University of Gdańsk

Subject card

Subject name and code	Mathematical Methods of Quantum INformation, PG_00205752						
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	1		ECTS credits	7.0			
Learning profile	academic		Assessment form	exam			
Conducting unit	Faculty of Mathematics, Physics and Informatics Office -> Faculty of Mathematics, Physics and Informatics -> Rector						
Name and surname of lecturer (lecturers)	Subject supervisor		dr inż. Paweł Mazurek				
	Teachers						
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	60.0	0.0	0.0	0.0	90
	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	90		0.0		85.0	175
Subject objectives	The aim of this lecture is to provide students with mathematical knowledge to understand basic concepts of quantum information theory as well as formulate and solve problems within this theory. Physical motivation and intuition behind the structures is provided in the accompanying course Introduction to Quantum Mechanics.						

Learning outcomes

Course outcome	Subject outcome	Method of verification
[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 mathematical structures and methods underlying quantum information theory, including linear algebra, operator theory, tensor products, and completely positive maps, and their application to quantum information processing.	[SW4] test/exam - oral or written
[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 apply advanced methods of linear algebra, operator theory, functional analysis, and quantum information theory to formulate and solve complex problems involving quantum states, measurements, operations, and quantum channels.	[SU4] test/exam - oral or written

Subject contents

Basic concepts of linear algebra: linear space, linear operator, matrix calculus
Basic concepts of functional analysis: Banach and Hilbert spaces, bounded and unbounded operators, differe similar operators, spectral theorem, functional calculus, positive definite operators
POVM and quantum measurement
Tensor products of Banach spaces and Hilbert spaces, operators on tensor products, Schmidt decomposition mathematical definition of entanglement, PPT states Fock space, CCR and CAR relations
Positive and fully positive maps on matrix algebras: k-positivity, decomposability, entanglement witnesses
Quantum channels, capacity of quantum channels, additivity problem
Tensor products of positive maps and entanglement distillation, bound entanglement

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

- **Bratteli, O., & Robinson, D. W.** (1987). *Operator Algebras and Quantum Statistical Mechanics 1: C*- and W*-Algebras, Symmetry Groups, Decomposition of States* (2nd ed.). Springer, Berlin. (Theoretical and Mathematical Physics). ISBN: 978-3-540-17093-8.
- **Størmer, E.** (2013). *Positive Linear Maps of Operator Algebras*. Springer, Berlin. (Springer Monographs in Mathematics). ISBN: 978-3-642-42913-2.
- **Hayashi, M.** (2017). *Quantum Information Theory: Mathematical Foundation* (2nd ed.). Springer. (Graduate Texts in Physics). ISBN: 978-3-662-49723-4 (Hardcover), 978-3-662-49725-8 (eBook).
- **Hall, B. C.** (2013). *Quantum Theory for Mathematicians*. Springer, New York. (Graduate Texts in Mathematics, Vol. 267). ISBN: 978-1-4614-7115-8 (Hardcover), 978-1-4614-7116-5 (eBook).

Supplementary literature: None

eResources addresses

Basic

https://almuhammadi.com/sultan/books_2020/Nielsen_Chuang.pdf - Quantum Computation and Quantum Information, Nielsen, Chuang

Example issues/ example questions/ tasks being completed	1. Mathematical Foundations of Quantum Information Discuss the mathematical structures underlying quantum information theory. 2. Composite Quantum Systems and Quantum Entanglement Explain the mathematical description of multipartite quantum systems and characterize quantum entanglement. 3. Positive Maps and Quantum Channels Discuss the mathematical theory of quantum channels and its applications in quantum information.
Work placement	Not applicable

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