

Subject card

Subject name and code	Basics of Quantum Computing, PG_00123542						
Field of study	Informatics						
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				
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 basic 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		
	[INFMU2_W02] has in-depth knowledge of formal languages, models of computation, and issues of computational complexity; is familiar with the formal apparatus for formulating and studying the properties of computer objects		The student knows the axioms of quantum information theory and the necessary notation allowing the study of the properties of quantum states and some protocols and algorithms designed to process classical and quantum information.		[SW3] text preparation/written work [SW5] implementation of a problem task		
	[INFMU2_W01] has in-depth knowledge of the branches of mathematics necessary for the study of computer science; has a good understanding of the role and importance of the construction of mathematical reasoning		The student knows the basic concepts of quantum informatics discussed during the lecture.		[SW4] test/exam - oral or written		

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	Subject passing criteria	Passing threshold	Percentage of the final grade
	exam	51.0%	50.0%
	test 2	51.0%	20.0%
	test 1	51.0%	20.0%
	activity during classes or homeworks	51.0%	10.0%
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 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) 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://journals.aps.org/rmp/abstract/10.1103/RevModPhys.81.865 - Review paper about quantum entanglement http://journals.aps.org/rmp/abstract/10.1103/RevModPhys.86.419 - Praca przeglądowa o nielokalności typu Bella	

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

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