

Subject card

Subject name and code	Basics of Quantum Resources, PG_00183327						
Field of study	Quantum Information Technology						
Date of commencement of studies	October 2025		Academic year of realisation of subject		2025/2026		
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		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	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 quantum resources as applicable phenomena in context of quantum and classical information processing.						
Learning outcomes	Course outcome		Subject outcome		Method of verification		
	[QITL3_W01] has extended knowledge in the field of general physics and advanced knowledge in the area of quantum information theory; knows the history of the development of quantum information theory and its importance for the progress of science, knowledge of the world and social development		The student knows the history of research and applications of quantum and extra-quantum contextuality, quantum coherence, quantum non-stabilization, purity (non-uniformity) and elements of quantum thermodynamics		[SW4] test/exam - oral or written		
	[QITL3_W06] has knowledge of current directions in the development of physics, in particular in the field of quantum information theory		The student has knowledge, among other things, of multipartite entanglement and quantum error correction, and is familiar with open problems related to the discussed resources.		[SW3] text preparation/written work [SW5] implementation of a problem task		
	[QITL3_U05] has the ability to synthesize methods and ideas from various areas of physics and other branches of science; is able to notice that distant phenomena are sometimes described by similar models		The student knows formal definitions and properties of several fundamental quantum resource theories and is aware of analogies and differences among them.		[SU4] 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%
	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 <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-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 law of general quantum resources" Quantum 4, 259 2022	
	eResources addresses	Basic https://doi.org/10.1103/RevModPhys.94.045007 - Review paper on quantum contextuality https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.81.865 - Review on Quantum Entanglement http://journals.aps.org/rmp/abstract/10.1103/RevModPhys.86.419 - Review paper on Bell non-locality https://doi.org/10.48550/arXiv.2402.05474 - Book about quantum resources https://iopscience.iop.org/article/10.1088/1367-2630/16/1/013009 - Paper presenting theory of resource of non-stabilizerness 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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