UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

DIPARTIMENTO INTERUNIVERSITARIO DI FISICA

General information	
Academic subject	Quantum Information
Degree course	Physics
Academic Year	2022-2023
European Credit Transfer and Accumulation System (ECTS)	6
Language	English
Academic calendar (starting and ending date)	September-December
Attendance	Not compulsory

Professor/ Lecturer	
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Department and address	*Physics Department, via Amendola 173, Bari*
Virtual headquarters (Microsoft Teams code)	
Tutoring (time and day)	Upon request

Syllabus	
Learning Objectives	
Course prerequisites	*Meccanica quantistica*
Contents	***States and Ensembles.*** *Axioms of quantum mechanics, The Qubit, Spin-1/2, Photon polarizations, The density operator, The bipartite quantum system, Bloch sphere, Schmidt decomposition, Entanglement, Ambiguity of the ensemble interpretation, Convexity, Ensemble preparation, Faster than light? Quantum erasure, The HJW theorem, How far apart are two quantum states?, Fidelity and Uhlmann's theorem, Relations among distance measures.* ***Measurement and Evolution.*** *Orthogonal measurement and beyond, Orthogonal Measurements, Generalized measurements, Quantum channels, The operator-sum representation, Reversibility, Quantum channels in the Heisenberg picture, Quantum operations, Linearity, Complete positivity, Channel-state duality and the dilation of a channel, Channel-state duality, Stinespring dilation, Axioms revisited, Three quantum channels, Depolarizing channel, Dephasing channel, Amplitude-damping channel, Master equations for open quantum systems, Markovian evolution, The Liouvillian, Damped harmonic oscillator, Non-Markovian noise, Gaussian phase noise, Spin echo, Qubits as noise spectrometers, Spin-boson model at nonzero temperature.* ***Quantum Entanglement.*** *Nonseparability of EPR pairs, Hidden quantum information, Einstein locality and hidden variables, The Bell inequality, Three quantum coins, Quantum entanglement vs. Einstein locality, More Bell inequalities, CHSH inequality, Maximal violation, Quantum strategies outperform classical strategies, All entangled pure states violate Bell inequalities, Photons, Experiments and loopholes, Using entanglement, Dense coding,Quantum teleportation, Quantum teleportation and maximal entanglement, Quantum software, Quantum cryptography, EPR quantum key distribution, No cloning, Mixed-state entanglement, Positive-partial-transpose criterion for separability, Nonlocality without entanglement, Multipartite entanglement, Three quantum boxes, Cat states, Entanglement-enhanced communication, Manipulating entanglement.*
Books and bibliography	*J. Preskill, Lecture Notes in Physics 229: Quantum Information and Computation, Cap. 2-3-4, available online* [*http://theory.caltech.edu/~preskill/ph219/ph219_2020-21.html*](http://theory.caltech.edu/~preskill/ph219/ph219_2020-21.html) *G. Benenti, G. Casati, D. Rossini and G. Strini, Principles of Quantum Computation and Information: A Comprehensive Textbook (World Scientific, Singapore, 2019)*
Additional materials	*Course lecture notes*

Work schedule	

Total	Lectures	Hands on (Laboratory, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
Hours			
150	24	45	81
ECTS			
6	3	3	

Teaching strategy	

Expected learning outcomes	
Knowledge and understanding on:	○ Acquire critical thinking, creativity, analytical ability. ○ Understand physical phenomena and focus on their precise formulation. ○ Understand the meaning of the mathematical (most concise) description of the physical world.
Applying knowledge and understanding on:	○ Define objectives, benchmarks, learning targets and standards. ○ Apply the powerful methods of theoretical physics to other fields and disciplines. ○ Acquire the ability to judge correctness. ○ Become aware of methods and tools of investigation. ○ Stimulate and direct collaborative learning and individual understanding.
Soft skills	• **Making informed judgments and choices** ○ Judge the value of acquired knowledge and methods. ○ Estabilish evaluation criteria and standards, both quantitative and qualitative. ○ Compare, contrast, distinguish, describe and finally identify physical phenomena. • **Communicating knowledge and understanding** ○ Grasp communication accurately, become able to adopt different and alternative forms of presentation. ○ Master physics and science communication. ○ Make examples that are not misleading and hinder scientific understanding. • **Capacities to continue learning** ○ Reorganize material in summary, with central meaning and crucial points. ○ Translate, interpret, extrapolate and view relationships. ○ Continuously update scientific knowledge. ○ Ask the right questions.

Assessment and feedback	
Methods of assessment	Oral examination
Evaluation criteria	• **Knowledge and understanding** ○ Demonstrate knowledge and understanding of content and concepts through developed and accurate descriptions, explanations and examples. • **Applying knowledge and understanding** ○ Apply concepts in practically relevant situations. • **Autonomy of judgment** ○ Consistently identify and analyze sources and data and consistently identify different views and their implications. • **Communicating knowledge and understanding** ○ Organize information and ideas effectively and communicate information and ideas in a way that is completely clear. • **Communication skills** ○ Communicate information and ideas in a way that is completely appropriate to the audience and purpose. • **Capacities to continue learning**

	○ Development of effective continuous assessment instruments and methods, and selection of appropriate continuous assessment instruments and methods.
Criteria for assessment and attribution of the final mark	Knowledge of the foundations and principles of quantum physics and information theory. Comprehension of quantum-enhanced methods and quantum applications.
Additional information	