

Subject card

Subject name and code	Basics of Quantum Resources, PG_00183327						
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				
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						
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 theories, 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	Course outcome		Subject outcome		Method of verification		
	[QITL3_W02] knows and understands on deepened level key and selected advanced detailed issues in the field of quantum information technology, including methods of their research and development, and their applications in the context of dynamic technological changes, in particular in the area of information processing, cryptography and the development of advanced computing systems		The student has an advanced understanding of quantum resource theories and their applications, including methods for identifying free operations, constructing resource witnesses, quantifying resources, and analyzing formal relations between different resources relevant to quantum information technologies.		[SW4] test/exam - oral or written		
	[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		The student is prepared to critically and responsibly assess applications of quantum resources, such as contextuality, coherence, magic, private randomness, quantum thermodynamics, and multipartite entanglement, in the context of their impact on the development of quantum technologies, information security, privacy, and the ethical aspects of professional practice in this field.		[SK4] test/exam - oral or written		

Subject contents	During lecture, we will introduce several important quantum resources (<i>not</i> 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 among others verifying construction of resource witnesses, computing measures of a given resource, recognizing free operations, and revealing formal interrelation among the resources. In particular numerical and theoretical 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 understanding 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%
	test1	51.0%	20.0%
	written exam	51.0%	50.0%
	activity during classes or homework	51.0%	10.0%
Recommended reading	Basic literature	- "The resource theory of stabilizer quantum computation" Victor Veitch <i>et al</i> 2014 <i>New J. Phys.</i> 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-Ake 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 law of general quantum resources" Quantum 4, 259 2022	
	eResources addresses	Basic https://iopscience.iop.org/article/10.1088/1367-2630/16/1/013009 - Paper presenting theory of resource of non-stabilizerness https://doi.org/10.48550/arXiv.2402.05474 - Book about quantum resources http://journals.aps.org/rmp/abstract/10.1103/RevModPhys.86.419 - Review paper on Bell non-locality https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.81.865 - Review on Quantum Entanglement https://doi.org/10.1103/RevModPhys.94.045007 - Review paper on quantum contextuality Supplementary https://doi.org/10.22331/q-2020-04-30-259 - Paper describing theory joining several quantum resources at once. https://doi.org/10.1088/1367-2630/acdf78 - Paper introducing simple measure of contextuality	

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

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