DIDACTIC REGULATIONS OF THE DEGREE PROGRAM
QUANTUM SCIENCE AND ENGINEERING

LM-44 (single-cycle)

School: Politecnica e delle Scienze di Base

Department: Physics E.Pancini

Regulations in force since the academic year 2024 - 2025

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

INDEX

Art. 1
Object

1. These Didactic Regulations govern the organisational aspects of the CdS in Quantum Science and Engineering (Scienza e Ingegneria Quantistiche), (classe LM-44). The CdS in Quantum Science and Engineering is hinged in the School Politecnica e delle Scienze di Base, Department of Physics "E.Pancini"

   Source: SUA-CdS

   Framework: General CdS Information

   CdS Quantum Science and Engineering (Scienza e Ingegneria Quantistiche

   Class LM-44 - Modellistica matematico-fisica per l'ingegneria

   Teaching language English

2. The CdS is governed by the Didactic Coordination Commission (CCD), pursuant to Art. 4 of the RDA.

   Source: SUA-CdS

   Framework: Dipartimento di Fisica "Ettore Pancini"

   Collegial Management Body of the CdS

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

Source: SUA

Framework: A4.a – RAD The Master's program in Quantum Science and Engineering (QSE) is designed to train graduates with solid understanding of quantum mechanics and its potential applications across a broad range of cutting-edge technologies. Students are expected to acquire a robust toolkit for addressing theoretical, experimental, computational, and technological challenges that employ quantum approaches, with the ultimate goal of harnessing these phenomena for advances in quantum computing, communication, simulation, as well as in sensing and metrology fields. Graduates will undertake a rigorous exploration of quantum mechanics, its underpinnings through linear algebra, and its manifestations in tangible physical systems with an emphasis on isolation and engineering capabilities. Consequently, they will be equipped to convert the tenets of quantum mechanics into actionable insights for quantum information processing, computational quantum paradigms, and to innovate, design, construct, and assess quantum machinery. They will be adept at conducting quantum measurements across a spectrum of applications. Particularly, through the exploitation of entanglement in photons, electrons, atoms, or molecules, quantum sensors are anticipated to achieve the utmost physical measurement limits, enhancing the precision and accuracy by several magnitudes compared to current standards.

Knowledge and skills will also be provided to identify, interpret, describe, formulate, and solve typical problems of information engineering, even complex ones, with innovative methodologies based on quantum technologies.

Upon completion, QSE graduates are expected to be well-prepared for leading-edge research or professional careers, demanding an intimate acquaintance with scientific culture and methods. They should demonstrate an agile and receptive mindset capable of swiftly assimilating novel methodologies and technologies and adept at managing complex apparatus and maximizing the

potentials of quantum technologies. Accordingly, graduates in Quantum Science and Engineering will have garnered:

O1) Mastery of experimental and theoretical principles in key segments of modern physics, centering on quantum models and physical systems pivotal to the deployment of quantum technologies.
O2) Advanced understanding of Mathematics, specifically tailored to articulate quantum mechanics via linear algebra.
O3) Computational strategies, simulation techniques, and potential quantum integrations of such skills.
O4) Operational laboratory competencies and autonomous processing, interpretation, and assessment of experimental data.
O5) Knowledge in the field of information engineering, both regarding more fundamental aspects and more innovative aspects that can be tackled with quantum methodologies.
O6) Aptitude for integrated teamwork and adherence to laboratory safety protocols.
O7) Adequate skills and tools for communication and information management.
O8) The ability to use modern cognitive tools for updates on scientific topics acquired.
O9) Familiarity with the scientific method, inclusive of multidisciplinary contexts, and adept problem-solving utilizing quantum concepts.
O10) Proficiency in English for both written and oral communication, inclusive of technical terminologies.

The two-year curriculum encompasses core mandatory courses, a selection of supplementary and elective subjects, hands-on activities, and a capstone project. The first year lays the groundwork with common courses for all enrollers, who may then personalize their education through elective credits (art.10, paragraph 5, letter a). Optional courses, primarily in the second year, offer specialized skills and expertise on various quantum platforms. This program aims to shape graduates into specialists in the field of emergent quantum technologies and their principal applications.

Students can select these electives from diverse academic areas, enhancing the interdisciplinary nature of their educational journey. Furthermore, credits may be allocated to internships in line with the university's active partnerships, providing real-world experience in public or private sectors.

Art. 3
Professional profile and work opportunities

Source: SUA Framework: A2.a - RAD

Expert in quantum technologies for advanced research and industry

Function in a work context:

The master's degree program prepares for the professional position of physicist, expert in quantum technologies for advanced research and industry. Graduates acquire skills that enable them to perform professional activities that require in-depth knowledge of quantum concepts, methodologies and technologies.
These activities include the functions of: laboratory technician in the field of physics; quantum computer programmer and manager of computer centers and websites; production process controller; developer of technological applications and services; problem solver in areas where analysis and modeling skills based on quantum technologies are required; communicator in the

field of quantum science and technologies; implementer of innovative experiments with consequent analysis and interpretation of results; evaluator of the impact of quantum engineering solutions; manager of innovation and production development, in relation to industrial solutions based on quantum technologies implementer and maintainer of apparata for quantum computation, quantum communication and quantum sensing.

Skills associated with the function:

Specific knowledge, skills, and abilities are required to perform the functions described above, which are acquired during the course of study and are here listed: basic knowledge of Quantum Mechanics and the physics of the main quantum systems, both material or photonic, of interest for applications in quantum technologies; multidisciplinary methodological and technological knowledge for physical investigation; sound technological skills and abilities of wide-ranging instrumental analysis, aimed at research, monitoring and control activities; skills in computer science and information engineering, including in particular communication and network theory and technologies, digital electronic and electromagnetic field technologies; computer skills that enable the development of code with modern programming languages for quantum control of systems or directly quantum codes; advanced knowledge of the English language in the specific area of expertise; appropriate skills and tools for communication and information management; the ability to work in a team and/or independently and to have the ability to fit into work environments; possession of the basic cognitive tools for continuous updating of one's knowledge.

Employment outlets:

QSE graduates will be the first link in ensuring the functioning of the entire quantum supply chain from basic research to the competitiveness of Italian high-tech companies, making our innovation system attractive and dynamic. Of course, the job market is global with an increasing number of opportunities. Graduates can easily find employment in research centers and laboratories, both public and private, in the fields of basic and applied research, industry, information technology, environment and advanced technological services in general; in companies devoted to technological innovation; in most of the companies that exploit and develop new technologies; in public or private environmental monitoring bodies with regard to physical or physicochemical problems; in companies devoted to scientific communication and popularization; and in publishing (publishing companies, newspapers and mass media) with regard to scientific and technological fields.

Art. 4

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

Source: SUA Framework: A3.a – RAD

In order to be admitted to the master's degree program in Quantum Science and Engineering it is necessary to already have a Laurea di I livello or equivalent, that is, a Bachelor of Science degree of three or more years. The curriculum needs to fulfil the following requirements:

- 24 CFU of classes in SSD of Mathematics (MAT/01-MAT/08), corresponding to a total of 192 course hours.
- 12 CFU of classes in SSD of Physics (FIS/01-FIS/08), corresponding to a total of 96 course hours.
- 6 CFU of classes in SSD of Computer Science (INF/01 or ING-INF/05), corresponding to a total of 48 course hours.

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

- Additional 12 CFU in any of the following SSD: FIS/01-FIS/08 - Physics; MAT/07 – Mathematical Physics; CHIM/01- Analytical Chemistry, CHIM/02 – Physical Chemistry, CHIM/03 -General and Inorganic Chemistry, ING-IND/06 - Fluidodynamics; ING-IND/10 – Industrial Technical Physics; ING-IND/11 Environmental Technical Physics, ING-IND/12 - Mechanical and Thermal Measurements; ING-IND/13 – Applied Mechanics to Machines; ING-IND/18 – Physics of Nuclear Reactors; ING-IND/19 Nuclear Plants; ING-IND/20 – Nuclear measurements and instrumentations; ING-IND/22 -Materials Science and Technology; ING-IND/31 - Electrotechnics; ING-INF/01 - Electronics; ING-INF/02 – Electromagnetic Fields; ING-INF/06 – Electronic and Informatic Bioengineering; ING-INF/07 – Electric and electronic measurements.

The 24 CFU in SSD MAT/01-MAT/08 prove mathematical knowledge at the level typically given in physics or informatic engineering degrees: real analysis, linear algebra, geometry, functional analysis and differential equations.
The 12 CFU in SSD FIS/01-FIS/08 prove knowledge of classical physics at the level typically given in the degrees of informatic engineering: mechanics, thermodynamics, electromagnetism.
The 6 CFU in INF/01 or ING-INF/05 prove knowledge on basic elements of computer science at the level typically given in the degrees of information engineering or physics.

Finally, it is required a knowledge of English language at the CEFR level at least B2.

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

Source: SUA Framework: A3.b

The CCD of the Degree Program normally regulates the admission criteria and any scheduling of enrolments, except in cases subject to different provisions of law[2]. Admission will be based primarily on the analysis of the candidates' university career, i.e. the overall average, the average in the SSDs listed in the previous section and the grades reported in the individual exams; where deemed necessary, an oral interview may be used to complete the assessment for admission purposes. Admission is aimed at verifying the initial preparation on the topics listed in the previous section, as well as the objectives of planning the number of enrollees.

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. Each CFU corresponds to 25 hours of overall training commitment[3] 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.

[2] National programmed access is regulated by L. 264/1999 and subsequent amendments and supplements.
[3] 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".

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 [4]:
Lecture or guided teaching exercises: 8 hours per CFU;
- Laboratory activities or fieldwork: 8 hours per CFU;

For internship activities, each credit corresponds to 25 hours of overall training commitment [5].
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 modality presence, in the classroom and in the laboratories.
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[6]

1. The CCD, within the prescribed regulatory limits[7], 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.
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.[8]
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.

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[4] 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.".

[5] 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.

[6] Article 22 of the University Didactic Regulations.

[7] 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".

[8] 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."

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 [9].

Art. 9
Degree Program structure and Study Plan

1. The legal duration of the Degree Program is 2 years. The student must acquire 120 CFU[10], attributable to the following Types of Training Activities (TAF):
   B) characterising,
   C) related or complementary,
   D) at the student's choice[11],
   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, including the final exam, 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. Examinations or assessments relating to activities independently chosen by the student may be taken into account in the overall calculation corresponding to one unit[12]. 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[13] are excluded from the count. Integrated Courses comprising of two or more modules are subject to a single examination.

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[9] 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."

[10] 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.

[11] 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).

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

[13] 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

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 CCD.

Art. 10
Attendance requirements[14]

1. In general, attendance of lectures is 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.

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).

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".

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

Art. 13

Criteria for the recognition of credits earned in other Degree Programs in the same Class[15]

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[16]; 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 [17].
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[18].
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.

[15] Art. 19 of the University Didactic Regulations.
[16] Art. 19 of the University Didactic Regulations.
[17] Art. 6, c. 9 of the University Didactic Regulations.
[18] Art. 19, c. 4 of the University Didactic Regulations.

- 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[19], is governed by the "University Regulations for enrolment in individual teaching courses activated as part of the Degree Program"[20].

Article 16
Features and modalities for the final examination

Source: SUA

Framework: A5a (RAD) and A5b. The final exam consists in the evaluation of a paper written in English having as its object an original project developed by the student independently under the guidance of a supervisor and any co-supervisors as further specified in the teaching regulations. The final exam is taken by the Candidate in front a Commission chaired by the Coordinator of the Course of Studies (or his substitute) and consists in the presentation of the thesis work carried out under the guidance of one or more Supervisors, and in the subsequent discussion of the contents with the members of the Commission**.** The Candidate must provide a copy of the Master's Degree Thesis to the Members of the Commission according to the methods specified in the Study Course Regulations. Upon presentation, the Candidate is allowed to use an audio-visual support to be projected publicly. At the end of the presentation each member of the Commission can make observations and ask questions to the Candidate relating to the topic of the thesis work. The presentation must last between 20 and 25 minutes and must be conducted in English.

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[21].
2. The CCD regulates the modalities and characteristics of traineeship and internship with specific regulations.
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.

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

Article 18
Disqualification of student status[22]

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[23].
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)[24] 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.

   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.

[22] Art. 24, c. 5 of the University Didactic Regulations.
[23] R.D No. 2482//2020.
[24] 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.

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

QUANTUM SCIENCE AND ENGINEERING

CLASSE LM-44/LM-120 (c.u.)

School: : Politecnica e delle Scienze di Base

Department: Fisica "Ettore Pancini"

Didactic Regulations in force since the academic year 2024-2025

STUDY PLAN

KEY

Type of Educational Activity (TAF):

B = Characterising

C = Related or Supplementary

D = At the student's choice

E = Final examination and language knowledge

F = Further training activities

Year 1									
Title Course	**SSD**	**Module**	**CREDITS**	**Hours**	**Type Activities** *(lectures, workshops, etc.)*	**Course Modalities** *(in-person, by distance)*	**TAF**	**Disciplinary area**	**Mandatory/ optional**

Foundations of Quantum Mechanics	FIS/02	Mod I Principles	12	48	Frontal lesson	In-person	B	Discipline matematiche ,fisiche e informatiche	Mandatory
Foundations of Quantum Mechanics	FIS/03	Mod II Physical systems		48		In-person	B		
Microwave circuits and technologies	ING-INF/02	single	6	48	Frontal lesson	In-person	B	Discipline ingegneristiche	Mandatory
Digital Electronics for Quantum Applications	ING-INF/01	single	6	48	Frontal lesson	In-person	B	Discipline ingegneristiche	Mandatory
Principles of Quantum Communications	ING-INF/03	single	6	48	Frontal lesson	In-person	C	Attività affini e integrative	Mandatory
Quantum Computation:	INF/01	Mod I: Theory	12	48	Frontal lesson	In-person	B	Discipline matematiche ,fisiche e informatiche	Mandatory
Quantum Computation:	ING-INF/05	Mod II:: Architectures and High Performance		48		In-person		Discipline ingegneristiche	
Applied Quantum Systems	FIS/03	single	9	72	Frontal lesson	In-person	B	Discipline matematiche, fisiche e informatiche	Mandatory
Mandatory (one of your choices)		single	6	48	Frontal lesson	In-person	C		Mandatory (one of your choices)

Year 2

Title Course	**SSD**	**Module**	**CREDITS**	**Hours**	**Type Activities** *(lectures, workshops, etc.)*	**Course Modalities** *(in-person, by distance)*	**TAF**	**Disciplinary area**	**Mandatory/ optional**
Quantum circuit electrodynamics and Quantum devices	ING-IND/31	single	9	72	Frontal lesson	In-person	B	Discipline ingegneristiche	Mandatory
Physical principles of quantum information	FIS/03	single	6+ 6	48	Frontal lesson	In-person	C	Attività affini e integrative	Mandatory (two of your choices) or see note 1
Quantum optics	FIS/03	single		48		In-person			
Quantum Simulators	FIS/03	single		48		In-person			
Quantum materials and solid-state qubits	FIS/03	single		48		In-person			
Advanced Programming	ING-INF/05	single		48		In-person			
Software quantistico	INF/01	single		48		In-person			
Quantum metrology and sensors	ING-INF/07	single		48		In-person			
Advanced Quantum Communication Networks	ING-INF/03	single		48		In-person			
Quantum Detectors for Fundamental Science	FIS/01	single		48		In-person			

Superconducting Quantum Technologies	FIS/03	single		48		In-person			
Quantum Chemistry	CHIM/02	single		48		In-person			
Quantum Measurement Theory	FIS/02	single		48		In-person			
Quantum Algoritms	FIS/02	single		48		In-person			
Nanoscale Processing and Characterization for Advanced Devices	FIS/01	single		48		In-person			
Nonlinear Systems	ING-INF/04	single		48		In-person			
Quantum detectors for applied science	FIS/07	single		48		In-person			
Mathematics for Quantum Mechanics	MAT/07	single		48		In-person			
Mathematical Methods for Quantum Information	MAT/05	single		48		In-person			
One of your choices or see note 2			12	96	Frontal lesson or internship		D	your choices	Mandatory (one of your choices) or see note 2
One of your choices or see note 2		single	6	48	Laboratory or internship		F	your choices	Mandatory (one internship)
One of your choices or see note 3			3	24			F	your choices	

Final test			21	168			E	Final test	Mandatory

Note 1: In addition to the courses listed in Table A, students may also include in this space any courses available for the following Master's degree programs: Physics, Computer Science, Electronic Engineering, Telecommunications Engineering, and Computer Engineering.

Note 2: Students may choose any course offered by the University. Additionally, internship activities may be incorporated into the curriculum, subject to prior approval.

Note 3: These credits can be strategically utilized by students seeking to broaden their language proficiency, enhance their computer and digital skills, participate in training and orientation internships, or acquire additional competencies conducive to professional integration. Specifically, these credits may be allocated to preparatory training activities related to the final assessment.

Beyond the standard academic pathway outlined above for those with Bachelor's degrees, expedited, streamlined tracks are also available for individuals who have already completed Master's degrees in Physics or Engineering. These accelerated routes are designed to facilitate the completion of the Master's degree in Quantum Science and Engineering within one year, equating to 60 credits. The specifics of these abbreviated tracks will be delineated by the Educational Coordination Committee, taking into account the student's previous Master's degree and their academic history.

ANNEX 2.1

DEGREE PROGRAM DIDACTIC REGULATIONS

QUANTUM SCIENCE AND ENGINEERING

CLASSE LM-44/LM-120 (c.u.)

School: : Politecnica e delle Scienze di Base

Department: Fisica “Ettore Pancini”

Didactic Regulations in force since the academic year 2024-2025

Course: Digital Electronics for Quantum Applications	**Teaching Language:** English	
SSD (Subject Areas): Ing-INF/01		**CREDITS:** 6
Course year: II	**Type of Educational Activity: C**	
Teaching Methods: In person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The activities of interest include: theoretical and experimental studies of physical principles and technologies; design and implementation of devices, circuits, apparatus, and systems based on specifications, regulations, and costs set by applications. The field encompasses a wide range of skills (semiconductor devices for low and high frequency, circuits, microcircuits, sensors, electronic instrumentation, nanotechnologies, nanoelectronic devices and circuits, photonic devices, energy efficiency of circuits and systems, computer tools for assisted design, etc.), each comprising methodological, design, technological, and experimental aspects.		
Objectives: Provide students with the fundamental concepts for the analysis of basic integrated analog electronic circuits for quantum applications. To this end, the characteristics of fundamental electronic devices are introduced: diodes and MOS transistors, and their applications are studied in elementary amplifiers, with specific reference to integrated analog circuits for qubits in semiconductor technology.		
Propaedeuticities: none **Is a propaedeuticity for:**		
Types of examinations and other tests: oral		

Course: Advanced Programming		**Teaching Language:** English
SSD (Subject Areas): ING-INF/05		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** B	
Teaching Methods: in-person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The sector is characterized by the set of scientific fields and scientific-disciplinary competences related to the design and realization of information processing systems, as well as their management and utilization in various application contexts with methodologies and techniques typical of engineering. This includes theoretical foundations, methods, and technologies aimed at producing technically valid projects, from both the adequacy of the proposed solutions and the feasibility of technical implementation, to economic feasibility and organizational effectiveness. These foundations, methods, and technologies cover all aspects related to a processing system, from hardware to software.		
Objectives: The course aims at providing students with advanced knowledge and expertise related to concurrent and distributed programming, introducing the tools to develop and debug multithreading and network applications using Python, and introducing the concept of middleware and of the different solutions used in industry, focusing on both the message-oriented and service-oriented models, with application on real technology.		
Propaedeuticities: none **Is a propaedeuticity for:** none		
Types of examinations and other tests: oral examination with project discussion		

Course: Applied Quantum Systems	**Teaching Language:** English
SSD (Subject Areas): FIS/03	**CREDITS:** 9
Course year: II	**Type of Educational Activity:** B
Teaching Methods: In-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Theoretical and experimental treatment of quantum electronics and quantum information. material science from metals to semiconductors and strongly correlated systems, superconductors, mesoscopic and nanoscale systems to build quantum machines.	
Objectives: This course aims at illustrating "quantum mechanics at work", not only as a key to interpret nature but also as a drive to build new "machines" It will be shown how to implement quantum machines on the basis of quantum effects. Ability to understand quantum platforms and the underlying physical concepts. This course will cover a breadth of archetypal systems for quantum technologies with a special focus on solid state systems: nuclear magnetic resonance, laser amplifiers and self-sustained oscillators, pulse sequence techniques, Ramsey spectroscopy, meso-scale low-dimensional devices, quantum Hall effect, quantum confinement, conductance quantization, magneto oscillation, macroscale quantum effect devices and circuits such as Cooper-pair boxes and superconducting quantum circuits. The course will also deal with materials challenges which provide opportunities for quantum computing hardware.	
Propaedeuticities: Foundations of Quantum Mechanics **Is a propaedeuticity for:**	
Types of examinations and other tests: oral	

Course: Advanced Quantum Communication Networks	**Teaching Language:** English
SSD (Subject Areas): ING-INF/03	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods: The course is organized by integrating traditional lectures with interactive laboratory sessions. Furthermore, seminars will be eventually organized during the course by inviting experts in the relevant fields, and innovative teaching methods, as for example flipped classroom and feedback teaching strategies, will be adopted.	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The sector studies the planning, design, construction (hardware and software) and operation of equipment, systems and infrastructures for applications aimed at: the transfer of signals via cable (copper or fibre), via radio (terrestrial or satellite) or other means of propagation, with the use of specific technologies such as optical and mobile communications; (omissis) to network interconnection for the transport of information (omissis). Basic aspects are included (theory of random phenomena, information, codes, signals, traffic, protocols, etc.) (omitted).	
Objectives: The aim of the course is to provide the students with the knowledge related to the analysis and design of communication protocols for quantum networks. First, the fundamentals of classical communication networks will be introduced. Then, the advanced notions related to the design of quantum networks, including the issues arising with the distribution of entanglement among remote nodes, are presented. Furthermore, the Quantum Internet protocol stack will be carefully presented and analyzed. To this aim, its unconventional requirements and peculiarities with respect to the classical TCP/IP protocol stack will be properly discussed. Some use cases, such as distributed quantum computing and quantum placement of quantum links, will be presented and analyzed.	
Propaedeuticities: Principles of Quantum Communications **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral and project discussion	

Course: Foundations of Quantum Mechanics Mod I: Principles	**Teaching Language:** English
SSD (Subject Areas): Fisica Teorica, Modelli e Metodi Matematici (FIS02)	**CREDITS:** 6
Course year: 1	**Type of Educational Activity:** B
Teaching Methods: in person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Knowledge and competences necessary for the theoretical treatment of quantum phenomena, starting from foundational laws and principles together with the necessary mathematical tools. It includes the competences needed for understanding the mathematics and the modelling of quantum physics at a deeper level.	
Objectives: Basic ideas and mathematics of Quantum Mechanics. This course will cover the fundamentals of quantum physics in its phenomenological, theoretical and experimental basis. The course is aimed at conveying working knowledge of the principles of quantum mechanics towards the understanding of quantum information processing and quantum computation.	
Propaedeuticities: none **Is a propaedeuticity for:** All the courses from the second semester of first year onwards.	
Types of examinations and other tests: Written and oral	

Course: Foundations of Quantum Mechanics (FQM) - Mod II: Physical systems	**Teaching Language:** English	
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: I (Semester I)	**Type of Educational Activity:** B	
Teaching Methods: In-person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: "theoretical and experimental treatment of the states of both atomic and molecular aggregates...treatment of the propagation properties and interaction of photons with fields and matter"		
Objectives: Knowledge of the principles of quantum mechanics towards the understanding of physical realizations of quantum computers.		
Propaedeuticities: Foundations of Quantum Mechanics Mod I: PRINCIPLES **Is a propaedeuticity for:** Quantum Computation, Applied Quantum Systems, Quantum circuit electrodynamics and Quantum devices		
Types of examinations and other tests: Oral		

Course: Mathematics for Quantum Mechanics		**Teaching Language:** English
SSD (Subject Areas): MAT/07		**CREDITS:** 6
Course year: first or second	**Type of Educational Activity:** affine and integrative (C)	
Teaching Methods: in-person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Aspects of mathematical physics and theory of dynamical systems applied to quantum mechanics, with both analytical and geometric techniques.		
Objectives: Working knowledge of mathematical tools and methods that find application in the field of quantum mechanics, such as partial differential equations, eigenvalue problems, developments in orthogonal functions, operator theory.		
Propaedeuticities: Foundations of quantum mechanics **Is a propaedeuticity for:** none		
Types of examinations and other tests: written and oral exam		

Course: Mathematical Methods for Quantum Information	**Teaching Language:** English	
SSD (Subject Areas): MAT/05		**CREDITS:** 6
Course year: first or second	**Type of Educational Activity:** affine and integrative (C)	
Teaching Methods: in-person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Calculus of variations and theory of functions, both real and complex, analytical number theory, applied to quantum information.		
Objectives: Working knowledge of mathematical tools and methods that find application in the field of quantum information, such as aspects of complex number theory, linear algebra in Hilbert spaces, operator theory, eigenvalue problems, probability theory, elements of number theory.		
Propaedeuticities: Foundations of quantum mechanics **Is a propaedeuticity for:** none		
Types of examinations and other tests: written and oral exam		

Course: Microwave circuits and technologies	**Teaching Language:** English
SSD (Subject Areas): ING-INF/02	**CREDITS:** 6
Course year: I	**Type of Educational Activity: B**
Teaching Methods: in-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The design of high frequency passive circuits has been developed in parallel, analysing scenario of increasing difficulties, with a variety of elements, including active ones: this is the area of microwave and millimeter wave components and circuits. ING-INF/02 Electromagnetic Fields. The sector has its historical origins from the study of electromagnetic waves by means of Maxwell's equations. This model, still very modern, offers continuous opportunities for deductive analysis and formal ideas, constituting a broad basis of work for scholars of electromagnetic fields. Initial developments were aimed at telecommunications; this is where studies on free and guided propagation and on antenna design methods originate, the true cornerstones of the sector, together with the analysis of scattering problems. The most recent developments in propagation studies have been directed towards the characterization of the channel for mobile communications and towards optical components and systems. The design of very high frequency passive circuits has been developed in parallel, analysing scenario of increasing difficulties, with a variety of elements, including active ones: this is the area of microwave and millimeter wave components and circuits. More recently, the sectors of remote sensing, fundamental for environmental diagnostics, in particular through modern radars, and that of the biological effects of electromagnetic fields, fundamental to check that the radio systems do not constitute harm to human beings and to identify medical applications, have been developed. Furthermore, the investigation on electromagnetic compatibility problems has been extended, together with industrial applications for the treatment of materials and the creation of sensors.	
Objectives: The course is aimed at providing the skills and methodological and operative tools necessary to concretely apply, in the field of quantum technologies, the operatvie principles of circuits and devices working at Microwaves and Radio Frequency, and the theoretical-numerical analysis techniques and synthesis and design techniques. In order to complete the training, the theoretical-numerical lessons will be accompanied by laboratory experiences and design sessions in which the student will be asked to use, also with the aid of the most recent calculation software, the skills acquired during the course to design and characterize specific components and circuits used in quantum systems.	
Propaedeuticities: **Is a propaedeuticity for:**	
Types of examinations and other tests: Oral	

Course: Nanoscale Processing and Characterization for Advanced Devices	**Teaching Language:** English
SSD (Subject Areas): FIS/03 – Physic of Matter	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods: Live lectures on theory for 70% of frontal time and measurements in lab for 30% of rest time.	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Skills and methods necessary for the low-noise fabrication and measurement at cryogenic temperatures of nanoscale devices. Skills necessary for the treatment of experimental techniques used in clean room environments as well as the theory of electronic transport in the classical and quantum limits of junctions and devices at the nanoscale. Cryogenic techniques and DC and RF measurement schemes for low-noise characterization of superconducting devices. Nanofabrication protocols for the creation of superconducting nanowires and applications in the field of quantum communication.	
Objectives: Experimental methods used in clean room environments, classical and quantum transport theory of junctions and devices, low temperature cryostats, DC and RF low noise measurement, realization of superconducting nanowires, properties and applications in quantum computation.	
Propaedeuticities: None **Is a propaedeuticity for:**	
Types of examinations and other tests: oral and project discussion	

Course: Physical principles of quantum information		**Teaching Language:** English
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: first or second	**Type of Educational Activity:** C	
Teaching Methods: in-person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Theoretical and experimental treatment of atomic and molecular physics, materials science and related technology from the nanoscopic to the macroscopic level, as well as photonics, optics, optoelectronics, quantum electronics and quantum information.		
Objectives: Learning of the principles of quantum information physics. Qubits, entanglement, Bell inequalities, no-cloning theorem, measurement theory, coherence and decoherence; the concepts of fidelity and quantum state reconstruction (with experimental aspects); quantum information with discrete and continuous variables, with examples of physical implementations using different platforms (atoms, ions, superconducting circuits, photonics); simple quantum protocols (quantum cryptography and teleportation); intrinsic and technological limits of quantum information. Quantum information compression, efficient quantum algorithms and quantum complexity.		
Propaedeuticities: Foundations of quantum mechanics **Is a propaedeuticity for:** none		
Types of examinations and other tests: written and oral exam		

Course: Quantum optics		**Teaching Language:** English
SSD (Subject Areas): FIS/03		**CREDITS:** 6
Course year: first or second	**Type of Educational Activity:** C	
Teaching Methods: **in-person**		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Theoretical and experimental treatment of atomic and molecular physics, as well as photonics, optics, optoelectronics, quantum electronics and quantum information.		
Objectives: Learning of the fundamental concepts of the quantum theory of electromagnetic radiation, with insights into: Fock states, coherent states, "squeezed" states; field-field and photon-photon interference; elements of quantum information using photons; experimental methods of quantum optics.		
Propaedeuticities: Foundations of quantum mechanics **Is a propaedeuticity for:** none		
Types of examinations and other tests: written and oral exam		

Course: Quantum Detectors for Fundamental Science	**Teaching Language:** English
SSD (Subject Areas): FIS-03 Physics of Matter	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods: IN-PERSON	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The training objectives of the course aim to develop both theoretical and experimental aspects concerning with the interaction of photons with matter, their detection with ultralow sensitive detection schemes, and more generally aspect of integrated, opto-electronics and quantum electronics for understanding the quantum detectors in fundamental science experiments. In particular: Theory of quantum noise. Fundamentals of Single-Photon Detectors (i.e. AVP, SMP, SNSPDs, PCC). Superconducting qubit-based detectors. Quantum sensing devices including magnetometers and interferometers, Applications of quantum detectors to fundamental science experiments.	
Objectives: The course is aimed at providing the fundamental aspects of quantum detectors including single photon detectors, superconducting qubit-based sensors, and quantum sensing devices. The use of such detectors in fundamental science experiments will be presented and discussed. The student will be able to perform single photon measurements on superconducting devices, and to perform basic measurements on superconducting quantum bits for evidencing basic properties in the detection context. The contents will develop the ability to explain and use the principles of quantum theory of electromagnetic radiation within the main experimental methods presented within the course. Moreover, they will develop the capability of sketch and explain the schematic layout of investigated quantum detectors and the configurations of the experiments where they are proposed or used.	
Propaedeuticities: Foundations of Quantum Mechanics **Is a propaedeuticity for:** none	
Types of examinations and other tests: A combination of an oral test (80%) and discussion on an assigned project (20%) inspired by the current literature	

Course: Principles of Quantum Communications	**Teaching Language:** English
SSD (Subject Areas): ING-INF/03	**CREDITS:** 6
Course year: second	**Type of Educational Activity:** C

Teaching Methods: The course is organized by integrating traditional lectures with interactive laboratory sessions based for example on the IBM Q-Experience platform. Furthermore, seminars will be eventually organized during the course by inviting experts in the relevant fields, and innovative teaching methods, such as flipped classroom and feedback teaching strategies, will be adopted.

Contents extracted from the SSD declaratory consistent with the training objectives of the course: The sector studies the planning, design, construction (hardware and software) and operation of equipment, systems and infrastructures for applications aimed at: the transfer of signals via cable (copper or fibre), via radio (terrestrial or satellite) or other means of propagation, with the use of specific technologies such as optical and mobile communications; (omissis) to network interconnection for the transport of information (omissis). Basic aspects are included (theory of random phenomena, information, codes, signals, traffic, protocols, etc.) (omitted).

Objectives: The aim of the course is to provide the students with the principles of quantum information theory and their application to quantum communications. First, the fundamentals of classical communications will be introduced. Then, the notion of quantum bit (qubit), together with the principles and the unconventional peculiarities of quantum information processing, are presented. Stemming from these preliminaries, the course will provide the students with the advanced notions related to quantum communications, namely, to the issues of transmitting classical/quantum information through quantum channels. To this aim, the quantum noise and its peculiarities with respect to classical noise will be properly introduced. Subsequently, secure communications will be discussed by analyzing Quantum Key Distribution (QKD) techniques (including BB84 and Ekert-91) and their practical realization. Furthermore, genuine entangled-based quantum communication techniques (including superdense coding and quantum teleportation) will be properly introduced and analyzed, by also discussing the strategies (e.g., quantum error correction) for counteracting the noise effects. Finally, the challenges arising with the design of quantum communications will be discussed in the light of an integration within the lowest layers of the Quantum Internet protocol stack, by also briefly introducing its unconventional requirements and differences with respect to the standard-de-facto TCP/IP protocol stack. The students will have the opportunity to perform simple experiments on a real quantum computer via for example the IBM Q- Experience platform.

Propaedeuticities: None

Is a propaedeuticity for: Advanced Quantum Communication Networks

Types of examinations and other tests: Oral and project discussion

Insegnamento: Quantum Algoritms		**Lingua di erogazione dell'Insegnamento:** English
SSD: Fisica Teorica, Modelli e Metodi Matematici (FIS02)		**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** C	
Modalità di svolgimento: In presence		
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Knowledge and competences necessary for the theoretical treatment of quantum phenomena, starting from foundational laws and principles together with the necessary mathematical tools. It includes the competences needed for understanding the mathematics and the modelling of quantum physics at a deeper level.		
Obiettivi formativi: This course covers the fundamental notions of quantum computation and quantum algorithms. The course will introduce the general concepts and methods of quantum computation and will focus on the necessary tools. It will also include a survey of the known most notable quantum algorithms with their features and challenges. The course will also contain topics from quantum communication, cryptography, and quantum error correction.		
Propedeuticità in ingresso: Foundations of Quantum Mechanics **Propedeuticità in uscita:**		
Tipologia degli esami e delle altre prove di verifica del profitto: scritto e orale		

Course: Quantum Chemistry	**Teaching Language:** English
SSD (Subject Areas): CHIM/02	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods: In person Live lectures on theory for 80% of frontal time, exercises for 20% of frontal time.	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Intro to Quantum Mechanics: the postulates that form the basis of quantum theory. The time-independent Schrödinger equation in one, two, and three dimensions. The hydrogen atom. Approximation methods and computational approaches for quantum chemistry: perturbation theory, nonlinear and linear variational method. Many-electron atoms: antisymmetry principle and Slater determinants; classification of atomic states; spin-orbit interaction. Molecules and the chemical bond: the Born-Oppenheimer approximation, the hydrogen molecule; homonuclear and heteronuclear diatomic molecules. Polyatomic molecules and molecular orbital theory. Use of group theory for the symmetry classification of molecular orbitals. Nuclear motion. Molecular spectroscopy: rotational, vibrational and electronic. Chemical reactions. The interaction of atoms and molecules with light.	
Objectives: Acquisition of basic knowledge of the physical theories, the approximations and some computational strategies that are involved in the quantum-mechanical description of atomic and molecular systems. Expertise in evaluation of the appropriateness of a quantum-chemical model for the description of molecular / chemical systems.	
Propaedeuticities: Foundations of quantum mechanics **Is a propaedeuticity for:**	
Types of examinations and other tests: Written and oral	

Course: Quantum circuit electrodynamics and Quantum devices	**Teaching Language:** English
SSD (Subject Areas): ING-IND/31	**CREDITS:** 9
Course year: II	**Type of Educational Activity:** Engineering Disciplines, B
Teaching Methods: In-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The field studies the theoretical and experimental aspects of the two complementary strands of electromagnetic fields and circuits and the development of their applications in various engineering sectors. In the first strand, electromagnetic field problems are studied... In the second strand, electrical and electronic circuits are studied..., as well as their models: linear, non-linear, and time-variant, with lumped and distributed parameters... The two complementary approaches are applied to the analysis, synthesis, physical and numerical modeling, and automatic design of equipment, devices..., to superconductivity, electromagnetic compatibility, and more.	
Objectives: In this course, students will first build a strong theoretical foundation, based on the classical Lagrangian and Hamiltonian formulations and their quantum counterparts, which is essential for understanding the quantum behavior of electrical circuits. This background will then serve as a basis for exploring superconducting qubits, where students will delve into the operational mechanisms of these qubits, including the role of Josephson junctions, and learn to differentiate between various qubit types such as charge, flux, phase, and Transmon. As the course progresses, the focus will shift to the dynamics of dissipative quantum circuits. Students will investigate how quantum fluctuations and environmental interactions contribute to decoherence processes, and study mechanisms of decay and dephasing that affect qubit stability and performance. A significant portion of the course will be dedicated to practical skills in qubit-cavity coupling and quantum control. Students will become adept at techniques for both resonant and dispersive couplings, which are critical for controlling qubits within cavities and crucial for accurate qubit readout. Finally, the course will explore the quantum state engineering and the practical implementation of quantum gates and algorithms. Attention will be given to scalability challenges, aiming to equip students with the understanding necessary to contribute to the advancement of scalable quantum computing technologies and error correction methods that underpin robust quantum information processing.	
Propaedeuticities: Foundations of Quantum Mechanics, Microwave Circuits and Technologies **Is a propaedeuticity for:**	
Types of examinations and other tests: oral	

Course: Quantum Computation - Mod I: Theory	**Teaching Language:** English
SSD (Subject Areas): INF/01	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B
Teaching Methods: In-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The scientific field is concerned with scientific and educational-educational activity in the fields of computer research and information theory, placed at the basis of the computer approach to the study of problems and, jointly, the design, implementation, and use of computer systems for innovation in society. Special attention is paid to the method, based on modeling, formalization, and experimental verification. Therefore, the field includes, alongside all basic and general aspects, algorithmic (algorithm design and analysis, computability and complexity, information theory, codes, and cryptography), logical, semantic, and methodological foundations of computer science, including classical and quantum computational models.	
Objectives: By the end of the course, students will develop: • A solid understanding of the fundamental concepts of quantum computing, with a focus on computational architectures, algorithms, and development tools. • Ability to design algorithms based on the quantum computing paradigm. • Problem solving skills to interpret a problem, develop a strategy to solve it, and model this strategy through an appropriate quantum algorithm. • A high level of understanding of the relationships existing between two significant areas of computer science, quantum computing and artificial intelligence.	
Propaedeuticities: Foundations of Quantum Mechanics **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral examination with project discussion.	

Course: Quantum Computation: Mod II: Architectures and High Performance	**Teaching Language:** English
SSD (Subject Areas): ING-INF/05	**CREDITS:** 6
Course year: I	**Type of Educational Activity:** B
Teaching Methods: in-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The sector is characterized by the set of scientific fields and scientific-disciplinary competences related to the design and realization of information processing systems, as well as their management and utilization in various application contexts with methodologies and techniques typical of engineering. This includes theoretical foundations, methods, and technologies aimed at producing technically valid projects, from both the adequacy of the proposed solutions and the feasibility of technical implementation, to economic feasibility and organizational effectiveness. These foundations, methods, and technologies cover all aspects related to a processing system, from hardware to software.	
Objectives: The course provides the definition of the internal mechanisms of information processing systems. The course will cover topic related to the definition of a computer system, its architecture, its operating modes and basic techniques for designing a digital circuit, the architecture of operating systems and concurrent and system programming. The course also covers the fundamentals of parallel architectures for high performance applications.	
Propaedeuticities: none **Is a propaedeuticity for:** none	
Types of examinations and other tests: oral examination with project discussion	

Course: Quantum materials and solid-state qubits	**Teaching Language:** English
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: 2	**Type of Educational Activity:** C
Teaching Methods: In-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The contents concern theoretical and computational research in the fields of solid state physics and materials science and related technology from the nanoscopic to the macroscopic level, quantum electronics and quantum information, as well as the statistical properties of matter and complex systems. The contents also concern issues related to the foundations of quantum physics.	
Objectives: The aim of the course is to introduce students to modern concepts il solid state physics necessary for understanding the basic elements related to the implementation of the hardware of a solid state quantum computer. The program of the course focuses on superconductor and semiconductor implementations. In both cases, it will be discussed the ideal operating scheme together with the most important challenges related to the control and reduction of noise and imperfections.	
Propaedeuticities: None **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral exam	

Course: Quantum metrology and sensors	**Teaching Language:** English
SSD (Subject Areas): ING-INF/07 – Electrical and Electronic Measurements	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods:in-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The sector's own methodologies concern the modeling and metrological characterization of measurement methods, components and systems, the extraction, interpretation, and representation of measurement information. Research topics include the design, implementation and characterization of measurement methods, components, and systems, with particular attention to improving the metrological performance obtained.	
Objectives: Providing students with specialized knowledge aimed at designing, implementing and characterizing methods, procedures and devices typical of electrical and electronic measurement engineering when applied to solutions and systems based on quantum technologies or when enhanced through the use of quantum technologies.	
Propaedeuticities: Foundations of Quantum Mechanics **Is a propaedeuticity for:**	
Types of examinations and other tests: Oral exam and discussion of a practical exercise	

Course: Quantum Simulators	**Teaching Language:** English
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: first or second	**Type of Educational Activity:** C
Teaching Methods: in-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Theoretical and experimental treatment of atomic and molecular physics, materials science and related technology from the nanoscopic to the macroscopic level, as well as photonics, optics, optoelectronics, quantum electronics and quantum information.	
Objectives: Learning the key concepts and main experimental methodologies of quantum simulation of strongly correlated many-body systems and their implementation with cold atoms, quantum dot systems, ions, superconducting circuits and photons.	
Propaedeuticities: Foundations of quantum mechanics **Is a propaedeuticity for:** none	
Types of examinations and other tests: written and oral exam	

Course: Quantum detectors for applied science	**Teaching Language:** English	
SSD (Subject Areas): FIS/07		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Teaching Methods: In person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The Course matches the contents of the declaratory of SSD FIS/07 as regards the study and the development of experimental physical methods in environmental, biological and medical fields, as well as the development and the utilization of instrumentation to control and detection of physical phenomena in the fields of environmental monitoring and bioremediation, diagnostics and therapy, and the physical techniques for biomedical diagnostics.		
Objectives: The Course will provide the students with advanced scientific contents, and related technical knowledge, on quantum radiation detectors, specifically on photon detectors, in various application fields of physics, particularly for medical and biosensors applications. The Course will also provide technical skills for the understanding and the practical use of quantum radiation sensors, through laboratory sessions in the applied biomedical field. All knowledge, capacity and ability so acquired could be applied also for research in experimental physics and applications to R&D in several fields of physics and engineering.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral exam with discussion of a written report of the laboratory activity.		

Course: Quantum Software	**Teaching Language:** English
SSD (Subject Areas): INF/01	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods: In-person	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The scientific field is concerned with scientific and educational-educational activity in the fields of computer research and information theory, placed at the basis of the computer approach to the study of problems and, jointly, the design, implementation, and use of computer systems for innovation in society. Special attention is paid to the method, based on modeling, formalization, and experimental verification. Therefore, the field includes, alongside all basic and general aspects, algorithmic (algorithm design and analysis, computability and complexity, information theory, codes, and cryptography), logical, semantic, and methodological foundations of computer science, including classical and quantum computational models; the skills needed to model and design languages (environments and methodologies for programming, software engineering).	
Objectives: By the end of the course, students will develop: • A solid understanding of the major quantum programming frameworks and languages (Qiskit, PennyLane, Cirq...). • Ability to implement and engineer applications based on quantum computing and hybrid classical/quantum approaches. • Ability to integrate quantum computing-based software into frameworks for optimization and artificial intelligence.	
Propaedeuticities: Quantum Computation **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral examination with project discussion.	

Course: Quantum Measurement Theory	**Teaching Language:** English	
SSD (Subject Areas): FIS02		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Teaching Methods: In person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: Knowledge and competences necessary for the theoretical treatment of quantum phenomena, starting from foundational laws and principles together with the necessary mathematical tools. It includes the competences needed for understanding the mathematics and the modelling of quantum physics at a deeper level.		
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 system and quantum decoherence.		
Propaedeuticities: none **Is a propaedeuticity for:**		
Types of examinations and other tests: Written and oral		

Course: Superconducting Quantum Technologies	**Teaching Language:** English
SSD (Subject Areas): FIS/03	**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C
Teaching Methods: In-person, lectures and lab experimental activities	
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The course focuses on scientific and educational - training activities in the field of the experimental study of condensed matter physics, superconducting devices, macroscopic quantum effects and quantum electronics. Skills and methods necessary for low-noise measurements at cryogenic temperatures of nanoscale devices and quantum circuits.	
Objectives: The course is aimed at providing the fundamental aspects of superconducting quantum computation. We intend to propose an experimental path, within which the student will have the chance to understand and apply concepts of quantum information science to real devices. The student will be able to perform spectroscopic and time domain measurements on superconducting quantum bits. For this purpose, Python softwares will be used for programming the control sequence of a quantum bit and the study of superconducting resonators.	
Propaedeuticities: Applied Quantum Systems **Is a propaedeuticity for:** None	
Types of examinations and other tests: Oral test with discussion of practical tests carried out in the laboratory	

Course: Nonlinear Systems		**Teaching Language:** English
SSD (Subject Areas): ING/INF-04		**CREDITS:** 6
Course year: II	**Type of Educational Activity:** C	
Teaching Methods: In-person		
Contents extracted from the SSD declaratory consistent with the training objectives of the course: The sector studies the methods and technologies for the processing of information aimed at the automation of plants, processes and dynamic systems in general. Despite the physical-structural differences existing between these types of systems, they lend themselves to being represented, modeled and simulated, and finally managed and controlled, using methodological tools that are largely invariant with respect to the particular application domain considered.:		
Objectives: The aim of the course is to introduce students to the foundations of the mathematical theory of nonlinear systems of ODEs and to illustrate the theory via some representative examples from applications.		
Propaedeuticities: None **Is a propaedeuticity for:** None		
Types of examinations and other tests: Oral exam and project discussion		

ANNEX 2.2

DEGREE PROGRAM DIDACTIC REGULATIONS

QUANTUM SCIENCE AND ENGINEERING

CLASSE LM-44/LM-120 (c.u.)

School: : Politecnica e delle Scienze di Base

Department: Fisica "Ettore Pancini"

Didactic Regulations in force since the academic year 2024-2025

Training Activity: under Art. 10, c. 5, letter d	**Training Activity Language:** English
Content of the activities consistent with the training objectives of the course: Other knowledge useful for job placement; IT and telematics skills; training and orientation periods, that contribute to the achievement of the CdS objectives	**CFU:** 3
Course year: II	**Type of Training Activity:** F
Teaching Methods: The activities can take place in person, remotely or by participating in schools, internships and physics promotion and dissemination events.	
Objectives: The main purpose of these training activities is to enable the student to acquire further knowledge and/or skills that are useful for completing his/her education, through the acquisition of further knowledge useful for his/her studies, and for the development of relational and organizational skills. or entering the world of work.	
Propaedeuticities: none **Is a propaedeuticity for:** none	
Types of examinations and other tests: The credits relating to these activities are assigned by the CCD coordinator upon presentation of suitable documentation.	

Training Activity: under Art. 10, c. 5, letter d	**Training Activity Language:** English
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: Activities in presence or remotely, depending on the type of training or orientation internship
Objectives: The aim of the activity is to have the student carry out a training and/or orientation internship useful for developing skills consistent with the professional activities envisaged by his study path and for entering the world of work.
Propaedeuticities: none **Is a propaedeuticity for:** none
Types of examinations and other tests: The credits for these activities will be recognized by the CCD Coordinator on the basis of suitable documentation certifying the completion of the internship and following a positive evaluation by a CCD commission.