Scientific curricula
Master degree in Physics A.Y. 2024/2025

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Contents

Choosing the set of courses that will lead you to the Master of Science degree in Physics is a very important process because it directs the area in which you will do your research or your work. This guide provides clarifications regarding the possible choices that the Physics major at Pisa offers and what are the steps to realise this choice.

1 Glossary and formal steps

The first step towards the choice of a student Master's degree program is the registration via the portal Alice. At this level, the options are the five major research areas, indicated below as *curriculum*, and a general curriculum. The option chosen serves for an initial definition of the courses one will have to follow in order to obtain the LM. Nonetheless, the choice can be refined, or even completely modified, at the time of submission of the Study Plan (PdS) once you are better acquainted with the teachings and all the various didactical offers that exist within the course of study[1].

[1] In case you are benefiting from scholarships that depend on the number of compulsory exams to be taken, it is strongly recommended that you contact the teaching secretary to check which exams are required for confirmation of your scholarship.

The various possible courses are summarized through Study Plans (PdS), recommended below, that serve as a guide for assembling an Individual Study Plan (PdSI). The PdSI is the set of examinations that the student aims to take in order to pursue a Master's degree. The PdS guides the choice in order to comply with the ground rules for being awarded the Laurea Master's Degree in Physics and to define a harmonious and complete study path on the subject you want to study in depth.

In each recommended PdS there are compulsory exams as well as choices among various teachings in the same or similar fields. The field of a course is identified by a label: FIS/xx. The first three letters indicate the scientific field, FIS for physics, and the numbers that follow indicate the sub-sector:

- FIS/01 - Experimental Physics;
- FIS/02 - Theoretical Physics, Models, and Mathematical Methods;
- FIS/03 - Matter Physics;
- FIS/04 - Nuclear and Subnuclear Physics;
- FIS/05 - Astronomy and astrophysics;
- FIS/06 - Earth system Physics;
- FIS/07 - Applied Physics;
- FIS/08 - Educational Physics and Physics History .

Some exams are not classified as the science area FIS but as other areas such as information science (INF) or mathematics (MAT).

When choosing exams to compile the PdSI, it is recommended that students consult syllabuses and prerequisites for the individual course at exams.unipi.it and following the link that is available for each course.

In each PdSI it is always possible to choose 12 CFUs among all those provided by the CdS in Physics but also more generally among those provided also in other Courses of Study and also at the Scuola Normale. Clearly, the choice of free CFUs must be functional to the completion of one's own CdS. Some courses of the CdS in Physics deal with general topics and are therefore not linked to a specific PdS and can be chosen in any of them. You can find the these exams in Section 3.

Once you have compiled a PdSI, this needs to be submitted for approval by the Course Council through the CAPS portal caps.df.unipi.it. The PdSI can be submitted at any time of the year and can be varied as many times as you wish.

In case you choose to submit a free PdSI, i.e., one that does not fall under any of the PdS listed below, you must comply with minimum rules listed in the relevant section and justify this choice with a comment on CAPS.

Approval of a PdSI is not automatic and therefore, especially in the case of submitting a PdSI with changes from the recommended PdSs, it is important to submit the PdSI on CAPS as soon as possible and in any case before starting to take the exams to be sure that the chosen course form an appropriate path of study.

2 Suggested Study Plans

The list is in alphabetical order, while the free PdSI is at the bottom of the list. At the end of each brief description of the PdS, it is indicated which curriculum it corresponds to.

Astronomy and Astrophysics Provides the necessary physics background and observational skills to obtain and interpret astrophysical observations in several wavelengths and messengers. (Astronomy and Astrophysics Curriculum)

Complex Systems Career path designed to study systems that are characterised by many interacting components with unpredictable and emergent behaviours. (General Curriculum)

Data Analysis in Experimental Physics Career path to deepen aspects related to data analysis, including applications in experimental physics. (General Curriculum)

Fundamental Interactions Provides knowledge in the field of nuclear and subnuclear physics, gravitational waves, and cosmic particles. (Fundamental Interactions Curriculum)

Medical Physics Medical physics provides knowledge of the physical methodologies and experimental techniques used in medicine for diagnostic and therapeutic purposes. (Medical Physics Curriculum)

Phenomenology of Fundamental Interactions Career path to delve into the theoretical and experimental aspects of fundamental interactions physics, hence bridging the gap between theoretical and experimental particle physics. (General Curriculum)

Physics for Cultural Heritage Aims to train physicists who are able to communicate effectively with Art Historians, Restorers and Archaeologists, in order to address, in a multidisciplinary field and within the limits of their respective competences, complex problems that can be solved through the use of typical tools and methods of physical research. (General Curriculum)

Physics of Biosystems Path to explore aspects related to the physics of matter and complex systems, focusing on phenomena relevant to life sciences. (Physics of Matter Curriculum)

Physics of Geofluids Dynamics and Solid Earth Provides the theoretical and applied tools for the study of the fundamental processes of geophysical fluids and solid earth, with applications to earthquake physics, volcanology and environmental physics. (General Curriculum)

Physics of Matter Career path focused on the theoretical and experimental study of states of matter, both classical and quantum, and their interaction with electromagnetic fields. (Physics of Matter Curriculum)

Physics of the Universe Provides skills for studying the phenomena of the Universe using an interdisciplinary theoretical and experimental approach based on the observation of different types of cosmic signals, such as gravitational waves, electromagnetic radiation, and astroparticles. It also benefits from the connections with the European Gravitational Observatory (EGO) and the research activities carried out at the gravitational wave detector Advanced Virgo. (General Curriculum)

Plasma Physics Career path to deepen aspects related to plasma physics. (Physics of Matter Curriculum)

Quantum Computing and Technologies Provides skills in the field of Quantum Computing, both from a theoretical and experimental perspective. (General Curriculum)

Theoretical Physics Provides skills in the field of theoretical physics, spanning from quantum field theories, phenomenology of fundamental interactions, gravitational physics theory, statistical physics, condensed matter physics, to nuclear interactions. (Theoretical Physics Curriculum)

Theory of Quantum Materials Develops theoretical and computational investigative methods for studying new materials. (General Curriculum)

Free Study Plan Allows you to build an Individual Study Plan that does not fit into any of the aforementioned PdS.

3 Exams not specific to a particular Study Plan

For courses that will be available for the first time in the academic year 2024/25, the link on the website esami.unipi.it will be active as soon as the website for the new academic year becomes available. For each course, a description in English is provided on the site by clicking on the "EN" symbol.

Elective courses	
II s ACCELERATORI LASER-PLASMA (FIS03)	6 CFU
II s ARMI NUCLEARI, DISARMO E PROLIFERAZIONE NUCLEARI (FIS 04)	6 CFU
I s PHYSICS OF SOUND (FIS 07)	6 CFU

4 New courses in the academic year 2024/5

I s	ADVANCED TECHNOLOGIES FOR GROUND-BASED ASTROPHYSICS: FROM MICROWAVES TO VISIBLE LIGHT (FIS 05)	6 CFU
A	ASTROPHYSICS AND MULTIMESSENGER LABORATORY (FIS 01)	12 CFU
II s	BIOPHYSICS FOR eFLASH THERAPY (FIS 07)	9 CFU
II s	DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s	FLEXIBLE AND NANO-ELECTRONICS (FIS 03)	9 CFU
II s	LABORATORY OF INSTRUMENTAL SEISMOLOGY (FIS 01)	9 CFU
II s	MECHANICS OF GEOPHYSICAL FLUIDS (FIS 06)	9 CFU
II s	MICROBIOROBOTICS (FIS 03)	6 CFU
I s	MULTIMESSENGER AND HIGH-ENERGY ASTROPHYSICS (FIS 01)	6 CFU
II s	NEUROENGENEERING (FIS 03)	6 CFU
I s	PHYSICS OF STAR FORMATION (FIS 05)	6 CFU
II s	QUANTUM MACHINE LEARNING (FIS 03)	3 CFU
II s	QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU

5 The suggested Study Plans in detail

For courses that will be available for the first time in the academic year 2024/25, the link on the website esami.unipi.it will be connected as soon as the website for the new academic year becomes available. For each course a description in English is provided on the site by clicking on the U.K. Flag icon.

ASTRONOMY AND ASTROPHYSICS

Compulsory courses		39 CFU
A	ASTROPHYSICS AND MULTIMESSENGER LABORATORY (FIS 01)	12 CFU
II s	EXTRAGALACTIC ASTROPHYSICS AND COSMOLOGY (FIS 05)	9 CFU
II s	STELLAR PHYSICS (FIS 05)	9 CFU
I s	ASTROPHYSICAL PROCESSES (FIS 05)	9 CFU
Alternative courses (at least one in each group)		18 CFU
Physics of matter, nuclear and subnuclear physics group		
I s	FISICA NUCLEARE (FIS 04)	9 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
Theoretical physics group		
I s	FISICA STATISTICA (FIS 02)	9 CFU
I s	FISICA TEORICA 1 (FIS 02)	9 CFU
I s	RELATIVITÀ GENERALE (FIS 02)	9 CFU
Elective courses (at least 6 CFU from the following courses)		18 CFU
I s	ADVANCED TECHNOLOGIES FOR GROUND-BASED ASTROPHYSICS: FROM MICROWAVES TO VISIBLE LIGHT (FIS 05)	6 CFU
I s	EXPERIMENTAL METHODOLOGIES FOR ASTROPARTICLE PHYSICS (FIS 01)	9 CFU
I s	EXPERIMENTAL METHODOLOGIES FOR ASTROPARTICLE PHYSICS S (FIS 01)	6 CFU
I s	FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
I s	MULTIMESSENGER AND HIGH-ENERGY ASTROPHYSICS (FIS 01)	6 CFU
I s	PHYSICS OF STAR FORMATION (FIS 05)	6 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s	ASTROPARTICLE PHYSICS (FIS 05)	9 CFU
II s	ASTROPARTICLE PHYSICS S (FIS 05)	6 CFU
II s	COMPACT STAR PHYSICS S (FIS 04)	6 CFU
II s	COSMOLOGIA DEL PRIMO UNIVERSO (FIS 05)	9 CFU
II s	COSMOLOGIA DEL PRIMO UNIVERSO S (FIS 05)	6 CFU
II s	DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s	EXOPLANETARY SYSTEMS (FIS 05)	6 CFU
II s	FISICA TEORICA 2 (FIS 02)	9 CFU
II s	GRAVITATIONAL WAVE PHYSICS (FIS 01)	9 CFU
II s	GRAVITATIONAL WAVE PHYSICS S (FIS 01)	6 CFU
II s	TEORIE DELLA GRAVITAZIONE (FIS 02)	9 CFU
II s	TEORIE DELLA GRAVITAZIONE S (FIS 02)	6 CFU
A	METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

Several thematic paths exist in the Astronomy and Astrophysics study plan, and the following elective courses are suggested for the different paths

1. **Stellar Physics path**: Compact star physics S (6 CFU), Physics of star formation (6 CFU)

2. **Galactic Astronomy and Cosmology path**: Astroparticle physics S (6 CFU), Early Universe Cosmology S (6 CFU), General relativity (9 CFU)
3. **Gravitational Waves and Compact Objects path**: Gravitational waves physics S (6 CFU), Compact star physics S (6 CFU), General relativity (9 CFU)
4. **Planetary Science path**: Physics of star formation (6 CFU), Exoplanetary systems (6 CFU)
5. **Observational Astronomy path**: Advanced technologies for ground-based astrophysics (6 CFU), Multimessenger and high-energy astrophysics (6 CFU)

COMPLEX SYSTEMS

Compulsory courses		18 CFU
I s	COMPLEX SYSTEMS (FIS 03)	9 CFU
I s	FISICA STATISTICA (FIS 02)	9 CFU
Alternative courses (one course for each of the following two groups)		15 CFU
Astronomy and astrophysics group		
II s	ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s	STELLAR PHYSICS S (FIS 05)	6 CFU
II s	STELLAR PHYSICS (FIS 05)	9 CFU
Experimental physics group		
I s	ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
I s	COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS (FIS 01)	9 CFU
A	BIO-SYSTEMS LAB (FIS 01/07)	15 CFU
A	METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
Elective courses All the alternative courses may be chosen as elective courses in addition to the following:		42 CFU
I s	BIOINFORMATICA (INF 01) (LM Bio. Mol. e Cell., cod. 178EE)	3 CFU
I s	DATA MINING AND MACHINE LEARNING (ING-INF 05) (LM Art. intel. and Data Eng., cod. 878II) (see note)	12 CFU
I s	DISORDERED SYSTEMS OUT OF EQUILIBRIUM (FIS 03)	9 CFU
I s	FISICA TEORICA 1 (FIS 02)	9 CFU
I s	GEOSPATIAL ANALYTICS (INF 01) (LM Data Science and Busin. Info, 783AA)	6 CFU
I s	FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
I s	INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
I s	MACHINE LEARNING (INF 01) (LM Inf., 654AA)	9 CFU
I s	PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
I s	QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
II s	ANALISI DEI DATI (MAT 06) (LM Mat., cod. 699AA)	6 CFU
II s	COMPLEX SYSTEMS - NEURAL DYNAMICS (FIS 03)	9 CFU
II s	COMPUTATIONAL NEUROSCIENCE (INF 01) (LM Bio. Eng., cod. 674AA) (see note)	6 CFU
II s	DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s	DYNAMICS OF COMPLEX SYSTEMS (LM e PhD Matematica)	6 CFU
II s	EARTHQUAKE SEISMOLOGY (GEO 11) (LM Expl. and Appl. Geo.)	6 CFU
II s	FISICA DELL'ATMOSFERA (LM Scienze Ambientali 363BB) (FIS 07)	6 CFU
II s	FISICA TEORICA 2 (FIS 02)	9 CFU
II s	LINGUISTICA COMPUTAZIONALE II (L-LIN 01) (LM Inf. Uman, cod. 513LL)	6 CFU
II s	MICROBIOROBOTICS (FIS 03)	6 CFU
II s	MODELLIZZAZIONE BIOFISICA DEI SISTEMI COMPLESSI (FIS03) (LM Ing Bio., cod. 273BB)	6 CFU
II s	NEUROENGENEERING (FIS03)	6 CFU
II s	NONLINEAR DYNAMICS (FIS 03)	9 CFU
II s	OCEANOGRAFIA FISICA SU GRANDE SCALA (FIS 03/06)	9 CFU
II s	QUANTUM MACHINE LEARNING (FIS 03)	3 CFU
II s	QUANTUM THERMODYNAMICS (FIS 03)	6 CFU
II s	SOCIAL NETWORK ANALYSIS (INF 01) (LM Data Science and Busin. Info., cod. 668AA)	6 CFU
II s	STATISTICS FOR DATA SCIENCE (SECS-S 01) (LM Data Science and Busin. Info., cod. 628PP)	9 CFU
II s	TEORIA DEI GIOCHI (MAT 09) (LM Matematica, cod. 211AA)	6 CFU
A	DATA MINING (INF 01) (LM Data Science and Busin. Info., cod. 420AA) (see note)	12 CFU
A	DATA MINING: FUNDAMENTALS (INF 01) (LM Inf. Uman., cod. 676AA) (see note)	6 CFU
–	MARKETS, TRADING AND TECHNOLOGIES (SNS)	3 CFU
–	MATHEMATICAL MODELS FOR QUANTITATIVE FINANCE: MARKET MICROSTRUCTURE, NETWORKS, AND SYSTEMIC RISK (FIS 03) (SNS)	5 CFU
–	QUANTITATIVE FINANCE (SNS)	6 CFU
–	STATISTICAL AND MACHINE LEARNING MODELS FOR TIME SERIES ANALYSIS (SNS)	6 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

Notes:

- At least 18 CFU of the 42 CFU electives must be in the FIS disciplinary sectors.
- The courses 878II and the courses 676AA and 420AA have overlapping content: it is therefore necessary to present a study plan to agree on how many CFU will be counted if you intend to take the exam for more than one of these courses.
- The course with code 676AA is the first part of the course with code 420AA, hence only one of the two can be chosen.
- The course with code 674AA is offered in a restricted entry LM program: the possibility of attending it depends on the availability of free spots and must be agreed upon with the lecturer at the beginning of the course.
- In the "Experimental physics" group it is possible to choose the couple "Computing methods for experimental physics and data analysis S" (6 CFU) + "Metodi numerici per la fisica S" (6 CFU). In this case both exams must be taken.

Based on the paths previously chosen by students who decided to follow a specific educational path within the complex systems subject, the following courses are typically included in their study plans:

"Finance" Path: Markets, Trading and Technologies; Mathematical Models for Quantitative Finance: Market Microstructure, Networks, and Systemic Risk; Quantitative Finance; Statistical and Machine Learning Models for Time Series Analysis; Social Network Analysis

"Neurons/Brain" Path: Complex Systems - Neural Dynamics; Computational Neuroscience; Numerical Methods for Physics (including the module Methods of Nonlinear Physics and Neuroscience); Neuroengineering; Nonlinear Dynamics; Data Mining

"Active Matter" Path: Disordered Systems Out of Equilibrium; Microbiorobotics; Biophysical Modeling of Complex Systems; Fluidodynamics; Introduction to Molecular Biophysics; Large Scale Physical Oceanography; Physics of Biosystems

"Earth System" Path: Fluidodynamics; Large Scale Physical Oceanography; Atmospheric Physics; Earthquake Seismology; Plasma Physics

"Chaos, Dynamical Systems" Path: Dynamics of Complex Systems; Numerical Methods for Physics (including the module Methods of Nonlinear Physics and Neuroscience); Nonlinear Dynamics; Quantum Thermodynamics

"Complexity and Networks" Path: Data Mining (420AA); Geospatial Analytics; Machine Learning (654AA); Social Network Analysis

DATA ANALYSIS IN EXPERIMENTAL PHYSICS

Compulsory courses	18 CFU
I s ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS (FIS 01)	9 CFU
Alternative courses (at least one in each group)	27-30 CFU
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s ASTROPARTICLE PHYSICS S (FIS 05)	6 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO S (FIS 05)	6 CFU
II s EXTRAGALACTIC ASTROPHYSICS AND COSMOLOGY (FIS 05)	9 CFU
II s STELLAR PHYSICS S (FIS 05)	6 CFU
Physics of matter, nuclear and subnuclear physics group	
II s ACCELERATOR PHYSICS (FIS 04)	9 CFU
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
I s SOLID STATE PHYSICS (FIS 03)	9 CFU
Experimental physics group	
I s FUNDAMENTAL INTERACTIONS LABORATORY S (FIS 01)	9 CFU
II s GRAVITATIONAL WAVE PHYSICS S (FIS 01)	6 CFU
II s INSTRUMENTATION FOR FUNDAMENTAL INTERACTIONS PHYSICS (FIS 01)	9 CFU
II s QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU
Theoretical physics	
I s FISICA STATISTICA (FIS 02)	9 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
I s RELATIVITÀ GENERALE (FIS 02)	9 CFU
Elective courses (at least 9 CFU from the following courses)	27 CFU
I s DATA MINING AND MACHINE LEARNING (ING-INF 05) (LM Art. intel. and Data Eng., cod. 878II) (see note)	12 CFU
I s MACHINE LEARNING (INF 01) (LM Inf., 654AA)	9 CFU
I s QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
I s SIGNAL PROCESSING FOR PHYSICS (FIS 01)	6 CFU
II s ANALISI DEI DATI (MAT 06) (LM Mat., cod. 699AA)	6 CFU
II s METODI MONTECARLO NELLA FISICA SPERIMENTALE (FIS 01)	6 CFU
II s SOCIAL NETWORK ANALYSIS (INF 01) (LM Data Science and Busin. Info., cod. 668AA)	6 CFU
A DATA MINING (INF 01) (LM Data Science and Busin. Info., cod. 420AA) (see note)	12 CFU
A DATA MINING: FUNDAMENTALS (INF 01) (LM Inf. Uman., cod. 676AA) (see note)	6 CFU
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

Notes:

- Courses 878II, 676AA and 420AA have some overlap in the contents: in case more than one of these is chosen, a study plan must be submitted in order to evaluate the number of accounted CFUs
- Course 676AA is the first section of course 420AA, therefore it is not possible to choose both.

FUNDAMENTAL INTERACTIONS

Compulsory courses	24 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
A FUNDAMENTAL INTERACTIONS LABORATORY (FIS 01)	15 CFU
Alternative courses (at least one for each of the following groups)	30 CFU
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s ASTROPARTICLE PHYSICS S (FIS 05)	6 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO S (FIS 05)	6 CFU
Theoretical physics group	
I s FISICA TEORICA 1 (FIS 02)	9 CFU
I s RELATIVITÀ GENERALE (FIS 02)	9 CFU
Experimental, nuclear and subnuclear physics group 1	
II s GRAVITATIONAL WAVE PHYSICS S (FIS 01)	6 CFU
II s PARTICLE PHYSICS S (FIS 04)	6 CFU
II s QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU
Experimental, nuclear and subnuclear physics group 2	
II s ACCELERATOR PHYSICS (FIS 04)	9 CFU
I s ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS (FIS 01)	9 CFU
II s INSTRUMENTATION FOR FUNDAMENTAL INTERACTIONS PHYSICS (FIS 01)	9 CFU
Elective courses (at least 9 CFU from the following courses or from the alternative courses, both in the 6 and in the 9 CFU versions)	21 CFU
I s EXPERIMENTAL METHODOLOGIES FOR ASTROPARTICLE PHYSICS (FIS 01)	9 CFU
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s FISICA STATISTICA (FIS 02)	9 CFU
I s FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s INTRODUCTION TO NEUTRINO PHYSICS (FIS 04)	3 CFU
I s PARTICLE DARK MATTER (FIS 01)	6 CFU
I s PROGETTAZIONE DI SISTEMI DIGITALI (ING-INF 01) (LM Ing. elettron., cod. 314II)	9 CFU
I s RADIATION PROTECTION (ING-IND 20) (LM Nuclear Eng., cod. 1095I)	6 CFU
I s SIGNAL PROCESSING FOR PHYSICS (FIS 01)	6 CFU
I s SOLID STATE PHYSICS (FIS 03)	9 CFU
II s BIOPHYSICS FOR eFLASH THERAPY (FIS 07)	9 CFU
II s DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s DOSIMETRY (FIS 07)	6 CFU
II s ELETTRONICA E SENSORI (FIS 07)	6 CFU
II s FISICA TEORICA 2 (FIS 02)	9 CFU
II s FLEXIBLE AND NANO-ELECTRONICS (FIS 03)	9 CFU
II s GRAVITATIONAL WAVE PHYSICS (FIS 01)	9 CFU
II s HADRON COLLIDER PHYSICS (FIS 01)	9 CFU
II s HADRON COLLIDER PHYSICS S (FIS 01)	6 CFU
II s METODI MONTECARLO NELLA FISICA SPERIMENTALE (FIS 01)	6 CFU
II s PARTICLE PHYSICS (FIS 04)	9 CFU
II s RECENT HIGHLIGHTS IN FUNDAMENTAL INTERACTIONS (FIS 01)	3 CFU
II s SIMMETRIE DISCRETE (FIS 04)	6 CFU
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
– STANDARD MODEL AND BEYOND (FIS 02) (SNS)	6 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

MEDICAL PHYSICS

Compulsory courses	27 CFU
A MEDICAL PHYSICS 1 (FIS 07)	9 CFU
II s MEDICAL PHYSICS 2 (FIS 07)	6 CFU
A MEDICAL PHYSICS LABORATORY (FIS 01/07)	12 CFU
Alternative courses (one in each of the following three groups)	21/24 CFU
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s ASTROPARTICLE PHYSICS S (FIS 05)	6 CFU
II s STELLAR PHYSICS S (FIS 05)	6 CFU
Physics of matter, nuclear and subnuclear physics group	
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
I s PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
Theoretical physics group	
I s FISICA STATISTICA (FIS 02)	9 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
I s RELATIVITÀ GENERALE (FIS 02)	9 CFU
Elective courses (at least 9 CFU from the following)	24/27 CFU
I s ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS (FIS 01)	9 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS S (FIS 01)	6 CFU
I s ELEMENTS OF PHYSIOLOGY, PATHOPHYSIOLOGY, AND DIAGNOSTICS (BIO 09)	6 CFU
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
I s PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
I s SIGNAL PROCESSING FOR PHYSICS (FIS 01)	6 CFU
II s ACCELERATOR PHYSICS (FIS 04)	9 CFU
II s ACCELERATOR PHYSICS S (FIS 04)	6 CFU
II s BIOPHYSICS FOR eFLASH THERAPY (FIS 07)	9 CFU
II s CELL BIOPHYSICS (FIS 03)	6 CFU
II s DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s DOSIMETRY (FIS 07)	6 CFU
II s FLEXIBLE AND NANO-ELECTRONICS (FIS 03)	9 CFU
II s METODI MONTECARLO NELLA FISICA SPERIMENTALE (FIS 01)	6 CFU
II s MICROBIOROBOTICS (FIS 03)	6 CFU
II s NEUROENGENEERING (FIS03)	6 CFU
II s NUCLEAR MAGNETIC RESONANCE (FIS 07)	6 CFU
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

Suggested paths:

MEDICAL PHYSICS path

Recommended for students interested in deepening the physical methodologies applied to medicine, also in view of a possible professional career as a specialist in medical physics.

From “Alternative courses”
Fisica nucleare (FIS 04) 9 CFU
From “Elective courses”
Comp. methods for exp. phys. and data analysis S (FIS 01) 6 CFU
Dosimetry (FIS 07) 6 CFU
Metodi montecarlo nella fisica sperimentale (FIS 01) 6 CFU
Nuclear magnetic resonance (FIS 07) 6 CFU

FLASH RT path
Recommended for students interested in acquiring an in-depth knowledge of the physical phenomena and radiobiological mechanisms underlying FLASH radiotherapy, providing computational and experimental skills required in the research field.
From “Alternative courses”
Introduction to molecular biophysics (FIS 03) 6 CFU
From “Elective courses”
Accelerator physics S (FIS 04) 6 CFU
Biophysics for eflash therapy (FIS07) 9 CFU
Comp. methods for exp. phys. and data analysis S (FIS 01) 6 CFU
Dosimetry (FIS 07) 6 CFU

BIOMEDICAL IMAGING path
Recommended for students interested in developing an in-depth understanding of the physical principles and technologies used in the generation and analysis of images of biological phenomena at different dimensional scales.
From “Alternative courses”
Introduction to molecular biophysics (FIS 03) 6 CFU
From “Elective courses”
Cell biophysics (FIS 03) 6 CFU
Comp. methods for exp. phys. and data analysis S (FIS 01) 6 CFU
Nuclear magnetic resonance (FIS 07) 6 CFU
Physics of biosystems (FIS 03) 9 CFU

PHENOMENOLOGY OF FUNDAMENTAL INTERACTIONS

Compulsory courses	45 CFU
II s ASTROPARTICLE PHYSICS (FIS 05)	9 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
II s FISICA TEORICA 2 (FIS 02)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s RELATIVITÀ GENERALE (FIS 02)	9 CFU
Alternative courses	21/30 CFU
(one course in each of the three groups)	
Theoretical, nuclear and subnuclear physics group	
II s CROMODINAMICA QUANTISTICA (FIS 02)	9 CFU
– EFFECTIVE FIELD THEORIES (FIS 02) (SNS)	6 CFU
I s FISICA NUCLEARE (FIS 04)	9 CFU
– STANDARD MODEL AND BEYOND (FIS 02) (SNS)	6 CFU
Experimental physics group	
I s ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS (FIS 01)	9 CFU
I s FUNDAMENTAL INTERACTIONS LABORATORY S (FIS 01)	9 CFU
II s QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU
A ASTROPHYSICS AND MULTIMESSENGER LABORATORY (FIS 01)	12 CFU
Experimental, nuclear and subnuclear physics	
II s HADRON COLLIDER PHYSICS (FIS 01)	9 CFU
I s PARTICLE DARK MATTER (FIS 01)	6 CFU
II s PARTICLE PHYSICS (FIS 04)	9 CFU
II s SIMMETRIE DISCRETE (FIS 04)	6 CFU
Elective courses	0/9 CFU
It is recommended to choose these CFUs among the courses indicated above	
Thesis work and dissertation	45 CFU
Total	120 CFU

PHYSICS FOR CULTURAL HERITAGE

Compulsory courses	27 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS (FIS 01)	9 CFU
I s FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s PHYSICS FOR CULTURAL HERITAGE + LABORATORY (FIS 07)	7+2 CFU
Alternative courses (at least one course in each of the three groups)	27/30 CFU
Microphysics group	
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s MATERIAL OPTICAL SPECTROSCOPY (FIS 03)	6 CFU
Theoretical physics group	
I s FISICA STATISTICA (FIS 02)	9 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s ASTROPARTICLE PHYSICS (FIS 05)	9 CFU
I s PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s STELLAR PHYSICS S (FIS 05)	6 CFU
Methodological courses in the archaeological/historical/historical-artistic field:	
I s ARCHEOLOGIA DELLA PRODUZIONE (L-ANT 10)	6 CFU
I s METODOLOGIE DELLA RICERCA ARCHEOLOGICA (L-ANT 10)	6 CFU
I s METODOLOGIA DELLA RICERCA STORICO-ARTISTICA (L-ART 04)	6 CFU
I s PALEOECOLOGIA E BIOARCHEOLOGIA (L-ANT 10)	6 CFU
I s STORIA DELLE TECNICHE ARTISTICHE (L-ART 04)	6 CFU
II s STORIA E TECNICA DEL RESTAURO (L-ART 04)	6 CFU
Elective courses All the courses indicated above and not already included in the PdS can be chosen in this section. Furthermore, all archaeological/historical/historical-artistic teachings with disciplinary content, and the related laboratory teachings	18/21 CFU
I s CHIMICA FISICA MOLECOLARE (CHIM 02)	9 CFU
I s COMPLEX SYSTEMS (FIS 03)	9 CFU
I s DIAGNOSTICA PER LO STUDIO DI OPERE D'ARTE (L-ART 04)	6 CFU
I s DISORDERED SYSTEMS OUT OF EQUILIBRIUM (FIS 03)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s FUNDAMENTAL INTERACTIONS LABORATORY S (FIS 01)	9 CFU
I s FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
I s PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
I s RADIATION PROTECTION (ING-IND 20) (LM Nuclear Eng., cod. 1095I)	6 CFU
I s SIGNAL PROCESSING FOR PHYSICS (FIS 01)	6 CFU
II s ACCELERATOR PHYSICS (FIS 04)	9 CFU
II s ATOM OPTICS (FIS 03)	9 CFU
II s COMPETENZE DIGITALI PER I BENI CULTURALI (L-ANT 10)	6 CFU
II s DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s DOSIMETRY (FIS 07)	6 CFU
II s ELETTRONICA E SENSORI (FIS 07)	6 CFU
II s NUCLEAR MAGNETIC RESONANCE (FIS 07)	6 CFU
II s PHYSICS OF PHOTONIC DEVICES (FIS 03)	9 CFU
II s QUANTUM OPTICS AND PLASMA (FIS 03)	9 CFU
A MEDICAL PHYSICS LABORATORY (FIS 01/07)	12 CFU
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
A PHYSICS OF MATTER AND NANOTECHNOLOGY LABORATORY S (FIS 01)	9 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

Note: the "Medical Imaging" module of the course COMPUTING METHODS FOR EXPERIMENTAL

PHYSICS AND DATA ANALYSIS is mandatory if this course is selected.

PHYSICS OF BIOSYSTEMS

Compulsory courses	18 CFU
I s FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
Alternative courses (one in each of the following groups)	36/39 CFU
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s STELLAR PHYSICS S (FIS 05)	6 CFU
Experimental physics group	
A BIO-SYSTEMS LAB (FIS 01/07)	15 CFU
A PHYSICS OF MATTER AND NANOTECHNOLOGY LABORATORY (FIS 01) (see note)	15 CFU
Theoretical physics group	
I s FISICA STATISTICA (FIS 02)	9 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
Physics of matter group	
I s DISORDERED SYSTEMS OUT OF EQUILIBRIUM (FIS 03)	9 CFU
I s INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
Elective courses All courses in the alternative choices can be selected as elective courses. Additionally you can choose the following courses:	18/21 CFU
I s CHIMICA FISICA MOLECOLARE (CHIM 02)	9 CFU
I s COMPLEX SYSTEMS (FIS 03)	9 CFU
I s COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS S (FIS 01)	6 CFU
I s INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
I s MATERIAL OPTICAL SPECTROSCOPY (FIS 03)	6 CFU
I s SOLID STATE PHYSICS (FIS 03)	9 CFU
II s CELL BIOPHYSICS (FIS 03)	6 CFU
II s BIOPHYSICS FOR eFLASH THERAPY (FIS 07)	9 CFU
II s MEDICAL PHYSICS 2 (FIS 07)	6 CFU
II s MICROBIOROBOTICS (FIS 03)	6 CFU
II s NEUROENGENEERING (FIS03)	6 CFU
II s SPECTROSCOPY ALGORITHMS (FIS 03)	3 CFU
II s SPECTROSCOPY AND MICROSCOPY OF NANOMATERIALS (FIS 03)	6 CFU
A MEDICAL PHYSICS 1 (FIS 07)	9 CFU
Erogati da LM in Mat. and Nanotechnology:	
I s BIOFLUIDS AND MATERIALS INTERACTIONS (ING-IND 22)	3 CFU
I s NANOMEDICINE AND REGENERATIVE MEDICINE (ING-IND 22)	6 CFU
I s MANUFACTURING OF POLYMERS AND NANOCOMPOSITES FOR BIOMEDICAL APPLICATION (ING-IND 22)	3 CFU
II s BIOMATERIALS (ING-IND 22)	6 CFU
A FUNDAMENTALS OF BIOPHYSICS AT NANOSCALE (FIS 03/07) (SNS)	9 CFU
– PHYSICS OF THE LIVING CELL (FIS 03/07) (SNS)	6 CFU
Altri CdS	
I s BIOINFORMATICA (INF 01) (LM Bio. Mol. e Cell., cod. 178EE)	3 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

Note: Alternatively to the course "Physics of Matter and Nanotechnology Laboratory" (15 CFU), it is possible to take the exam "Physics of Matter and Nanotechnology Laboratory S" (9 CFU) and at least two modules (for 6 CFU) of "Numerical Methods for Physics" (it is suggested to follow the modules

"First-principles Calculations" and "Classical Molecular Dynamics").

Within the scope of possible thematic pathways in Biophysics, the following courses are suggested:

- **"Biophysics" Pathway**: This pathway delves into the processes and techniques involved in cellular and molecular biophysics. Suggested courses: Bio-systems lab (15 CFU), Cell biophysics (6 CFU), Disordered systems out of equilibrium (9 CFU), Introduction to molecular biophysics (6 CFU).
- **"Active Matter" Pathway**: This pathway provides the physical foundations that characterize the complexity and mechanisms underlying "bio-inspired" materials. Suggested courses: Complex systems (9 CFU), Disordered systems out of equilibrium (9 CFU), Microbiorobotics (6 CFU), Physics of matter and nanotechnology laboratory (15 CFU).
- **"Biophysics for Flash (experimental)" Pathway**: This pathway provides basic physical skills in experimental biophysical mechanisms and techniques aimed at studying the effects induced by Flash radiotherapy. Suggested courses: Biophysics for eflash therapy (9 CFU), Bio-systems lab (15 CFU), Introduction to molecular biophysics (6 CFU), Medical physics 1 (9 CFU), Spectroscopy algorithms (3 CFU).
- **"Biophysics for Flash (computational)" Pathway**: This pathway provides basic physical skills in computational biophysical mechanisms and techniques for studying the effects induced by Flash radiotherapy. Suggested courses: Biophysics for eflash therapy (9 CFU), Introduction to molecular biophysics (6 CFU), Medical physics 1 (9 CFU), Physics of matter and nanotechnology laboratory S (9 CFU) + Numerical methods in physics S (6 CFU).

PHYSICS OF GEOFLUIDS DYNAMICS & SOLID EARTH

Compulsory courses		39/45 CFU
I s	FISICA STATISTICA (FIS 02)	9 CFU
I s	GEOPHYSICAL INSTRUMENTATION AND GEOPHYSICAL POTENTIAL FIELDS (LM Expl. and Appl. Geo., cod 337BB) (FIS03)	6 CFU
I s	FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
II s	LABORATORY OF INSTRUMENTAL SEISMOLOGY (FIS 01)	9 CFU
II s	MECHANICS OF GEOPHYSICAL FLUIDS (FIS 06)	6 CFU
I s	ROCK PHYSICS (FIS 03) (LM Expl. and Appl. Geo., cod 346BB)	6 CFU
Alternative courses (at least two courses of the following)		12/24 CFU
I s	COMPLEX SYSTEMS (FIS 03)	9 CFU
I s	FLUIDODINAMICA COMPUTAZIONALE (ING-IND 06) (LM Ing. Aerospaziale, codice 454II)	6 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
I s	SIGNAL PROCESSING FOR PHYSICS (FIS 01)	6 CFU
II s	EARTHQUAKE SEISMOLOGY (GEO 11) (LM Expl. and Appl. Geo.)	6 CFU
II s	OCEANOGRAFIA FISICA SU GRANDE SCALA (FIS 03/06)	9 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

Note that the total number of CFU corresponding to non-FIS exams (including mandatory and elective courses) can be at most 24.

PHYSICS OF MATTER

An asterisk indicates courses borrowed from the Phd courses.

Compulsory courses		24 CFU
I s	FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
A	PHYSICS OF MATTER AND NANOTECHNOLOGY LABORATORY (FIS 01) (see note)	15 CFU
Alternative courses		33/36 CFU
(one couse in each of the following four groups)		
Astronomy and astrophysics group		
II s	ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s	ASTROPARTICLE PHYSICS S (FIS 05)	6 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s	STELLAR PHYSICS S (FIS 05)	6 CFU
Theoretical physics group		
I s	FISICA STATISTICA (FIS 02)	9 CFU
I s	FISICA TEORICA 1 (FIS 02)	9 CFU
Physics of matter 1		
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
I s	SOLID STATE PHYSICS (FIS 03)	9 CFU
Physics of matter 2		
I s	COMPLEX SYSTEMS (FIS 03)	9 CFU
I s	DISORDERED SYSTEMS OUT OF EQUILIBRIUM (FIS 03)	9 CFU
Elective courses		15/18 CFU
It is suggested in relation to the detailed course of study you intend to follow, to choose these CFUs from the courses indicated above or among the following		
I s	CHIMICA FISICA MOLECOLARE (CHIM 02)	9 CFU
I s	COMPLEX SYSTEMS (FIS 03)	9 CFU
I s	DISORDERED SYSTEMS OUT OF EQUILIBRIUM (FIS 03)	9 CFU
I s	FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
I s	INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
I s	MATERIAL OPTICAL SPECTROSCOPY (FIS 03)	6 CFU
I s	PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
I s	QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
I s	SOLID STATE PHYSICS (FIS 03)	9 CFU
II s	ATOM OPTICS (FIS 03)	9 CFU
II s	CELL BIOPHYSICS (FIS 03)	6 CFU
II s	CONDENSED MATTER PHYSICS (FIS 03)	9 CFU
II s	DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s	ENTANGLEMENT: ADVANCED THEORETICAL CONCEPTS AND APPLICATIONS IN QUANTUM TECHNOLOGIES (FIS 03)	3 CFU
II s	FLEXIBLE AND NANO-ELECTRONICS (FIS 03)	9 CFU
II s	KINETIC THEORY OF PLASMAS (FIS 03)	6 CFU
II s	NONLINEAR DYNAMICS (FIS 03)	9 CFU
II s	PHYSICS OF PHOTONIC DEVICES (FIS 03)	9 CFU
II s	QUANTUM LIQUIDS* (FIS 03)	9 CFU
II s	QUANTUM OPTICS AND PLASMA (FIS 03)	9 CFU
II s	QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU
II s	SPECTROSCOPY ALGORITHMS (FIS 03)	3 CFU
II s	SPECTROSCOPY AND MICROSCOPY OF NANOMATERIALS (FIS 03)	6 CFU
A	METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

Note: Alternatively to the course "Physics of Matter and Nanotechnology Laboratory" (15 CFU), it is possible to take the exam "Physics of Matter and Nanotechnology Laboratory S" (9 CFU) and at least two modules (for 6 CFU) of "Numerical Methods for Physics" (it is suggested to follow the modules "First-principles Calculations" and "Classical Molecular Dynamics").

PHYSICS OF THE UNIVERSE

Compulsory courses	39 CFU
II s ASTROPARTICLE PHYSICS (FIS 05)	9 CFU
A ASTROPHYSICS AND MULTIMESSENGER LABORATORY (FIS 01)	12 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
I s RELATIVITÀ GENERALE (FIS 02)	9 CFU
Alternative courses (one in each of the following three groups)	21/24/27 CFU
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
I s ASTROPHYSICAL PROCESSES (FIS 05)	9 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO S (FIS 05)	6 CFU
II s STELLAR PHYSICS S (FIS 05)	6 CFU
Physics of matter, nuclear and subnuclear physics group	
II s COMPACT STAR PHYSICS S (FIS 04)	6 CFU
I s FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
Experimental physics group	
I s ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
II s GRAVITATIONAL WAVE PHYSICS (FIS 01)	9 CFU
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
II s QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU
Elective courses	12/15 CFU
I s ADVANCED TECHNOLOGIES FOR GROUND-BASED ASTROPHYSICS: FROM MICROWAVES TO VISIBLE LIGHT (FIS 05)	6 CFU
I s EXPERIMENTAL METHODOLOGIES FOR ASTROPARTICLE PHYSICS (FIS 01)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s FUNDAMENTAL INTERACTIONS LABORATORY S (FIS 01)	9 CFU
I s INTRODUCTION TO NEUTRINO PHYSICS (FIS 04)	3 CFU
I s MULTIMESSENGER AND HIGH-ENERGY ASTROPHYSICS (FIS 01)	6 CFU
I s PARTICLE DARK MATTER (FIS 01)	6 CFU
I s PHYSICS OF STAR FORMATION (FIS 05)	6 CFU
I s PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s COMPACT STAR PHYSICS S (FIS 04)	6 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO (FIS 05)	9 CFU
II s DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s EXTRAGALACTIC ASTROPHYSICS AND COSMOLOGY (FIS 05)	9 CFU
II s FISICA TEORICA 2 (FIS 02)	9 CFU
II s GRAVITATIONAL WAVE PHYSICS (FIS 01)	9 CFU
II s GRAVITATIONAL WAVE PHYSICS S (FIS 01)	6 CFU
II s TEORIE DELLA GRAVITAZIONE (FIS 02)	9 CFU
II s TEORIE DELLA GRAVITAZIONE S (FIS 02)	6 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

Notes: for some specific educational paths within the Physics of the Universe plan, the following can be identified:

- Gravitational waves and compact objects: choose Compact star physics S (6 CFU), Gravitational wave physics (6 or 9 CFU), Teorie della Gravitazione (6 or 9 CFU)
- Cosmology and dark matter: choose Cosmologia del primo universo (9 CFU), Extragalactic astrophysics and cosmology (9 CFU), Particle dark matter (6 CFU)

PLASMA PHYSICS

Compulsory courses		42/48 CFU
I s	FISICA STATISTICA (FIS 02)	9 CFU
I s	FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s	FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
A	METODI NUMERICI PER LA FISICA S (FIS 01)	6 CFU
A	PHYSICS OF MATTER AND NANOTECHNOLOGY LABORATORY S (FIS 01)	9 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
At least two among the following		12/18 CFU
I s	COMPLEX SYSTEMS (FIS 03)	9 CFU
I s	FLUIDODINAMICA COMPUTAZIONALE (ING-IND 06) (LM Ing. Aerospaziale, codice 454II)	6 CFU
II s	KINETIC THEORY OF PLASMAS (FIS 03)	6 CFU
II s	MECHANICS OF GEOPHYSICAL FLUIDS (FIS 06)	6 CFU
Elective courses		9/21 CFU
I s	ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
I s	COMPUTING METHODS FOR EXPERIMENTAL PHYSICS AND DATA ANALYSIS S (FIS 01)	6 CFU
I s	DISORDERED SYSTEMS OUT OF EQUILIBRIUM (FIS 03)	9 CFU
I s	FISICA TEORICA 1 (FIS 02)	9 CFU
I s	INTRODUCTION TO MOLECULAR BIOPHYSICS (FIS 03)	6 CFU
I s	MACHINE LEARNING (INF 01) (LM Inf., 654AA)	9 CFU
I s	PHYSICS OF BIOSYSTEMS (FIS 03)	9 CFU
I s	QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
I s	SOLID STATE PHYSICS (FIS 03)	9 CFU
II s	ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s	ATOM OPTICS (FIS 03)	9 CFU
II s	COMPLEX SYSTEMS - NEURAL DYNAMICS (FIS 03)	9 CFU
II s	CONDENSED MATTER PHYSICS (FIS 03)	9 CFU
II s	NONLINEAR DYNAMICS (FIS 03)	9 CFU
II s	OCEANOGRAFIA FISICA SU GRANDE SCALA (FIS 03/06)	9 CFU
II s	QUANTUM OPTICS AND PLASMA (FIS 03)	9 CFU
II s	QUANTUM THERMODYNAMICS (FIS 03)	6 CFU
II s	STELLAR PHYSICS S (FIS 05)	6 CFU
–	STATISTICAL AND MACHINE LEARNING MODELS FOR TIME SERIES ANALYSIS (SNS)	6 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

QUANTUM COMPUTING AND TECHNOLOGIES

An asterisk indicates courses borrowed from the Phd courses.

Compulsory courses		18 CFU
I s	FISICA STATISTICA (FIS 02)	9 CFU
I s	QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
Alternative courses (at least one in any of the following three groups)		24 CFU
Astronomy and astrophysics group		
II s	ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
Physics of matter group		
I s	FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s	SOLID STATE PHYSICS (FIS 03)	9 CFU
Experimental physics group		
I s	ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
A	METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
A	PHYSICS OF MATTER AND NANOTECHNOLOGY LABORATORY S (FIS 01)	9 CFU
Elective courses All the courses offered as alternative courses may be used as elective courses in addition to the following courses:		33 CFU
I s	CHIMICA FISICA MOLECOLARE (CHIM 02)	9 CFU
I s	FISICA TEORICA 1 (FIS 02)	9 CFU
II s	ATOM OPTICS (FIS 03)	9 CFU
II s	CONDENSED MATTER PHYSICS (FIS 03)	9 CFU
II s	DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s	ENTANGLEMENT: ADVANCED THEORETICAL CONCEPTS AND APPLICATIONS IN QUANTUM TECHNOLOGIES (FIS 03)	3 CFU
II s	FISICA TEORICA 2 (FIS 02)	9 CFU
II s	MATERIALS AND DEVICES FOR NANOSCALE ELECTRONICS (ING-INF 01) (LM Mat and Nano)	9 CFU
II s	PHYSICS OF PHOTONIC DEVICES (FIS 03)	9 CFU
II s	QUANTUM LIQUIDS* (FIS 03)	9 CFU
II s	QUANTUM MACHINE LEARNING (FIS 03)	3 CFU
–	METHODS IN QUANTUM TECHNOLOGIES: THEORY AND APPLICATIONS (FIS 03) (SNS)	6 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

THEORETICAL PHYSICS

An asterisk indicates courses borrowed from the Phd courses, which may take place in periods other than the canonical I s and II s. It is suggested to contact the teachers for further information.

Compulsory courses	18 CFU
I s FISICA TEORICA 1 (FIS 02)	9 CFU
II s FISICA TEORICA 2 (FIS 02)	9 CFU
Two courses among the following	18 CFU
II s CROMODINAMICA QUANTISTICA (FIS 02)	9 CFU
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s FISICA STATISTICA (FIS 02)	9 CFU
I s RELATIVITÀ GENERALE (FIS 02)	9 CFU
Alternative courses	24 CFU
(one course in each of the following groups)	
Astronomy and astrophysics group	
II s ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
II s ASTROPARTICLE PHYSICS (FIS 05)	9 CFU
II s ASTROPARTICLE PHYSICS S (FIS 05)	6 CFU
I s ASTROPHYSICAL PROCESSES (FIS 05)	9 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO (FIS 05)	9 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO S (FIS 05)	6 CFU
I s PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s STELLAR PHYSICS (FIS 05)	9 CFU
II s STELLAR PHYSICS S (FIS 05)	6 CFU
Physics of matter, nuclear and subnuclear physics group	
(not necessary in case FISICA NUCLEARE has been selected before)	
I s COMPLEX SYSTEMS (FIS 03)	9 CFU
II s CONDENSED MATTER PHYSICS (FIS 03)	9 CFU
I s FISICA NUCLEARE (FIS 04)	9 CFU
I s FUNDAMENTAL OF LIGHT-MATTER INTERACTION (FIS 03)	9 CFU
I s FUNDAMENTAL INTERACTIONS (FIS 04)	9 CFU
I s QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
I s SOLID STATE PHYSICS (FIS 03)	9 CFU
Experimental physics group	
I s ANALISI STATISTICA DEI DATI (FIS 01)	9 CFU
A ASTROPHYSICS AND MULTIMESSENGER LABORATORY (FIS 01)	12 CFU
I s FUNDAMENTAL INTERACTIONS LABORATORY S (FIS 01)	9 CFU
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
A PHYSICS OF MATTER AND NANOTECHNOLOGY LABORATORY S (FIS 01)	9 CFU
Elective courses	15 CFU
Depending on the detailed course of study you intend to follow, it is suggested to choose between the remaining alternative courses and the following ones	
A METODI NUMERICI PER LA FISICA (FIS 01)	9 CFU
A METODI NUMERICI PER LA FISICA S (FIS 01)	6 CFU
I s ASPETTI NON PERTURBATIVI DELLE TEORIE DI CAMPO QUANTISTICHE* (FIS 02)	9 CFU
I s ASPETTI NON PERTURBATIVI DELLE TEORIE DI CAMPO QUANTISTICHE S* (FIS 02)	6 CFU
I s PARTICLE DARK MATTER (FIS 01)	6 CFU
II s COMPACT STAR PHYSICS S (FIS 04)	6 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO (FIS 05)	9 CFU
II s COSMOLOGIA DEL PRIMO UNIVERSO S (FIS 05)	6 CFU
II s GRAVITATIONAL WAVE PHYSICS (FIS 01)	9 CFU
II s QUANTUM THERMODYNAMICS (FIS 03)	6 CFU
II s TEORIE DELLA GRAVITAZIONE (FIS 02)	9 CFU
– EFFECTIVE FIELD THEORIES (FIS 02) (SNS)	6 CFU
– STANDARD MODEL AND BEYOND (FIS 02) (SNS)	6 CFU
Thesis work and dissertation	45 CFU
Total	120 CFU

THEORY OF QUANTUM MATERIALS

An asterisk indicates courses borrowed from the Phd courses.

Compulsory courses		33 CFU
I s	FISICA STATISTICA (FIS 02)	9 CFU
I s	FISICA TEORICA 1 (FIS 02)	9 CFU
A	METODI NUMERICI PER LA FISICA S (FIS 01)	6 CFU
I s	SOLID STATE PHYSICS (FIS 03)	9 CFU
Alternative courses (one in each of the following groups):		15/18 CFU
Astronomy and astrophysics group		
II s	ASTROFISICA GENERALE (FIS 05) (if not already taken in bachelor)	6 CFU
I s	PLASMA PHYSICS (FIS 03/FIS 05)	9 CFU
II s	STELLAR PHYSICS S (FIS 05)	6 CFU
Physics of matter group		
II s	CONDENSED MATTER PHYSICS (FIS 03)	9 CFU
II s	QUANTUM LIQUIDS* (FIS 03)	9 CFU
Elective courses		at least 24 CFU
I s	COMPLEX SYSTEMS (FIS 03)	9 CFU
I s	FLUIDODYNAMICS (FIS 03) (if not already taken in bachelor)	6 CFU
I s	QUANTUM COMPUTING AND TECHNOLOGIES (FIS 03)	9 CFU
II s	CONDENSED MATTER PHYSICS (FIS 03)	9 CFU
II s	DETECTION TECHNIQUES: FROM LAB TO SPACE (FIS 01)	9 CFU
II s	ENTANGLEMENT: ADVANCED THEORETICAL CONCEPTS AND APPLICATIONS IN QUANTUM TECHNOLOGIES (FIS 03)	3 CFU
II s	FISICA TEORICA 2 (FIS 02)	9 CFU
II s	FLEXIBLE AND NANO-ELECTRONICS (FIS 03)	9 CFU
II s	QUANTUM LIQUIDS* (FIS 03)	9 CFU
II s	QUANTUM TECHNOLOGIES FOR FUNDAMENTAL INTERACTION PHYSICS (FIS 01)	9 CFU
II s	QUANTUM THERMODYNAMICS (FIS 03)	6 CFU
–	METHODS IN QUANTUM TECHNOLOGIES: THEORY AND APPLICATIONS (FIS 03) (SNS)	6 CFU
Thesis work and dissertation		45 CFU
Total		120 CFU

Note: For the course "Numerical Methods for Physics S", the modules "First-principles Calculations" and "Classical Molecular Dynamics" must be completed. It is also possible to choose "Numerical Methods for Physics" worth 9 CFU, in which case an additional module must be added to the two mandatory ones.

FREE STUDY PLAN

A free PdS must contain at least 6 CFUs of teaching in the areas: FIS01, FIS02, FIS03 or FIS04 and FIS05. In addition, the PdS must respect some very general constraints in terms of CFUs related to characterizing and supplementary related courses, as well as include 45 CFUs for the final examination.

The easiest way to compose a free PdS is to start from one of the suggested PdS, substituting some of the exams for others, to obtain a PdS that meets the administrative requirements and composes a complete and coherent course.

When submitting a free PdS it is required to justify the choice with a comment in CAPS. Approval of the PdSI will be based on the appropriateness of the proposed set of courses, which should consist of a set of teachings that not only meet the general rules but also form a complete and coherent pathway. In particular make sure to respect propedeuticities and make sure not to have teachings with redundant programs.