Subject card

Subject name and code	Basic of Quantum Computing, PG_00205059		
Field of study	Quantum Information Technology		
Date of commencement of studies	October 2025	Academic year of realisation of subject	2025/2026
Education level	Master's studies	Subject group	Obligatory subject group in the field of study Optional subject group
Mode of study	full-time studies	Mode of delivery	at the university
Year of study	1	Language of instruction	English
Semester of study	2	ECTS credits	6.0
Learning profile	academic	Assessment form	exam
Conducting unit			
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. Karol Horodecki	
	Teachers		

Lesson types

Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
Number of study hours	30.0	0.0	30.0	0.0	0.0	60
E-learning hours included: 0.0						

Learning activity and number of study hours

Learning activity	Participation in didactic classes included in study plan	Participation in consultation hours	Self-study	SUM
Number of study hours	60	0.0	0.0	60

Subject objectives

To provide students with knowledge in the fields of mathematics, physics and computer science, necessary to understand and design ways of processing information recorded on quantum media.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[QITL3_W01] has extended knowledge in the field of general physics and advanced knowledge in the area of quantum information theory; knows the history of the development of quantum information theory and its importance for the progress of science, knowledge of the world and social development	Knows the history of the development of quantum computing.	[SW4] test/exam - oral or written
[QITL3_W06] has knowledge of current directions in the development of physics, in particular in the field of quantum information theory	He has knowledge in, among others, quantum error correction and quantum communication and cryptography protocols.	[SW4] test/exam - oral or written [SW5] implementation of a problem task
[QITL3_U01] is able to apply the scientific method in solving physical problems and reasoning in the field of quantum information theory	Can apply the formalism of quantum mechanics and Dirac notation in the description of quantum protocols.	[SU4] test/exam - oral or written [SU5] implementation of a problem task

Subject contents	The course will include a presentation of the basic achievements of quantum information processing, including • a brief presentation of the historical foundations of quantum mechanics • introduction of the formalism of quantum mechanics (QM), including the QM axioms, Dirac notation, and the notion of Hilbert space. • a detailed discussion of the fundamental effects of quantum communication, including quantum teleportation, quantum dense coding, quantum cryptography (protocols E91, B92, BBM, BB84 and their variants), and the ban on quantum cloning • In the context of the security proof of the BB84 protocol, the basics of quantum error-correcting codes will be introduced. • in the field of quantum computing, the Deutsch-Jozsa algorithm, Simon's algorithm, Grover's algorithm and Shor's algorithm (the latter as a basis for breaking RSA encryption) will be discussed. • The QASM programming language will be introduced • The phenomenon of entanglement will be discussed in detail (measures of entanglement, different classes of mixed entangled states such as states with bound entanglement and safe states), • The phenomenon of non-local correlations (Bell's inequalities and their application to device-independent cryptography) will be discussed. • Elements of Shannon information theory will be introduced, including the concept of Shannon entropy and the concept of mutual information, as well as their quantum counterparts and their application in the context of the Quantum Internet.
Prerequisites and co-requisites	Fundamentals of linear algebra and probability theory, basic knowledge of computational complexity theory and logical gates, and the ability to program in imperative languages.
Assessment methods and criteria	see table below

Subject passing criteria	Passing threshold	Percentage of the final grade
homework	51.0%	10.0%
test 1	51.0%	20.0%
test 2	51.0%	20.0%
exam	51.0%	50.0%

Recommended reading		
	Basic literature	- Quantum computation and Quantum information M. A. Nielsen and I. L. Chuang Cambridge University Press,Cambridge (2000) - Quantum entanglement R. Horodecki, M. Horodecki, P. Horodecki, K. Horodecki Rev. Mod. Phys. (2009) -"Bell nonlocality" N. Brunner, D. Cavalcanti, S. Pironio, V. Scarani, S. Wehner. Rev. Mod. Phys., 86:839, (2014). - Elements of Information Theory T. M. Cover and J. A. Thomas Wiley Series in Telecommunications (1991)
	Supplementary literature	- publications on the lecture topics included in the database www.arxiv.org/quant-ph - "Introduction to quantum algorithms", K. Giaro, M. Kamiński, Exit 2003 - Introduction to Quantum Computation and Information H.-K. Lo, S. Popescu T. Spiller, World Scientific (1998)
	eResources addresses	Basic http://journals.aps.org/rmp/abstract/10.1103/RevModPhys.86.419 - Praca przeglądowa o nielokalności typu Bella https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.81.865 - Review paper about quantum entanglement https://www.amazon.pl/Thomas-M-Cover-Elements-Information/dp/B00HTK9U28 - - "Elements of Information Theory" T. M. Cover and J. A. Thomas Wiley Series in Telecommunications (1991) https://www.cambridge.org/highereducation/books/quantum-computation-and-quantum-information/01E10196D0A682A6AEFFEA52D53BE9AE#overview - book "Quantum computation and Quantum information" M. A. Nielsen and I. L. Chuang Cambridge University Press,Cambridge (2000)

Example issues/ example questions/ tasks being completed	Show the operation of the quantum state teleportation protocol using an example Give the quantum measurement axiom Calculate the subsystems of a two-system quantum state and quantum mutual information Calculate for what values of the noise parameter a system that is a mixture of a Popescu-Rohrlich system and a fully noisy system is quantum and not locally realistic Describe the operation and applications of Grover's algorithm Using the partial transposition criterion, check whether the given two-qubit state is entangled
Work placement	Not applicable