University of Gdańsk

Subject card

Subject name and code	Advanced Topics in Quantum Foundations, PG_00159194						
Field of study	Quantum Information Technology						
Date of commencement of studies	October 2025		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	2		Language of instruction	English			
Semester of study	4		ECTS credits	6.0			
Learning profile	academic		Assessment form	exam			
Conducting unit							
Name and surname of lecturer (lecturers)	Subject supervisor		dr Marco Erba				
	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		30.0	90
Subject objectives	The aim of this elective course is to provide students with exposure to various topics in the field of quantum foundations that would allow them to go beyond learning course material to becoming research ready for a career in quantum foundations. The students will learn fundamental skills to distinguish between classical notions and quantum notions by becoming familiar with ontological models. They will become familair with post quantum theories, such as generalised or operational probabilities theories as well as models of quantum causality.						

Learning outcomes

Course outcome	Subject outcome	Method of verification
[QITL3_W06] has knowledge of current directions in the development of physics, in particular in the field of quantum information theory	Student knows extensions of notion of Einstein-Podolsky-Rosen paradox beyond quantum, understands the notions of resource theory of coherence and resource theory of nonclassicality of common-cause boxes. Students understands the notion of quantum switch	[SW4] test/exam - oral or written
[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	Student knows a process-theoretic approach to the phenomenon of Einstein-Podolsky-Rosen inference, can review its quantum manifestation. Understands realist notions of classicality, their operational consequences, unification of these notions	[SW4] test/exam - oral or written
[QITL3_W04] knows advanced methods of theoretical and mathematical physics necessary in creating models of quantum mechanics	Student knows and understands the notion of operational probabilistic theories and their applications in approaches to the foundations of physics	[SW4] test/exam - oral or written
[QITL3_K02] is aware of the decisive role of experiment in the verification of physical theories; is aware of the existence of the scientific method in acquiring knowledge	Student is aware of the decisive role of experiment in demonstration of the quantum violations.	[SK4] test/exam - oral or written
[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	Though the use of resource theories, student has the ability to synthesize methods and ideas from various areas of physics and other exact and natural sciences; is able to notice that sometimes distant phenomena are described by similar models	[SU4] test/exam - oral or written
[QITL3_W02] has in-depth knowledge in the field of advanced mathematics and mathematical and computer methods, necessary to solve physical problems of medium complexity, and advanced knowledge in the area of quantum information and its technological aspects	Student knows general structure and properties of resource theories.	[SW4] test/exam - oral or written

Subject contents

1. Einstein-Podolsky-Rosen inference

2. Operational probabilistic theories

3. Resource theories

4. Indefinite causal structure

5. Realist framework, notions of classicality

6. Generalized Noncontextuality

Prerequisites and co-requisites

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	Sainz, A. B., Hoban, M. J., Skrzypczyk, P., & Aolita, L. (2020). Bipartite postquantum steering in generalized scenarios. Physical Review Letters, 125(5), 050404. Sainz, A. B., Brunner, N., Cavalcanti, D., Skrzypczyk, P., & Vértesi, T. (2015). Postquantum steering. Physical review letters, 115(19), 190403. D'Ariano, G. M., Chiribella, G., & Perinotti, P. (2017). Quantum theory from first principles: an informational approach. Cambridge University Press. Chiribella, G., DAriano, G. M., & Perinotti, P. (2010). Probabilistic theories with purification. Physical Review A, 81(6), 062348. Coecke, Fritz, and Spekkens in the paper "A mathematical theory of resources". Coecke, B., Fritz, T., & Spekkens, R. W. (2016). A mathematical theory of resources. Information and Computation, 250, 59-86. Selby, J. H., & Lee, C. M. (2020). Compositional resource theories of coherence. Quantum, 4, 319. Hardy, L. (2005). Probability theories with dynamic causal structure: a new framework for quantum gravity. arXiv preprint grqc/0509120. Oreshkov, O., Costa, F., & Brukner, Č. (2012). Quantum correlations with no causal order. Nature communications, 3(1), 1092. Harrigan, N., & Spekkens, R. W. (2010). Einstein, incompleteness, and the epistemic view of quantum states. Foundations of Physics, 40, 125-157. Background material (ontological models and operational theories): Chaturvedi, A., & Saha, D. (2020). Quantum prescriptions are more ontologically distinct than they are operationally distinguishable. Quantum, 4, 345. Spekkens, R. W. (2005). Contextuality for preparations, transformations, and unsharp measurements. Physical Review A, 71(5), 052108. Schmid, D., Selby, J. H., Wolfe, E., Kunjwal, R., & Spekkens, R. W. (2021). Characterization of noncontextuality in the framework of generalized probabilistic theories. PRX Quantum, 2(1), 010331.
	Supplementary literature	None.
	eResources addresses	
Example issues/ example questions/ tasks being completed		
Work placement	Not applicable	

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