Basic/Essential Course Information	
Course title	Quantum Technologies
Degree Course title	Physics
ECTS	6
Compulsory attendance	No
Course teaching language	ENGLISH

Teacher	Milena D'Angelo	milena.dangelo@gmail.com

ECTS Details	**Disciplinary area/broad field:**	SSD	ECTS
		FIS/02	6

Time management and teaching activity type	Period	Year	lesson type
	2nd semester	1st	Lessons (40h) Laboratory (15h)

Time management,	Total hours	in-class/in-lab study hours	out-of-class study hours
	150	55	95

Course calendar	Starting date	Ending date
	First week of March	Last week of May

Syllabus	
Prerequisites	Quantum Mechanics, Mathematical Methods for Physics
Expected learning outcomes (according to Dublin Descriptors)	**Knowledge and understanding**: 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. **Applied knowledge and understanding:** 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. **Judging autonomy:** 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. **Communicative Skills:** Grasp communication accurately, become able

	to adopt different forms of presentation. Master physics and science communication. Make examples that are not misleading and hinder scientific understanding. **Learning Skills:** Summarize the acquired knowledge and identify central meaning and crucial points. Translate, interpret, extrapolate and view relationships. Continuously update scientific knowledge.
Course contents summary	Overview. Quantum entanglement. Quantum vs classical computation. Quantum computers. Quantum simulators of many-body systems.
detailed syllabus	***Overview.*** The "quantum" advantage in computation, communication, sensing, metrology and imaging. ***Quantum entanglement.*** Pure and mixed states: from wavefunctions to density matrices. Factorizable and entangled states. Entanglement measures. ***Quantum vs classical computation.*** Motivation: polynomial vs exponential scaling. Quantum bits and elementary quantum circuits. Quantum algorithms. Applications: search algorithms, Quantum Fourier Transform, phase estimation, factoring. ***Quantum computers.*** Guiding principles. Cavity Quantum Electrodynamics. Trapped ions. Quantum dots. Superconducting qubits. Hybrid quantum-classical algorithms: theory and experimental realizations. ***Quantum simulators of many-body systems.*** The need for a quantum simulator. The problem of constraints: the case of lattice gauge theories. Optical trapping of ultracold atoms on lattices. First experimental realization with trapped ions.
books	M. A. Nielsen and I. L Chuang, *Quantum computation and quantum information* (Cambridge University Press, 2010). G. Benenti, G. Casati, D. Rossini, G. Strini, *Principles of quantum computation and information* (World Scientific, 2019). M. Lewenstein, A. Sanpera, V. Ahufinger, *Ultracold atoms in optical lattices. Simulating quantum many-body systems* (Oxford University Press, 2012).
notes	Selected chapters
Teaching methods	Lectures, exercises, case studies.
Assessment % of final mark	100% Oral examination
Evaluation criteria	Knowledge of the principles of quantum mechanics and their application to quantum technlologies. Understanding of the physical processes that make a natural or artificial system a good candidate for a quantum computer. Critical comparison between different implementation platforms.