University of Gdańsk

Subject card

Subject name and code	Basic of Quantum Computing, PG_00205059						
Field of study	Quantum Information Technology						
Date of commencement of studies	October 2026			Academic year of realisation of subject		2026/2027	
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, prof. UG				
	Teachers		dr hab. Karol Horodecki, prof. UG				
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_K02] is ready to responsibly fulfill the role of of a quantum technologies specialist, taking into account the changing needs of society, including developing the professional achievements, maintaining the professional ethos, and adhering to and developing the principles of professional ethics and working to ensure compliance with these principles	Student knows main possibilities and limitations of quantum information processing in context of emerging quantum technologies such as design of quantum internet and quantum computing.	[SK4] test/exam - oral or written [SK6] demonstration of practical skills
[QITL3_W01] knows and understands in depth selected facts, objects and phenomena, as well as the methods and theories related to them, explaining the complex relationships between them, constituting advanced general knowledge in the field of quantum information technology, as well as the scientific research methodology specific to this discipline and its importance in the context of contemporary directions of development of science and technology	Student knows the tools needed for desigining quantum protocols and algorithms and gain deep insight certain phenomena such as bipartite entanglement, quantum non-locality and key secret against quantum adversary quantum technologies, enabling quantum technolgies.	[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
test 1	51.0%	20.0%
test 2	51.0%	20.0%
exam	51.0%	50.0%
homework	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 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

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