative solutions across these vital sectors.

- **Dive into our research**

  For more information on the research activities of the related groups, please visit the following links.

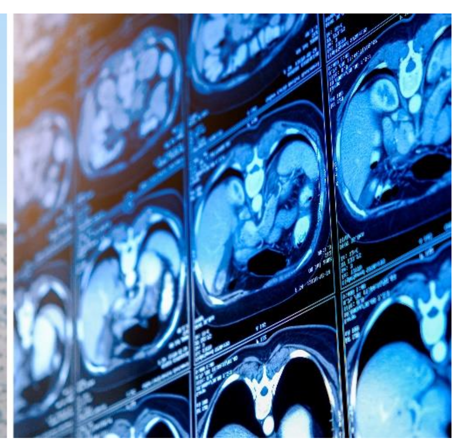
  → Radioactivity and environment

  → Medical physics

Physics applied to health, energy and environment: relevant courses

Fundamental			
Course	**Table**	**Hours**	**Semester**
Artificial intelligence	B1	54	2
Classical electrodynamics and beyond	B2	54	2
Environmental radioactivity	B1	54	2
Ionizing radiation physics	B2	54	2
Laboratory of medical imaging	B1	60	1
Mathematical methods of physics	B2	54	1
Physics and technology of solar energy	B3	54	2
Physics of medical imaging	B1	54	2
Quantum mechanics	B2	54	1
Statistics and modelling	B1	54	1
Characterizing			
Course	**Table**	**Hours**	**Semester**
Bayesian Inference	C	54	1
Beyond the surface: exploring the physics of 2D and 3D printing technologies	C	66	1
Computational methods for medical physics	C	54	1
Energy and society	C	54	1
From space physics to space economy	C	54	2
Nuclear and subnuclear geophysics	C	54	1





3.4 Physics of condensed matter

- **Topics**

  The condensed matter physics career path is solidly grounded in a joint theoretical and experimental framework, where mathematical tools, experimental facts, and measurement techniques are essential for mastering the properties of solids to tailor them to desired purposes. This foundational discipline comprehensively explores atomic arrangements, excitations, and interactions within solids, integral for a deep comprehension of material behaviour across various scales. This educational trajectory is designed to provide students with a profound understanding of material properties and combines two specialized sub-tracks: Magnetism of Nanostructures and Semiconductor Physics. The curriculum encompasses a broad spectrum of topics, starting with the essential properties of materials including crystal structures, electronic and magnetic properties, and lattice dynamics. Students engage with theoretical foundations and practical applications concurrently, reflecting the approach of the program. This involves rigorous analysis of the experimental properties alongside the theoretical models, covering the detailed behaviours of materials as well as their practical implications. This approach prepares students for advanced research and development roles in material science, enabling significant contributions to scientific and technological innovation.

- **Research activity**

  The research activity of the different groups is performed in the context of international collaborations. The group focusing on the physics of matter delves deeply into the development and comprehensive analysis of crystals, leading the student to mastering cutting edge fabrication and characterization techniques for applications spanning from charged particle channelling, to gas sensing devices and multifunctional magnetic systems. Crystal channelling bridges solid-state physics with state-of-the-art high-energy particle beam steering. Its versatility enables novel applications otherwise unattainable, fostering collaborations with particle accelerators and high-energy physics experiments worldwide. On the other side, crystal surfaces, designed for gas sensing activity, are specifically targeted for environmental and agro-food monitoring, and medical diagnostics. The focus is the understanding of the interaction between gases and semiconductor interfaces. The group's research is boosted by both industrial and academic partners across Italy and Europe. The experimental research in magnetism focuses on the distinctive properties of hybrid green and biocompatible systems, combining magnetic nanostructures (nanoparticles or thin films) and organic biopolymers. The goal is to tailor nanostructures magnetic properties so to use these systems in the field of soft electronics, in sensors or actuation devices and for biomedical applications. In addition, the research also extends to the exploration of nanomagnetic logic devices through the analysis of the magnetization reversal in magnetic nanodot arrays, as well as the understanding of stripe domains in ferromagnetic films. On the theoretical front, simulations and modelling are devised to understand the magnetization dynamics within periodic nanostructured materials, including magnonic crystals, artificial spin ice, corrugated ferromagnetic films and hybrids of those. The ultimate purpose is controlling magnons (the spin wave quanta) at the nanoscale, as alternatives to electron current, and thereby contributing significantly to the development of greener, portable, and multifunctional devices.

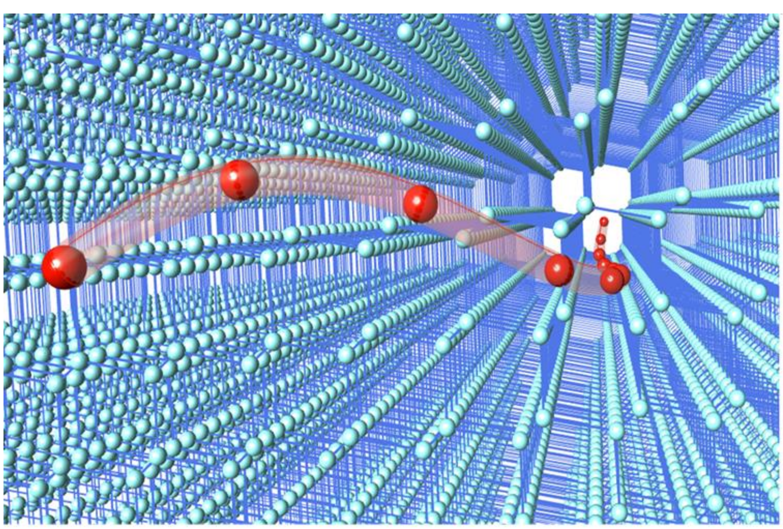
- **Dive into our research**

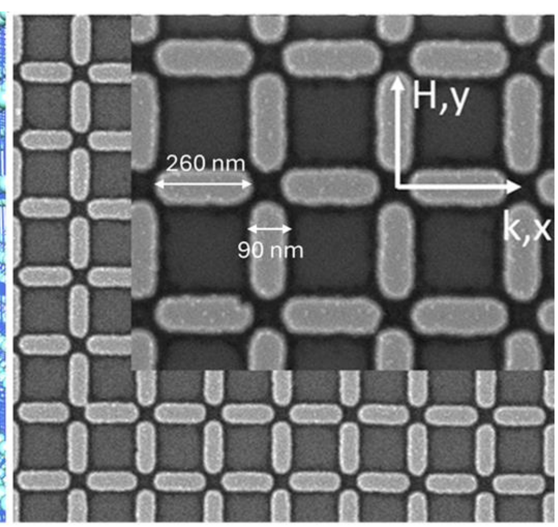
  For more information on the research activities of the related groups, please visit the following link.

  → Condensed matter

Physics of condensed matter: relevant courses

Fundamental			
Course	**Table**	**Hours**	**Semester**
Classical electrodynamics and beyond	B2	54	2
Electron microscopy for materials science	B3	60	1
Laboratory for solid state technologies	B1	60	1
Magnetic materials: from fundamentals to advanced application	B1	56	1
Mathematical methods of physics	B2	54	1
Physics and technology of solar energy	B3	54	2
Quantum mechanics	B2	54	1
Sensors: physics and technology	B3	56	2
Solid state physics	B2	54	1
Statistics and modelling	B1	54	1
Surface physics and nanostructures	B2	54	1
Characterizing			
Course	**Table**	**Hours**	**Semester**
Bayesian Inference	C	54	1
Beyond the surface: exploring the physics of 2D and 3D printing technologies	C	66	1





3.5 Physics of fundamental interactions

- **Topics**

  The career path in physics of fundamental interactions embarks upon a rigorous exploration of the fundamental constituents of matter and the forces orchestrating their interactions. The recommended courses focus on the theoretical foundations of high energy physics, including the mathematical methods necessary to deeply understand the Standard Model of particles and their interactions, particle physics phenomenology and detection techniques through the interaction with light and matter and related phenomena, the experimental mechanisms and methodologies used to design and operate particle detectors and accelerators, and the study of the building blocks of matter within atomic nuclei. A substantial emphasis is placed on laboratory activities and the technological challenges involved in the construction of cutting-edge particle detectors for a variety of currently existing experiments or for future prospects.

- **Research activity**

  The physics of fundamental interaction path delves into the profound mysteries of the universe, such as the asymmetry between matter and antimatter, and the nature of dark matter and dark energy, flanked by a deeply study of the properties of matter and its interactions. It integrates cutting-edge experimental methodologies and advanced theoretical frameworks, positioning students at the forefront of uncovering fundamental physical truths. These include studying matter's slight dominance over antimatter through the LHCb experiment at CERN Large Hadron Collider (LHC), and dissecting hadron and τ-charm physics via the BESIII experiment at the BEPCII accelerator. The search of so-called exotic particles is also a common outstanding topic between LHCb and BESIII experiments. Significant efforts are also dedicated to understanding the neutrino oscillation phenomenon through cutting-edge experiments like JUNO and DUNE. JUNO, located in China, aims to precisely measure the properties of neutrinos, potentially shedding light on the hierarchy problem of neutrino masses, while the DUNE project in the United States seeks to explore the reasons behind the prevalence of matter over antimatter in the universe, using a long-baseline neutrino experiment. Additionally, collaboration with Thomas Jefferson Lab (JLab) aims to decode the behaviour of hadrons and nuclei through electron scattering, integrating a robust theoretical framework to complement experimental pursuits. More specifically, the Electron-Ion Collider will take three-dimensional precision snapshots of the internal structure of protons and nuclei and will shed light on proton spin puzzle. Finally, intense research and development activities on innovative particle detectors, machine-learning analysis techniques, and new technologies for particle accelerators, are ongoing and will enable the development and construction of next-generation experiments and accelerator facilities. This comprehensive approach underscores the importance of both global collaboration and the synergy between theoretical and experimental methodologies in advancing our understanding of fundamental physics.

- **Dive into our research**

For more information on the research activities of the related groups, please visit the following links.

→ Subnuclear physics

→ Neutrino physics

→ Nuclear physics

→ Physics of fundamental interactions

Physics of fundamental interactions: relevant courses

Fundamental			
Course	**Table**	**Hours**	**Semester**
Classical electrodynamics and beyond	B2	54	2
Experimental particle physics	B3	60	2
Fundamentals of particle physics	B2	54	1
High energy physics laboratory	B1	60	1
Introduction to particle accelerators and detectors	B1	60	2
Mathematical methods of physics	B2	54	1
Nuclear physics	B3	54	1
Quantum mechanics	B2	54	1
Characterizing			
Course	**Table**	**Hours**	**Semester**
Advanced Data Analysis in High Energy Physics	C	60	1
Bayesian Inference	C	54	1
Nuclear and subnuclear geophysics	C	54	1

3.6 Theoretical Physics

- **Topics**

  The theoretical physics career path is dedicated to developing precise mathematical models that explain and predict the behaviour of natural phenomena. This discipline leverages abstract mathematical theories to deepen understanding of the fundamental forces and particles that construct the universe. Theoretical physics builds models to uncover universal symmetries, guided by critical analyses of sometimes contradictory experimental data. This field uses advanced mathematics to formulate theories, exploring quantum mechanics for particle behaviour at microscopic levels and employing statistical physics to understand collective particle dynamics. Additionally, theoretical physicists delve into the geometry of spacetime and the dynamics of gravitational fields, pivotal in the study of general relativity and gravitational waves. Supported by a robust network of collaborations, both within Italy and internationally, the department's theoretical research addresses a broad spectrum of physics topics. These range from the large-scale dynamics of the universe, explored under general relativity, to the intricate behaviours of quarks, the fundamental constituents of hadrons, studied by using quantum mechanics and field theory.

- **Research activity**

  The research in theoretical physics in Ferrara encompasses a broad spectrum, from the investigation of physics beyond the standard model, to theoretical cosmology, to nuclear physics and astrophysics, to computational physics including quantum computing. Theoretical physics beyond the standard model and its implications for cosmology are explored by research groups focusing on these areas, while another group emphasizes a phenomenological and data analysis approach to cosmology. The key issues investigated include the composition of dark matter, the mechanisms of inflation, and the application of effective fluid theories in cosmology. This research activity is closely associated with numerous INFN experiments and theoretical investigations such as those conducted by the InDark research group. Theoretical research in nuclear physics and astrophysics is carried out by research groups focusing on areas such as the composition of matter under extreme conditions of density and temperature, and the modelling of SuperNovae, Gamma Ray Bursts, and the merger of two compact stars. This activity is conducted in close collaboration with other research teams and is connected to experiments like Virgo and the future Einstein Telescope, as well as to the research activities of the INFN group Neumatt. Strong research activity in computational physics and High Performance Computing (HPC) is conducted by specialized research groups. HPC integrates modelling, algorithms, software, and hardware to optimize computations on modern high-end computing architectures. This technology is applied to a variety of theoretical problems, from spin glasses to the implementation of the lattice Boltzmann method. Recently, research has begun on quantum computing and its potential applications in data analysis, in collaboration with other research teams. Significant computing resources, such as the COKA cluster, support these activities in Ferrara.

- **Dive into our research**

  For more information on the research activities of the related groups, please visit the following links.

  → Theoretical physics

  → Computing On Kepler Architectures (COKA) computing cluster

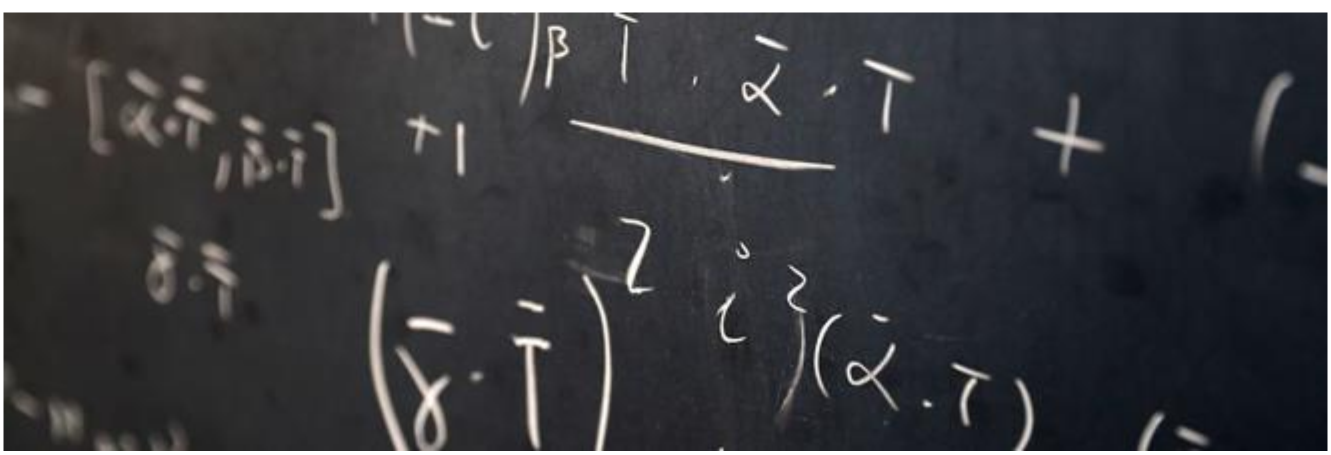
  → Neumat research group

  → InDark research group

→ Theoretical Astroparticle Physics Research Network (TAsP)

Theoretical Physics: relevant courses

Fundamental			
Course	**Table**	**Hours**	**Semester**
Artificial intelligence	B1	54	2
Astroparticle cosmology	B2	54	1
General relativity and gravitational waves	B2	54	2
Mathematical methods of physics	B2	54	1
Nuclear physics	B3	54	1
Quantum mechanics	B2	54	1
Statistical physics	B2	54	2
Statistics and modelling	B1	54	1
Characterizing			
Course	**Table**	**Hours**	**Semester**
Bayesian Inference	C	54	1
Collider physics phenomenology, gauge theories at work	C	54	1
Elements of quantum field theory	C	54	2
Quantum computing	C	54	2
Standard model and beyond	C	58	1



3.7 F Credits

To fulfil the master's degree requirements in Physics, students must acquire a total of 3 F-credits, equivalent to 75 hours of work (1 CFU credit for internships equals 25 hours). Two credits must be obtained through a internship, while the third credit is achieved by participating in "third mission" activities. The final grade for F-credits will be a weighted average of the grades from these two activities.
Planning for both internship and third mission activities should begin approximately six months before the intended graduation date to ensure adequate time for preparation and alignment with thesis requirements (see 3.8. for details about graduation deadlines).

- **Internship**

  To activate the internship (2 CFU), students must first choose an academic tutor from the Unified Council of Physics Degree Programs (for both undergraduate and graduate programs), with expertise relevant to the intended internship topics. The tutor may also serve as the thesis advisor, facilitating the collection of data necessary for the thesis work. In agreement with the academic tutor, the student may undertake either an internal or an external internship.

  - The internal internship allows students to undertake a traineeship within the University of Ferrara's departments, centers, or institutes, or in affiliated research institutions (e.g., INFN, INAF, CNR) in Italy or abroad. If the internship occurs within the Department of Physics and Earth Sciences, the supervisor can be a faculty member from the Unified Council of Physics Degree Programs and may also serve as the academic tutor. If the internship takes place at an institution external to the University of Ferrara, an additional representative from the host institution must be appointed alongside the academic tutor.
  - The external internship is a period of professional training in companies, research institutions and universities (national or foreign). The activity is carried out under the supervision of an external contact

person from the host organization that is required to oversee the student's work. The procedure to follow in this case is described in the following UNIFE web page: → **external traineeship.**

- **Thid mission**

  "Third mission" credits (1 CFU) are acquired by participating in one of the scientific communication, orientation, scientific, and cultural dissemination activities organized by the Department of Physics and Earth Sciences. Students can choose from the activities listed on this page: → **third mission activities.** After making the selection, the student must contact the activity supervisor, who will coordinate the implementation of the activity by defining the specific objectives and timeline.

- **Administrative procedure for F-credit completion**
  - Before starting activities, fill out the activation form, detailing the planned traineeship and third mission activities, and submit it to the teaching manager (see 5.1). → **internship activation module**
  - Upon completion of activities, fill out the attendance register related to both the third mission activities and the workforce orientation activities by logging in with UNIFE credentials at: → **attendance log**.
  - Complete the following questionnaire: → **questionnaire.**
  - Ask the supervisor of the third mission activities to fill out the "Third Mission Activity Evaluation Questionnaire" using this form: → **supervisor card**.
  - Request that the academic tutor, responsible for the internship's completion, fill out the "Academic Tutor Evaluation Form" using this form: → **academic tutor card**

- For external internship at companies, request the company tutor to complete the "Company Tutor Evaluation Form" using this form: → **company tutor card.**
- Register for the F credits exam via the website: → **registration.**
- Send an email to Prof. Fabio Mantovani (mantovani@fe.infn.it) informing him that this procedure has been completed.

3.8 Master thesis

The master's thesis in Physics is a core component of the final examination, showcasing a student's capacity to understand complex research problems and to propose original solutions. This research may also be conducted as part of a traineeship (see 3.7).

- **Thesis selection**

  Students are encouraged to initiate discussions with one or more faculty members to identify potential thesis topics, often within the context of a research group. After selecting an advisor, the student develops their thesis sometimes through active participation in meetings with research collaborators. Upon completion of the thesis, at the request of the advisor, the Unified Council of Physics Degree Programs will assign a referee to the thesis. The referee will review the thesis, participate in its evaluation, and attend the final defense.

- **Content and presentation**

  The thesis must be written and presented in English and must include an abstract in Italian. Students should also include a title page formatted according to university guidelines → frontespizio. The final examination includes a 20-minute public presentation of the thesis, where the student will discuss their research findings. Access to previous dissertations can be found here → past dissertations.

- **Important Deadlines**

  All deadlines are available on the **Bacheca Appelli di Laurea**. After selecting the department and course of study, students can access detailed information. The degree application procedures consists in compiling evaluation forms in the “Conseguimento titolo” section of the reserved area → reserved area.

  - Complete the degree application at least one month before the appeal date. This process includes compiling evaluation forms and paying the graduation tax of €16. Students are encouraged to apply even if the thesis title is not finalized. More information on the application process can be found on the **degree application page**.
  - The final thesis title and the names of the supervisor and referee must be confirmed at least 15 working days before the appeal date. By this deadline, students must also complete all required exams for their study plan, including the F-credit registration (see 3.7).
  - Thesis submission: submit the final thesis in digital PDF/A format online at least 9 working days before the appeal date. Follow the online submission procedure outlined on the **thesis submission page**.

3.9 Tripiccione awards

The Raffaele Tripiccione memorial graduation award honours the memory of Professor Raffaele Tripiccione, a distinguished theoretical physics chair, who passed away in November 2021. Professor Tripiccione was renowned both nationally and internationally, with research interests spanning theoretical and computational studies of complex systems. The annual award is open for applications each year, with the application period closing in autumn. This has been made possible through generous donations received in the wake of Professor Tripiccione's passing and the family's desire to commemorate his legacy by supporting the next generation of physicists.

- **Prize amount:** the award consists of a €1000 prize
- **Eligibility:** all students who have obtained a master's degree in the previous academic year can apply
- **Application deadline:** applications must be submitted by September 30 at the following page → Tripiccione award

3.10 Perspectives

The master's degree aims at completing the physicist profile, in view of different employment opportunities. For R&D careers in private firms, the Degree favours the development of a high-level technical profile, that can handle both modern and innovative technologies and complex systems, to model and design systems and processes. For the research activity, the graduates have a deep and advanced knowledge in theoretical and experimental physics, and with the degree thesis make a first research work experience, in view of the participation in the PhD program → PhD admission. Finally, the degree course paves the way for both teaching in high schools and lecturing at the University → after graduating.

4. Study Exchange

4.1 Double degree

The University of Ferrara and Université Paris-Saclay, two leading science universities in Europe, have established a Dual Master Degree in Physics program. It is designed for students interested in both fundamental and applied physics who are seeking an international experience. Successful participants will earn a Master's degree from both institutions after the two-year program and may pursue a PhD at either university or elsewhere globally. Students will complete a two-year program, studying alongside the same cohort in both Italy and France. Courses are taught in English at Ferrara, while in Paris, instruction may be in English or French. All students will have access to language courses in either French or Italian.

Each student is mentored by both an Italian and a French professor who will also supervise their Master's Thesis. Admission to the DMDP is competitive, based on academic performance, with selections made by an international jury. Mobility grants are available for the year spent abroad.

The call for applications is released annually during February-March. Students are enrolled at both universities but are only required to pay the tuition fees of their home university. **→ double degree**

4.2 Erasmus

The University of Ferrara offers its academic community the chance to engage in mobility and international cooperation activities within Europe and beyond, through the Erasmus charter for higher education. This accreditation, granted by the European Commission, enables participation in the activities of the most renowned European international mobility program, Erasmus+. In addition to the standard Erasmus scholarship, mobility grants may be awarded based on the general university ranking order. To apply for the Erasmus+ study program, follow the instructions and the deadlines reported on the following page: → **Erasmus.**

5. General information

5.1 Study administration

For all questions relating to your studies you can reach the teaching manager Dr.ssa Claudia Zamorani → **teaching manager** or the coordinator of studies of studies Prof. Fabio Mantovani → **coordinator of studies.**

5.2 Student Online Support (SOS)

The University of Ferrara is committed to supporting its students throughout their academic journey, ensuring they have all the resources and guidance needed to navigate university life successfully. Recognizing the importance of accessibility and personalized assistance, the university has established a comprehensive online support service accessible to all students → **SOS.**

5.3 Student representatives

The University of Ferrara values the voice and participation of its students in academic and departmental matters. To this end, student representatives play a pivotal role within the physics department, acting as a vital link between the student body and faculty members. One can find all the contacts in the “student representatives” section of the following page: → **organization.**

5.4 Locations

The Department of Physics and Earth Sciences is included in the scientific and technological centre of the University of Ferrara. The complex is located in via Giuseppe Saragat 1 in Ferrara and includes the faculties of engineering, physics, and earth sciences. All lectures and exams of the course of study in physics are held here: → **location.**

5.5 Benefits for international students

The first step for international students is to download the Ufirst app and schedule an appointment with the → **Ufficio Orientamento, Welcome e Incoming**. Then international students at the University of Ferrara can have access to benefits provided by **ER.GO**, the Regional Agency for the Right to Higher Education in Emilia-Romagna. These benefits include scholarships, accommodation, tuition fee reductions, regional tax exemptions, and support for international mobility.

- **Required documentation**
  The documentation requirements for benefit access depend on the student's financial situation and residency status. All students must provide proof of their family's economic condition:
  - Students with family income and assets only outside Italy need to submit financial statements from their home country: → **Income and assets abroad**
  - Students with financial resources in both Italy and abroad must submit documentation for both locations: → **Income and assets in Italy and abroad**.
  - Refugees, stateless students, and those with complementary protection: → **International protection or stateless status**.
- **Eligibility thresholds and deadlines**
  To remain eligible for ER.GO benefits, students must also meet certain financial, academic, and administrative requirements:

- ➢ Economic criteria: applicants must meet specific income and asset thresholds as defined by ER.GO, detailed in: → **economic thresholds.**
- ➢ Academic merit: students must earn a minimum number of CFU (University Credit Units) each year, as outlined in: → **merit requirements**.
- ➢ Enrollment requirement: students must pay tuition and any university fees by the deadlines in ER.GO's annual call for applications. Enrollment requirements can be reviewed under: → **enrollment requirements**.
- ➢ Application deadlines: submit the complete application by ER.GO's strict deadlines. You may apply even if your university enrollment is not yet finalized: → **application deadlines**.

- **Application steps:**
  - ➢ Each year, ER.GO publishes a new **call for applications** in early July for the upcoming academic year. The call outlines all available benefits, eligibility requirements, application steps, and deadlines.
  - ➢ All official communications regarding application status and updates are posted in the **Dossier Utente**, that is each student's personal ER.GO account. If you do not yet have Italian identification or university credentials to access the Dossier, please contact ER.GO directly at ergoid@er-go.it for assistance.
  - ➢ ER.GO evaluates applications and publishes a ranked list based on academic and financial criteria. Rankings and updates are posted throughout the year; for ongoing status updates, consult: → **rankings**

5.6 Student's life

The University of Ferrara, one of the world's oldest universities, was established on March 4, 1391, by a papal decree at the request of Marquis Alberto V d'Este. Initially offering courses in law, arts, and theology, it quickly became a hub for intellectuals, enhancing the city's prestige and economic activity.

Throughout its history, the University of Ferrara has been a significant centre for scholarship, attended by renowned figures like Nicolaus Copernicus and Paracelsus. After becoming part of the Papal State in 1598, it was revitalized in the late 18th century by the French Revolution, which introduced disciplines such as Constitutional Law. Resuming normal operations in 1816, the university expanded its faculties and student body following Italy's unification.

In recent decades, the University of Ferrara has continued to evolve, establishing new faculties and expanding its academic offerings to include 68 Bachelor's and Master's degree programs. Today, it serves over 25,000 students across thirteen departments and several faculties, housed in a mix of historic and modern buildings that contribute to its unique campus identity.

Enrolling in the Master's degree in Physics at the University of Ferrara offers a vibrant student life in a city known for its excellent gastronomy and historical ambiance. Although Ferrara has a higher cost of living compared to other Italian cities, with a shared student flat costing between €400-550 and a private flat over €1,000, it remains a popular choice for students. Typical monthly expenses including accommodation, food, and leisure average around €600.

Ferrara's student-friendly environment offers a vibrant local scene with numerous dining options, enhancing the living experience for those studying there.

The city's cultural landscape is a fusion of Roman, medieval, and Renaissance architectures, with highlights including the Castello Estense, Ferrara Cathedral, and the scenic Via delle Volte. Overall, Ferrara provides a comprehensive experience that combines academic rigor with cultural richness, making it an excellent choice for pursuing a master's degree in physics → Living Unife.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