UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

DIPARTIMENTO
INTERUNIVERSITARIO DI FISICA

General information	
Academic subject	Quantum Technologies
Degree course	Physics
Academic Year	2022-23
European Credit Transfer and Accumulation System (ECTS)	6
Language	English
Academic calendar (starting and ending date)	01 March 2023 – 31 May 2023
Attendance	Not mandatory

Professor/ Lecturer	
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Virtual headquarters (Microsoft Teams code)	
Tutoring (time and day)	Tue-Wed-Thu, 11:00-13:00

Syllabus	
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
Contents	**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.
Books and bibliography	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). M. Lewenstein, A. Sanpera, V. Ahufinger, Ultracold atoms in optical lattices. Simulating quantum many-body systems (Oxford University Press, 2012).
Additional materials	

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

Teaching strategy	

Expected learning outcomes	
Knowledge and understanding on:	○ Acquire critical thinking, analytical ability, problem-solving ○ Understand the potential of the different quantum technologies and focus on their possible applications ○ Compare different technological implementations and find their strengths and bottlenecks
Applying knowledge and understanding on:	○ Define objectives, benchmarks, learning targets and standards ○ Apply the methods of theoretical physics to applications ○ Become aware of theoretical tools of investigation and technological implementations ○ Stimulate and direct collaborative learning and individual understanding
Soft skills	• **Making informed judgments and choices** ○ Judge the value of acquired knowledge. Establish evaluation criteria and standards, both quantitative and qualitative ○ Compare, contrast, distinguish, describe novel technologies and the underlying physical phenomena • **Communicating knowledge and understanding** ○ Grasp communication accurately, become able to adopt different forms of presentation ○ Master physics and science communication ○ Make examples that are not misleading and foster scientific understanding • **Capacities to continue learning** ○ Summarize the acquired knowledge and identify central meaning and crucial points ○ Continuously update scientific knowledge.

Assessment and feedback	
Methods of assessment	Oral examination (100 %)
Evaluation criteria	• **Knowledge and understanding** ○ Knowledge of the principles of quantum mechanics and their application to quantum technologies • **Applying knowledge and understanding** ○ Understanding of the physical processes that make a natural or artificial system a good candidate for a quantum computer ○ Understanding of the advantages entailed by using and developing quantum technologies • **Autonomy of judgment** ○ Compare, contrast, distinguish, describe novel technologies and the underlying physical phenomena • **Communicating knowledge and understanding** ○ 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
Criteria for assessment and attribution of the final mark	Verify 1) the accuracy of knowledge and presentation of the principles of quantum mechanics and of their application to quantum technologies; 2) the ability to describe and compare quantum technologies, identifying the underlying physical phenomena.
Additional information	