Subject card

Subject name and code	Introduction to Quantum Information, PG_00210600						
Field of study	Informatics						
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		Polish		
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						
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
[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	Student knows the probability theory and its role in quantum formalizm and is able to follow the rules enabling prediction of the outcomes of quantum information processing	[SW4] test/exam - oral or written [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	Student extends the knowledge about algebra by incorporating deep study of Hilbert spaces on complex field. (S)he is able to extend to pursue the proofs of properties of quantum states and chosen resources	[SW4] test/exam - oral or written [SW5] implementation of a problem task
[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	Student knows basic quantum algorithms and their complexity analyzis. (S)he knows the way the properties of quantum states can be studied and designed.	[SW4] test/exam - oral or written [SW5] implementation of a problem task
[INFMU2_W02] has in-depth knowledge of models of computation, and issues of computational complexity; is familiar with the formal apparatus for formulating and studying the properties of computer objects	Student knows formalizm of Dirac notation, axioms of quantum mechanics enabling desiging and predicting results of quantum information protocols	[SW4] test/exam - oral or written [SW5] 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

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

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