University of Gdańsk

Subject card

Subject name and code	Signatures of Nonclassicality, PG_00199713						
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 Subject group related to scientific research in the field of study			
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 Beata Zjawin				
	Teachers						
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	30.0	0.0	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	90.0	150	
Subject objectives	Get acquainted with the concept of nonclassical phenomena as a fundamental property of Nature.Learn about the traditional phenomena of Entanglement and Bell nonclassicality, the recently reformulated notions of Steering and Kochen-Specker contextuality, and the newly identified phenomena of Spekkens contextuality and Network nonclassicality.Understand not only the foundational implications of these nonclassical phenomena, but also their role as resources for information processing.						

Learning outcomes

Course outcome	Subject outcome	Method of verification
[QITL3_U02] is able to use their knowledge of quantum information technology – formulate and solve complex and unusual problems and innovatively perform tasks in unpredictable conditions by appropriately selecting sources and information derived from them, evaluating, critically analyzing, synthesizing, creatively interpreting, and presenting this information, as well as by selecting and applying appropriate methods and tools, including advanced information and communication techniques and adapting existing methods and tools or developing new ones	The student is able to analyze and characterize nonclassical properties of quantum systems by selecting appropriate theoretical models, analytical methods, and mathematical tools to investigate entanglement, Bell nonlocality, contextuality, quantum steering, and network nonclassicality, and to critically interpret the obtained results and their significance for quantum information technologies.	[SU5] implementation of a problem task
[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	The student has an advanced understanding of the fundamental nonclassical phenomena in quantum systems, including entanglement, nonlocality, contextuality, and quantum steering, as well as the theoretical and experimental methods used to investigate them and their significance for the development of quantum information science and modern quantum technologies.	[SW4] test/exam - oral or written
[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 the signatures of nonclassicality in quantum systems, including entanglement, Bell nonlocality, contextuality, quantum steering, and network nonclassicality, as well as the methods used to characterize them and their applications in quantum information processing, cryptography, and quantum communication.	[SW4] test/exam - oral or written

Subject contents

Entanglement theory: bipartite and multipartite entanglement; separability criteria; entanglement distillation and monogamy; applications (e.g.,teleportation).Bell nonclassicality: Bells theorem; Fines theorem; Bell inequalities; Entanglement vs. Bell nonclassicality; bipartite and multipartite Bell scenarios;activation of Bell nonclassicality; the geometry of correlations (No-Signalling and Classical polytopes, the quantum set); applications.Contextuality: Kochen-Specker contextuality; state dependent vs. state independent contextuality; inequalities from hypergraphs; Spekkenscontextuality; applications.Steering: bipartite and multipartite steering; steering inequalities; applications.Network nonclassicality: brief introduction to networks, examples, and applications

Prerequisites and co-requisites

None.

Assessment methods and criteria

Subject passing criteria	Passing threshold	Percentage of the final grade
tutorial part: test	51.0%	50.0%
lecture part: exam	51.0%	50.0%

Recommended reading	Basic literature	R. Horodecki, P. Horodecki, M. Horodecki, and K. Horodecki. Quantum entanglement, Rev. Mod. Phys. 81, 865 (2009).N. Brunner, D. Cavalcanti, S. Pironio, V. Scarani, and S. Wehner. Bell nonlocality, Rev. Mod. Phys. 86, 419 (2014).D. Cavalcanti and P. Skrzypczyk. Quantum steering: a review with focus on semidefinite programming, Rep. Prog. Phys. 80, 024001 (2017).A. Cabello, S. Severini, and A, Winter. (Non-)Contextuality of Physical Theories as an Axiom, arXiv: 1010.2163 (2010).A. Acín, T. Fritz, A. Leverrier, and A. B. Sainz. A Combinatorial Approach to Nonlocality and Contextuality, Comm. Math. Phys. 334, 533 (2015).R. W. Spekkens. Contextuality for preparations, transformations, and unsharp measurements, Phys. Rev. A 71, 052108 (2005).C. Branciard, D. Rosset, N. Gisin, and S. Pironio. Bilocal versus non-bilocal correlations in entanglement swapping experiments, Phys. Rev. A 85,032119 (2012).T. Van Himbeeck, et al. Quantum violations in the Instrumental scenario and their relations to the Bell scenario, Quantum 3, 186 (2019).
	Supplementary literature	None.
	eResources addresses	
Example issues/ example questions/ tasks being completed	• Bell's theorem and local hidden-variable theories. • Entanglement versus Bell nonlocality. • Applications in device-independent quantum information processing. • Kochen–Specker theorem. • Applications of network nonclassicality to distributed quantum information processing and quantum repeaters.	
Work placement	Not applicable	

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