COURSE OF STUDY *Physics*

ACADEMIC YEAR *2023-2024*

ACADEMIC SUBJECT *Quantum Technologies (6 ECTS)*

General information	
Year of the course	2023-2024
Academic calendar (starting and ending date)	01 March 2024 – 31 May 2024
Credits (CFU/ETCS):	6
SSD	FIS/03
Language	English
Mode of attendance	Not mandatory

Professor/ Lecturer	
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Department and address	Dipartimento Interateneo di Fisica, Via Amendola 173, 70126 Bari (BA)
Virtual room	
Office Hours (and modalities: e.g., by appointment, on line, etc.)	Tue-Wed-Thu, 11:00-13:00, appointment by email

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
150	40	15	95
CFU/ETCS			
6	1,6	0,6	3,8

Learning Objectives	Acquire knowledge of the principles of quantum mechanics and how they are applied to the development of novel technologies. Gain an overview of the diversified technological applications of quantum mechanics. Identify and distinguish technological challenges and fundamental physical limits.
Course prerequisites	Quantum Mechanics, Mathematical Methods for Physics

Teaching strategies	Lectures, exercises, case studies
Expected learning outcomes in terms of	
Knowledge and understanding on:	○ Acquiring critical thinking, analytical ability, problem-solving ○ Understanding the potential of the different quantum technologies and focusing on their possible applications ○ Comparing different technological implementations and find their strengths and bottlenecks
Applying knowledge and understanding on:	○ Defining objectives, benchmarks, learning targets and standards ○ Applying the methods of theoretical physics to applications ○ Becoming aware of theoretical tools of investigation and technological implementations ○ Stimulating and directing collaborative learning and individual understanding

Soft skills	• **Making informed judgments and choices** o Judge the value of acquired knowledge. Establish evaluation criteria and standards, both quantitative and qualitative o Compare, contrast, distinguish, describe novel technologies and the underlying physical phenomena • **Communicating knowledge and understanding** o Grasp communication accurately, become able to adopt different forms of presentation o Master physics and science communication o Make examples that are not misleading and foster scientific understanding • **Capacities to continue learning** o Summarize the acquired knowledge and identify central meaning and crucial points o Continuously update scientific knowledge.
Syllabus	
Content knowledge	**Introduction**. The quantum advantage in different technological fields. **Classical and quantum communication**. Motivation: polynomial and exponential scaling. Elements of classical computation: circuit model, relation between energy and information. Quantum bits and quantum elementary circuits. Quantum algorithms: search in an unstructured database, Quantum Fourier Transform, period finding and factorization. **Quantum entanglement**. Pure and mixed states: from the wavefunction to the density matrix. Factorized and entangled states. Entanglement measures. **Quantum communication**. No cloning theorem. Dense coding and quantum teleportation. **Quantum computers**. General principles. Hamiltonian implementation of quantum logical operators (gates). Unitary errors. Sources of decoherence. Experimental platform for quantum technology implementation: cavity quantum electrodynamics, trapped ions, quantum dots, superconducting qubits. Hybrid quantum-classical algorithms. **Quantum simulators of many-body systems**. The need for a quantum simulator. Implementation of physical constraints. First experimental realizations.
Texts and readings	G. Benenti, G. Casati, D. Rossini, G. Strini, Principles of quantum computation and information (World Scientific, 2019). M. A. Nielsen and I. L Chuang, Quantum computation and quantum information (Cambridge University Press, 2010).
Notes, additional materials	
Repository	

Assessment	
Assessment methods	Oral examination
Assessment criteria	• **Knowledge and understanding** o Knowledge of the principles of quantum mechanics and their application to quantum technologies • **Applying knowledge and understanding** o Understanding of the physical processes that make a natural or artificial system a good candidate for a quantum computer o Understanding of the advantages entailed by using and developing quantum technologies • **Autonomy of judgment** o Compare, contrast, distinguish, describe novel technologies and the underlying physical phenomena • **Communicating knowledge and understanding** o Master physics and science communication • **Communication skills**

	○ Make accurate and not misleading examples, that foster scientific understanding • **Capacities to continue learning** ○ Summarize the acquired knowledge and identify central meaning and crucial points
Final exam and grading criteria	Verification of 1) accuracy of knowledge and presentation of the principles of quantum mechanics and of their application to quantum technologies; 2) ability to describe and compare quantum technologies, identifying the underlying physical phenomena.
Further information	
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