DIDACTIC REGULATIONS OF THE DEGREE PROGRAM
PHYSICS (FISICA)

CLASS LM-17 R

School: Politecnica e delle Scienze di Base

Department: Physics "Ettore Pancini"

Regulations in force since the academic year 2025 - 2026

ACRONYMS

CCD	[Commissione di Coordinamento Didattico]	Didactic Coordination Commission
CdS	[Corso/i di Studio]	Degree Program
CPDS	[Commissione Paritetica Docenti-Studenti]	Joint Teachers-Students Committee
OFA	[Obblighi Formativi Aggiuntivi]	Additional Training Obligations
SUA-CdS	[Scheda Unica Annuale del Corso di Studio]	Annual single form of the Degree Program
RDA	[Regolamento Didattico di Ateneo]	University Didactic Regulations

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IMPORTANT: When filling in the Didactic Regulations' fields, it is necessary to remember that articles referring to areas in the SUA must contain the exact wording as present in the SUA. If you wish to change part of the text, you must remember that this action involves a change of the Rules or, if the field to be changed is RAD, of the CdS detail sheet.

Art. 1
Object

1. These Didactic Regulations govern the organisational aspects of the CdS in Physics (Fisica) (class LM-17 R - FISICA). The CdS in Physics is hinged in the Department of Physics “Ettore Pancini”.

2. The CdS is governed by the Didactic Coordination Commission (CCD), pursuant to Art. 4 of the RDA. According to provision 4 of Article 4 of the RDA, the CCD makes use of a subcommittee for student affairs composed by the academic advisors of the curricula along with the Coordinator.

3. The Didactic Regulations are issued in compliance with the relevant legislation in force, the Statute of the University of Naples Federico II, and the RDA.

Art. 2
Training objectives

The MSc Degree Program in Physics aims at providing an advanced cultural education in physics, ensuring:

a) an in-depth cultural foundation in the fields of macro and microphysics;
b) a thorough knowledge of modern measurement instruments and data analysis techniques;
c) a solid understanding of mathematical and computational tools;
d) a high proficiency in the scientific method of investigation;
e) an advanced scientific and practical training in the field of physical sciences, with substantial knowledge and skills in at least one of the following disciplinary areas: Astrophysics, Physics Education and History of Physics, Electronics, Applied Physics, Biomedical Physics, Condensed Matter Physics, Nuclear Physics, Subnuclear and Astroparticle Physics, Theoretical Physics, and Geophysics.

The MSc Degree in Physics prepares students for professional activities to be carried out with autonomy and independence. The Degree offers a high level of qualification, combining research and development tasks in industrial and service sectors with a strong scientific and technological foundation (e.g., in electronics, mechanics, chemistry and materials science, energy, telecommunications, medicine, environment, cultural heritage, computer science, data analysis, etc.). The Degree opens to professional fields requiring the ability to analyze and model complex phenomena using scientific methods (e.g., in economics, finance, security, etc.). Also, it allows accessing to third-level educational paths, such as PhD programs and specialization schools in Medical Physics.

The structure of the MSc program is closely connected to the lines of physics research developed at the University, ensuring the achievement of a broad scientific education along with specific expertise in the proposed curricular pathways. To this end, the educational pathway includes a common training on the fundamental aspects of the discipline across all curricula. It focuses on a bulk of core courses mandatory to train highly qualified experts in the disciplinary areas listed in point e). Moreover, activities related to "Further Language Skills" within the “Additional Educational Activities (Art. 10, Paragraph 5, Letter d)” are planned to enhance communication skills in foreign languages. Each curriculum further complements the disciplinary training of the educational pathway with an additional number of credits from core courses, providing adequate preparation in at least one of the disciplinary areas mentioned in point e). The curriculum is selected by the student during the first year, and each curriculum includes a wide and varied range of core activities, covering at least three of the four disciplinary fields of the degree class LM-17 R (Experimental and Applied; Theoretical and Fundamental Physics; Microscopic Physics of Matter and Fundamental Interactions; Astrophysical, Geophysical, Climatic, and Space).

Art. 3
Professional profile and work opportunities

- *Professional Profile: Physicist (MSc degree).*
- *Roles in a work context* - The graduates of the MSc Degree Program acquire skills that enable them to carry out professional activities requiring advanced knowledge of experimental physical methodologies, theoretical modeling of physical processes, as well as data analysis and evaluation in various industrial, scientific, and public administration contexts. Roles in a work context may include:

- Design, development, and use of advanced instrumentation for the measurement and/or control of physical quantities in industrial settings (e.g., production process control specialist; laboratory technologist in physical and physico-chemical fields), research (e.g., research associate in universities, research institutions, or company R&D departments), or service sectors (e.g., environmental and radiation monitoring specialist), in the medical field for diagnosis, treatment, and prevention (e.g., radiation protection technologist; expert in diagnostic imaging technologies using ionizing and non-ionizing radiation; specialist in physical technologies for radiotherapy with ionizing radiation), or in health services and technologies (e.g., expert in data analysis methodologies using computational simulations and artificial intelligence).
- Development of models of physical systems, or inspired to physical systems, in corporate or research contexts and in the medical field of diagnosis, treatment, prevention, and health technologies (e.g., models for the analysis of time series of physical or other parameters/data and definition of a scenario in economic-financial, environmental monitoring, healthcare fields; modeling and simulation with Monte Carlo computational techniques applied to the use of radiation beams, both ionizing and non-ionizing, for diagnostics, physical therapy, and health technologies).
- Problem-solving for non-standard issues using methodologies like those employed in Physics (e.g. using physical models to describe system responses, etc.).
- Technical support in various industrial and corporate fields.
- Development of innovative software related to the functions listed above.
- Innovation, research, and development in industrial or scientific contexts.
- Presentation of scientific results, scientific communication, and advanced training of personnel in various fields (e.g., technologist for survey development and analysis, scientific article writer, trainer on aspects related to safety and use of physical and electronic devices, data collection and analysis).
- Study of complex social issues with a scientific background such as interdisciplinarity, sustainability, inclusion, diversity, identity, and social equity.

– *Competencies associated with the role* - To train the graduate students for the functions described above, the educational pathway is structured into several curricula, providing fundamental physics competencies along with specific knowledge, skills, and abilities related to various functions, including:
  - General technical-scientific skills.
  - Advanced and specialized disciplinary competencies in Physics or related fields.
  - General problem-solving and modeling skills.
  - Communication skills, particularly in scientific contexts.
  - Computational skills.
  - Expertise in solving complex problems through theoretical modeling and experimental validation.
  - Competencies in the disciplinary areas mentioned in point e) of section A4.a, including the ability to handle advanced problems in the disciplinary areas of the LM-17 R degree class (Experimental and Applied; Theoretical and Fundamental Physics; Microscopic Physics of Matter and Fundamental Interactions; Astrophysical, Geophysical, Climatic, and Space).
  - Proficiency in quantitative, qualitative, and mixed methods, educational data mining, and learning analytics.

- Skills in developing laboratory methods, prototypes, teaching materials (including multimedia), and evaluation tools for outreach and public engagement activities.
- Expertise in safeguarding, enhancing, and making the historical-scientific heritage publicly accessible, including instrument collections, historical archives, and book funds.

– *Career Opportunities* - Graduates with an MSc in Physics can find employment in public institutions and companies with professional profiles such as:
  - Highly qualified employee, often with R&D roles, in technology-based industries and industrial sectors like electronics, mechanics, chemistry and materials, energy, telecommunications, economics, medicine, environment, and cultural heritage.
  - Highly qualified employee in companies in the IT sector (e.g., software development, technology service manager, and website manager).
  - Researcher or technologist in training at universities or research institutions in Italy or abroad, and medical physicist in healthcare facilities.
  - Graduates with sufficient credits in appropriate groups of fields may also be eligible, as provided by current legislation, to take admission tests for secondary education teaching training programs.

Art. 4
Admission requirements and knowledge required for access to the Degree Program[1]

Admission to the MSc Degree Program in Physics requires foundational knowledge in classical physics, modern physics, mathematical analysis, algebra, and geometry, typically acquired through a first-level (BSc) degree in the degree class L-30 – Physical Sciences and Technologies. Candidates holding a first-level degree in a different degree class or a qualification obtained abroad and recognized as suitable according to current regulations must have acquired adequate knowledge and skills in the scientific-disciplinary sectors (SSD) characterizing the MSc Degree in Physics.

The curricular requirements for admission are defined as follows:

- a qualifying degree obtained in degree class L-30 Physical Sciences and Technologies;

or:

- another valid first-level degree and at least 60 ECTS credits obtained in the following disciplines:

i) at least 30 ECTS credits in SSD FIS/01, FIS/02, FIS/03, FIS/04, FIS/05, FIS/06, FIS/07;
ii) at least 12 ECTS credits in SSD MAT/03, MAT/05;
iii) at least 6 ECTS credits in SSD INF/01, MAT/08, ING-INF/05;

[1] Artt. 7, 13, 14 of the University Didactic Regulations.

iv) at least an additional 12 ECTS credits in SSD FIS or in one of the following SSDs: MAT/07 - Mathematical Physics; CHIM/02 - Physical Chemistry; GEO/10 - Solid Earth Geophysics; GEO/11 - Applied Geophysics; GEO/12 - Oceanography and Atmospheric Physics; ING-IND/06 - Fluid Dynamics; ING-IND/10 - Industrial Technical Physics; ING-IND/12 - Mechanical and Thermal Measurements; ING-IND/13 - Applied Mechanics; ING-IND/18 - Nuclear Reactor Physics; ING-IND/20 - Nuclear Measurements and Instrumentation; ING-IND/22 - Materials Science and Technology; ING-IND/31 - Electrical Engineering; ING-INF/01 - Electronics; ING-INF/02 - Electromagnetic Fields; ING-INF/06 - Electronic and Computer Bioengineering; ING-INF/07 - Electrical and Electronic Measurements; SECS-S/01 - Statistics.

All students are required to undergo an assessment of their personal preparation, with the procedures defined in the academic regulations of the degree program.

Art. 5
Procedures for access to the Degree Program (CdS)

The verification of personal preparation is mandatory in all cases, and only students who meet the curricular requirements may undergo the assessment. Current regulations (Ministerial Decree of 22 October 2004, no. 270, RDA) require the verification of the adequacy of a student's personal preparation for admission to a MSc Degree Program. To successfully pursue the MSc Degree in Physics, students must have adequate knowledge of Physics, Mathematics, Chemistry, and scientific English. Therefore, admission to the MSc Degree Program in Physics is subject to a preliminary evaluation of the student's academic curriculum by a the CCD subcommittee of student affairs, consisting of the academic advisors of the degree curricula and the MSc Coordinator.

Students are exempt from the verification of personal preparation if they meet one of the following conditions:

1) A BSc Degree in Physics (L-30 Physical Sciences and Technologies) awarded by University of Naples Federico II or another state university in Italy;

2) A first-level degree in a scientific discipline other than Physics awarded by a state university in Italy, with an academic curriculum meeting the following requirements:

a) At least 60 ECTS credits obtained in the following disciplines:

i) At least 30 ECTS credits in SSD FIS/01, FIS/02, FIS/03, FIS/04, FIS/05, FIS/06, FIS/07;
ii) At least 12 ECTS credits in SSD MAT/03, MAT/05;
iii) At least 6 ECTS credits in SSD INF/01, MAT/08, ING-INF/05;
iv) At least an additional 12 ECTS credits in SSD FIS or in one of the following SSDs: MAT/07 - Mathematical Physics; CHIM/02 - Physical Chemistry; GEO/10 - Solid Earth Geophysics; GEO/11 - Applied Geophysics; GEO/12 - Oceanography and Atmospheric Physics; ING-IND/06 - Fluid Dynamics; ING-IND/10 - Industrial Technical Physics; ING-IND/12 - Mechanical and Thermal Measurements; ING-IND/13 - Applied Mechanics; ING-IND/18 - Nuclear Reactor Physics; ING-IND/20 - Nuclear Measurements and Instrumentation; ING-IND/22 - Materials Science and Technology; ING-IND/31 - Electrical Engineering; ING-INF/01 - Electronics; ING-INF/02 - Electromagnetic Fields; ING-INF/06 - Electronic and Computer Bioengineering; ING-INF/07 - Electrical and Electronic Measurements; SECS-S/01 - Statistics.

b) A grade point average of at least 27/30 (weighted based on ECTS credits) for exams related exclusively to the disciplines listed above.

Applications from students who do not meet the above criteria are reviewed by the "student practices" subcommittee. The subcommittee assesses whether the candidate possesses the necessary knowledge and skills in foundational mathematics and chemistry, related mathematical and computational disciplines, classical physics, quantum mechanics, laboratory activities, and English language proficiency, based on the student's prior academic documentation and, if necessary, through an interview, written test, and/or practical laboratory assessment. The subcommittee then issues a judgment of suitability that allows enrollment in the MSc Degree Program in Physics. If the candidate is deemed unsuitable, the subcommittee will specify the knowledge and skills that need to be acquired to reach the required level of preparation before enrollment.

Art. 6
Teaching activities and university training credit
(Teaching activities and CFU)

Each training activity, prescribed by the CdS detail sheet, is measured in CFU (ECTS credits). Each CFU corresponds to 25 hours of overall training commitment[2] per student and includes the hours of teaching activities specified in the curriculum as well as the hours reserved for personal study or other individual training activities.

For the Degree Program covered by this Didactic Regulations, the hours of teaching specified in the curriculum for each CFU, established in relation to the type of training activity, are as follows [3]:

- Lecture or guided teaching exercises: 8 hours per CFU;
- Laboratory activities or fieldwork: 12 hours per CFU;
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For internship activities, each credit corresponds to 25 hours of overall training commitment [4].

The CFU corresponding to each training activity acquired by the student is awarded by satisfying the assessment procedures (examination, pass mark) indicated in the Course sheet relating to the course/activity attached to these Didactic Regulations.

Art. 7
Description of teaching methods

The didactic activity is carried out in Conventional Degree Programs modality.

If necessary, the CCD decides which courses also include teaching activities offered online.

Some courses may also take place in seminar form and/or involve classroom exercises, language, and computer laboratories.

Detailed information on how each course is conducted can be found in the course sheets.

Art. 8
Testing of training activities[5]

1. The CCD, within the prescribed regulatory limits[6], establishes the number of examinations and other means of assessment that determine the acquisition of credits. Examinations are individual and may consist of written, oral, practical, graphical tests, term papers, interviews, or a combination of these modes.

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[2] According to Art. 5, c. 1 of Italian Ministerial Decree No 270/2004, "25 hours of total commitment per student correspond to university training credits; a ministerial decree may justifiably determine variations above or below the aforementioned hours for individual classes, by a limit of 20 per cent".

[3] The number of hours considers the instructions in Art. 6, c. 5 of the RDA: "of the total 25 hours, for each CFU, are reserved: a) 5 to 10 hours for lectures or guided teaching exercises; b) 5 to 10 hours for seminars; c) 8 to 12 hours for laboratory activities or fieldwork, except in the case of training activities with a high experimental or practical content, and subject to different legal provisions or different determinations by DD.MM.".

[4] For Internship activities (Inter-ministerial Decree 142/1998), subject to further specific provisions, the number of working hours equal to 1 CFU may not be less than 25.

[5] Article 22 of the University Didactic Regulations.

[6] Pursuant to the DD.MM. 16.3.2007 in each Degree Programs the examinations or profit tests envisaged may not be more than 20 (Bachelor's Degrees; Art. 4. c. 2), 12 (Master's Degrees; Art. 4, c. 2), 30 (five-year single-cycle Degrees) or 36 (six-year single-cycle Degrees; Art. 4, c. 3). Pursuant to the RDA, Art. 13, c. 4, "the assessments that constitute an eligibility evaluation for activities referred to in Art. 10, c. 5, letters c), d), and e) of Ministerial Decree no. 270/2004, including the final examination for obtaining the degree, are excluded from the calculation." For Master's Degree Program and single-cycle Master's Degree Program, however, pursuant to the RDA, Art. 14, c. 7, "the assessments that constitute a progress evaluation for activities referred to in Art.10, c. 5, letters d) and e) of Ministerial Decree no. 270/2004 are excluded from the exam count; the final examination for obtaining the Master's Degree and single-cycle Master's Degree is included in the maximum number of exams".

2. The examination procedures published in the course sheets and the examination schedule will be made known to students before the start of classes on the Department's website.[7]
3. Examinations are held subject to booking, which is made electronically. In case the student is unable to book an exam for reasons that the President of the Board considers justifiable, the student may still be admitted to the examination, following those students already booked.
4. Before examination, the President of the Board of Examiners verifies the identity of the student, who must present a valid photo ID.
5. Examinations are marked out of 30. Examinations involving an assessment out of 30 shall be passed with a minimum mark of 18; a mark of 30 may be accompanied by honours by a unanimous vote of the Board. Examinations are marked out of 30 or with a simple pass mark. Assessments following tests other than examinations are marked out with a simple pass mark.
6. Oral exams are open to the public. If written tests are scheduled, the candidate has the right to see his/her paper(s) after correction.
7. The University Didactic Regulations govern Examination Boards [8].

Art. 9
Degree Program structure and Study Plan

1. The legal duration of the Degree Program is 2 years. It is also possible to enrol, based on the contract, in compliance with the provisions of Article 24 of the RDA and according to the criteria and procedures defined in the following paragraph 5.]
   The student must acquire 120 CFU[9], attributable to the following Types of Training Activities (TAF):

   B) characterising,
   C) related or complementary,
   D) at the student's choice[10],
   E) for the final exam,
   F) further training activities.

2. The degree is awarded after having acquired 120 CFU by passing examinations, not exceeding 12, and the performance of other training activities.
   Unless otherwise provided for in the legal framework of University studies, examinations taken as part of basic, characterising, and related or supplementary activities, as well as activities chosen autonomously by the student (TAF D) are taken into consideration for counting purposes.

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[7] Reference is made to Art. 22, c. 8, of the University Teaching Regulations, which states that "the Department or School ensures that the dates for progress assessments are published on the portal with reasonable advance notice, which normally cannot be less than 60 days before the start of each academic period, and that an adequate period of time is provided for exam registration, which is generally mandatory."

[8] Reference is made to Art. 22, paragraph 4 of the RDA according to which "Examination Boards and other assessments committees are appointed by the Director of the Department or by the President of the School when provided for in the School's Regulations. This function may be delegated to the CCD Coordinator. The Commissions comprise of the President and, if necessary, other professors or experts in the subject. In the case of active courses, the President is the course instructor, and in such cases, the Board can validly make decisions even in the presence of the President alone. In other cases, the President is a professor identified at the time of the Board's appointment. In the comprehensive evaluation of the overall performance at the conclusion of an integrated course, the professors in charge of the coordinated modules participate, and the President is appointed when the Commission is appointed."

[9] The total number of CFU for the acquisition of the relevant degree must be understood as follows: six-year single-cycle Degree, 360 CFU; five-year single-cycle Degree, 300 CFU; Bachelor's Degree, 180 CFU; Master's Degree, 120 CFU.

[10] Corresponding to at least 12 ECTs for Bachelor's Degrees and at least 8 CFU for Master's Degrees (Art. 4, c. 3 of Ministerial Decree 16.3.2007).

Examinations or assessments relating to activities independently chosen by the student may be taken into account in the overall calculation corresponding to one unit[11]. Tests constituting an assessment of suitability for the activities referred to in Article 10, paragraph 5, letters d) and e) of Ministerial Decree 270/2004[12] are excluded from the count. Integrated Courses comprising of two or more modules are subject to a single examination.

3. In order to acquire the CFU relating to independent choice activities, the student is free to choose among all the Courses offered by the University, provided that they are consistent with the training project. This consistency is assessed by the Didactic Coordination Commission. Also, for the acquisition of the CFU relating to autonomous choice activities, the "passing the exam or other form of profit verification" is required (Art. 5, c. 4 of Ministerial Decree 270/2004).
4. The study plan summarises the structure of the Degree Program, listing the envisaged teachings broken down by course year and, in case, by curriculum. At the end, the propedeuticities envisaged by the Degree Program are listed. The study plan offered to students, with an indication of the scientific-disciplinary sectors and the area to which they belong, of the credits, of the type of educational activity, is set out in Annex 1 to these Didactic Regulations.
5. Pursuant to Art. 11, paragraph 4-bis, of Ministerial Decree 270/2004, it is possible to obtain the Degree according to an individual study plan that also includes educational activities different from those specified in the Didactic Regulations, as long as they are consistent with the CdS detail sheet of the academic year of enrollment. The individual study plan is approved by the CCD.

Art. 10
Attendance requirements[13]

1. In general, attendance of lectures is a) strongly recommended but not compulsory. In the case of individual courses with compulsory attendance, this option is indicated in the relative teaching/activity course sheet available in Annex 2.
2. If the lecturer envisages a different syllabus modulation for attending and non-attending students, this is indicated in the individual Course details published on the CdS web page and on the teacher’s UniNA website.
3. Attendance at seminar activities that award training credits is compulsory. The relative modalities for the attribution of CFU are the responsibility of the CCD.

[11] Pursuant to the D.M. 386/2007.

[12] Art. 10, c. 5 of Ministerial Decree. 270/2004: "In addition to the qualifying training activities, as provided for in paragraphs 1, 2 and 3, Degree Programs shall provide for: a) training activities autonomously chosen by the student as long as they are consistent with the training project [TAF D]; b) training activities in one or more disciplinary fields related or complementary to the basic and characterising ones, also with regard to context cultures and interdisciplinary training [TAF C]; c) training activities related to the preparation of the final exam for the achievement of the degree and, with reference to the degree, to the verification of the knowledge of at least one foreign language in addition to Italian [TAF E]; d) training activities, not envisaged in the previous points, aimed at acquiring additional language knowledge, as well as computer and telematic skills, relational skills, or in any case useful for integration in the world of work, as well as training activities aimed at facilitating professional choices, through direct knowledge of the job sector to which the qualification may give access, including, in particular, training and guidance programs referred to in Decree no. 142 of 25 March 1998 of the Ministry of Labour [TAF F]; e) in the hypothesis referred to in Article 3, paragraph 5, training activities relating to internships and apprenticeships with companies, public administrations, public or private entities including those of the third sector, professional orders and colleges, on the basis of appropriate agreements".

[13] Art. 22, c. 10 of the University Didactic Regulations.

Art. 11

Prerequisites and prior knowledge

1. The list of incoming and outgoing propedeuticities (necessary to sit a particular examination) can be found at the end of Annex 1 and in the teaching/activity course sheet (Annex 2).
2. Any prior knowledge deemed necessary is indicated in the individual Teaching Schedule published on the course webpage and on the teacher's UniNA website.

Art. 12

Degree Program Calendar

The Degree Program calendar can be found on the Department's website well before the start of the activities (Art. 21, c. 5 of the RDA).

Art. 13

Criteria for the recognition of credits earned in other Degree Programs in the same Class[14]

For students coming from Degree Programs of the same Class, the Didactic Coordination Commission ensures the full recognition of CFU, when associated with activities that are culturally compatible with the training Degree Program, acquired by the student at the originating Degree Program, according to the criteria outlined in Article 14 below. Failure to recognise credits must be adequately justified. It is without prejudice to the fact that the number of credits relating to the same scientific-disciplinary sector directly recognised by the student may not be less than 50% of those previously achieved.

Article 14

Criteria for the recognition of credits acquired in Degree Programs of different classes, in university or university-level Degree Programs, through single courses, at online Universities and in international Degree Programs[15]; criteria for the recognition of credits acquired in extra-curricular activities

1. With regard to the criteria for the recognition of CFU acquired in Degree Programs of different Classes, in university or university-level Degree Programs, through single courses, at online Universities and in International Degree Programs, the credits acquired are recognised by the CCD on the basis of the following criteria:
   - analysis of the activities carried out;
   - evaluation of the congruity of the disciplinary scientific sectors and of the contents of the training activities in which the student has earned credits with the specific training objectives of the Degree Program and of the individual training activities to be recognised.

   Recognition is carried out up to the number of credits envisaged by the didactic system of the Degree Program. Failure to recognise credits must be adequately justified. Pursuant to Art. 5, c. 5-bis, of Ministerial Decree 270/2004, it is also possible to acquire CFU at other Italian universities on the basis of agreements established between the concerned institutions, in accordance with the regulations current at the time [16].

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[14] Art. 19 of the University Didactic Regulations.

[15] Art. 19 and Art. 27, c.6 of the University Didactic Regulations.

[16] Art. 6, c. 9 of the University Didactic Regulations.

2. Any recognition of CFU relating to examinations passed as single courses may take place within the limit of 36 CFU, upon request of the interested party and following the approval of the CCD. Recognition may not contribute to the reduction of the legal duration of the Degree Program, as determined by Art. 8, c. 2 of Ministerial Decree 270/2004, except for students who enrol while already in possession of a degree of the same level[17].
3. With regard to the criteria for the recognition of CFU acquired in extra-curricular activities, within the limit of 12 CFU the following activities may be recognised:
   - Professional knowledge, skills, and certified skills, taking into account the congruence of the activity carried out and/or of the certified skill with the aims and objectives of the Degree Program as well as the hourly commitment of the duration of the activity.
   - Knowledge and skills acquired in post-secondary-level training activities, which the University contributed to developing and implementing.

Art. 15
Criteria for enrolment in individual teaching courses

Enrolment in individual teaching courses, provided for by the University Didactic Regulations[18], is governed by the "University Regulations for enrolment in individual teaching courses activated as part of the Degree Program"[19].

Article 16
Features and modalities for the final examination

The MSc Degree Examination consists in the presentation and defense of a thesis (dissertation) in front of an appointed committee. The thesis is prepared under the supervision of a faculty advisor and must be an original written work that addresses a specific problem (theoretical, experimental, or technological in nature) relevant to research in the field of modern physics and its applications, or in an interdisciplinary field employing methodologies typical of Physics.
The CCD (Didactic Coordination Committee) establishes the procedures for the assignment and completion of the MSc thesis, the regulations for admission to the degree examination, the methods for conducting the degree examination, and the evaluation criteria for the awarding of the MSc Degree in Physics (LM) at the University of Naples Federico II, through its own regulations.
Upon passing the MSc Degree Examination, the student is awarded the title of "MSc Degree in Physics (Dottore Magistrale)" regardless of the chosen curriculum and/or study plan, with any specific mention reflected in the student's academic record.

Article 17
Guidelines for traineeship and internship

1. Students enrolled in the Degree Program may decide to carry out internships or training periods with organisations or companies that have an agreement with the University. Traineeship and internship are not compulsory and contribute to the award of credits for the other training activities chosen by the student and included in the study plan, as provided for by Art. 10, par. 5, letters d and e, of Ministerial Decree 270/2004[20].
2. The CCD regulates the modalities and characteristics of traineeship and internship with specific regulations.

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[17] Art. 19, c. 4 of the University Didactic Regulations.
[18] Art. 19, c. 4 of the University Didactic Regulations.
[19] R.D. No. 348/2021.
[20] Traineeships ex letter d can be both internal and external; traineeships ex letter e can only be external.

3. The University of Naples Federico II, through “Scuola Politecnica e delle Scienze di Base”, ensures constant contact with the world of work to offer students and graduates of the University concrete opportunities for internships and work experience and to promote their professional integration.

Article 18
Disqualification of student status[21]

A student who has not taken any examinations for eight consecutive academic years incurs forfeiture unless his/her contract stipulates otherwise. In any case, forfeiture shall be notified to the student by certified e-mail or other suitable means attesting to its receipt.

Article 19
Teaching tasks, including supplementary teaching, guidance, and tutoring activities

1. Professors and researchers carry out the teaching load assigned to them in accordance with the provisions of the RDA and the Regulations on the teaching and student service duties of professors and researchers and on the procedures for self-certification and verification of actual performance[22].
2. Professors and researchers must guarantee at least two hours of reception every 15 days (or by appointment in any case granted no longer than 15 days) and, in any case, guarantee availability by e-mail.
3. The tutoring service has the task of orienting and assisting students throughout their studies and of removing the obstacles that prevent them from adequately benefiting from attending courses, also through initiatives tailored to the needs and aptitudes of individuals.
4. The University ensures guidance, tutoring and assistance services and activities to welcome and support students. These activities are organised by the Schools and/or Departments under the coordination of the University, as established by the RDA in Article 8.

Article 20
Evaluation of the quality of the activities performed

1. The Didactic Coordination Commission implements all the quality assessment forms of teaching activities envisaged by the regulations in force according to the indications provided by the University Quality Presidium.
2. In order to guarantee the quality of teaching to the students and to identify the needs of the students and all stakeholders, the University of Naples Federico II uses the Quality Assurance (QA)[23] System, developed in accordance with the document "Self-evaluation, Evaluation and Accreditation of the Italian University System" of ANVUR, using:
    - surveys on the degree of placement of graduates into the world of work and on post-graduate needs;
    - data extracted from the administration of the questionnaire to assess student satisfaction for each course in the curriculum, with questions relating to the way the course is conducted, teaching materials, teaching aids, organisation, facilities.

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[21] Art. 24, c. 5 of the University Didactic Regulations.

[22] R.D No. 2482//2020.

[23] The Quality Assurance System, based on a process approach and adequately documented, is designed in such a way as to identify the needs of the students and all stakeholders, and then translate them into requirements that the training offer must meet.

The requirements deriving from the analysis of student satisfaction data, discussed, and analysed by the Teaching Coordination Committee and the Joint Teachers' and Students' Committee (CPDS), are included among the input data in the service design process and/or among the quality objectives.

3. The QA System developed by the University implements a process of continuous improvement of the objectives and of the appropriate tools to achieve them, ensuring that planning, monitoring, and self-assessment processes are activated in all the structures to allow the prompt detection of problems, their adequate investigation, and the design of possible solutions.

Article 21
Final Rules

The Department Council, on the proposal of the CCD, submits any proposals to amend and/or supplement these Rules for consideration by the Academic Senate.

Article 22
Publicity and Entry into Force

1. These Rules and Regulations shall enter into force on the day following their publication on the University's official notice board; they shall also be published on the University website. The same forms and methods of publicity shall be used for subsequent amendments and additions.
2. Annex 1 (CdS structure) and Annex 2 (Teaching/Activity course sheet) are integral parts of this Didactic Regulations.

ANNEX 1

DEGREE PROGRAM DIDACTIC REGULATIONS
FISICA (PHYSICS)

CLASS LM-17 R

School: Politecnica e delle Scienze di Base

Department: Fisica "Ettore Pancini"

Didactic regulations in force since the academic year 2025 - 2026

STUDY PLAN

KEY

Type of Educational Activity (TAF):

B = Characterising
C = Related or Supplementary
D = At the student's choice
E = Final exammination and language knowledge
F = Further training activities

CURRICULUM ASTROPHYSICS

The "Astrophysics" curriculum, in addition to the general objectives of the MSc Degree Program in Physics, aims specifically at providing graduates with an in-depth knowledge in at least one disciplinary area of astrophysics, such as cosmology and extragalactic astronomy e.g., or the experimental techniques of modern astrophysics. Furthermore, it aims at developing the ability to apply this knowledge in professional contexts related to astrophysical research or in the development of advanced software and hardware technologies, even in the industrial sector.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(lecture, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Astrophysics	FIS/05	single	9	72	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory
Cosmology	FIS/05	single	6	48	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Physics of Galaxies	FIS/05	single	6	48	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory

Quantum Physics	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Further training activities (art. 10 comma 5 lett d) –	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5 lett d)	-		2	-	-		-	Mandatory

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Ambito disciplinare	Mandatory /optional
High-Energy Astrophysics	FIS/05	single	6	48	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory
Astroinformatics	FIS/05	single	12	48	Frontal lesson	C	-	Mandatory (two of your choices)
Multimessenger Astrophysics	FIS/05							
Complements of Cosmology	FIS/05							
Stellar Evolution	FIS/05							
Philosophy of Scientific Knowledge	M-FIL/01							
Physics of Stellar Atmospheres	FIS/05							
Laboratory of Astrophysics	FIS/05							
Planetology	FIS/05							
History of Astronomy	FIS/05							
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

The Astrophysics course is a prerequisite for: High-Energy Astrophysics, Multimessenger Astrophysics, Cosmology, Cosmology Complements, Stellar Evolution, Physics of Galaxies, Astrophysics Laboratory, and Planetology.
The course in Cosmology is a prerequisite for: Cosmology Complements.

Course Modalities: All courses are taken in person.

CURRICULUM PHYSICS EDUCATION AND HISTORY OF PHYSICS

The "Physics Education and History of Physics" curriculum aims at training professionals with expertise in research methodologies in physics education and history of Physics, as well as in educational technologies for Physics. The graduate student will be capable of designing, delivering, and validating educational pathways based on the theoretical and experimental foundations of research in Physics education and history of Physics. They will also be proficient in evaluation methodologies and skilled in designing and using investigative tools, including the latest statistical analysis techniques (e.g., educational data mining). The acquired skills will enable the graduate student to manage software and hardware environments relevant to education. The developed competencies will be useful in various fields, including teaching (both in schools and universities), research (educational, historical, socio-scientific, complex systems, etc.), design of innovative tools for dissemination and education (software, hardware), and scientific communication.

I Anno

Title Course	**SSD**	**Module**	**CREDITS**	**Hours**	**Type Activities** *(Frontal lesson, workshop, etc.)*	**TAF**	**Ambito disciplinare**	**Mandatory /optional**
Physics Education	FIS/08	single	9	72	Frontal lesson and laboratory	B	Theoretical and fundamental Physics	Mandatory
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Quantum Physics	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Didactical Design for Physics Design of Educational Activities *(borrowed from MSc in Mathematics)*	FIS/08	single	6	48	Laboratory workshop	B	Theoretical and fundamental Physics	Mandatory (one of your choices)
History of Classical Physics History of Modern Physics	FIS/08	single	6	48	Frontal lesson	C	Theoretical and fundamental Physics	Mandatory (one of your choices)
Further training activities (art. 10 comma 5 lett d)	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5 lett d)	-		2	-	-		-	Mandatory

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Didactics of Modern Physics	FIS/08	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Research Methods in Physics Education	FIS/08	single	6	48	Frontal lesson	C	-	Mandatory (one of your choices)
Educational Technologies for Physics Teaching								
Didactics of Mathematics *(borrowed from MSc in Mathematics)*	MAT/04	single	6	48	Frontal lesson	C	-	Mandatory (one of your choices)
STEM Education	FIS/08							
Philosophy of Scientific Knowledge	M-FIL/01							
Physics and Philosophy	FIS/08							
History of Astronomy	FIS/05							
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

The course in Physics Education is a prerequisite for: Didactics of Modern Physics.

Course Modalities: All courses are taken in person.

CURRICULUM ELECTRONICS

The "Electronics" curriculum of the Master's Degree Program in Physics aims to train professionals capable of contributing to the scientific and technological development of experimental apparatus for physical measurements in research and industry through the design of electronic instruments for data acquisition, processing, and control. Graduates in Physics with a specialization in the Electronics Curriculum will be able to design, simulate, and implement original architectures of electronic systems for physical applications, employing the most innovative design and analysis techniques. They will have the opportunity to study, use, and apply the latest technologies in analog and digital electronic devices, with a particular focus on reconfigurable and programmable components, such as Field Programmable Gate Arrays (FPGA) and microprocessors.

The Curriculum also includes educational pathways that allow for an in-depth study of digital signal processing, sensors and data acquisition, integrated digital electronics, and analog electronics.

The proposed Curriculum includes laboratory activities focused not only on experimental methodologies, measurement, and data processing but also, in particular, on the design and implementation of electronic measurement and data acquisition systems, including those based on FPGA and microprocessors.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Digital Electronics	FIS/01	single	6	48	Frontal lesson	B	Experimental and applied	Mandatory
Solid State Physics I	FIS/03	single	6	48	Frontal lesson	C	Microphysics of Matter and of fundamental interactions	Mandatory
Electronics Fundamentals	FIS/01	single	6	48	Frontal lesson	B	Experimental and applied	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Quantum Mechanics	FIS/02	single	9	72	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Further training activities (art. 10 comma 5)	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-		2		-			

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Integrated Systems Architecture *(borrowed from MSc in Electonic Engineering)*	ING-INF/01	single	9	72	Frontal lesson	C	-	Mandatory (one of your choices)

Digital Systems Laboratory	FIS/01	single	9	72	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

None.

Course Modalities: All courses are taken in person.

CURRICULUM BIOMEDICAL PHYSICS

Graduates of the MSc Degree Program in Physics, with a specialization in "Biomedical Physics", will:

- Acquire knowledge of the physical methodologies (theoretical and experimental) necessary for describing and understanding the living matter in the biological and medical context;
- Gain in-depth knowledge of the development and use of instruments required for the control and detection of physical phenomena in the fields of prevention, diagnosis, and treatment;
- Be able to apply the specific knowledge acquired in modeling, radiation biophysics, physical techniques related to biomedical diagnostics, biomedical image analysis, and the measurement of ionizing radiation in medical physics and environmental contexts.

In terms of postgraduate education, graduates will be eligible to pursue PhD programs and the Specialization School of Medical Physics. For the latter, some of the credits earned may be recognized, subject to approval by the School's Academic Board.

To achieve these objectives, the curriculum in Biomedical Physics:

- Includes activities aimed at acquiring specialized knowledge and skills in imaging, biophysics, and medical physics;
- Provides laboratory activities focused on learning experimental methodologies, data measurements and processing, and, in particular, the use of modern biomedical instrumentation.

I Anno

Title Course	SSD	Module	CREDITS	Ore	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Radiation Dosimetry	FIS/07	single	6	52	Frontal lesson and laboratory workshop	C	-	Mandatory
Radiation Biophysics	FIS/07	single	6	52	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Medical Physics	FIS/07	single	6	48	Frontal lesson	B	Experimental and applied	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Quantum Mechanics	FIS/02	single	9	72	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Further training activities (art. 10 comma 5)	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-		2		-			

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional

Laboratory of Medical Physics	FIS/07	single	6	64	Frontal lesson and Workshop	B	Experimental and applied	Mandatory
Physical Basis of Magnetic Resonance Radiotherapy Physics Digital Image Processing Environmental Radioactivity	FIS/07	single	6	52	Frontal lesson	C	-	Mandatory (One of your choices)
Further training activities (art. 10 comma 5, lettera d)	-	single	6	150	Learning and orientation traineeship	F	-	Mandatory
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

None.

Course Modalities: All courses are taken in person.

CURRICULUM PHYSICS OF MATTER

The "Physics of Matter" curriculum, in addition to the general objectives of the MSc Degree Program in Physics, specifically aims at providing graduates with an in-depth knowledge of at least one disciplinary area of physics of matter. This may include, for example, solid-state physics, including semiconductors and nanostructured systems, superconductors and other strongly correlated materials, soft condensed matter physics, including polymers, liquid crystals, and biological systems, atomic and molecular physics, as well as modern optics and photonics. Graduates will also acquire the ability to apply this specific knowledge in professional contexts related to the development and application of advanced technologies. Examples include industrial sectors such as semiconductors, information and communication technology, optoelectronics, new materials, and advanced diagnostic techniques, with a high level of autonomy and the ability to tackle and solve complex, non-standard problems.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Solid State Physics I	FIS/03	single	6	48	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Quantum Mechanics	FIS/02	single	9	72	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Statistical Mechanics I	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
At the student's choice	-	single	6	48	-	D	-	Mandatory
Further training activities (art. 10 comma 5)	-	-	4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-	-	2	-	-	F		Mandatory

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Laboratory of Modern Optics	FIS/03	single	6	56	Frontal lesson and laboratory workshop	B	Microphysics of Matter and of fundamental interactions	Mandatory (one of your choices)
Many-Body Quantum Theory	FIS/03			48	Frontal lesson			
Experimental Methods for Nanotechnologies and Condensed Matter Physics	FIS/03			56	Frontal lesson and laboratory workshop			

Biophotonics	FIS/03	single	18	48	Frontal lesson	C	-	Mandatory (tre of your choices)
Quantum Phases of Matter	FIS/03	single		48	Frontal lesson			
Plasma Physics	FIS/03	single		48	Frontal lesson			
Soft Matter Physics	FIS/03	single		48	Frontal lesson			
Solid State Physics II	FIS/03	single		48	Frontal lesson			
Fundamentals of nanomagnetism and applications	FIS/03	single		48	Frontal lesson			
Photonics	FIS/03	single		48	Frontal lesson and laboratory workshop			
Materials Computational Modelling	FIS/03	single		48	Frontal lesson			
Quantum Optics and Information	FIS/03	single		48	Frontal lesson			
Modern Optics	FIS/03	single		48	Frontal lesson			
Quantum Open Systems	FIS/03	single		48	Frontal lesson			
Optical Spectroscopy	FIS/03	single		48	Frontal lesson			
Superconducting Quantum Technologies	FIS/03	single		48	Frontal lesson			
Computational Thermodynamics	FIS/03	single		48	Frontal lesson			
At the student's choice	-	single	6	48	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

The course in Solid State Physics I is a prerequisite for: Solid State Physics II; Materials Computational Modelling.
The course in Quantum Mechanics is a prerequisite for: Quantum Open Systems.

Course Modalities: All courses are taken in person.

CURRICULUM NUCLEAR PHYSICS

The "Nuclear Physics" curriculum of the MSc Degree Program in Physics has the following educational objectives:

- To provide an in-depth knowledge of the latest developments in Nuclear Physics in its various aspects (theoretical, experimental, and applied) and related interdisciplinary topics. This level of knowledge will enable graduates to engage in both fundamental and applied research activities, as well as in the productive sectors;
- To acquire advanced skills in computer science, with a particular focus on computational and data analysis aspects, which are also common to other fields of scientific research, facilitating their integration into activities beyond the nuclear field;
- To gain advanced knowledge of experimental methodologies, including the development and use of advanced instrumentation and measurement apparatus, enabling graduates to make innovative and managerial contributions to both fundamental and applied research, as well as to productive and public utility activities, such as the production and study of new materials, environmental risk prevention and control, analysis in the field of cultural heritage, and radiation protection.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Nuclear Physics	FIS/04	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Laboratory of Nuclear Physics	FIS/01	single	9	72	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Quantum Mechanics	FIS/02	single	9	72	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Further training activities (art. 10 comma 5)	-	-	4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-	-	2	-	-	F	-	-

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Nuclear Reactions	FIS/04	single	6	48	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Nuclear Astrophysics	FIS/01, FIS/04	single	12	48	Frontal lesson	C	-	Mandatory (two of your

Physics of Exotic Nuclei	FIS/04	single		48					choices)
Nuclear Physics for Environment and Cultural Heritage	FIS/01, FIS/04	single		48					
Computational Intelligence *(borrowed from MSc in Data Science)*	INF/01	single		48					
Statistical Mechanics I	FIS/02	single		48					
Machine Learning Methods for Physics	INF/01	single		48					
Nuclear Measurements	FIS/01, FIS/04	single		48					
Theory of Nuclear Structure	FIS/04	single		48					
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

The course in Nuclear Physics is a prerequisite for: Physics of Exotic Nuclei; Nuclear Structure Theory.
The course in Nuclear Reactions is a prerequisite for: Physics of Exotic Nuclei.

Course Modalities: All courses are taken in person.

CURRICULUM SUBNUCLEAR AND ASTROPARTICLE PHYSICS

The "Subnuclear and Astroparticle Physics" curriculum of the MSc Degree Program in Physics has the following educational objectives:

- To provide an in-depth understanding of the latest experimental topics in subnuclear and astroparticle physics and related interdisciplinary issues. This knowledge will enable graduates to effectively engage in both fundamental and applied research activities;
- To acquire advanced knowledge of experimental methodologies, including the design, development, and use of sophisticated instrumentation and measurement systems, allowing graduates to contribute significantly to both fundamental and applied research as well as to productive or public utility activities;
- To develop advanced skills in computer science, with a focus on data analysis, the control and monitoring of complex instrumentation systems, and the management of advanced computing systems and networks, facilitating productive engagement in a wide range of activities beyond specifically research-oriented tasks;
- To acquire a work methodology based on solid foundational knowledge, flexibility, initiative, and collaboration in the workplace, enabling graduates to constructively integrate into a broad spectrum of activities related to both fundamental and applied research as well as to productive sectors.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Astroparticle Physics	FIS/01, FIS/04	single	6	48	Frontal lesson	B	Experimental and applied	Mandatory
Particle Physics	FIS/01	single	9	72	Frontal lesson	B	Experimental and applied	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Particle Physics Laboratory	FIS/01	single	9	96	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Quantum Mechanics	FIS/02	single	9	72	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Further training activities (art. 10 comma 5)	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-		2	-	-	F	-	-

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Data Analysis in Subnuclear Physics	FIS/01	single	12	48	Frontal lesson	C	-	Mandatory (two of your choices)
Nuclear Astrophysics	FIS/01	single		48				
Digital Electronics	FIS/01	single		48				

Flavor Physics	FIS/01	single		48				
Physics of the Dark Universe	FIS/01, FIS/04	single		48				
Physics of Cosmic Radiation	FIS/01, FIS/04	single		48				
Experimental Standard Model Physics	FIS/01	single		48				
Experimental Gravitational Physics	FIS/01	single		48				
Theoretical Physics of Fundamental Interactions	FIS/02	single		48				
Electronics Fundamentals	FIS/01	single		48				
Computational Intelligence *(borrowed from MSc in Data Science)*	INF/01	single		48				
Statistical Mechanics I	FIS/02	single		48				
Machine Learning Methods for Physics	INF/01	single		48				
Perturbative QCD	FIS/02	single		48				
Sensors, detectors and related electronics	FIS/01	single		48				
Techniques for particle acceleration	FIS/01, FIS/03	single		48				
Experimental techniques in Particle Physics	FIS/01	single		48				
Quantum Field Theory I	FIS/02	single		48				
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

The course in Classical Electrodynamics is a prerequisite for: Quantum Field Theory I.
The course in Quantum Mechanics is a prerequisite for: Perturbative QCD; Quantum Field Theory I.
The course in Quantum Field Theory I is a prerequisite for: Theoretical Physics of Fundamental Interactions; Perturbative QCD.

Course Modalities: All courses are taken in person.

CURRICULUM THEORETICAL PHYSICS

The "Theoretical Physics" curriculum of the MSc Degree Program in Physics aims at developing individuals with an in-depth understanding of the key topics in modern theoretical physics and proficiency in contemporary techniques for solving related problems. Graduates of the MSc Degree Program in Physics, specializing in "Theoretical Physics," will acquire specific skills to use their knowledge for interpreting and predicting the behavior of complex systems. Graduates will be prepared to join research groups in public or private institutions or to apply their modeling skills in other professional environments.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Complements of Mathematical Methods of Physics	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Quantum Mechanics	FIS/02	single	9	72	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Quantum Field Theory I	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Numerical Methods of Physics Models of Biological Systems General Relativity and Gravitation	FIS/02	single	6	48	Frontal lesson	C		Mandatory (one of your choices)
Statistical Mechanics I Statistical Mechanics II	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory (one of your choices)
Further training activities (art. 10 comma 5)	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-		2	-	-	F	-	-

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Phenomenology of Elementary Particles	FIS/02	single	12	48	Frontal lesson	C	-	Mandatory (two of your choices)
Theoretical Astroparticle	FIS/02	single		48				

Physics								
Theoretical Physics of Fundamental Interactions	FIS/02	single		48				
Introduction to Quantum Gravity	FIS/02	single		48				
Models of Biological Systems	FIS/02	single		48				
Perturbative QCD	FIS/02	single		48				
Complex Systems	FIS/02	single		48				
Classical Field Theory	FIS/02	single		48				
Group Theory and Applications	FIS/02	single		48				
String Theory	FIS/02	single		48				
Theory of Quantum Information	FIS/02	single		48		C		
Quantum Field Theory II	FIS/02	single		48				
Quantum Theory of Measurement	FIS/02	single		48				
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

The course in Classical Electrodynamics is a prerequisite for: Classical Field Theory, Quantum Field Theory I.

The course in Quantum Mechanics is a prerequisite for: Perturbative QCD; Group Theory and Applications; Quantum Information Theory; Quantum Field Theory I; Quantum Theory of Measurement.

The course in Quantum Field Theory I is a prerequisite for: Phenomenology of Elementary Particles; Theoretical Astroparticle Physics; Theoretical Physics of Fundamental Interactions; Introduction to Quantum Gravity; Perturbative QCD; Quantum Field Theory II; String Theory.

The course in General Relativity and Gravitation is a prerequisite for: Theoretical Astroparticle Physics; Introduction to Quantum Gravity; String Theory.

Course Modalities: All courses are taken in person.

CURRICULUM GEOPHYSICS

In addition to the general objectives of the MSc Degree Program in Physics, the "Geophysics" curriculum aims at achieving the following educational objectives:

- To provide a solid cultural background in both theoretical and applied geophysics, along with an in-depth understanding of modern instrumentation and techniques for acquiring, processing, and interpreting geophysical data;
- To ensure comprehensive mastery of methods for monitoring, classifying, and modeling complex dynamic phenomena at planetary, continental, regional, and local scales;
- To develop advanced scientific and operational expertise for improving and developing methods for geophysical exploration of the subsurface and studying the physical parameters of rocks.

Graduates of the MSc Degree Program in Physics, specializing in Geophysics, will be prepared to engage in activities such as promoting and developing scientific and technological innovations in Earth Science field, as well as managing and designing technologies and methodologies for analysis in related sectors, including industry, cultural heritage, civil engineering, environment, and land management. Graduates may find employment in observatories and research institutions focused on fundamental and applied research, natural and environmental risk prevention and control, and other areas of significant utility, such as the exploration and exploitation of natural resources, land management, non-invasive analysis in cultural heritage, design of instrumentation for geophysical exploration of the subsurface and monitoring of natural phenomena, and applied computing in Earth Science.

I Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /optional
Signal Processing and Analysis	FIS/01, FIS/06, FIS/07	single	6	52	Frontal lesson and laboratory workshop	C	Astrophysics, geophysics, climate, and space	Mandatory
Classical Electrodynamics	FIS/03	single	9	72	Frontal lesson	B	Microphysics of Matter and of fundamental interactions	Mandatory
Earth and Atmospheric Physics	FIS/06	single	6	48	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory
Quantum Physics	FIS/02	single	6	48	Frontal lesson	B	Theoretical and fundamental Physics	Mandatory
Physics Laboratory	FIS/01	single	9	84	Frontal lesson and laboratory workshop	B	Experimental and applied	Mandatory
Continuum Mechanics	FIS/06	single	6	48	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory
Inversion Methods	FIS/06	single	6	48	Frontal lesson	B	Astrophysics, geophysics, climate, and space	Mandatory
Further training activities (art. 10 comma 5)	-		4	-	-	F	Further language skills	Mandatory
Further training activities (art. 10 comma 5)	-		2	-	-	F	-	-

II Anno

Title Course	SSD	Module	CREDITS	Hours	Type Activities *(Frontal lesson, workshop, etc.)*	TAF	Disciplinary Area	Mandatory /of your choices
Seismology	FIS/06	single	9	72	Frontal lesson and laboratory workshop	B	Astrophysics, geophysics, climate, and space	Mandatory
Complements of Mathematical Methods	FIS/02	single	6	48	Frontal lesson	C		Mandatory (one of your choices)
Applied Geophysics	GEO/11	single						
Introduction to Volcano and Non Standard Seismology	FIS/06	single						
Statistical Mechanics I	FIS/02	single						
Mathematical Methods for Geophysics	FIS/02	single						
Big Data Seismology	FIS/06	single						
Computational Thermodynamics	FIS/03	single						
At the student's choice	-	single	12	96	Frontal lesson	D	-	Mandatory
Final examination	-	single	39	-	-	E	-	Mandatory

List of propaedeuticities

None.

Course Modalities: All courses are taken in person.

ANNEX 1

DEGREE PROGRAM DIDACTIC REGULATIONS
FISICA (PHYSICS)

CLASS LM-17 R

School: Politecnica e delle Scienze di Base

Department: Fisica "Ettore Pancini"

Didactic regulations in force since the academic year 2025 - 2026

COURSES SHEETS

Course Modality: All courses are taken in person.

Key

Type of Educational Activity (TAF):

B = Characterising
C = Related or Supplementary
D = At the student's choice
E = Final exammination and language knowledge
F = Further training activities

Course: Applied Geophysics	**Teaching Language:** Italian
SSD (Subject Areas): GEO/11	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: During the course the methodologies of data measurement and acquisition for the determination of the subsoil physical characteristics will be described. The same attention will be devoted to the methods for data processing, modeling, and interpretation.	
Learning objectives: The course aims at providing an adequate knowledge of the physical methods of investigation of the subsoil, of the theory and experiments of geophysical prospecting, as well as of data processing and interpretation techniques. Students will be prepared to critically and independently tackle more advanced studies on the subject, as well as to develop simple feasibility projects for geophysical investigation. - The student will develop the problems related to the different geophysical methods and will have to discuss the geophysical data in relation to the different application contexts and the main characteristics of the inherent methods. - The student will process the data correctly and will interpret the data processed in a geological, environmental, engineering, archaeological key. - The student will independently evaluate the correctness of the methods used and the quality of the data acquired in relation to the objectives of the study. He will be able to present the main results of the data analysis in the form of a written report. - The student will be able to explain to non-experts the physical principles underlying the geophysical survey methodologies and to communicate with an appropriate language the basic principles of geophysical methods and their application, with limitations and possible extensions, to specific cases.	

- The student will autonomously expand its knowledge with texts, scientific articles and research and will attend specialized seminars, conferences and masters, in the field of methodologies and case studies in the applied geophysical field.
Propaedeuticities: none. A good knowledge of the basic concepts of potential field theory, electromagnetism, geometrical optics, and basic numerical computation (MATLAB) and linear algebra. **Is a propaedeuticity for:** none.
Types of examinations and other tests: oral exam.

Course: Astroinformatics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/05		**CREDITS:** 6
Course year: II	**Type of Educational Activity: C**	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.		
Learning objectives: The course addresses in a multidisciplinary way the main theoretical and practical aspects underlying the virtuous synergy between Astrophysics, Data Science and Machine Learning. The ultimate aim is to train young astrophysicists in scientific investigation through the paradigm of 'data-driven' exploration, i.e. allowing themselves to be 'guided by the data', acquiring the ability to analyze, understand, correlate, process and make large volumes of data, heterogeneous and characterized by complex parameter spaces, interoperable in a semi-automatic way. The various topics proposed are formalized theoretically and assimilated through practical examples of Python implementation in a multi-tasking environment and the execution of use cases in the astrophysical field, enabling the student to learn the underlying methodology and to transfer it to other areas of scientific and industrial research. The collegial analytical discussion of the presented use cases is able to stimulate personal interest in various areas of Astrophysics as well as learning the collaborative approach on a single scientific project.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Realization of a project and oral examination.		

Course: Astroparticle Physics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/01, FIS/04		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data. The competences of this subject area also cover research in the fields of physics related to nuclear reactors and radiogenic sources in general, as well as in the fields of nuclear electronics, radioactivity and particle physics of cosmic origin.		
Objectives: The course is designed to introduce students to astroparticle physics, an advanced field of research at the boundary between astrophysics, cosmology and elementary particle physics that is constantly and rapidly evolving. The main topics are treated from both a phenomenological and an experimental point of view. In particular, at the end of the course the student will be able to: - understand the results of the main astroparticle physics experiments - interpret plots and numerical data in relation to the proposed physical models - will have developed the ability to present the topics of a constantly evolving branch of physics and will be able to independently follow its future developments		
Propaedeuticities: None. **Is a propaedeuticity for:** None.		
Types of examinations and other tests: Oral examination and practical test.		

Course: Astrophysics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/05	**CREDITS:** 9
Course year: II	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
The course introduces the student to the fundamentals of Astrophysics from a theoretical, observational and experimental point of view. In particular, the student will learn how to determine the physical characteristics of celestial bodies from telescope-observable quantities, with emphasis on
observations in the visible part of the electromagnetic spectrum. The student will learn how to use these observables to construct a physical model of celestial systems, and in particular of interstellar clouds, stars, end products of stellar evolution such as white dwarfs, neutron stars and black holes, and understand their formation and evolution. At the end of the course, students should be able to apply these notions to understand simple scientific articles on astronomy and astrophysics as well as to carry out astronomical observations.

Propaedeuticities: -
Is a propaedeuticity for: -

Types of examinations and other tests: Written and/or oral exam.

Course: Big Data Seismology	**Teaching Language:** Italian
SSD (Subject Areas): FIS/06	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course the necessary skills to define and develop physical and mathematical methods to study solid Earth will be given.

Learning objectives:
The course aims at providing knowledge and understanding of the informatic tools to analyze, model and represent big data from observations carried on earth surface.
Machine learning, deep learning, mixed effects regression approaches will be introduced and applied to large datasets to infer seismic source properties, ground motion prediction equations and to characterize the temporal and spatial variability of seismic noise. In particular, at the end of the course the student will:
- Master the basic concepts of the analysis, representation, and modeling of geophysical big data.
- Autonomously develop applications of studied techniques to real cases.

Propaedeuticities: none. Nevertheless, a prior knowledge of the basics of signal processing and programming is required.
Is a propaedeuticity for: none.

Types of examinations and other tests: oral with the discussion of a brief numerical application to seismic data previously assigned.

Course: Biophotonics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the experimental treatment of the properties of propagation and interaction of photons with biological matter.

Learning objectives:
Biophotonics is an emerging area of research in a particularly topical field concerning the most advanced studies of biological systems with relevant scientific and technological implications. It is a research area with a strong interdisciplinary connotation. In fact, biophotonics aims at the use of very advanced photonic techniques to investigate biological systems, from the mesoscopic scale to that of a single molecule.
The aim of the course is to give a broad, but not too narrow, overview of this wide field, taking care of both the theoretical and experimental aspects of the main techniques.

Propaedeuticities: None **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral exam	

Course: Classical Electrodynamics		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/03			**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B		
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: It includes the competencies on the properties of photon propagation and interaction with fields and matter. The skills also pertain to research in the fields of photonics, optics, optoelectronics, and quantum electronics.			
Learning objectives: The student will acquire advanced knowledge on the main phenomena of electromagnetism in vacuum and in material media, including the relativistic formulation of electromagnetism. This will require learning the basics of special relativity and the covariant formalism. Regarding applied skills, the student will be able to solve electromagnetism problems of basic/intermediate-level and will gain familiarity with some more advanced mathematical tools to solve partial differential equations typical of electromagnetism, such separation of variables, Green's function, and expansion in functional bases.			
Propaedeuticities: None **Is a propaedeuticity for:** Classical Field Theory, Quantum Field Theory I.			
Types of examinations and other tests: Written and oral exam.			

Course: Classical Field Theory		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/02			**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C		
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena. Research on foundations of physics, dynamical systems, special relativity, general relativity and relativistic theories.			
Learning objectives: The course aims at furnishing the theoretic and mathematical bases which are needed to approach modern field theory, with particular emphasis on gauge theories of fundamental interactions and general relativity. At the end of the course the successful student will be able to: − Understand and use the geometric formalism of field theory; − Revise her/his knowledge of electrodynamics and relativity in a unified approach to fundamental interactions; − Apply the techniques and methods which have been taught, to different contexts, not necessarily treated in class, such as condensed matter physics and modern theories of gravity; − Formalize and schematize problems in theoretical physics.			
Propaedeuticities: Classical Electrodynamics. **Is a propaedeuticity for:** None.			
Types of examinations and other tests: Written and/or oral exam.			

Course: Complements of Cosmology		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/05			**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C		
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.			
Learning objectives: The course aims to provide students with advanced skills in theoretical and observational aspects of modern cosmology and theories of gravitation, starting from relativistic cosmology. Consideration will be given to the so-called Standard Cosmological Model, inflationary models, up to physical models of dark energy. The course will take an advanced theoretical approach without neglecting phenomenological aspects. In particular, advanced topics such as gravitational waves in cosmology,			

gravitational lensing, Quantum Cosmology and modified theories of gravitation will be considered. Classes of solutions of Einstein's equations such as black holes, compact objects and wormholes will be covered during the course.
Propaedeuticities: Cosmology **Is a propaedeuticity for:** None
Types of examinations and other tests: Written and/or oral exam.

Course: Complements of Mathematical Methods for Physics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/02		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.		
Learning objectives: The aim of the course is to provide the student with some advanced mathematical tools of Theoretical and Applied Physics, concerning, for example, some arguments of Functional Analysis and of the theory of partial differential equations. At the end of the course the student must be able to: - clearly and rigorously present the studied topics; - frame the topics dealt with in the context of the reference mathematical theories; - mindfully use the acquired tools in applicative contexts, paying particular attention to the limits imposed by the needed assumptions.		
Propaedeuticities: - / Topics of Mathematical Analysis and Mathematical Methods for Physics covered in the BSc in Physics (First Degree in Physics). **Is a propaedeuticity for:** -		
Types of examinations and other tests: The exam consists in a written/oral exam during which it will be possible to discuss a report prepared by the student.		

Course: Complex Systems		**Teaching Language:** Italian
SSD (Subject Areas): FIS/02		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Research on statistical aspects of complex physical systems.		
Learning objectives: This is an advanced Statistical Mechanics course on the Theory of Complex Systems in Physics. Its topics include: Probability Theory and Stochastic Processes; Advanced Statistical Mechanics of equilibrium and off-equilibrium processes; Theory of Phase Transitions, Critical Phenomena and Emergent behaviors; Renormalization Group and Universality; Spin Glasses; Network theory; Computer simulations (Monte Carlo and Simulated Annealing). The course also covers important applications in Physics as well as in Quantitative Biology and Finance, to highlight related international careers in science and business.		
Propaedeuticities: Quantum Mechanics / Elements of Statistical Mechanics at the level of a BSc degree. **Is a propaedeuticity for:** None.		
Types of examinations and other tests: Written and/or oral exam		

Course: Computational Thermodynamics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: I/II	**Type of Educational Activity:** Frontal lectures	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Comprende le competenze necessarie alla trattazione teorica e sperimentale degli stati di aggregati sia atomici sia molecolari, nonché le competenze atte alla trattazione delle proprietà di propagazione e interazione dei fotoni con i campi e con la materia. Le competenze di questo settore riguardano anche la ricerca nei campi della fisica atomica e molecolare, degli stati liquidi e solidi, dei composti e degli elementi metallici e semiconduttori, degli stati diluiti e dei plasmi, nonché della		

fotonica, dell'ottica, dell'optoelettronica e dell'elettronica quantistica.

Learning objectives:
Introduction to the link between thermodynamics and statistical physics, use of computational tools to calculate thermodynamic properties of materials via computer simulation of free energies.

Propaedeuticities: -
Is a propaedeuticity for: -

Types of examinations and other tests: Written report

Course: Continuum Mechanics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/06	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course the necessary skills to define and develop physical and mathematical methods to study solid and fluid Earth will be given.

Learning objectives:
The course aims at providing knowledge and understanding of the basic theory of elasticity and fluid dynamics. Also, the course aims to show how this knowledge and understanding is applied in geophysics to the modeling of the Earth, both solid and fluid. During the course, exercises, both analytical and numerical, will be given to increase the ability of the student to make judgements about the application of the knowledge to geophysical modeling. In particular, at the end of the course the student will:

- Master the basic concepts of the theory of elasticity and fluid dynamics.
- Understand and autonomously develop applications of that concepts to the modeling of the Earth.
- Autonomously develop, even if in a simple fashion, numerical and analytical solutions to given problems.

Propaedeuticities: none. Knowledge about fundamentals of mechanics and thermodynamics is required.
Is a propaedeuticity for: none. Nevertheless, the acquired knowledge may be useful for the courses of "Earth and Atmospheric Physics" and "Seismology".

Types of examinations and other tests: oral exam.

Course: Data Analysis in Subnuclear Physics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/01	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory consistent with the training objectives of the course:
The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.

Objectives:
The course aims at providing knowledge and hands-on skills about the techniques for the statistical treatment and interpretation of experimental data, and the communication and presentation of the results. It deepens and broadens the topics of basic statistics, describing their application in modern particle physics experiments, and provides additional advanced statistical tools of common application in current analyses.
At the end of the course the student will be able to:
- master advanced probability theory concepts and apply them to concrete physics cases
- understand the designs of experiments and the techniques they use to reach their physics goals
- understand and assimilate procedures in other data analysis using the skills, language, and mindset acquired
- critically examine, design and carry out data analyses

Propaedeuticities: None.
Is a propaedeuticity for: None.

Types of examinations and other tests: Oral examination and practical test.

Course: Design of Educational Activities	**Teaching Language:** Italian
SSD: FIS/08	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course, skills are provided for the transfer of fundamental concepts and knowledge of physics

Learning objectives:
The course will enable learners to gain in-depth knowledge of research results in physics education with particular emphasis on strategies for designing and evaluating teaching interventions in upper secondary schools. In addition, learners will gain in-depth knowledge of data analysis techniques commonly used in education.
The student must demonstrate
At the end of the course the student must demonstrate that he/she
- be able to carry out experiments, document activities, design worksheets and evaluation tools for structuring teaching interventions in upper secondary schools.
- to be able to select appropriate teaching materials and activities to be proposed to upper secondary school students in accordance with the provisions of the National Indications for Licei and Italian school practice.
- to know how to reconstruct the knowledge and research methodologies of physics from an educational point of view in order to design teaching interventions suitable for upper secondary school students

Propaedeuticities: General Physics and Laboratory
Is a propaedeuticity for: Didactical Design for Physics and Educational Technologies for Physics Teaching

Types of examinations and other tests:
Examination centred on the discussion of a written project paper consisting of a portfolio and fact sheets

Course: Didactical Design for Physics	**Teaching Language:** Italian
SSD: FIS/08	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course, skills are provided for the transfer of fundamental concepts and knowledge of physics

Learning objectives:
The course is designed to enable students to acquire skills in micro- and macro-teaching design, aimed at promoting physics learning at upper secondary school level. The course also promotes the acquisition of skills in observation, documentation, verification and evaluation of process, product and context, interrelated and interconnected, aimed at improving learning and the educational success of students.
At the end of the course, students will have acquired mastery in relation to: - didactic planning, also by learning units, and flexibility; organisation and management of class/interclass groups also by level, task and elective groups such as to favour personalisation and the enhancement of each individual's talents, the development of transversal, linguistic-communicative skills and meaningful, critical and aware learning for all
students; - knowledge of the national guidelines/indications and correlation with disciplinary knowledge and the school curriculum, if any, with reference to the learning objectives, to the competence targets or to the learning outcomes envisaged by the educational systems in force - promotion of the eight European key competences for lifelong learning; modulation of the educational pathway according to a planned and gradual subdivision of the contents, providing appropriate tools for the different levels of ability and cognitive styles of the pupils;

Propaedeuticities: Design of Educational Activities
Is a propaedeuticity for: Educational Technologies for Physics Teaching

Types of examinations and other tests:
Written examination focusing on the design, also using multimedia digital technologies, of an innovative teaching activity, including the illustration of the content, teaching and methodological choices made

Course: Didactics of Modern Physics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/08	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course allows the students to acquire competences in the study and development of teaching methods and transfer of the fundamental concepts and knowledge of physics. It also aims at familiarizing the students with issues related to foundational physics concepts

Learning objectives:
The course offers students an overview of the theoretical and experimental aspects of Didactics of Physics, with a focus on modern and contemporary physics. In terms of knowledge, the course will provide contents of disciplinary education, mainly based on papers from the current scientific literature. In terms of skills, the course will provide an

opportunity to get acquainted with the main topics of research in Didactics of Physics, with the perspective of application to real educational contexts. Furthermore, the course will give the opportunity to strengthen the skills of communication in the educational contexts
Propaedeuticities: Physics Education I. / Students possessing a three-year degree in Physics will attend the course without difficulty. For students with different backgrounds, a good knowledge of General Physics and notions of Didactics of Physics are required. For such students, the course will allow a targeted reinforcement on some themes of modern physics. **Is a propaedeuticity for:** None
Types of examinations and other tests: Examination based on the discussion of a written project report

Course: Digital Electronics	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/01		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: the course provides the necessary skills to investigate the working principles of instrumentation used for detection of particle physics interactions, for the acquisition of radiation detectors, and for the digital elaboration of experimental data.		
Learning objectives: Knowledge of the main techniques for analysis and synthesis of digital circuits. Redundancy and minimization of combinatorial circuits. Analysis of the sequential building blocks (counters, shifters, LFSR, architecture of programmable logic). Design of Finite State Machine in high performance applications, including self-initialization features. Timing analysis of digital circuits and error recovery techniques. Design of complex systems with application to laboratory equipment. Ability to master in autonomy advanced literature, including scientific and technical papers.		
Propaedeuticities: none. A basic knowledge of electronics is required. **Is a propaedeuticity for:** none. Nevertheless, the knowledge acquired may be useful for the course of Digital Systems Laboratory.		
Types of examinations and other tests: oral exam, consisting in the discussion of argument presented during the course.		

Course: Digital Image Processing	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/07		**CREDITS:** 6 CFU
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course includes the skills suitable for the study and development of physical methodologies (theoretical and experimental) necessary both for the description and understanding of living matter in particular in the medical context, and for the development and use of the necessary tools (information systems) in area of prevention, diagnosis and treatment. The skills of this sector also concern research in the field of image analysis in the field of radiation protection of man, the environment and things.		
Learning objectives: The course is aimed at providing students with knowledge on the fundamentals of digital image processing and will have to demonstrate the acquired ability to apply this knowledge to image analysis in the medical and clinical fields, through the use of application software used in scientific field. Furthermore, students will acquire basic knowledge on the main image formats and information systems for the management and transmission of images in the medical field, and on the parameters used in the analysis of image quality and medical imaging systems.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral exam		

Course: Digital Systems Laboratory	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/01		**CREDITS:** 9
Course year: II	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: the course		

provides the necessary skills to investigate the operating principles of electronic instrumentation for the control and detection of physical phenomena and for the acquisition of experimental data.
Learning objectives: the course aims at learning the main techniques of analysis and synthesis of digital circuits for applications in instrumentation of physics experiments. The learning path includes the study of the architecture of field programmable gate arrays (FPGA) devices, of the techniques for the implementation in FPGA of the main combinatorial and sequential logic blocks, with particular attention to finite state machines and high-speed data transmission systems. Specifically, at the end of the course the student will be able to: - use hardware description languages, both for the synthesis and for the simulation of digital circuits; - design complex digital systems in FPGA devices for applications in instrumentation; - understand specialized texts and research articles in the sector.
Propaedeuticities: none. / Basic notions of analog electronics (MOSFET transistor operation, transmission lines) and digital electronics (truth tables of Boolean functions, elementary logic functions, flip-flops). **Is a propaedeuticity for:** none.
Types of examinations and other tests: oral exam, consisting in the presentation of the design and implementation of an FPGA-based digital system and in the oral discussion of topics developed during the lessons of the course.

Course: Earth and Atmospheric Physics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/06	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: During the course the necessary skills to define and develop physical and mathematical methods to study solid and fluid Earth will be given.	
Learning objectives: The course is aimed at learning methods and tools for understanding the Earth-Atmosphere system, through the integration of observations and analytical and numerical models, realizing a transversal path starting from seismic waves and going to the Earth's magnetic field and the atmosphere dynamics. Specifically, at the end of the course the student will be able to: - Use analytical and numerical methods and tools to solve problems concerning the Earth-Atmosphere system. - Integrate data and models to constrain solutions related to problems of the Earth-Atmosphere system. - Rework his/her knowledge of physics for the analysis of new experimental situations and the definition of new models. - Simulate the internal processes of the Earth-Atmosphere system	
Propaedeuticities: none. A basic knowledge of analysis of PDE, elements of wave mechanics, elements of continuum mechanics is required. **Is a propaedeuticity for:** none. Nevertheless, the knowledge acquired may be useful for the Seismology course.	
Types of examinations and other tests: written exam consisting in the numerical solution of une problem involving PDE, and oral consisting in the discussion of argument presented during the course.	

Course: Educational Technologies for Physics Teaching	**Teaching Language:** Italian
SSD (Subject Areas): FIS/08	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: During the course, skills are provided for the transfer of fundamental concepts and knowledge of physics	
Learning objectives: The course is aimed at enabling students to acquire skills relating to the ability to: promote media literacy, use digital technologies for organizational communication, collaboration and professional growth; identify, evaluate and select digital resources useful for teaching, taking into due consideration - also in the design phase - the specific learning objectives, the context of use, and the needs of the students who will use them; use digital technologies to foster greater inclusion, personalization and active involvement of students helping students to use digital technologies creatively and responsibly for activities concerning information, communication, content creation,	

personal well-being and problem solving; using digital technologies to support self-regulated learning processes (planning, monitoring, metacognitive reflection); using digital tools and strategies to improve assessment practices. At the end of the course the student will have to show: the ability to integrate information and communication technologies within the activity; the ability to transform, also with the use of digital tools and didactics, in presence and at a distance, teaching into meaningful and critical learning by the student
Propaedeuticities: Design of Educational Activities or Didactical Design for Physics **Is a propaedeuticity for:** None
Types of examinations and other tests: Written examination focusing on the design, also using multimedia digital technologies, of an innovative teaching activity, including the illustration of the content, teaching and methodological choices made

Course: Electronics Fundamentals		**Teaching Language:** Italian
SSD: FIS/01		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: the course provides the necessary skills to investigate the working principles of instrumentation used for detection of particle physics interactions, for the acquisition of radiation detectors, and for the digital elaboration of experimental data.		
Learning objectives: Knowledge of all discrete circuit elements commonly used in modern applications. Role of the corresponding elements in integrated microelectronics. In-depth study of circuit theory, from principles to frequency and stability analyses. Ability to evaluate analogue circuit diagrams and design circuits, for the processing of signals from sensors and detectors and for the preparation for digital data acquisition; particular attention to applications in the field of "front end" electronics of detectors in the physical field. Understanding of noise phenomena in electronics.		
Propaedeuticities: none. Basic knowledge of electronics in terms of linear devices and circuits. **Is a propaedeuticity for:** none. Nevertheless, the knowledge acquired may be useful for the courses of “Digital Systems Laboratory” and “Sensors and Detectors”.		
Types of examinations and other tests: oral exam, consisting in the discussion of argument presented during the course.		

Course: Environmental Radioactivity		**Teaching Language:** Italian
SSD (Subject Areas): FIS/07		**CREDITS:** 6 CFU
Course year: II	**Type of Educational Activity:** C	
Contents extracted from SSD declaratory consistent with the learning objectives of the course: The course focuses the skills for the study and development of physical methodologies (theoretical and experimental) necessary both for the description and understanding of environmental radioactivity, and for the use of the instrumentation for the control and the detection of the physical phenomena concerned. The skills also concern the radiation protection of man and environment.		
Learning objectives: The course is aimed at providing students with the fundamental and advanced knowledge on radioactivity and its implications in the environmental field. The following topics will be covered: process of radioactive decay; properties of ionizing radiation; effects in matter crossed by ionizing radiation; radiation effect on humans; ionizing radiation sources in the environment, both of natural origin and artificial origin; production method of artificial radioactive isotopes; environmental contamination in soil, water and air; monitoring systems for the environmental radioactivity; techniques used for detection of ionizing radiation; notions of radiation protection. The course will include frontal lectures alternating with various laboratory experiences on some topics covered, in particular: thermoluminescence dosimetry, alpha(α) and gamma(γ) spectrometry, and passive and active measurements of radon (^{222}Rn, ^{220}Rn) indoor and outdoor. This laboratory activity will have the dual purpose of both experimental deepening and that of improving the skills in data analysis and in the treatment of measurement uncertainties. The knowledge acquired in this course will allow students to: (i) have a more complete vision of the phenomenon of radioactivity and its applications; (ii) autonomously understand new experimental research results based on environmental radioactivity principles; (iii) communicate, with mastery, the arguments of a branch of physics in continuous evolution.		
Propaedeuticities: None		

Is a propaedeuticity for: None	
Types of examinations and other tests: Oral exam with discussion of laboratory reports	

Course: Experimental Gravitational Physics	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/01		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.		
Objectives: The course aims to foster understanding of experiments in the physics of gravitation and the critical review of experimental results in relation to current theories. At the end of the course the student will be able to: - Understand the tools of experimental investigation in gravitation; - Understand the different experimental approaches to explore the validity of different alternative theories; - Apply the data analysis methodologies characteristic of this field.		
Propaedeuticities: None. **Is a propaedeuticity for:** None.		
Types of examinations and other tests: Oral and written examination.		

Course: Experimental Methods for Nanotechnologies and Condensed Matter Physics	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical and experimental treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Learning objectives: This course is meant to encourage students to study the physical ideas, the design and the realization of frontier experiments in Solid State Physics, with a special focus in the fields of Quantum Technologies and Nanotechnologies. Quantum hardware is what transforms the novel concepts of quantum computation and communication into reality. The key challenge is to control, couple, transmit and read out the fragile stage of quantum systems with great precision, and in a technologically viable way. This course aims at illustrating some aspects of this key challenge in realizing quantum hardware and technology, focusing on superconducting quantum devices. Some key notions on advanced solid-state physics will be introduced as a bridge to standard courses, including phase transitions, quantum effects in transport properties and mesoscopic physics. Three experiments are part of the course: realization of a nanostructure, measurement of its transport properties in low noise environment at the lowest temperatures and measurement of the properties of a Josephson junction or of a superconducting qubit.		
Propaedeuticities: - **Is a propaedeuticity for:** -		
Types of examinations and other tests: Oral exam with discussion of a project report		

Course: Experimental Standard Model Physics	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/01		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory consistent with the training objectives of the course:		

The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.
Objectives: The course aims at providing advanced knowledge of the experimental basis of the Standard Model of subnuclear physics as well as of the search for its possible extensions. At the end of the course the student will have acquired: -knowledge of the advanced experimental techniques used to study the Standard Model; -knowledge, understanding and ability to critically evaluate recent specialist literature and the ability to independently follow research developments in the field.
Propaedeuticities: None. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Oral examination.

<table>
<tr><td colspan="2">Course:
Experimental techniques in Particle Physics</td><td colspan="2">Teaching Language:
Italian</td></tr>
<tr><td colspan="3">SSD (Subject Areas):
FIS/01</td><td>CREDITS:
6</td></tr>
<tr><td>Course year: II</td><td colspan="3">Type of Educational Activity: C</td></tr>
<tr><td colspan="4">Contents extracted from the SSD declaratory consistent with the training objectives of the course:
The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.</td></tr>
<tr><td colspan="4">Objectives:
The course aims at providing knowledge and understanding of the most advanced experimental techniques used in elementary particle physics to study the fundamental constituents of matter and their interactions.
At the end of the course the student will have acquired
- knowledge of the physical quantities actually measured to study elementary particles and characterise their interactions and of the relevant reconstruction/processing techniques from the collected data;
- knowledge and understanding of the structure of the complex experimental apparatuses required to realise such measurements;
- understanding and ability to critically evaluate the most recent experimental literature in the field of physics of fundamental interactions</td></tr>
<tr><td colspan="4">Propaedeuticities: None.
Is a propaedeuticity for: None.</td></tr>
<tr><td colspan="4">Types of examinations and other tests: Oral examination.</td></tr>
</table>

<table>
<tr><td colspan="2">Course:
Flavor Physics</td><td colspan="2">Teaching Language:
Italian</td></tr>
<tr><td colspan="3">SSD (Subject Areas):
FIS/01</td><td>CREDITS:
6</td></tr>
<tr><td>Course year: II</td><td colspan="3">Type of Educational Activity: C</td></tr>
<tr><td colspan="4">Contents extracted from the SSD declaratory consistent with the training objectives of the course:
The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.</td></tr>
<tr><td colspan="4">Objectives:
The course aims at introducing the student to flavour physics, an advanced field of research in elementary particle physics that aims to investigate Standard Model (SM) physics and search for processes beyond the SM in virtual processes through precision studies. The main topics are dealt with from both a phenomenological and an experimental point of view.
In particular, at the end of the course the student will be able to:
- understand the role of flavour physics in the context of elementary particle physics
- understand the results of the main flavour physics experiments
- interpret plots and numerical data in relation to the proposed physical models
- have developed the ability to present the arguments of a constantly evolving branch of physics and be able to follow its future developments independently</td></tr>
</table>

Propaedeuticities: None **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral examination and practical test.	

Course: Fundamentals of nanomagnetism and applications	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/01		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical and experimental treatment of the magnetic properties of nanometric-sized aggregates. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements as well as photonics, optics and optoelectronics.		
Learning objectives: The course aims to provide students with the fundamental methodologies to understand the magnetic response of a collection of magnetic nanoparticles and thin films. • Starting from a review of the properties of dia-, para- and ferromagnetic materials, the magnetic stability of magnetic nanoparticles of different sizes, shapes, crystalline structure and composition will be investigated, as well as the role of intra-particle and inter-particle magnetic interactions on behaviour of a nanoparticles ensemble. Finally, using this fundamental knowledge, the possibilities of controlling the magnetic properties of particles at the nanoscale will be presented. • The role of magnetic nanoparticles in some medical, biosensing and environmental applications will be described: contrast enhancement in magnetic resonance imaging (MRI), magnetic hyperthermia for cancer therapy, targeted drug delivery, immunosesnosors, separation of environmental contaminants, soil and groundwater remediation. • Experimental techniques to investigate collective and individual static magnetic responses of superparamagnetic nanoparticle and thin film will be presented, including a visit to the laboratories with the realisation of simple experiences related to the course contents. By the end, the students will have acquired the basic skills on the main experimental techniques to address specific problems in nanomagnetism.		
Propaedeuticities: Propaedeutic exams are not required **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral exam with discussion of a written project report		

Course: General Relativity and Gravitation	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/02		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena. Research on special relativity, general relativity and relativistic theories.		
Learning objectives: The objective of the course is to introduce the student to General Relativity, reaching a solid understanding of its conceptual structure and good familiarity with the techniques needed for the analysis of its most significant effects. By the end of the course the student will be able to use the Schwarzschild solution for the description of planetary systems; to establish whether a geometry is singular; to find a cosmological solution when the energy-momentum tensor of matter and radiation is known; to establish whether or not a spacetime is maximally symmetric; to model simple mechanisms for the production of gravity waves.		
Propaedeuticities: - **Is a propaedeuticity for:** Introduction to Quantum Gravity; String Theory		
Types of examinations and other tests: Written and/or oral exam		

Course: Group Theory and Applications	**Teaching Language:** Italian

SSD (Subject Areas):		CREDITS:
FIS/02		6
Course year: II	**Type of Educational Activity:** C	

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.

Learning objectives:
The main aim of the course is to provide the student with ideas, concepts and methods of the theory of groups, and of their representations, that are fundamental for a deeper understanding of quantum mechanics and quantum field theory, as well as of other areas of modern theoretical physics. The course is also aimed at introducing some remarkable applications. After the course, the student should be able to:
- Understand basic concepts of group theory and of its applications;
- Master some methods of the theory of groups and of their representations (e.g., representations of the Lorentz and Poincare' groups, of SU(2) and SU(3)).

Propaedeuticities: Quantum Mechanics.
Is a propaedeuticity for: None.

Types of examinations and other tests: Written and/or oral exam

Course:	Teaching Language:
High Energy Astrophysics	Italian
SSD (Subject Areas): FIS/05	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
The course aims to provide students with the essential skills to achieve a panchromatic view of astrophysical phenomena. In particular, it aims to provide an understanding of high energy processes, combining theoretical, observational and phenomenological aspects, with a focus on the fundamental physical principles underlying the phenomena studied. The course also aims to provide students with knowledge of the main detection techniques and the most important high-energy photon detectors. The description of the basic mechanisms and that of the devices used for detection will focus on rigorous and well-established analytical and numerical methods. In particular, at the end of the course students will be able to:
- Examine and describe the mechanisms involved in the radiation-matter interaction processes in the various astrophysical phenomena typical of high energies.
- Rework their knowledge of high energy astrophysics to solve extra-manual problems to address the most recently developed topics.
- Understand the detection techniques for high energies and know the most widely used detectors.
- Demonstrate the operation of the devices studied.

Propaedeuticities: Astrophysics
Is a propaedeuticity for: None

Types of examinations and other tests: Written and/or oral exam.

Course:	Teaching Language:
History of Astronomy	Italian
SSD (Subject Areas): FIS/05	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
The course aims to introduce students to the historical development of astronomy from its earliest developments in ancient civilisations to the birth of modern astrophysics and cosmology, with particular emphasis on the Hellenistic

and modern scientific revolutions and the transition from the geocentric to the heliocentric conception. The aim of the course is to enable students to conduct independent research on historical topics related to astronomy.
Propaedeuticities: None **Is a propaedeuticity for:** None
Types of examinations and other tests: written and/or oral exam.

Course: History of Classical Physics	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/08		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course allows the students to acquire competences in the study of the history of physics as resulting from the onset of the physical ideas. It also aims at familiarizing the students with historical problems related to foundational concepts of classical physics.		
Learning objectives: The general purpose of the course is to help the student to critically rethink – through historical paths – the fundamental aspects of classical physics learned during university courses, deepening the inter-relationships between the different and successive interpretations of physical phenomena and the models used to describe them. The cognitive goals to be achieved are the historical-critical knowledge of some physical themes studied from a positive and curricular point of view. The skills to be acquired concern the structuring of a historical picture regarding the evolution of physical science from the 16th to the 19th century. The course also aims to provide the student with the proper approach to the History of Physics required to understand the research methods in this field. The student will be guided in the application of his knowledge, also participating in activities (visits to the Physics Museum of the University, illustrative reconstructions of historical experiments) to familiarize with the methodologies presented.		
Propaedeuticities: Mastering of the course of Mechanics and Thermodynamics, as well as that of Electromagnetism. **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral Examination		

Course: History of Modern Physics	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/08		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course allows the students to acquire competences in the study of the history of physics as resulting from the onset of the physical ideas. It also aims at familiarizing the students with historical problems related to foundational concepts of modern physics.		
Learning objectives: The purpose of the course is to critically supplement – through historical paths – fundamental aspects of the 20th century physics with critical directions coming from the historical analysis. The cognitive goals to be achieved pertain to the historical-critical knowledge of some themes of modern physics, through the examination of case studies, with particular attention to the conceptual aspects, the role of instrumentation and the socio-cultural context of physics research. The skills to be acquired concern the placement of specialized topics (already addressed by the student in his studies) within a historiographical reference framework. The course also aims to provide research skills in the history of physics, with particular reference to the problem of historical sources, their identification and their critical evaluation. The student will be guided in the application of his knowledge, also participating in activities (visits to the Physics Museum of the University, etc.) to familiarize with the methodologies presented.		
Propaedeuticities: Mastering of the courses of: Mechanics and Thermodynamics; Electromagnetism; Quantum Mechanics; Modern Physics. Knowledge of the main contents of the course of Quantum Physics. **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral Examination		

Course: Introduction to Quantum Gravity	**Teaching Language:** Italian	
SSD (Subject Areas): FIS/02		**CREDITS:** 6

Course year: II	Type of Educational Activity: C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena. Research on foundations of physics, special relativity, general relativity and relativistic theories.

Learning objectives:
The objective of the course is for the student to learn about the structure of the quantum-gravity problem and how different approaches to the problem are related to that structure. The student will also enrich his/her knowledge of techniques of theoretical physics, including those used in the first stages of development of the spacetime-noncommutativity approach, the string-theory approach and the loop-quantum-gravity approach. By the end of the course the student will be able, for example, to establish the presence of “anomalies” in a quantum theory (Weyl anomaly), will be able to analyze the symmetries of a system when they are described by a Hopf algebra and will be able to work within the version of quantum mechanics known as the Schroedinger Functional Picture.

Propaedeuticities: General Relativity and Gravitation, Quantum Field Theory I.
Is a propaedeuticity for: -

Types of examinations and other tests: Written and/or oral exam

Course: Introduction to Volcano and Non Standard Seismology	Teaching Language: Italian
SSD (Subject Areas): FIS/06	CREDITS: 6
Course year: II	Type of Educational Activity: C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course the necessary skills to define and develop physical and mathematical methods to study solid Earth will be given.

Learning objectives:
The course aims at introducing the volcano and non-ordinary seismicity. Such seismicity shows peculiar properties of the wave field and of the scaling laws, also for the active role of fluids in the source process. Under these respects these properties are not effectively modeled as double-couple sources.
In the lectures volcanic seismicity (volcano-tectonic, Long-Period and Very Long Period events, tremor), tectonic tremor and Low Frequency events, human-induced seismicity will be introduced. The seismic signals recorded in the different contexts will be presented together with their characteristics in time and frequency, the physical models of the source, the statistical properties, emphasizing the deviation of these aspects from those of the standard seismicity. Also, numerical tools for the analysis of the presented seismicity will be introduced.
At the end of the course the student will:

- Master the basic aspects of the modeling and analysis of seismic data gathered in non-tectonic areas
- Understand and autonomously develop applications of the studied techniques to real cases.

Propaedeuticities: none. Nevertheless, a basic knowledge of signal processing and programming is required.
Is a propaedeuticity for: none.

Types of examinations and other tests: oral with the discussion of a brief project on one of the topics introduced in the course.

Course: Inversion Methods	Teaching Language: Italian
SSD (Subject Areas): FIS/06	CREDITS: 6
Course year: I	Type of Educational Activity: B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course the necessary skills to define and develop physical and mathematical methods to study solid and fluid Earth will be given.

Learning objectives:
The main goal of the course is to promote the knowledge and understanding of parameter estimation and inverse problem philosophy and methodology, specifically regarding such key issues as uncertainty, ill-posed problems, regularization, bias, and resolution. Learning skill of theoretical points is developed through MATLAB numerical codes.
At the end of the course, the student should be able to:

- understand and refer to inverse problems
- implement numerical tools needed for resolving some case-studies

- have matured skills for interpreting and critically commenting obtained results.

Propaedeuticities: none. Students are expected to be familiar with linear algebra, differential equations, vector calculus, probability, statistics, and calculus.
Is a propaedeuticity for: none. Nevertheless, the acquired knowledge may be useful for the courses of Seismology.

Types of examinations and other tests: oral presentation and discussion of some exercises developed during the course.

Course: Laboratory of Astrophysics
Teaching Language: Italian

SSD (Subject Areas): FIS/05
CREDITS: 6

Course year: II
Type of Educational Activity: C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
The aim is to enable students to design and conduct a simple observational or experimental programme, including the acquisition, reduction and analysis of data.
The course programme includes recollections of advanced statistics, an introduction to modern astronomical technologies (ground-based and space-based) and an introduction to computer tools for analysing astronomical data. The course includes one or more laboratory experiences on different topics. In preparation for the final exam, students will write a report on the experience conducted.

Propaedeuticities: None
Is a propaedeuticity for: None

Types of examinations and other tests: Final report and oral exam.

Course: Laboratory of Medical Physics
Teaching Language: Italian

SSD (Subject Areas): FIS/07
CREDITS: 6

Course year: II
Type of Educational Activity: B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course includes competences for the study and development of physical methodologies (theoretical and experimental) for the description and understanding of living matter in the medical field, as well as related to the development and use of necessary instrumentation for the control and detection of physical phenomena in the field of prevention, diagnosis and treatment. Competences include also the research in the field of physical techniques in biomedical diagnosis, as well as in the field of radioprotection.

Learning objectives:
The student will be requested to conduct experiments in the field of the medical physics and radiation physics. In particular, exercises and experiments will involve the use of specialistic instrumentation of common use in the field of the medical imaging with ionizing radiation as well as in the field of dose measurements. The student will work in small groups and will cope with theoretical and practical exercises to elaborate and analyze raw data. In addition, he/her will be requested to produce a written text and a presentation with the scope of illustrating the methods adopted and results, also with the aim of acquiring expertise in scientific reporting.

Propaedeuticities: Medical Physics, Radiation Dosimetry
Is a propaedeuticity for: None

Types of examinations and other tests: Oral and practice. The student will be requested to illustrate and comment on the experimental activities performed during the course.

Course: Laboratory of Modern Optics
Teaching Language: Italian

SSD (Subject Areas): FIS/01,FIS/03
CREDITS: 6

Course year: II
Type of Educational Activity: Frontal lectures and laboratory

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
An overview of the experimental techniques most used in the manipulation of the properties of electromagnetic radiation, such as beam intensity profile, polarization states, temporal and spectral profile, will be provided. The

course will provide the description of various methods based on suitably formed light and photon beams in the study of atomic and molecular physics, liquid and solid states, metal and semiconductor compounds and elements, dilute states and plasmas.
Learning objectives: The student will learn the operating principles of the main optical radiation detectors, of many spectroscopic techniques as well as optical, near field (SNOM, STM, AFM) and electronic (SEM, TEM) microscopy. Furthermore, some time-resolved spectroscopic methods such as THz spectroscopy and the measurement of ultrashort light pulse durations will be illustrated. Depending on the type of application, the student will be able to design experiments based on the use of laser sources with high spectral purity or short duration. Part of the training will take place in a laboratory with the implementation of some measurement techniques in the field of physics of matter.
Propaedeuticities: - **Is a propaedeuticity for:** -
Types of examinations and other tests: Oral exam with discussion of a measurement technique

Course: Laboratory of Nuclear Physics	**Teaching language:** Italian	
SSD: FIS/01		**CFU:** 9
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course provides the knowledge on the physical processes and the working principles of the instrumentation devoted to the monitoring and the detection of particles and radiation, their production, their metrology and the connected data collection and analysis.		
Learning objectives: - The student will acquire a detailed knowledge on the principles and the use of the instrumentation typical of the measurements in Nuclear Physics studies. - The student will be able to use analog and digital data acquisition systems, as well as the more common analysis practices in Nuclear Physics experiments at low and moderate energies. - The student will be able to apply the acquired knowledge to plan and conduct experiments in Nuclear Physics fundamental research, in the environmental surveillance, in the radioprotection assessments, in medical physics, in the metrology of ionizing radiations. - The student will be able to understand and present with appropriate terminology the principles, the techniques and the results of measurements with exotic nuclei ion beams. - The student will be able to understand and autonomously interpret the results of experimental measurements in Nuclear Physics and will be in position to evaluate the appropriateness of the instrumentation and the applied methodologies.		
Propaedeuticities: none. / A good knowledge of classical physics, as well as the basics in quantum mechanics and modern physics, is expected. **Is a propaedeuticity for:** none		
Types of examinations and other tests: Preparation of a report on an assigned topic and oral examination.		

Course: Machine learning methods for physics	**Teaching Language:** Italian	
SSD (Subject Areas): INF/01		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area brings together competences and research areas from the fields of computer science and information theory, which form the basis of the computer science approach to the study of problems [...] the field includes application and experimental areas related to innovative uses of computer science, such as image and sound processing, computer recognition and vision, neural networks, artificial intelligence and soft computing[…].		
Objectives: The course will provide knowledge and understanding in the field of artificial intelligence and machine learning algorithms. The main areas of machine learning such as supervised, unsupervised and reinforcement learning will be covered. Knowledge of data pre-processing (feature selection and extraction, dimensionality reduction, handling of missing data and categorical data) and knowledge related to validation techniques of machine learning models will also be provided. In this context, students will develop knowledge and applied skills related to the use of the Python		

language, distributed programming for the implementation of machine learning algorithms, as well as the ability to critically evaluate the performance of machine learning algorithms, effectively communicate information related to this research domain and learn new methodologies independently.
Propaedeuticities: None. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Oral examination and practical test.

Course: Many-Body Quantum Theory		**Teaching Language:** Italian
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical and experimental treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Learning objectives: The course deals with the physics of strongly interacting many-body systems, focusing on theoretical methods and approaches. More specifically, at the end of the Course, the student will be able to use both exact and approximated methods suitable to study the Green functions, dielectric function, magnetic susceptibility, optical conductivity, superconductivity and superfluidity. The techniques introduced will be seen in action by analysing some paradigmatic models, both in the classical and in the quantum setting. The student will be asked to present an introduction to the main general topics and to prove more specific results, making connections among the different parts of the syllabus. The organization of the presentation and the use of a rigorous scientific language will be also considered to formulate the final grade.		
Propaedeuticities: - **Is a propaedeuticity for:** -		
Types of examinations and other tests: Oral exam		

Course: Materials Computational Modelling		**Teaching Language:** Italian
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics		
Learning objectives: The course aims at giving an introduction to the modern computational “first principles” approaches for the study of material properties. In particular they will be analysed: • ab initio approaches based on density functional theory (DFT) for the study and the prediction of the materials electronic structure; • limitations of DFT, its extensions and recent “improvements” in the framework of the description of the van der Waals interaction; • computational methods, with high accuracy, of the electronic properties of the ground state of a physical system, quantum Monte Carlo in particular; • numerical approaches less accurate than DFT but less computationally expensive, based on the use of semiempirical potentials, or even potentials obtained from “machine learning” techniques starting from DFT-based approaches. In the course computational laboratory lectures will be scheduled, with the opportunity for the students to consolidate and practice the acquired knowledge on real systems of physical and technological interest.		

Propaedeuticities: Solid State Physics I **Is a propaedeuticity for:** -	
Types of examinations and other tests: Oral exam	

Course: Mathematical Methods for Geophysics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/02	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: During the course the necessary skills to model physics phenomena using suitable mathematical and numerical techniques will be given.	
Learning objectives: The course aims at providing knowledge and understanding of solutions of equations arising in geophysical problems (i.e., elasticity, wave propagation, heat conduction). In particular, at the end of the course the student will: - Master the characteristic of the fundamental equations in geophysics. - Autonomously develop applications of their analytical and numerical solutions.	
Propaedeuticities: none. Basics of programming are required. **Is a propaedeuticity for:** none.	
Types of examinations and other tests: oral, including a discussion of an assigned exercise.	
Course: Medical Physics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/07	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course includes the skills for the study and development of physical methodologies (theoretical and experimental) necessary both for the description and understanding of living matter in the environmental, biological and medical context, and for the development and use of the instrumentation necessary for the control and to the detection of physical phenomena in the field of prevention, diagnosis and treatment. The skills of this sector also concern research in the field ... of the physical techniques of biomedical diagnostics, as well as in the field of radiation protection of man, the environment and things.	
Learning objectives: The student will acquire knowledge of the main fields of physics applied to medicine, including the basic physical aspects of planar, tomographic and interventional radio-diagnostic imaging, image quality assessment in relation to the radiation dose and brief introduction to the physical principles of nuclear medicine imaging.	
Propaedeuticities: None **Is a propaedeuticity for:** Laboratory of Medical Physics	
Types of examinations and other tests: Oral exam	

Course: Models of Biological Systems	**Teaching Language:** Italian
SSD (Subject Areas): FIS/02	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** C
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.	
Learning objectives: The course is aimed at understanding the process of modeling and its application to biological systems, and to solve specific models, both analytically (where possible) and using numerical simulations.	
Propaedeuticities: - **Is a propaedeuticity for: -**	
Types of examinations and other tests: Written and/or oral exam	

Course: Modern Optics	**Teaching Language:** Italian

SSD (Subject Areas): FIS/03		CREDITS: 6
Course year: I/II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The diffraction theory is reviewed by introducing the Fourier optics and its applications to near- and far-field microscopy and to the realization of light beams with peculiar spatial, temporal, spectral and polarization profiles. Skills will be developed in the treatment of the propagation properties of electromagnetic fields and their interaction with matter. The competences of this area also concern research where Optics is employed in the fields of atomic and molecular physics, liquid and solid states, metal and semiconductor compounds and elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Learning objectives: The course provides the tools to deepen several classical concepts underlying the propagation of light and its interaction with matter. In greater detail, phenomena such as diffraction and polarization of light and the concept of spatial and temporal coherence will be studied. Furthermore, both the propagation of light in anisotropic media and some basic phenomena of non-linear optics will be described. The course includes the description of the operating principle of the laser and the role of optical cavities in determining the properties of light beams. Finally, the quantization of the electromagnetic field and the concept of photon will be introduced.		
Propaedeuticities: - **Is a propaedeuticity for:** -		
Types of examinations and other tests: Oral exam		

Course: Multimessenger Astrophysics		Teaching Language: Italian
SSD (Subject Areas): FIS/05		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.		
Learning objectives: The course addresses some of the central topics in the new discipline known as multi-messenger astronomy. Particular attention is devoted to the most powerful astrophysical transient phenomena: gamma-ray bursts, fast radio flashes, supernovae explosions, and their mutual connections. Special interest is reserved for recently observed transient classes in different windows of the electromagnetic spectrum, through the detection of gravitational waves, and/or high-energy neutrinos. These sources are of interest for the physics at the origin of the highly energetic processes observed (strong gravity regime, implications for stellar evolution, astrophysical jet formation, explosive stellar nucleosynthesis and origin of elements, relativistic shocks, cosmic ray acceleration) and due to their luminosity are also important tools for the exploration of the Universe over cosmological distances, up to the epoch of reionisation. The course also offers a review of current and future dedicated experiments in this field of research. The course aims to enable students to acquire the formal rigor and skills necessary to set up and solve problems related to the above topics.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Written and/or oral exam.		

Course: Nuclear Astrophysics		Teaching language: Italian
SSD: FIS/01, FIS/04		**CFU:** 6
Course year: I/II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course will deal with the theoretical and experimental methodologies required for the study of the nuclear processes of astrophysical interest.		
Learning objectives: - The course aims at providing a sufficient level of knowledge and ability to understand the nuclear physics in the very low energy regimes, with a focus on the processes of astrophysical interest.		

- The student will deal with the peculiarities of the nuclear processes that determine the nucleosynthesis of the elements at the birth of the universe and in the other astrophysical objects appeared afterwards. Nuclear reactions determine the stellar evolution, the energy production, the neutrino luminosity.
- The student will be able to apply the acquired knowledge to the comprehension of the nucleosynthesis, and will be able to present with appropriate terminology, also to non-experts, the origin of the elements.
- The student will be able to understand and autonomously interpret the results of experimental measurements in Nuclear Astrophysics, and more in general in low energy Nuclear Physics, currently published in the literature, as well as to autonomously assess the soundness of the applied methodologies and of the results.

Propaedeuticities: none. / A knowledge of the fundamentals in experimental methods and statistical data analysis, quantum mechanics and nuclear physics, is expected.
Is a propaedeuticity for: none

Types of examinations and other tests: Oral examination with a presentation on an assigned project.

Course: Nuclear Measurements	**Teaching language:** Italian
SSD: FIS/01, FIS/04	**CFU:** 6
Course year: I/II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course provides the knowledge required to perform experimental investigations aimed at the monitoring and detection of radioactivity related phenomena, at the production and detection of ionizing radiation and the related applications.

Learning objectives:
- The student will acquire a detailed knowledge of the basic principles governing radioactive decay, the production of ionizing radiation from natural and artificial sources, its effects, the dosimetry and the methodologies used to detect ionizing radiation.
- The student will be able to apply the knowledge on radioactivity and the interaction of radiation with matter to plan and conduct measurements with the most common experimental methods at the atomic and nuclear scales.
- The student will be able to understand and autonomously interpret the results of experimental measurements currently published in the literature.
- The student will be able explain with proper terminology, also to non-experts, the principles, the methodologies and the results of measurements that use ionizing radiations, in fundamental Nuclear Physics research, in dosimetry and radioprotection and applied physics.

Propaedeuticities: none.
Is a propaedeuticity for: none

Types of examinations and other tests: Oral examination based on the discussion of a paper from recent literature.

Course: Nuclear Physics	**Teaching language:** Italian
SSD: FIS/04	**CFU:** 9
Course year: I	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course provides the theoretical and experimental tools needed to investigate the atomic nuclei, with a focus on their structure and the nuclear reaction mechanisms at low projectile kinetic energies.

Learning objectives:
The student will comprehend the main achievements in the study of the atomic nuclei at low energy. The most widely used nuclear models, and their experimental confirmation, will be introduced with the goal of understanding the nuclear structure and the nuclear reaction mechanisms.
At the end of the class, the student will be able to:
- Understand and describe the nucleon-nucleon interaction, discerning the diverse contributions in the phenomenological potentials on the basis of the symmetries and the experimental evidence on the nucleon-nucleon scattering and deuteron properties.
- Comprehend the exchange character of the nuclear forces and their description as quantum operators in the interaction potentials.
- Comprehend and describe the most widely used nuclear structure models and the related experimental

results, deriving their fundamental relationships from classical and quantum physics frameworks.

- Understand and apply the quantum physics principles and the Green functions thecnique, being aware of the corresponding approximations, to the elastic scattering theory and the complex collisions model.
- Understand and depict the processes occurring in heavy ion collisions and the most widely used models describing them.
- Take part in an experimental nuclear physics research project, using the acquired knowledge to design and conduct measurements, analyze the collected data, interpretate the obtained results.

Propaedeuticities: none. Basic knowledge of nuclear physics and quantum mechanics is expected.
Is a propaedeuticity for: Physics of Exotic Nuclei; Nuclear Structure Theory.

Types of examinations and other tests: oral examination.

Course: Nuclear Physics for Environment and Cultural Heritage	**Teaching language:** Italian
SSD: FIS/01, FIS/04	**CFU:** 6
Course year: I/II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course will deal with the methodologies required for the study of the environmental radioactivity and nuclear techniques for archaeometric research and the diagnosis of cultural heritage, and those related to environmental modeling.

Learning objectives:

- The course aims at providing a sufficient level of knowledge and ability to understand the typical methods used in nuclear physics applied to the non-destructive or minimally invasive study of cultural heritage and environment.
- The student will learn the basic principles that govern natural phenomena of interest and how they can be exploited for applications to cultural heritage and environment.
- The student will be able to apply the acquired knowledge to the comprehension and the management of related applications with the major diagnostic techniques.
- The student will be able to understand and autonomously interpret the results of experimental measurements currently published in the literature.
- The student will be able to autonomously broaden their knowledge with textbooks, scientific papers, and research in the field of applied nuclear physics methodologies.

Propaedeuticities: none
Is a propaedeuticity for: none

Types of examinations and other tests: Oral examination.

Course: Nuclear Reactions	**Teaching language:** Italian
SSD: FIS/04	**CFU:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course provides the theoretical and experimental knowledge required to study the phenomena arising from the interaction of nuclei, and the related spectroscopic methodologies.

Learning objectives:

- The student will acquire the knowledge on the mechanisms that underlie nuclear reactions and the most relevant models that describe them and allow to understand nuclear structure properties. The student will also understand the production of nuclei not naturally present on Earth, in laboratory or other environments as the astrophysical ones, for fundamental physics research and for applications.
- The student will be able to understand the nuclear reaction mechanisms through conservation principles, corresponding observables and detection methodologies.
- The student will be able to apply the acquired knowledge to design and realize measurements aimed at the determination of the properties of the nuclei and their excited states.
- The student will be able to explain, also to non-experts in the field, with proper terminology the principles and the methodologies for nuclear physics studies and related applications.

Propaedeuticities: none. A good understanding of classical physics, quantum theory and modern physics fundamentals is expected.

Is a propaedeuticity for: Physics of Exotic Nuclei.
Types of examinations and other tests: short essay on an assigned topic and oral examination.

Course: Numerical Methods of Physics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/02		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools.		
Learning objectives: The course initiates the student to the use of the algorithms for numerical calculation used for solving complex problems in Physics. The student will also deepen his/her skills in analyzing the conditioning of problems and the stability of the algorithms. The topics of the course range from linear algebra to optimization problems, from numerical integration to Monte Carlo methods, and resolution of ordinary and partial differential equations.		
Propaedeuticities: - **Is a propaedeuticity for: -**		
Types of examinations and other tests: Written and/or oral exam		

Course: Optical Spectroscopy		**Teaching Language:** Italian
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Learning objectives: The course aims at developing the acquisition of practical and theoretical knowledge on the experimental observation of natural phenomena exploiting the main techniques of the modern optical spectroscopy. At the end of the course the student will be able to: • Examine and describe basic physical processes underlying the modern optical spectroscopy techniques. • Understand and design experiments for the analysis of physical phenomena by using optical spectroscopy techniques based on both steady-state and time-resolved approaches. • Analyse and understand experimental findings of optical spectroscopy experiments and the corresponding physical mechanisms in different application fields (material analysis, diagnostics, sensors, etc.).		
Propaedeuticities: - **Is a propaedeuticity for:** -		
Types of examinations and other tests: Oral exam		

Course: Particle Physics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/01		**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.		
Objectives: The course aims at providing knowledge and understanding of the fundamental constituents of matter and their interactions as well as the experimental basis of the Standard Model. At the end of the course the student will have		

acquired: -knowledge about the interactions of leptons, quarks and hadrons and the ability to perform calculations of cross sections and decay widths at the lowest perturbative level using the laws of quantum electrodynamics, the theory of strong and weak interactions and the unified electroweak model; -Knowledge, understanding and ability to critically evaluate the experimental results that allowed to establish the Standard Model.
Propaedeuticities: None. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Written and oral examination.

Course: Particle Physics Laboratory		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/01			**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.			
Objectives: Study of modern experimental techniques used in Elementary Particle Physics, with particular emphasis on the use of particle detectors for the measurement of fundamental quantities related to their detection and identification. Acquisition of skills in the handling and characterisation, in laboratory, of detection systems, suitably equipped with readout electronics and data acquisition in digital format.			
Propaedeuticities: None. **Is a propaedeuticity for:** None.			
Types of examinations and other tests: Oral examination and practical test.			

Course: Perturbative QCD		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/02			**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C		
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.			
Learning objectives: The course is aimed at developing the student's knowledge of the characteristics of a perturbative calculation of quantum chromodynamics as a function of its radiative content. In particular, at the end of the course the student will be able to: - Interpret the results of perturbative chromodynamics and evaluate the limits of the approximations used to obtain them. - Link the radiative content of the perturbation calculation with the phenomenological aspects that highlight chromodynamic effects. Design/Use code generators, Monte Carlo programs for fixed order computation and event generators.			
Propaedeuticities: Quantim Mechanics; Quantum Field Theory I. **Is a propaedeuticity for: -**			
Types of examinations and other tests: Written and/or oral examination with discussion of a written project report.			

Course: Phenomenology of Elementary Particles		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/02			**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C		
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools, as well as the skills appropriate for the application of mathematics aimed at			

investigating, treating theoretically and creating models of physical phenomena.
Learning objectives: The course aims at providing students interested in Theoretical Physics of Elementary Particles with the tools to understand the current description of the processes between elementary particles induced by the strong and electroweak interactions within the Standard Model and to study the evidences of New Physics. Focus is on theoretical methods of analysis and their application, in the current research landscape. Effective theories of light and heavy quarks and non-perturbative methods such as quark models and applications of group theory will be studied. The phenomenology of π,, K, D, B mesons, the violation of Charge*Parity (CP) symmetry and the phenomenology connected to neutrino physics and to the gauge sector of the Standard Model (including the Higgs boson physics) will be addressed.
Propaedeuticities: Quantum Field Theory I **Is a propaedeuticity for: -**
Types of examinations and other tests: Written and/or oral exam

Course: Philosophy of Scientific Knowledge		**Teaching Language:** Italian	
SSD: M-FIL/01			**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C		
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Theoretical philosophy. Analysis of the concepts of knowledge, experience and nature. Comparative evaluation of science as a form of understanding reality.			
Obiettivi formativi: The teaching aims to provide the key elements to define the concept of ‘scientific knowledge’. The main skills to be acquired concern the ability to assess the legitimacy of the different epistemological approaches (empiricism, rationalism, conventionalism) used historically by physicists and philosophers to interpret physical theories and, more generally, the concept of ‘scientific knowledge’ itself. The course also aims to train the skills to evaluate ‘science’ more broadly in relation to the different ‘non-scientific’ forms of understanding reality (demarcation problem).			
Propedeuticità in ingresso: None. A textbook knowledge of the main authors and major philosophical currents is sufficient. **Propedeuticità in uscita:** None			
Tipologia degli esami e delle altre prove di verifica del profitto: : Oral exam.			

Course: Photonics		**Teaching Language:** Italian	
SSD (Subject Areas): FIS/03			**CREDITS:** 6
Course year:	**Type of Educational Activity:** C		
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical and experimental treatment of the propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements as well as photonics, optics, optoelectronics and quantum electronics.			
Learning objectives: The course is intended to provide students with competences essential to understanding the nature of light and its behaviour during propagation through diverse optical media. This is expected to enable students to utilize and/or design devices for waveguiding, for generation of radiation (LEDs, lasers), manipulation of optical beams (modulators of wavelength, polarization, wavefront), detection of the different properties of radiation, as well as fiber and waveguide interconnects, optical filters, and photonic crystals. The course explores both fundamental and applicative mechanisms, based on rigorous and well-established analytical and numerical methods. Specifically, students will be enabled to: • Analysing and presenting the mechanisms of generation, propagation, manipulation and detection of the different properties of light exploiting the most recent methods developed in the framework of Photonics. • Using and designing photonic devices relevant at both the concept and applied levels. • Reprocessing and effectively utilizing acquired knowledge to solve practical problems satisfying customized operation requirements • Illustrating the operation of the studied devices, used or designed with proper simulation methods.			

• Illustrating fundamental concepts and device design and operation.
Propaedeuticities: Propaedeutic exams are not required **Is a propaedeuticity for:** None
Types of examinations and other tests: Oral exam

Course: Physical Basis of Magnetic Resonance		**Teaching Language:** Italian
SSD (Subject Areas): FIS/07; ING-INF/02		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course includes skills to understand and utilize the basic physical phenomena of Magnetic Resonance for diagnostic applications and related radiation protection aspects.		
Learning objectives: The course aims at providing knowledge of the basic aspects of Magnetic Resonance, used in medical diagnostics, related to both hardware and imaging as well as to the patient and worker safety. Students will also use some instrumentation and software for electromagnetic dosimetry.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral exam		

Course: Physics and Philosophy		**Teaching Language:** Italian
SSD (Subject Areas): FIS/08		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course allows the students to acquire competences in the study of the history of physics as resulting from the onset of the physical ideas. It also aims at familiarizing the students with historical, philosophical and epistemological problems related to foundational concepts in classical and modern physics.		
Learning objectives: The purpose of the course is to offer the student the basic elements for evaluating the historical, philosophical, and epistemological path of physical science, as well as the methods used in scientific investigation. The cognitive goals pertain to the cultural study of the development and evolution of the ideas on which the scientific theories of physics are based, providing the student with a general picture of the complex history of scientific thought. The skills to be acquired concern the ability to identify the essential elements of a scientific work and the correlations between the different scientific conceptions of Nature, as well as the ability to criticize historically determined approaches, also with reference to the conceptual change from classical to relativistic and quantum physics. In addition to the knowledge of the open problems in the foundations of physics, the course also aims to support the ability to argue on the interpretations of some fundamental physical phenomena, providing the student to critically position himself with respect to the topics and research methods in physics.		
Propaedeuticities: Mastering of the courses of: Mechanics and Thermodynamics; Electromagnetism; Quantum Mechanics; Modern Physics. Knowledge of the main contents of the courses of Classical Electrodynamics and Quantum Physics. **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral Examination		

Course: Physics Education I		**Teaching Language:** Italian
SSD (Subject Areas): FIS/08		**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course allows the students to acquire competences in the study and development of teaching methods and transfer of the fundamental concepts and knowledge of physics. It also aims at familiarizing the students with issues related to foundational physics concepts		
Learning objectives: The course is aimed at acquiring skills in designing and implementing educational activities for the teaching of		

physics in secondary school. In particular, by studying proposals that emerge from experimentations in the fields of education and training and from research in physics education, we work around proposals that aim at the development of longitudinal paths based on a unitary vision of physics with particular attention to modeling processes and interpretation problems in the transition from classical to modern physics. At the end of the course, students will acquire skills in: -knowing research in physics education and planning educational activities for students and for teacher training; integrating strategies and appropriate technologies to improve learning and teaching, enhancing the resources of students and working simultaneously on physics and language, physics and mathematics, physics and technology; -recognize the role of pedagogy, the history of physics and epistemology in designing proposals in the teaching of classical and modern physics; -knowing how to communicate the evolution of the key concepts of physics and concepts that cross the various scientific disciplines.
Propaedeuticities: General Physics and laboratory **Is a propaedeuticity for:** None
Types of examinations and other tests: Examination based on the discussion of a written project report

Course: Physics Laboratory		**Teaching Language:** Italian
SSD (Subject Areas): FIS/01		**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Skills required to carry out experimental research, particularly those for investigating physical processes and the operating principles of instrumentation used to control and detect physical phenomena, as well as for handling experimental data.		
Learning objectives: The course aims at developing the student's ability to describe and measure natural phenomena, design experimental apparatus, and analyze experimental results by using rigorous statistical-numerical processing. During the course, the student will carry out two or more laboratory experiments, consisting in the determination of specific physical quantities. The data produced will be collected and analyzed to draft reports that will be discussed during the exam. At the end of the course, the students will be able to: • Approach the measurement of physical quantities by placing the problem both in the theoretical context of acquired physical knowledge and within the framework of modern experimental physics techniques; • Design and carry out methodologically and conceptually relevant experiments in physics; • Rework their knowledge of Physics in new experimental situations; • Process the collected data using rigorous statistical-numerical processing techniques; • Present written reports on the main results of the data analysis.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral exam consisting in the discussion of the reports on the laboratory experiments and the contents covered during the course.		

Course: Physics of Cosmic Radiation		**Teaching Language:** Italian
SSD (Subject Areas): FIS/01, FIS/04		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data. The competences of this subject area also cover research in the fields of physics related to nuclear reactors and radiogenic sources in general, as well as in the fields of nuclear electronics, radioactivity and particle physics of cosmic origin.		
Objectives: The course aims at illustrating various advanced topics in the physics of cosmic radiation, in order to understand developments in the various observations up to the most recent discoveries. Developments in experimental techniques for the various observations of cosmic radiation are explained to the student during the course, also with		

a view to future research applications in the field. At the end of the course the student will have acquired knowledge of the physics of cosmic rays, gamma photons, astrophysical neutrinos, gravitational waves and the experimental techniques and apparatus used to measure their properties.
Propaedeuticities: None. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Oral examination.

Course: Physics of Exotic Nuclei		**Teaching language:** Italian
SSD: FIS/04		**CFU:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course will deal with the theoretical and experimental methodologies required for the study of exotic nuclei, those having a ratio of the number of neutrons to the one of protons very different from corresponding stable nuclei. Connected experimental and technological challenges are presented.		
Learning objectives: - The student will acquire a detailed knowledge about the structure of exotic nuclei and of the most relevant reaction mechanisms that can be used for their characterization, of the main production and selection methods of exotic nuclei ion beams, as well as the main applications. - The student will be able to apply the acquired knowledge to plan and conduct measurements to experimentally determine exotic nuclei relevant characteristics. - The student will be able to understand and present with appropriate terminology the principles, the techniques and the results of measurements with exotic nuclei ion beams. - The student will be able to understand and autonomously interpret the results of experimental measurements currently published in the literature.		
Propaedeuticities: Nuclear Physics, Nuclear Reactions **Is a propaedeuticity for:** none		
Types of examinations and other tests: Oral examination.		

Course: Physics of Galaxies		**Teaching Language:** Italian
SSD (Subject Areas): FIS/05		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.		
Learning objectives: the course introduces the study of the physical laws that determine the structure, dynamics and evolution of galaxies and cosmic structures with the aim of interpreting the observational evidence from photometric and spectroscopic studies within the framework of coherent physical models. The student will acquire the ability to construct simple models of galaxies at dynamical equilibrium, through the quantitative solution of exercises of varying difficulty proposed in lectures. The student will develop the ability to critically read contemporary literature.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Written and/or oral exam.		

Course: Physics of stellar atmospheres		**Teaching Language:** Italian
SSD (Subject Areas): FIS/05		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical		

phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
The course introduces the essential phenomenology and basic concepts of the physics of stellar atmospheres, with emphasis on the atmosphere of the Sun and solar-type stars. In particular, students will learn the main techniques to derive quantitative information from observations with both ground-based and space-based instruments of the electromagnetic and particle emission of the Sun and solar-type stars. By the end of the course, students will then be able to understand simple theoretical and observational articles on the physics of the Sun and solar-type stars.

Propaedeuticities: Astrophysics
Is a propaedeuticity for: None

Types of examinations and other tests: Written and/or oral exam.

Course: Physics of the Dark Universe	**Teaching Language:** Italian
SSD (Subject Areas): FIS/01, FIS/04	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory consistent with the training objectives of the course:
The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.
The competences of this subject area also cover research in the fields of physics related to nuclear reactors and radiogenic sources in general, as well as in the fields of nuclear electronics, radioactivity and particle physics of cosmic origin.

Objectives:
The course is designed to introduce students to the physics of the Dark Universe, an advanced field of research at the boundary between astrophysics, cosmology and elementary particle physics that is constantly and rapidly evolving. The main topics are treated from both a phenomenological and an experimental point of view. In particular, at the end of the course the student will be able to:
- understand the cosmological context and the models of dark matter and dark energy;
- understand the results and observations of the main experiments related to the Dark Universe;
- interpret plots and numerical data in relation to the proposed physical models.
The student will also have developed the ability to present the topics covered and will be able to follow future developments independently.

Propaedeuticities: None.
Is a propaedeuticity for: None.

Types of examinations and other tests: Oral examination.

Course: Planetology	**Teaching Language:** Italian
SSD (Subject Areas): FIS/05	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
the course aims to introduce students to the study of planets. In the course, the formation, evolution and structure of the Solar System and planetary systems in general will be discussed. Subsequently, the main methods for the research and study of extrasolar planets will be studied, with particular emphasis on the study of extraplanetary atmospheres. The course also includes an introduction to the topics of astrobiology, i.e. the study of astrophysical conditions favourable to the formation and evolution of life. Finally, the main current and future observational projects in this field of research will be discussed. The aim of the course is to enable the student to acquire a solid physical basis for the study of advanced research problems in the field of exoplanetology and astrobiology.

Propaedeuticities: Astrophysics
Is a propaedeuticity for: None

Types of examinations and other tests: written and/or oral exam.

Course:
Plasma Physics

Teaching Language:
Italian

SSD (Subject Areas):
FIS/03

CREDITS:
6

Course year: I/II

Type of Educational Activity: C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the theoretical and experimental treatment of the states of plasmas as well as the skills suitable for the treatment of the interaction properties of plasmas with fields and matter.
The competences of this sector also concern research in the fields of plasma physics.

Learning objectives:
The course aims at providing a basic knowledge of plasma physics that is relevant:
- to describe the main fundamental physical processes that indicate that matter, in addition to ordinary aggregation states (solid, liquid and gas) can also occur in the state of plasma, also called the fourth state of matter;
- to attribute plasma to the role of a unifying element between various frontier disciplines: from the physics of ultra-intense gradient particle accelerators to the physics of controlled thermonuclear fusion;
- to enable the acquisition of physical methodologies that provide the description of collective phenomena in both kinetic and fluid theories of plasma.

Propaedeuticities:
Propaedeutic exams are not required
Is a propaedeuticity for:

Types of examinations and other tests:
Oral exam with discussion of a project report

Course:
Quantum Field Theory I

Teaching Language:
Italian

SSD (Subject Areas):
FIS/02

CREDITS:
6

Course year: I

Type of Educational Activity: B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena. Research on relativistic theories.

Learning objectives:
The aim of the course is to introduce the student to Quantum Field Theory, i.e., the Quantum Mechanics of physical systems with infinitely many degrees of freedom in the relativistic regime. We start with the interpretative difficulties in combining Special Relativity with Quantum Mechanics and we proceed with the Second Quantization of the Klein-Gordon and Dirac fields. Perturbation theory will be developed to deal with interaction theories and the Feynman diagram method will be introduced. Quantum electrodynamics will be discussed as a gauge theory and the elementary processes in this theory will be studied at the lowest order. Once a Lagrangian has been assigned, the student, at the end of the course, will be able to derive the symmetries of the theory, write the Feynman rules and calculate the cross sections of elementary processes involving spin-0 and spin-1 bosons, and fermions of spin 1 / 2.

Propaedeuticities: Quantum Mechanics; Classical Electrodynamics.
Is a propaedeuticity for: Phenomenology of Elementary Particles; Theoretical Astroparticle Physics; Theoretical Physics of Fundamental Interactions; Introduction to Quantum Gravity; Perturbative QCD; Quantum Field Theory II; String Theory.

Types of examinations and other tests: Written and/or oral exam.

Course:
Quantum Field Theory II

Teaching Language:
Italian

SSD (Subject Areas):
FIS/02

CREDITS:
6

Course year: II

Type of Educational Activity: C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate

mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena. Research on relativistic theories.
Learning objectives: The aim of the course is to form students who have a detailed understanding of the fundamental aspects of Quantum Field Theory not only from a perturbative point of view. The methods for dealing with the divergences that arise, in perturbation theory, at next-to-leading orders, as well as the regularization and renormalization methods, will be addressed. The renormalizability of the field theories and the renormalization group will be discussed. Non-Abelian gauge theories (Yang-Mills theories) will be introduced and their quantization will be done with the functional integral formalism. The study of symmetries and spontaneous symmetry breaking will also be addressed in relation to the construction of the Standard Model of strong and electroweak interactions. Non-perturbative aspects of field theory will be treated, such as, for example, the Gribov problem. At the end of the course, the student will, among other things, be able to evaluate scattering amplitudes and cross sections within gauge theories, Abelian and non-Abelian, of physical processes even at higher perturbative orders.
Propaedeuticities: Quantum Field Theory I. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Written and/or oral exam

Course: Quantum Mechanics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/02		**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.		
Learning objectives: The course provides students with a solid knowledge of scattering theory in Quantum Mechanics, and of modern developments connected with the concept of entanglement, including the Bell inequality and quantum teleportation. Much space is reserved also to the systematic study of invariance and symmetry properties of quantum systems, under rotations and translations (Wigner and Wigner-Echart theorems, tensor operators). The course includes as well an introduction to the Feynman path integral.		
Propaedeuticities: - **Is a propaedeuticity for:** Quantum Field Theory I.		
Types of examinations and other tests: Written and/or oral exam		

Course: Quantum Open Systems		**Teaching Language:** Italian
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year:	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Learning objectives: Closed systems are always an idealization of reality. Interactions of the system with its environment are a key aspect for the description of real experiments. The course will provide information on: i) Quantum Probability e Density Matrix; ii) Quantum Master Equations; iii) Notion of Markovian Open Systems and Lindbladian Evolution; iv) Kraus maps; v) Brief Introduction of Non-Markovian Dynamic; vi) Feynman Path Integral for system-environment applications (real and imaginary time); vii) Feynman-Vernon functional; viii) Polarons; ix) Caldeira-Legget model and macroscopic quantum tunneling; x) Spin-Boson model; xi) Many-Body dissipative systems and Keldysh approach for out-equilibrium systems; xii) Quantum Information Applications.		
Propaedeuticities: Quantum Mechanics, Statistical Mechanics I **Is a propaedeuticity for:** -		
Types of examinations and other tests: Oral exam		

Course: Quantum Optics and Information	**Teaching Language:** Italian

SSD (Subject Areas):	CREDITS:
FIS/03	6
Course year: I/II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the theoretical treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter.
The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.

Learning objectives:
To be able to describe and understand experimental results and theoretical modelling of photonic and light-matter interactions, including quantum-optical implementation of quantum-information protocols.
To be able to properly describe the quantum optical measurements using operator and density matrix formalisms.
To be able to use different quantum state and process representations such as density matrix, quasi-probability distribution, Master equation for describing quantum optical systems.
To get confidence with quantum information principles and the main bounding blocks of its protocols with regards, in particular, to description and evolution of the involved quantum states from generation techniques to detection.

Propaedeuticities: -
Is a propaedeuticity for: -

Types of examinations and other tests: Oral exam

Course:	Teaching Language:
Quantum Phases of Matter	Italian
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the theoretical and experimental treatment of the states of both atomic and molecular aggregates.
The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas.

Learning objectives:
Quantum mechanics is used as a tool for the description of the phases of matter at low temperatures and of the transitions towards states of macroscopic quantum coherence such as Superfluidity, Superconductivity, integer and fractional quantum Hall effect. Furthermore, the topological phases of matter and the devices for quantum computation are introduced.
The course presents:

- superfluidity and superconductivity as states showing macroscopic coherence.
- fundamental characteristics of low dimensional semiconductor devices such as tunnel junctions, Hall bars and superconducting devices such as Josephson junctions, dc/ac SQUID, superconducting quantum bits for universal and adiabatic quantum information.
- properties of materials in which the electronic conduction is topologically protected, starting from the Berry Phase of the electronic wave function in polyacetylene, up to the topologically protected edge electronic states in Topological Insulators and Superconductors with discussion on their relevance in spintronics and in topological quantum information.

Propaedeuticities: Statistical Mechanics
Is a propaedeuticity for: None

Types of examinations and other tests: Oral exam

Course:	Teaching Language:
Quantum Physics	Italian
SSD (Subject Areas): FIS/02	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Skills necessary for the theoretical treatment of physical phenomena, starting from principles and fundamental laws, with the aid of appropriate mathematical tools, as well as skills required for the application-focused deepening of the mathematics aimed at investigation, theoretical treatment, and modeling of physical phenomena.

Learning objectives:
The student will gain a solid understanding of the principles of Quantum Physics and the related fundamental phenomena, including atomic structure, particle scattering processes, angular momentum theory, identical particles, time-dependent Hamiltonians, and relativistic wave equations.

Propaedeuticities: none.
Is a propaedeuticity for: none.

Types of examinations and other tests: written and oral exam.

Course:	**Teaching Language:**
Quantum Theory of Measurement	Italian

SSD (Subject Areas):	**CREDITS:**
FIS/02	6

Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena. Research on foundations of physics.

Learning objectives:
The main aim of the course is to provide the student with some concepts and tools of quantum measurement theory that are fundamental for a deeper understanding of quantum mechanics and quantum information, and of the sharp differences – but also of the analogies – between classical and quantum theory. The course is also aimed at introducing the student to the theory of open quantum systems and quantum decoherence. Moreover, during the course some advanced technical tools will be discussed that are of central importance for the modern applications of quantum physics and for quantum information science.

Propaedeuticities: Quantum Mechanics.
Is a propaedeuticity for: None.

Types of examinations and other tests: Written and/or oral exam.

Course:	**Teaching Language:**
Radiation Biophysics	Italian

SSD (Subject Areas):	**CREDITS:**
FIS/07	6

Course year: I	**Type of Educational Activity: B**

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
The course entails the skills required to understand the mechanistic bases and biophysical models of the biological action of interest for human health exerted by the interaction of ionising radiations with the biological matter at the molecular, cellular and tissue level. Theoretical and experimental notions will be also provided for the quantification of such effects and their relevance in radiation protection and radiotherapy. In addition, novel therapeutical approaches will be illustrated that are based on nuclear physics reactions (e.g., BNCT, PBCT) or peculiar temporal regimes.

Learning objectives:
The course aims at providing the student with a basic knowledge of the biological action of ionising radiations in order for them to:
- Understand the role of the spatio-temporal distribution of the energy deposition events at the nano- and micrometric scale plays in the induction of biomolecular, cellular and systemic effects;
- Correlate the diversity and severity of such effects with physical and biological parameters such as the dose, the track ionization density and structure, the DNA repair efficiency and the genetic profile;
- Learn some techniques to quantify radiation-induced cytogenetic damage to compare the effectiveness of varying quality radiations and/or varying dose rates that justify novel approaches such as hadrontherapy or FLASH radiotherapy.

Propaedeuticities: None
Is a propaedeuticity for: None

Types of examinations and other tests: Oral examination

Course:	**Teaching Language:**
Radiation Dosimetry	Italian

SSD (Subject Areas):	**CREDITS:**
FIS/07	6

Course year: I	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The Course includes competences for understanding the absorption of ionizing radiation in matter, and for using instruments for radiation dose measurements related to medical diagnosis and therapy.
Learning objectives: The course aims at providing knowledge of the basic aspects of ionizing radiation dosimetry, used in medical diagnostics and therapy, and of the corresponding main physical quantities and their relationships, of the dosimetric principles, of protocols, and usage of radiation dosimeters. Students will also use some of these instruments in laboratory sessions.
Propaedeuticities: None **Is a propaedeuticity for:** Laboratory of Medical Physics
Types of examinations and other tests: Oral exam

Course: Radiotherapy Physics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/07		**CREDITS:** 6 CFU
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course includes skills suitable for the study and development of physical methodologies (theoretical and experimental) necessary for both the description and understanding of living matter in the biological and medical context, and the development and use of instrumentation necessary for the control and detection of physical phenomena in the field of ionizing radiation therapy.		
Learning objectives: The students will learn about radiotherapy physics, particularly concerning external beam radiotherapy. The course will describe beam production and delivery, theoretical basis for fractionation and treatment planning, and new methods such as SBRT and charged particle therapy.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Written exam		

Course: Research Methods in Physics Education		**Teaching Language:** Italian
SSD (Subject Areas): FIS/08		**CREDITS:** 9
Course year: I	**Type of Educational Activity:** B	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course allows the students to acquire competences in the study and development of teaching methods and transfer of the fundamental concepts and knowledge of physics.		
Learning objectives: The course is designed to allow learners to acquire a thorough and rigorous knowledge about the statistical methods used in physics education and science education research. The course will address the different types of investigation tools used in the educational field (Likert scales, concept inventories, etc ..). Moreover, the course will focus on the use of the most common data analysis software in educational and sociological research such as, for example: IBM SPSS, IBM AMOS, SPAD, Process, Jamovi, Winsteps. At the end of the course the student will be able to: - Autonomously choose the most suitable type of investigation tool to answer his/her research questions - Autonomously choose the most appropriate type of data analysis to analyze the data collected through the adopted survey tools - Process and organize independently the data collected using quantitative and qualitative techniques - Report the results in form of a research article		
Propaedeuticities: None. However, some basic elements of statistics acquired in the laboratory courses can help **Is a propaedeuticity for:** None		
Types of examinations and other tests: Writing of a short research article		

Course: Seismology	**Teaching Language:** Italian
SSD (Subject Areas): FIS/06	**CREDITS:** 9

Course year: II	Type of Educational Activity: B
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: During the course the necessary skills to define and develop physical and mathematical methods to study solid Earth will be given.	
Learning objectives: The course aims at providing knowledge and understanding of the theory and experimental application of seismogram and general seismic data analysis. Also, the course aims to show how this knowledge and understanding is applied to the simulation of seismic signals generated by an extended source in a heterogeneous medium. During the course, numerical exercises will be given to increase the ability of the student to make judgements about the application of the knowledge to seismic modeling using numerical techniques developed in modern seismological labs. In particular, at the end of the course the student will: - Master the basic concepts of the theory of generation and propagation of seismic signals. - Understand and autonomously develop applications of that concepts to the analysis of seismic signals generated by an extended source in a heterogeneous medium. - Autonomously develop simple seismogram simulations.	
Propaedeuticities: none. A good knowledge of the basic concepts of linear and vector algebra, differential equations, Fourier theory of function expansion, signal processing, elasticity, probability and statistics is required. **Is a propaedeuticity for:** none.	
Types of examinations and other tests: oral with the discussion of a brief numerical application of seismic techniques previously assigned.	

Course: Sensors, detectors and related electronics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/01	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data.	
Objectives: The course aims at developing the ability to analyse and design measurement equipment, including the related electronics (analogue and digital) required for signal processing. In particular, at the end of the course, the student will be able to: - Know some of the most recent types of sensors and detectors. - Investigate the physics underlying the operation of sensors and detectors as well as signal formation. - Analyse the dynamics of signals by means of the Laplace transform method also with the use of numerical programmes. - Learn some of the techniques for analogue signals processing. - Consolidate and deepen some aspects of digital electronics. - Critically analyse and design some measuring equipment.	
Propaedeuticities: None. **Is a propaedeuticity for:** None.	
Types of examinations and other tests: Oral examination and practical test.	

Course: Signal Processing and Analysis	**Teaching Language:** Italian
SSD (Subject Areas): FIS/01, FIS/06, FIS/07	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** C
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: During the course the necessary skills to develop and improve methods of data collection, analysis and interpretation will be given.	
Learning objectives: The course aims at providing knowledge and understanding of the theory and experimental application of digital signal processing. Also, the course aims to show how this knowledge and understanding is applied to, but not limited to, the modeling of seismic signals. During the course, numerical exercises will be given to increase the ability of the student to make judgements about the application of the knowledge to seismic modeling using numerical	

techniques and sw. In particular, at the end of the course the student will:
- Master the basic concepts of the theory of digital signal processing.
- Understand and autonomously develop applications of that concepts to the modeling of seismic signals, but not only to that
- Autonomously develop simple applications of numerical methods and sw to digital signal processing.

Propaedeuticities: none. Nevertheless, a good knowledge of the basic concepts of linear and vector algebra, differential equations, Fourier theory of function expansion, probability and statistics.
Is a propaedeuticity for: none. Nevertheless, the knowledge acquired may be useful for the Seismology course.

Types of examinations and other tests: oral with the discussion of a brief numerical application to seismic signals previously assigned.

Course: Soft Matter Physics	**Teaching Language:** Italian
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: I/II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the theoretical and experimental treatment of liquid and solid states, of compounds, of diluted states. Skills for dealing with the properties of soft matter.

Learning objectives:
The course aims at providing to the students a basic knowledge about Soft Matter Physics, which is the subclass of Condensed Matter Physics that deals with materials and systems characterized by a high degree of deformability and by the emergence of self-organizing phenomena. In particular, the course deals with the study of liquids, polymers, liquid crystals, colloids, gels, foams and biological matter, as well as self-organization and thermodynamics and kinetics of phase transitions. It also addresses application aspects based on the use of some of the materials listed above.
The course aims at:

- Strengthening the student's general knowledge in the field of condensed matter
- Developing new knowledge in the field of soft matter and its applications
- Encouraging communication skills through the guided preparation of presentations on some specific topics.

Propaedeuticities: Propaedeutic exams are not required
Is a propaedeuticity for: None

Types of examinations and other tests: Oral exam

Course: Solid State Physics I	**Teaching Language:** Italian
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the theoretical and experimental treatment of the states of both atomic and molecular aggregates, as well as the skills needed for the treatment of the mechanical, optical and transport properties of condensed matter.
The skills of this sector also concern research in the fields of physics of liquid and solid states, of compounds and of metallic and semiconductor elements.

Learning objectives:
The main objective of the course is to develop the student's ability to build descriptive theoretical models of the most significant phenomena about solid state physics. In particular, at the end of the course the student will be able to:
- Examine the phenomenology of thermal and electrical conduction processes as well as of optical properties of solids.
- Understand, use and, if necessary, extend the theoretical models.
- Judge the quality of a model on the basis of comparison with empirical data.
- Contextualize a model by placing it in the domain to which similar models belong.
- Expose the results of their own elaborations in the form of a written report, public presentation etc.

Propaedeuticities: Propaedeutic exams are not required
Is a propaedeuticity for: None

Types of examinations and other tests: Oral exam

Course: Solid State Physics II	Teaching Language: Italian
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Necessary skills for the theoretical and experimental treatment of the states of both atomic and molecular aggregates, as well as the skills needed for the treatment of the mechanical, optical and transport properties of condensed matter.
The skills of this sector also concern research in the fields of physics of liquid and solid states, of compounds and of metallic and semiconductor elements.

Learning objectives:
The course is aimed at providing students with knowledge on the most modern developments in Solid State Physics, concerning both novel materials and devices and application of advanced theoretical methods to their study and comprehension.
In particular, at the end of the course the students will have fundamental knowledge in the fields of:

- quantum confinement and nanostructured materials, including two-dimensional materials;
- advanced methods in the study of materials, Density Functional Theory in particular, with computer simulations aimed at showing the applications of these methods to the calculations of the electronic and structural properties of simple materials (including graphene).

The course aims at guiding the student towards modern perspectives in the field of condensed matter, on the one hand and, on the other hand, to provide basic knowledge in the context of a curriculum of Matter Physics (such as quantum confinement) that are not already object of study in fundamental courses.

Propaedeuticities: Solid State Physics I
Is a propaedeuticity for: None

Types of examinations and other tests: Oral exam

Course: Statistical Mechanics I	Teaching Language: Italian
SSD (Subject Areas): FIS/02	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B, C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Research on statistical aspects of complex physical systems

Learning objectives:
This is an Institutional Statistical Mechanics course that covers the fundamentals of Statistical Mechanics and its applications ranging from Theoretical Physics (e.g. entropy of black holes), Astrophysics (e.g. background radiation), Solid State Physics (e.g. Bose-Einstein condensation) to the thresholds of Complex Systems theory. Important applications in e.g. finance are also discussed.

Propaedeuticities: -
Is a propaedeuticity for: Statistical Mechanics II

Types of examinations and other tests: Written and/or oral exam.

Course: Statistical Mechanics II	Teaching Language: Italian
SSD (Subject Areas): FIS/02	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
Research on statistical aspects of complex physical systems.

Learning objectives: This is an advanced course in Statistical Mechanics focused on topics ranging from Statistical Field Theory to dynamical processes and chaos, up to the theory of Self-Organized Criticality. The course also covers important applications in Theoretical Physics as well as in Condensed Matter Physics.

Propaedeuticities: - / Knowledge of the fundamentals of Statistical Mechanics is required.
Is a propaedeuticity for: -

Types of examinations and other tests: Written and/or oral exam

Course: Stellar Evolution	**Teaching Language:** Italian
SSD (Subject Areas): FIS/05	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
It includes the skills necessary for the theoretical and observational study of astronomical and astrophysical phenomena, i.e. celestial bodies and systems of celestial bodies, cosmology, the physics of self-gravitating systems and gravitation, especially in its classical, statistical-mechanical and computational aspects, as well as space and cosmic physics.

Learning objectives:
The course is aimed at understanding the structure and evolution of stars as a function of their initial mass and chemical composition and at interpreting the color-magnitude diagrams observed through stellar physics.
In particular, at the end of the course the student will be able to:
- Describe the evolutionary path of a star as its mass and chemical composition changes, up to the final stages.
- Interpret observed colour-magnitude diagrams.
- Explain evolutionary differences in terms of differences in physical and numerical inputs.
- Understand the difference between evolutionary and isochronous tracks and between simple, composite and unresolved stellar populations.

Describe the fundamentals of stellar pulsation and the physical basis for using classical pulsating stars as distance indicators and stellar population tracers.

Propaedeuticities: Astrophysics
Is a propaedeuticity for: None

Types of examinations and other tests: Written and/or oral exam.

Course: STEM Education	**Teaching Language:** Italian
SSD: FIS/08	**CFU:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course:
During the course, skills are provided for the transfer of fundamental concepts and knowledge of physics

Learning objectives:
The course will enable learners to acquire in-depth knowledge on the design and implementation of multidisciplinary educational interventions centered on STEM (Science - Technology - Engineering - Mathematics) subjects for secondary school. The course will complete the training of the master's degree student by enabling him or her to apply educational technologies and pedagogical methodologies learned in other courses to the expanded STEM field, with a view to teaching civic education and implementing pathways for transversal skills and orientation (PCTO). Finally, the Course will allow students to explore cross-curricular themes of physics present in the national indications and which can be declined from the perspective of STEM teaching.
At the end of the course the student will have to demonstrate that he/she
- be able to document activities, design worksheets and assessment tools to structure teaching interventions in secondary school in the STEM perspective.
- to know how to select appropriate teaching materials and activities to propose to secondary school students in accordance with what is provided in the National Directions for High Schools and in Italian school practice for STEM subjects
- to know how to reconstruct from the educational point of view the knowledge and research methodologies peculiar to physics and other STEM disciplines in order to be able to design educational interventions suitable for secondary school students of first and second grade

Propaedeuticities: Educational Technologies for Physics Teaching, Didactical Design for Physics or Design of Educational Activities
Is a propaedeuticity for: None

Types of examinations and other tests: Examination centered on the discussion of written educational worksheets designed by the student

Course: String Theory	**Teaching Language:** Italian
SSD (Subject Areas): FIS/02	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C

Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.
Learning objectives: The course intends to transmit to the student knowledge of the primary concepts and the fundamental mathematical tools of String Theory and of its recent developments. At the end of the course, the student will know: - methods to quantize the open and closed bosonic string including BRST quantization and path integral methods; - conformal field theory in two and higher dimensions and its application in String Theory and holography; - modern Quantum Field Theory methods relevant for string theory applications; - dualities in String Theory and the holographic principle; - strings and branes, low energy effective field theories.
Propaedeuticities: Quantum Field Theory I; General Relativity and Gravitation. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Written and/or oral exam.

Course: Superconducting Quantum Technologies		**Teaching Language:** Italian
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Necessary skills for the theoretical treatment of the states of both atomic and molecular aggregates, as well as the skills for dealing with the properties of propagation and interaction of photons with fields and with matter. The skills of this sector also concern research in the fields of atomic and molecular physics, liquid and solid states, compounds and metallic and semiconductor elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Learning objectives: This course is meant to accompany the student in advanced knowledge on concepts and experiments of quantum computing and quantum communication, both employing low-power superconducting electronics. We intend to privilege an experimental path, which enables the student to understand and apply notions of quantum information to real quantum devices. The student will be able to design and characterize a qubit or an ensemble of qubits, coupled to a superconducting resonator. This will be realized through suitable programming of the measurement sequences and protocols through Phyton.		
Propaedeuticities: - **Is a propaedeuticity for:** -		
Types of examinations and other tests: Oral exam		

Course: Techniques for particle acceleration		**Teaching Language:** Italian
SSD (Subject Areas): FIS/01, FIS/03		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The subject area encompasses the skills necessary to carry out experimental research, in particular those for investigating physical processes and the principles of operation of instrumentation suitable for the control and detection of phenomena, the production and detection of radiation, metrology and the processing of experimental data. The competences of this subject area also cover research in the fields of atomic and molecular physics, liquid and solid states, metallic and semiconductor compounds and elements, dilute states and plasmas, as well as photonics, optics, optoelectronics and quantum electronics.		
Objectives: The course aims at providing an understanding of modern experimental techniques of particle beam acceleration with a focus on the role of the plasma state in this context. At the end of the course the student will be able to - describe the main fundamental physical processes governing the plasma state - understand the physics of ultra-intense gradient particle accelerators - understand the role of plasma in other aspects such as the physics of controlled thermonuclear fusion.		

Propaedeuticities: None. **Is a propaedeuticity for:** None.
Types of examinations and other tests: Oral examination.

Course: Theoretical Astroparticle Physics		**Teaching Language:** Italian
SSD (Subject Areas): FIS/02		**CREDITS:** 6
Course year: I	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.		
Learning objectives: The course aims at forming students who are familiar with the leading subjects in the field of "Astroparticle" today: physical Cosmology and Cosmic Rays. A rigorous understanding of the physics taking place throughout (and at "crucial" points of) the evolution of the Cosmological Universe (e.g., Primordial Nucleosynthesis to Structure Formation) is one main goal, and for this the students will have to: become familiar with the physical processes taking place in the Universe described by the Cosmological model (and the model itself); relate those physical processes to observables that can be measured by experiments; test those observables against the underlying cosmological model to verify/falsify it, this identifying the most crucial "issues" of the Cosmological model today. In the second part of the course, the students will gain familiarity with the empirical evidence for Cosmic Rays, and the physics underlying their detection, production, and propagation.		
Propaedeuticities: Quantum Field Theory I; General Relativity and Gravitation **Is a propaedeuticity for: -**		
Types of examinations and other tests: Written and/or oral exam, based on the independent development of an elaborate on subject identified by teacher and student together. The goal of the exam is to prove the independence of the student in understanding and identifying the leading themes in the course subject.		

Course: Theoretical Physics of Fundamental Interactions		**Teaching Language:** Italian
SSD (Subject Areas): F IS/02		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.		
Learning objectives: The course introduces the student to the systematic study of fundamental interactions. Students will learn to use quantum field theory and group theory to describe the results of experimental data in particle physics. The topics of the most recent theories at the frontiers of our knowledge of the physical world will be addressed. Students will acquire the tools to construct new theories describing the phenomenology of fundamental interactions.		
Propaedeuticities: Quantum Field Theory I; **Is a propaedeuticity for: -**		
Types of examinations and other tests: Written and/or oral exam		

Course: Theory of Nuclear Structure		**Teaching language:** Italian
SSD: FIS/04		**CFU:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: The course provides the knowledge required to study the phenomena proper of the nucleus structure. The theories,		

based on fundamental principles and laws, are presented using of state of the art mathematical and computational methodologies.
Learning objectives: - The student will understand the most widely used theories and models that describe the nucleus structure, and the fundamentals of the theory of nuclear forces. - The student will know the conditions, and the corresponding limits, to describe the structure of the nucleus with different modern theoretical approaches and related models. - The student will be able to use the acquired knowledge to compare theoretical predictions with experimental data, possibly using existing software. - The student will be able to read and understand relevant literature and assess its methodological soundness. Will be able to communicate, with proper terminology, the features of the models and their applications, their limitations and possible extensions. - The student will widen his/her knowledge through discussions of open issues in actual research.
Propaedeuticities: Nuclear Physics. **Is a propaedeuticity for:** none.
Types of examinations and other tests: short essay on an assigned topic and oral examination.

Course: Theory of Quantum Information		**Teaching Language:** Italian
SSD (Subject Areas): FIS/02		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Contents extracted from the SSD declaratory list consistent with the learning objectives of the course: Cultural background necessary for the theoretical treatment of physical phenomena, with the help of appropriate mathematical and computational tools, as well as the skills appropriate for the application of mathematics aimed at investigating, treating theoretically and creating models of physical phenomena.		
Learning objectives: This course is aimed at giving students a command of the methods, tools and goals of Quantum Information Theory. The student will be able to understand the literature in the field, potentially towards beginning research. Topics include quantum circuits, quantum Fourier transform and search algorithms, quantum operations formalism, theory of error correction, fault tolerant quantum computation, entanglement, cryptography, quantum measurement, quantum metrology, quantum complexity, applications to quantum many-body systems, black holes, quantum thermodynamics.		
Propaedeuticities: Quantum Mechanics. **Is a propaedeuticity for:** None.		
Types of examinations and other tests: Written and/or oral exam.		

Training Activity: under Art. 10, c. 5, letter d	**Training Activity Language:** Italiano
Content of the activities consistent with the training objectives of the course: Other knowledge useful for favouring job placement, enhancing computer and information technology, and other skills.	**CFU:** 2
Course year: I	**Type of Training Activity:** F
Teaching Methods: The activities can be carried out in person, remotely, or by participating in schools, internships, and events promoting and disseminating physics.	
Objectives: Training activities aimed at acquiring additional knowledge and/or skills, such as language skills other than English, computer and information technology skills, relational and organizational abilities through participation in or organization of events for the promotion and dissemination of physics, professional activities or activities useful for job placement, as well as supplementary training activities for acquiring knowledge and methodologies aimed at thesis work not already included in the course of study. The main purpose of these training activities is to provide the student with additional knowledge and/or skills that are useful for completing their education, by acquiring further knowledge relevant to their course of study, developing relational and organizational skills, or facilitating entry into the workforce.	
Propaedeuticities: None. **Is a propaedeuticity for:** None	

Types of examinations and other tests: The credits related to these activities are awarded by the CCD coordinator upon submission of appropriate documentation.	

Training Activity: under Art. 10, c. 5, letter d	**Training Activity Language:** Italian and other selected European Union language
Content of the activities consistent with the training objectives of the course: Additional language skills.	**CFU:** 4
Course year: I	**Type of Training Activity:** F
Teaching Methods: The activities can be carried out in person or remotely by attending courses at the University Language Center or by attending courses at institutions that issue foreign language proficiency certificates.	
Objectives: Training activities aimed at acquiring additional language skills, with the ability to use at least one European Union language other than Italian fluently, both in written and oral form, including disciplinary and technical lexicons. The purpose of this training activity is to provide the student, in accordance with regulatory guidelines, with the ability to fluently use at least one European Union language other than Italian, both in written and oral form, including disciplinary and technical lexicons, at a level comparable to B2 of the Common European Framework of Reference for Languages (CEFR).	
Propaedeuticities: None. **Is a propaedeuticity for:** None.	
Types of examinations and other tests: Proficiency is achieved through a specific test administered by the University Language Center or through certifications from institutions authorized to issue foreign language proficiency certificates. The credits related to the knowledge of a European Union language other than Italian are awarded by the CCD coordinator upon submission of appropriate documentation.	

Training Activity: under Art. 10, c. 5, letter d	**Training Activity Language:** Italian
Content of the activities consistent with the training objectives of the course: Training and orientation internships.	**CFU:** 6
Course year: II	**Type of Training Activity:** F
Teaching Methods: In-person or remote activities, depending on the type of training or orientation internship.	
Objectives: Carrying out training and/or orientation internships that are consistent with the course of study. The purpose of the activity is to provide the student with a training and/or orientation internship that is useful for developing skills aligned with the professional activities anticipated by their study program and for entering the workforce.	
Propaedeuticities: None. **Is a propaedeuticity for:** None.	
Types of examinations and other tests: Credits for these activities will be awarded by the CCD Coordinator based on appropriate documentation confirming the completion of the internship and following a positive assessment by a CCD committee.	

Conclusive remark: where necessary, all lessons can also be delivered in English, e.g. in the presence of foreign students (Erasmus, Educational Agreement, etc.).