Annexe B1 (academic year 2023/2024)

Training paths description:

Curriculums and study plan

The Joint Master's Degree in Physics teaching offer includes 6 curriculums and their related study plans. In this document, you will find:

1. The structure of curriculums established by the teaching offer with the distribution of the ECTS by type, by field and by Scientific-Disciplinary Sector (SDS);
2. The Curriculums with:
    a. their training purposes;
    b. a table for preparing the standard study plan, with the possible choices of courses and their time schedule;
    c. further indications for standard study plans.

Standard study plans are automatically approved and are designed in the interests of students to provide a balanced educational offer between basic and specialist preparation. For these study plans, we try to ensure that lesson times do not overlap. Individual study plans, whose characterising (TAF B) and related (TAF C) teachings differ from those that are present in standard study plans, are feasible. However, such individual study plans have to:

- respect the ECTS limits established by the degree course regulations;
- be adequately justified by the student;
- be examined by the Teaching Commission, which evaluates its coherence;
- and be eventually approved by the Joint Master's Degree Course Council.

Except for the curriculum in Quantum Sciences and Technologies, study plans have to contain at least one teaching from SDS FIS/03 and at least one teaching from SDS FIS/04. This rule also applies to individual plans.

According to regulations in force, the total number of credits for obtaining the qualification is 120, distributed as described below:

- a number between 40 and 96 ECTS of characterising activities (TAF B), distributed as follows:
    - between 6 and 24 ECTS in the Experimental Application field;
    - between 6 and 24 ECTS in the Theoretical and Fundamentals of Physics field;
    - between 6 and 24 ECTS in the field of Microphysics and the Structure of Matter;
    - between 6 and 24 ECTS in the Astrophysics, Geophysics and Space fields;
- a number between 15 and 21 ECTS of Master’s Degree-related activities or supplementary training activities (TAF C);
- A number between 46 and 66 ECTS of Other Activities (TAF D/E/F), distributed as follows:
    - between 9 and 12 ECTS of free-choice activities;
    - between 35 and 40 ECTS for the final exam;

- between 0 and 3 ECTS of further linguistic knowledge;
- between 0 and 3 ECTS of IT and telematic skills;
- between 2 and 6 ECTS of training and orientation internships;
- between 0 and 2 ECTS of other knowledge useful for entering the world of work.

1. Structure of curriculums

The subdivision credits for the different training activities of each curriculum is shown below, in tabular format.

The type of training activities (TAF for short, from the Italian *Tipologie di Attività Formative*) are

- characterising activities; TAF B
- master's degree-related activities; TAF C
- free-choice activities; TAF D
- final exam; TAF E
- further activities; TAF F

Curriculum of Physics of Matter

Type of activity (TAF)	Fields	Scientific-Disciplinary (SDS)	Sector	ECTS
B	Experimental application field	FIS/01, FIS/07		6
	Theoretical and Fundamentals of Physics field	FIS/02		6
	Field of Microphysics and the Structure of matter	FIS/03, FIS/04		24
	Astrophysics, Geophysics and Space field	FIS/05, FIS/06, GEO/10, GEO/12		6
C	Master's degree-related activities			18
D	Free-choice activities			12
E	Final exam			40
F	Internship			5
F	IT tools for Physics			3

Curriculum of Nuclear and Subnuclear Physics

Type of activity (TAF)	Fields	Scientific-Disciplinary (SDS)	Sector	ECTS
B	Experimental application field	FIS/01, FIS/07		12
	Theoretical and Fundamentals of physics field	FIS/02		6
	Field of Microphysics and the Structure of matter	FIS/03, FIS/04		18
	Astrophysics, Geophysics and Space fields	FIS/05, FIS/06, GEO/10, GEO/12		6
C	Master's degree-related activities			21
D	Free-choice activities			12
E	Final exam			40
F	Internship			5

Curriculum of Theoretical Physics

Type of activity (TAF)	Fields	Scientific-Disciplinary (SDS)	Sector	ECTS
B	Experimental application field	FIS/01, FIS/07		6
	Theoretical and Fundamentals of physics field	FIS/02		18
	Field of Microphysics and the Structure of matter	FIS/03, FIS/04		12
	Astrophysics, Geophysics and Space fields	FIS/05, FIS/06, GEO/10, GEO/12		6
C	Master's degree-related activities			21
D	Free-choice activities			12
E	Final exam			40
F	Internship			5

Curriculum of Environmental and Inter-disciplinary Physics

Type of activity (TAF)	Fields	Scientific-Disciplinary (SDS)	Sector	ECTS
B	Experimental application field	FIS/01, FIS/07		12
	Theoretical and Fundamentals of physics field	FIS/02		6
	Field of Microphysics and the Structure of matter	FIS/03, FIS/04		12
	Astrophysics, Geophysics and Space fields	FIS/05, FIS/06, GEO/10, GEO/12		12
C	Master's degree-related activities			18
D	Free-choice activities			12
E	Final exam			40
F	Internship			5
F	IT and telematic abilities			3

Curriculum of Astrophysics and Cosmology

Type of activity (TAF)	Fields	Scientific-Disciplinary (SDS)	Sector	ECTS
B	Experimental application field	FIS/01, FIS/07		6
	Theoretical and Fundamentals of physics field	FIS/02		6
	Field of Microphysics and the Structure of matter	FIS/03, FIS/04		12
	Astrophysics, Geophysics and Space fields	FIS/05, FIS/06, GEO/10, GEO/12		18
C	Master's degree-related activities			18
D	Free-choice activities			12
E	Final exam			40
F	Internship			5
F	IT and telematic abilities			3

Curriculum of Quantum Sciences and Technologies

Type of activity (TAF)	Fields	Scientific-Disciplinary (SDS)	Sector	ECTS
B	Experimental application field	FIS/01, FIS/07		6
	Theoretical and Fundamentals of physics field	FIS/02		24
	Field of Microphysics and the Structure of matter	FIS/03, FIS/04		6
	Astrophysics, Geophysics and Space fields	FIS/05, FIS/06, GEO/10, GEO/12		6
C	Master's degree-related activities			18
D	Free-choice activities			12
E	Final exam			40
F	Internship			5
F	IT and telematic abilities			3

2. Curriculums and study plans

2.1 Curriculum of Physics of Matter

Teaching purposes

The curriculum of Physics of Matter aims to train and give graduates a sound cultural knowledge of the physics of experimental and/or theoretical-computational matter. In general, this curriculum allows graduates to have an overview of the current problems in various sectors of the Physics of Matter, such as classical disordered systems, topological materials, electronic models with strong correlation, atomic or molecular systems at low temperatures, the physics of surfaces and nanomaterials. Different paths, which are focused on experimental techniques or theoretical-computational methods and which lead to a scientific preparation in the disciplines that characterise this curriculum, are available.

The **experimental path** allows graduates to obtain:

- an in-depth knowledge of modern measurement instruments and data analysis techniques for systems of interest for condensed matter physics;
- familiarity with laboratory instrumentation and techniques;
- the ability to use mathematical and IT support tools.

The **theoretical-computational path** allows graduates to obtain:

- an in-depth knowledge of cutting-edge numerical techniques in order to deal with significant classical and quantum systems in condensed matter physics;
- familiarity with the use of high-performance scientific calculations;
- an ability to use the assimilated specific knowledge for the modelling of complex physical systems,

The **mixed path** allows graduates to have an overview of the two previous paths and to assimilate both experimental and theoretical-computational techniques in order to obtain a broad understanding of the variety of aspects in the physics of matter.

All paths allow graduates to obtain a high ability to work independently and to participate in scientific collaborations at both national and international level. The preparation will allow graduates to continue their educational development in a PhD in Physics or in similar disciplines, with a view to a possible entry into the world of research. Alternatively, graduates will have the tools to enter the sectors of technological or IT industry. In particular, the curriculum of Physics of Matter train students in scientific innovation developing activities, as well as in management and design of technologies in fields related to the Physics of Matter disciplines. Lastly, graduates will acquire the skills necessary to write scientific and educational texts, even in English.

Physics of Matter – Courses 1st year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Condensed Matter Physics I	FIS/03	B	6	Principles of Astrophysics and Cosmology	FIS/05	B	6
Field theory I *or* Statistical mechanics	FIS/02	B	6	Condensed Matter Physics II	FIS/03	B	6
Condensed Matter Physics Laboratory *or* Computational Physics Laboratory	FIS/01	B	6	Nanomaterials Physics Laboratory *or* Atomistic and Molecular Simulations Laboratory *or* Introduction to Quantum Many-Body Systems	FIS/03	B	6
1st Master's degree-related course*		C	6	2nd Master's degree-related course*		C	6
IT Tools for Physics		F	3	1st Free-choice activity**		D	6
Total number of credits in the first year							57
2nd year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
3rd Master's degree-related course*		C	6	Thesis		E	30
2nd Free-choice activity**		D	6				
Symmetry and Fundamental interaction	FIS/04	B	6				
Internship		F	5				
Thesis		E	10				
Total number of credits in the second year							63

***Master's degree-related courses – Curriculum offer**

- 1st year, 1st semester
  - Synchrotron Radiation Applications (FIS/03);
  - Phase Transition and Critical Phenomena (FIS/03);
  - Atmos, Molecules and Photons (FIS/03);
- 1st year, 2nd semester
  - Numerical Methods for the Electronic Structure (FIS/03);
  - Principles of Surface Physics (FIS/03);
  - Low Dimensional Non-Conventional Electronic States (FIS/03);
  - Disorganised Systems Physics (FIS/03);
- 2nd year, 1st semester
  - Image Formation and Analysis in Physics (FIS/07);

****Free-choice courses with automatic approval – Curriculum offer**

- 1st year, 2nd semester
  - Nanostructures (FIS/03);
- 2nd year, 1st semester
  - Photonics (FIS/03)

- Classical Simulations of Many-Body Systems (FIS/03);
- Experimental Biophysics (FIS/07);

****Free-choice courses with automatic approval – Courses from other curriculums**

- Quantum Liquids (FIS/02) (2nd semester, 1st year);
- Advanced Quantum Mechanics (FIS/02) (1st semester, 1st year).

Standard study plans, with the choices of courses as indicated above, are automatically approved. As "free-choice courses", it is also possible to select characterising (TAF B) or Master's degree-related (TAF C) courses of this or other curriculums, with the condition they are not already included in the study plan as such, or courses offered by other study courses of the University. If not listed courses are chosen, the study plan will be examined by the Teaching Commission, considering feasibility and coherence of such courses with the training programme, and will be eventually approved by the Joint Master's Degree Course Council.

Example of an experimental path study plan

- Condensed Matter Physics Laboratory;
- Nanomaterials Physics Laboratory;
- 1st Related course: Synchrotron Radiation Applications *or* Atmos, Molecules and Photons;
- 2nd Related course: Principles of Surface Physics;
- 3rd Related Course: Image Formation and Analysis in Physics;
- 1st Free-choice course: Nanostructures *or* Quantum Liquids;
- 2nd Free-choice course: Photonics *or* Experimental Biophysics;

Example of a theoretical-computational path study plan

- Computational Physics Laboratory;
- Atomistic and Molecular Simulations Laboratory *or* Introduction to Quantum Many-Body Systems;
- 1st Related course: Phase Transition and Critical Phenomena *or* Atmos, Molecules and Photons;
- 2nd Related course: Numerical Methods for the Electronic Structure *or* Low Dimensional Non-Conventional Electronic States;
- 3rd Related course: Disorganised Systems Physics;
- 1st Free-choice course: Nanostructures *or* Quantum Liquids;
- 2nd Free-choice course: Classical Simulations of Many-Body Systems *or* Advanced Quantum Physics;

A mixed theoretical-experimental study plan is also possible, with courses selected from those of the two previous paths.

2.2 Curriculum of Nuclear and Subnuclear Physics

Teaching purposes

The curriculum of Physics of Matter aims to train and give graduates:

- a sound cultural preparation in the field of nuclear and subnuclear theoretical-phenomenological and/or experimental-practical physics;
- an in-depth knowledge of modern measurement instruments and of data analysis techniques;
- an in-depth knowledge of mathematical and IT support tools;
- a high scientific and operative preparation in the disciplines that characterise this curriculum;
- a high familiarity with laboratory instruments and techniques;
- skills to use fluently the English language, in both written and oral form, in addition to the Italian, and possibly another European Union language, also with reference to disciplinary lexicons;
- skills to both work independently and take part in national and international scientific collaborations, taking on responsibilities for projects and structures;
- skills to use assimilated specific knowledge for the modelling of complex physical systems and in the field of applied sciences.

Master's graduates in Nuclear and Subnuclear Physics will have the necessary preparation to carry out activities in the following fields: promotion and development of scientific and technological innovation; management and design of technologies in fields related to nuclear and subnuclear physics disciplines and in the sectors of industry, environment, healthcare, cultural heritage, and public administration; the high-level divulgation of scientific culture with particular reference to the experimental and applicative aspects of nuclear and subnuclear physics. Graduates will also have excellent preparation to undertake a PhD both in Italy and abroad.

Nuclear and Subnuclear Physics– Courses 1st year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Condensed Matter Physics I	FIS/03	B	6	Cosmology I *or* Principles of Astrophysics and Cosmology	FIS/05	B	6
Field Theory I	FIS/02	B	6	General Characteristics of Detectors	FIS/01	B	6
Symmetry and Fundamental Interaction	FIS/04	B	6	Data Acquisition and Control Laboratory	FIS/01	B	6
1st Master's degree-related course*		C	6	Nuclear Physics	FIS/04	C	6
				2nd Master's degree-related course*		C	6
1st Free-choice activity**						D	6
Total number of credits in the first year							60
2nd year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
3rd Master's degree-related course: Nuclear and Subnuclear Physics Laboratory	FIS/04	C	9	Thesis		E	30
2nd Free-choice activity**		D	6				
Internship		F	5				
Thesis		E	10				
Total number of credits in the second year							60

NB. Cosmology I requires passing General Relativity I.

***Master's degree-related courses – Curriculum offer**

- 1st semester
  - Advanced Statistics for Physics (FIS/01), 6 ECTS;
  - Advanced Programming and Simulation Techniques for Physics (FIS/01), 6 ECTS;
  - Gravitational Waves (FIS/01), 6 ECTS;
- 1st year, 1st semester
  - Principles of Medical Physics (FIS/07), 6 ECTS;
  - Semiconductor Detector and Devices for Nuclear and Subnuclear Physics (FIS/04), 6 ECTS;
- 1st year, 2nd semester
  - Medical Physics Laboratory (FIS/07), 6 ECTS;
  - Nuclear and Subnuclear Physics (FIS/04), 6 ECTS;
  - Nuclear and Subnuclear Astrophysics (FIS/04), 6 ECTS;
- 2nd year, 1st semester
  - Nuclear and Subnuclear Physics Laboratory (FIS/04), 9 ECTS;
  - Nuclear and Subnuclear Experimental Physics (FIS/04), 6 ECTS.

****Free-choice courses – Curriculum offer**

- Advanced Optics (FIS/04), 6 ECTS, 1st year 2nd semester.

****Free-choice courses (ECTS) – Courses from other curriculums**

- Image Formation and Analysis in Physics (FIS/07), 1st semester;
- General Relativity I (FIS/02), 1st semester;
- Synchrotron Radiation Applications (FIS/03), 1st year, 1st semester;
- Electroweak and Strong Interactions Dynamics (FIS/02), 2nd year, 1st semester.

Automatically approved standard study plans

a – Particle Physics path

- 1st Master's degree-related course: Advanced Statistics for Physics;
- 2nd Master's degree-related course: Standard Model of Fundamental Interactions;
- 2 courses to be chosen among the following activities:
    - Semiconductor Detector and Devices for Nuclear and Subnuclear Physics;
    - Advanced Programming and Simulation Techniques for Physics;
    - Advanced Optics;
    - General Relativity I;
    - Electroweak and Strong Interactions Dynamics;
    - Nuclear and Subnuclear Experimental Physics;

b – Astroparticle Physics path

- 1st Master's degree-related course: Gravitational waves;
- 2nd Master's degree-related course: Nuclear and Subnuclear Astrophysics;
- 2 courses to be chosen among the following activities:
    - Advanced Statistics for Physics;
    - Advanced Programming and Simulation Techniques for Physics;
    - Advanced Optics;
    - General Relativity I;
    - Standard Model of Fundamental Interactions;

c – Medical Physics path

- 1st Master's degree-related course: Principles of Medical Physics;
- 2nd second Master's degree-related course: Medical Physics Laboratory;
- 2 courses to be chosen among the following activities:
    - Advanced Statistics for Physics;
    - Advanced Programming and Simulation Techniques for Physics;
    - Image Formation and Analysis in Physics;
    - Semiconductor Detector and Devices for Nuclear and Subnuclear Physics;
    - Synchrotron Radiation Applications;

Standard study plans, with the choices of courses as indicated above, are automatically approved. As "free-choice courses", it is also possible to select characterising (TAF B) or Master's degree-related (TAF C) courses of this or other curriculums, with the condition they are not already included in the study plan as such, or courses offered by other study courses of the University. If not listed courses are chosen, the study plan will be examined by the Teaching Commission, considering feasibility and coherence of such courses with the training programme, and will be eventually approved by the Joint Master's Degree Course Council.

2.3 Curriculum of Theoretical Physics

Teaching Purposes

The curriculum of Theoretical Physics aims to train and give graduates:

- an overview of current frontier issues in various sectors of research in theoretical physics, from elementary particle physics to the more formal aspects of quantum field theory, from the new frontiers of quantum physics to the most recent developments in theories of gravitation and study of complex systems;
- a high ability to master abstract theoretical formulations and produce concrete modelling of physical systems;
- a sound knowledge of advanced mathematical methods and mathematical support tools;
- a high scientific and operational preparation in the disciplines that characterize this Master's degree
- an adequate knowledge of modern measurement instruments and data analysis techniques;
- skills to use fluently the English language, in both written and oral form, in addition to the Italian, and possibly another European Union language, also with reference to disciplinary lexicons
- a good ability to tackle new problems and to propose solutions;
- a high ability to both work independently and participate in scientific collaborations extended at both the national and international level;

Those who obtain the Master's degree in Theoretical Physics will be prepared to carry out high-level activities such as research and development in the public and private sectors on topics ranging from fundamental physics to complex systems. They will also be able to find employment in the growing sector of scientific culture divulgation and in the transfer of advanced knowledge. They will also have a solid preparation to undertake a PhD both in Italy and abroad.

Theoretical Physics– Courses 1st year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Field theory I	FIS/02	B	6	Field Theory II *or* Introduction to Quantum Information	FIS/02	B	6
Symmetry and fundamental interaction	FIS/04	B	6	Introduction to Quantum Many-Body Systems	FIS/03	B	6
General relativity I *or* Statistical Mechanics	FIS/02	B	6	Cosmology I	FIS/05	B	6
Condensed Matter Physics Laboratory *or* Computational Physics Laboratory	FIS/01	C	6	1st Master's degree-related course*		C	6
Complements of Field Theory (2nd semester) *or* Quantum Mechanics and Special Relativity (1st semester)					FIS/02	C	3
2nd Master's degree-related course*						C	6
1st Free-choice activity**						D	6
Total number of credits in the first year							63
2nd year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
2nd Free-choice activity**		D	6	Thesis		E	30
3rd Master's degree-related course*		C	6				
Internship		F	5				
Thesis		E	10				
Total number of credits in the second year							57

NB Cosmology I requires passing General Relativity I.

Study plans containing related courses (TAF C) and free-choice courses (TAF D) among those indicated below are automatically approved.

***Related courses (TAF C)**

The two groups contain homogeneous courses in relation to the training offer; the first one covers the field of Quantum and Statistical Mechanics, the second one focuses on the field of Field Theories and Elementary Particles.

Group 1: Statistical and Quantum Mechanics

- 1st semester
  - Advanced Quantum Mechanics (FIS/02), 6 ECTS;
  - Quantum Physics and Special Relativity (FIS/02), 6 ECTS;
- 1st year 1st semester
  - Statistical Mechanics (FIS/02), 6 ECTS;
- 1st year 2nd semester
  - Introduction to Quantum Information (FIS/02), 6 ECTS;
  - Quantum Liquids (FIS/02), 6 ECTS;

Group 2: Fields and Particles

- 1st semester
  - Statistical Mechanics, 1st or 2nd year, (FIS/02), 6 ECTS;
- 1st year, 2nd semester
  - Field Theory II (FIS/02), 6 ECTS;
  - Complements of Field Theory (FIS/02), 3 ECTS;
  - Standard Model of Fundamental Interactions (FIS/02), 6 ECTS;
  - Particle Physics and Cosmology (FIS/02), 6 ECTS;
- 2nd year, 1st semester
  - Field Theory III (FIS/02), 6 ECTS;
  - Electroweak and strong Interactions Dynamics (FIS/02), 6 ECTS;
  - General Relativity II (FIS/02), 6 ECTS;

****Free-choice courses (TAF D) – Curriculum offer**

- Quantum Algorithms in Open Quantum Systems, 1st year 1st semester (FIS/02), 6 ECTS;

****Free-choice courses (TAF D) – Courses from other curriculums**

- 1st semester
  - Atoms, Molecules and Photons (FIS/03), 6 ECTS;
  - Advanced Geometry 1 (MAT/03), 6 ECTS;
  - Advanced Geometry 2 (MAT/03), 6 ECTS;
- 2nd year, 1st semester
  - Phase Transition and Critical phenomena (FIS/03), 6 ECTS;
  - Cosmology II (FIS/05), 6 ECTS;

Related courses indicated in the two baskets also contribute to constitute the free-choice courses.

2.4 Curriculum of Environmental and Inter-disciplinary Physics

Teaching purposes

This curriculum of Environmental and Inter-disciplinary Physics aims to train and give graduates:

- a sound cultural preparation in theoretical-phenomenological and/or experimental-applicative environmental physics;
- an in-depth knowledge of modern measurement instruments and of data analysis techniques;
- an in-depth knowledge of mathematical and IT support tools;
- a high scientific and cultural preparation in the disciplines that characterise this Master's degree;
- a high familiarity with laboratory instruments and techniques;
- skills to use fluently the English language, in both written and oral form, in addition to the Italian, and possibly another European Union language, also with reference to disciplinary lexicons;
- skills to work independently, taking on responsibilities for projects and structures;
- specific knowledge for the modelling of complex physical systems and in the field of applied sciences with particular focus on environmental physics.

Master's degree students in Environmental and Inter-disciplinary Physics will carry out activities on the following fields:

- promotion and development of scientific and technological innovation, as well as the management and design of technologies in fields related to terrestrial, environmental and circumterrestrial means physics disciplines;
- in the sectors of industry, healthcare, cultural heritage and public administration;
- the high-level divulgation of scientific culture with particular focus on the experimental and applied aspects of terrestrial and environmental physics (e.g. the management of natural risks).

Graduates will also have excellent preparation to undertake a PhD both in Italy and abroad.

Environmental and Inter-disciplinary Physics– Courses 1st year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Field Theory I *or* Statistical Mechanics	FIS/02	B	6	Atmospheric Physics	FIS/06	B	6
Condensed Matter Physics I	FIS/03	B	6	Nuclear Physics	FIS/04	B	6
Computational Physics Laboratory	FIS/01	B	6	Principles of Astrophysics and Cosmology	FIS/05	B	6
1st Master's degree-related activity*: Methods of Potential *From the Master's degree in Geophysics and Geodata*	GEO/10	C	6	2nd Master's degree-related activity*: Fluid Dynamics and Geophysics	FIS/06	C	6
1st Free-choice activity**		D	6	2nd Free-choice activity**		D	6
Total number of credits in the first year							60
2nd year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Spatial Astrophysics Laboratory *or* Condensed Matter Physics Laboratory	FIS/01	B	6	Thesis		E	30
3rd Master's degree-related activity*: Climate Dynamics		C	6				
IT and telematic skills		F	3				
Internship		F	5				
Thesis		E	10				
Total number of credits in the second year							60

***Master's degree-related activities (1st, 2nd and 3rd)**

Curriculum offer

- Fluid Dynamics and Geophysics (FIS/06), 1st year, 2nd semester;
- Climate Dynamics (FIS/06), 2nd year, 1st semester;

Courses from other curriculums and degrees

- Methods of Potential (GEO/10) 2nd year, 1st semester;

Other related activities

- Introduction to Astrophysics (FIS/05), 1st semester, 1st year;
- Electronic Devices Physics (FIS/01), 1st semester, 1st year;
- Radioprotection in Environmental and Work Field (FIS/07), 2nd semester (6 ECTS);

****Free-choice courses with automatic approval**

Curriculum offer

- Quantitative Methods for Finance (FIS/02), 1st year, 2nd semester, 6 ECTS;

Courses from other curriculums and degrees

- Meteorology and Climatology of Space (FIS/05), 2nd semester, 6 ECTS;
- Experimental Biophysics (FIS/07), 1st semester, 6 ECTS;
- Seismology (GEO/10), 1st year 2nd semester, 6 ECTS, *from the Master's Degree in Geophysics and Geodata*;

Notes

1. Study plans that contain courses chosen among those indicated above are automatically approved. As "free-choice courses" it is also possible to select Characterising (TAF B) or Related (TAF C) courses of this or other curriculums, with the condition they are not already included in the study plan as such, or courses offered by other study courses of the University. If not listed courses are chosen, the study plan will be examined by the Teaching Commission, considering feasibility and coherence of such courses with the training programme;
2. Choosing "Introduction to Astrophysics (FIS/05)" is permitted exclusively in an individual study plan that does not already feature a Characterising FIS/05 course (in particular "Principles of Astrophysics and Cosmology", contemplated in the Standard Study Plan, within the ECTS reserved for the field of Astrophysics, Geophysics and Space (FIS/05, FIS/06, GEO/10, GEO/12)).

2.5 Curriculum of Astrophysics and Cosmology

Teaching purposes

The curriculum of Astrophysics and Cosmology aims to train and give graduates:

- an excellent mastery of investigation scientific method;
- a sound basic knowledge of classical and modern physics;
- an in-depth preparation in modern astrophysics and cosmology;
- an advanced knowledge of modern observation and data collection tools and of their related analysis techniques;
- an in-depth knowledge of mathematical and IT support tools;
- a high operative and scientific ability in the disciplines that characterise this field of studies;
- skills to use fluently the English language, in both written and oral form, in addition to the Italian, and possibly another European Union language, also with reference to disciplinary lexicons
- a broad autonomy in their work, which also enables them to assume responsibility for projects and structures;
- skills to use their specific knowledge for the modelling of complex physical systems and in the field of applied sciences.

The preparation offered by this degree will allow students to continue their educational path by undertaking a PhD in Physics, in Astronomy or in other similar disciplines, with the aim of a possible entering in the world of fundamental research in universities or research institutions. More generally, this preparation will allow students to enter work activities in the world of industry and tertiary sector that require high level knowledge, broad autonomy and coordination skills. Among the activities graduates specialised in this sector will be able to do, we highlight:

- promotion and development of scientific and technological innovation in the field of astrophysics, cosmology and space as well as management and design of their related technologies;
- design in fields related to astrophysics, cosmology and space disciplines in the sectors of industry, environment, cultural heritage and public administration;
- high-level astrophysics and astronomical divulgation as well as organization and management of educational projects and the diffusion of scientific culture;

Astrophysics and Cosmology– Courses 1st year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Astrophysics of Galaxies	FIS/05	B	6	Cosmology I	FIS/05	B	6
General Relativity I *or* Field Theory I	FIS/02	B	6	1st Master's degree-related activity*	FIS/05	C	6
Atoms, Molecules and Photons	FIS/03	B	6	2nd Master's degree-related activity*	FIS/05	C	6
Stellar astrophysics	FIS/05	B	6	1st Free-choice activity**		D	6
IT and telematic skills		F	3				
2nd Free-choice activity**						D	6
Total number of credits in the first year							57
2nd year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Spatial Astrophysics Laboratory *or* Advanced Programming for Astrophysics Laboratory	FIS/01	B	6	Thesis		E	30
3rd Master's degree-related activity*	FIS/05	C	6				
Symmetry and Fundamental Interactions	FIS/04	B	6				
Internship		F	5				
Thesis		E	10				
Total number of credits in the second year							63

NB Cosmology I requires passing General Relativity I

Study plans automatically approved

Standard study plans have to contain at least 2 laboratories. Moreover, such plans have to satisfy the following rules:

- 1st and 2nd related activities are chosen from the group of curriculum offer of activities that will be held during 2nd semester of the 1st year;
- 3rd related activity is chosen from the group of curriculum offer of activities that will be held during 1st semester of the 1[2nd] year;
- The two free-choice activities are chosen from the group of curriculum offer or among the activities from other curriculums or degrees (see *Free-choice activities* below for more details).

***Related activities – Curriculum offer of FIS/05 activities with 6 ECTS, which will be held during the 2nd semester of the 1st year (1st and 2nd activities)**

- Astronomical Technologies Laboratory;
- Radioactive Processes;
- Observational Cosmology;
- Radio Astronomy;
- Meteorology and Climatology of Space;
- Astrophysics of Compact Objects;

***Related activities – Curriculum offer of FIS/05 activities with 6 ECTS, which will be held during the 1st semester of the 2nd year (3rd activity)**

- Cosmology II;
- Planets and Astrobiology;

****Free-choices activities**

As "free-choice courses" it is possible to select Characterising or Related courses of this or other curriculums, with the condition they are not already included in the study plan as such, or courses offered by other study courses of the University. If Characterising or Related courses offered by the curriculum are chosen or if one of the courses offered by other curriculums and present in the list below is chosen, the study plan is automatically approved. In the case of other choices, the study plan will be approved by the Teaching Commission, considering feasibility and coherence of such courses with the training programme.

Courses from other curriculums (all with 6 ECTS)

- Nuclear and Subnuclear Astrophysics (FIS/04), 2nd semester;
- Gravitational Waves (FIS/01), 1st semester;
- Particle Physics and Cosmology (FIS/02), 1st year 2nd semester.

2.6 Curriculum of Quantum Sciences and Technologies

Teaching purposes

This curriculum aims to train and give graduate:

- an overview of current frontier issues related to quantum systems-based information manipulation, to metrology, and to classical and quantum systems simulation;
- a high ability to understand and describe the use of quantitative platforms in fields such as computation, machine learning, communication and information theory;
- a sound knowledge of quantum systems physics used in information manipulation, in metrology, and in the simulation of the theoretical modelling relating to the concrete use of such systems;
- an in-depth knowledge of mathematical and IT support tools;
- a high level of scientific and operational preparation in the disciplines that characterize this degree;
- an adequate knowledge of modern measurement instruments and data analysis techniques;
- the ability to use fluently the English language, in both written and oral form, in addition to Italian, and possibly another European Union language, also with reference to disciplinary lexicons
- a good ability to tackle new problems and propose solutions;
- a high ability to both work independently and participate in scientific collaborations at national and international level.

Master's degree students will be prepared to carry out high-level activities such as research and development in the public and private sector on topics ranging from computation to quantum communication and information. Therefore, Students they will respond to the ever-increasing demand for people with quantum skills who know how to fit into the so-called second industrial revolution. They will also have a sound preparation to undertake a PhD both in Italy and abroad.

1quantum Technologies and Sciences– Courses 1st year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Advanced Quantum Mechanics	FIS/02	B	6	Introduction to Quantum Information	FIS/02	B	6
Atoms, Molecules and Photons	FIS/03	B	6	Quantum Metrology	FIS/02	B	6
Computational Physics Laboratory *or* Condensed Matter Physics Laboratory	FIS/01	B	6	2nd Master's degree-related activity: Quantum Liquids	FIS/02	C	6
IT and telematic skills		F	3	3rd Master's degree-related activity Algorithmic Design *From the Master's degree in Mathematics* *or* Stochastic Modelling and Simulation *From the Master's degree in Electronic and IT Engineering*	INF/01	C	6
1st Master's degree-related activity: Introduction to Machine Learning *From the Master's degree in Electronic and IT Engineering*	ING-ING/03	C	6	1st Free-choice activity**: Nanostructures *or* Introduction to Quantum Many-Body Systems	FIS/03	D	6
Total number of credits in the first year							57
2nd year							
1st semester	SDS	TAF	ECTS	2nd semester	SDS	TAF	ECTS
Methods of Potential *From the Master's degree in Geophysics and Geodata*	GEO/10	B	6	Thesis		E	30
Quantum Calculus Algorithms	FIS/02	B	6				
2nd Free-choice activity**: Errors Corrective Codes *From the Master's degree in Electronic and IT Engineering* *or* Quantum Informatics and Software *From the Master's degree in Scientific and Data-Intensive Computing*	ING-INF/05 INF/01	D	6				
Internship		F	5				
Thesis		E	10				
Total number of credits in the second year							63

****Free-choice courses from other curriculums**

- 1st year 1st semester
    - Statistical Mechanics (FIS/02), 6 ECTS;
    - Electronic Devices Physics (FIS/01), 6 ECTS;
- 1st year 2nd semester
    - Atomistic and Molecular Simulations Laboratory (FIS/03), 6 ECTS;
    - Numerical Methods for the Electronic Structure (FIS/03);
    - Nanostructures (FIS/03), 6 ECTS;
- 2nd year 1st semester
    - Climate Dynamics (FIS/06), 6 ECTS;

****Free-choice courses from other degree courses**

- 1st year 1st semester
    - High Performance and Cloud Computing (ING-INF/05), 9 ECTS;
    - Dynamical Systems (ING-INF/04);
- 1st year 2nd semester
    - Algorithmic Design (INF/01), 6 ECTS;
    - Logical Nets (ING-INF/01);
    - Quantum Chemistry (CHIM/02), 6 ECTS;
- 2nd year 1st semester
    - Deep Learning (INF/01), 6 ECTS
    - Quantum Machine Learning (INF/01), 6 ECTS;
    - Quantum Informatics and Software (INF/01), 6 ECTS;

Automatically approved study plans

a – Quantum Technologies and Devices path

- 1st related course: Introduction to Machine Learning;
- 2nd related course: Quantum Liquids;
- 3rd related course: Algorithmic Design;
- 1st free-choice course: Nanostructures;
- 2nd free-choice course: Errors Corrective Codes;

b – Information Theory and Quantum Technologies path

- 1st related course: Introduction to Machine Learning;
- 2nd related course: Quantum Liquids;
- 3rd related course: Stochastic Modelling and Simulation;
- 1st free-choice course: Introduction to Quantum Many-Body Systems;
- 2nd free-choice course: Quantum Informatics and Software;

NB Related courses that are not already included in the study plan as such may be chosen as “free-choice courses”.

Approved by Joint Master's Degree Course Council on November 24th, 2022.