Subject card

Subject name and code	Basics of Quantum Resources, PG_00210604						
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	The goal of this lecture is to provide the student a broad perspective on quantum information processing by introducing in details frameworks of several resource theries, exhibiting similarities and differences among the latter. It aims also at letting to know the quntum resources as applicable phenomena in context of quantum and classical information processing.						

Learning outcomes	(see table below)

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 mathematics behind each class of free operations and states of a given resource theory and the way of its quantification.	[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 knows in deep various approaches to quantum information processing such as quantum POVMs and instruments, and is able to identify its role in possibilities and limitations of processing a given quantum resource theory.	[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 such models as universal quantum computing and quantum fault tolerant computation and is able to study various quantum resource theories.	[SW4] test/exam - oral or written
[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 the basics of different models of quantum resources including based on states and operations as well as behaviours and wirings, enabling quantification and processing the resource content of quantum objects.	[SW4] test/exam - oral or written

Subject contents

During lecture, we will introduce several important quantum resources *(not* covered or not covered in deep by the lecture "Podstawy Informatyki Kwantowej") including quantum and supra-quantum contextuality as generalization of quantum non-locality, quantum coherence, quantum non-stabilizerness, quantum purity (non-uniformity), elements of quantum thermodynamics, device dependent private randomness, and multipartite entanglement. We plan to discuss their exemplary applications: fault
tolerant quantum computing, classical communication complexity, privacy, quantum engines etc.).

Laboratories will involve verifying construction of resource witnesses, computing measures of a given resource, recognizing free operations, and revealing formal interrelation among the resources. In particular numerical validation of the facts from lecture will be considered. To this end, during laboratories Mathematica programming language will be used.

Prerequisites and co-requisites

It is recommended, but not obligatory, that a student either have completed course "Podstawy Informatyki Kwantowej" (or its equivalent), or is attending the latter course (or equivalent) in parallel. While these two courses are independent, student will have deeper undertanding of Basics of Quantum Resources if she/he knows a broader context.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
test2	51.0%	20.0%
activity during classes or homework	51.0%	10.0%
written exam	51.0%	50.0%
test1	51.0%	20.0%

Recommended reading

Basic literature

- "The resource theory of stabilizer quantum computation" Victor Veitch *et al* 2014 *New J. Phys.* **16** 013009

-"Resources of the Quantum World" arxiv.org/abs/2402.05474 Gilad Gour

- "Kochen Specker Contextuality" Rev. Mod. Phys. **94**, 045007 Costantino Budroni, Adán Cabello, Otfried Gühne, Matthias Kleinmann, and Jan-Åke Larsson
- 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).

	Supplementary literature	- Karol Horodecki et al. "The rank of contextuality" New J. Phys. 25 073003 (2023) - C. Sparaciari et al. "The first low of general quantum resources" Quantum 4, 259 2022
	eResources addresses	
Example issues/ example questions/ tasks being completed	Describe the formal definition of resource theory of non-stabilizerness. What is the difference between state-dependent and state-independent quantum contextuality (provide examples of both)? Give examples and show differences among known classes of free operations in theories of quantum coherence. Compute in Mathematica the amount of local purity that one can obtain from a pure 2-qubit state. How many parameters are needed to describe a 3-qubit pure state (up to local unitary transformations)? Describe Landauer's principle. What is thermomajorization, and what is its role in quantum thermodynamics?	
Work placement	Not applicable	