University of Gdańsk

Subject card

Subject name and code	Mathematical Aspects of Quantum Information Theory , PG_00179337		
Field of study	Physics		
Date of commencement of studies	October 2024	Academic year of realisation of subject	2025/2026
Education level	Master's studies	Subject group	Obligatory subject group in the field of study Optional subject group
Mode of study	full-time studies	Mode of delivery	at the university
Year of study	2	Language of instruction	Polish In the event that a student who does not speak Polish joins the course, it will be taught in English.
Semester of study	3	ECTS credits	6.0
Learning profile	academic	Assessment form	credit
Conducting unit			
Name and surname of lecturer (lecturers)	Subject supervisor	dr hab. Marcin Marciniak	
	Teachers	dr hab. Marcin Marciniak dr Anubhav Chaturvedi	

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	0.0	60

Subject objectives	Quantum information theory employs a mathematical formalism that encompasses elements of linear algebra, functional analysis, and probability theory. The aim of the course is to present this formalism as well as the main theorems and mathematical problems arising from the theory.

Learning outcomes

Course outcome	Subject outcome	Method of verification
[FIZMU2_U05] has the ability to synthesize methods and ideas from different areas of physics and other sciences; is able to see that even distant phenomena are described by similar models	The student can recognize analogies between the mathematical formalism of quantum information theory and other areas of physics, such as thermodynamics and statistical mechanics.	[SU1] oral statement/conversation/ discussion
[FIZMU2_U06] is able to adapt knowledge and methodology of physics as well as applied experimental and theoretical methods to related scientific disciplines	The student is able to use the mathematical methods of quantum information theory for the description of biological and chemical phenomena.	[SU2] presentation/project/paper/ report
[FIZMU2_W06] has knowledge of current developments in physics, especially within his chosen specialty	The student is aware of how quantum information theory relates to other developing fields of physics.	[SW1] oral statement/ conversation/discussion
[FIZMU2_U12] is able to use English in the field of physics, mathematics and computer science, in accordance with the requirements specified for level B2+ of the Common European Framework of Reference for Languages, to a degree that allows him/her to independently supplement his/her education and communicate with specialists in the same or related specialization	The student is able to use English-language literature on the mathematical methods of quantum information theory.	[SU2] presentation/project/paper/ report
[FIZMU2_K05] understands the need to popularize knowledge of physics including the latest scientific and technological developments	The student is aware of the potentially significant impact of quantum information theory on the development of communication and computational technologies in the coming years and shares knowledge on this subject.	[SK1] oral statement/conversation/ discussion
[FIZMU2_K01] knows the limits of his own knowledge and skills; can formulate questions precisely; understands the need for further education of himself and others	The student is able to participate in discussions, formulate questions, and verify the correctness of their own problem solutions.	[SK1] oral statement/conversation/ discussion [SK8] observation of student's independent or team work
[FIZMU2_K02] is aware of the conclusive role of experiment in the verification of physical theories; is aware of the scientific method in the accumulation of knowledge	The student is aware that the mathematical formalism of quantum information theory is a model, which should be experimentally verified.	[SK1] oral statement/conversation/ discussion
[FIZMU2_U10] is able to popularize science within his specialty or related areas of physics	The student can clearly present the main principles of quantum information theory and its mathematical formalism.	[SU2] presentation/project/paper/ report
[FIZMU2_U11] is able to determine the directions of further improvement of knowledge and skills (including self-education) in the chosen specialty and beyond it	The student is capable of utilizing quantum information to acquire profound self-understanding and establish proper life objectives.	[SU1] oral statement/conversation/ discussion [SU8] observation of student's independent or team work

<table>
<tr><td>Subject contents</td><td>

Basics of probability theory and classical information theory
Elements of Hilbert Space Theory and Bounded Operators
Operator Algebras and Their Fundamental Properties
Tensor Products of Hilbert Spaces and Operator Algebras, Quantum Entanglement Theory
Positive Maps and Their Applications in Entanglement Detection
Quantum Correlations, Bell Inequalities
Quantum Control Theory, Steering Inequalities
Quantum Channels, Channel Capacity, the Channel Additivity Problem

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<tr><td>Prerequisites and co-requisites</td><td>Courses completed: Linear Algebra, Mathematical Analysis for Physicists, Mathematical Methods of Physics.</td></tr>
<tr><td>Assessment methods and criteria</td><td>
<table>
<tr><th>Subject passing criteria</th><th>Passing threshold</th><th>Percentage of the final grade</th></tr>
<tr><td>Written exam</td><td>51.0%</td><td>50.0%</td></tr>
<tr><td>Test</td><td>51.0%</td><td>50.0%</td></tr>
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</td></tr>
<tr><td>Recommended reading</td><td>
<table>
<tr><td>Basic literature</td><td>T. Heinosaari, M. Ziman, Guide to mathematical concepts of quantum theory, Acta Physica Slovaca vol. 58, 487-674 (2008), arXiv:0810.3536

E. Størmer, Positive linear maps of operator algebras, Springer, Berlin 2012.

M. M. Wilde, Quantum Information Theory, Cambridge University Press, 2017, https://fenix.tecnico.ulisboa.pt/downloadFile/1407993358931417/Quantum%20Information%20Theory%20[Mark%20M.%20Wilde]%20(2017).pdf</td></tr>
<tr><td>Supplementary literature</td><td>not applicable</td></tr>
<tr><td>eResources addresses</td><td></td></tr>
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<tr><td>Example issues/ example questions/ tasks being completed</td><td>not applicable</td></tr>
<tr><td>Work placement</td><td>Not applicable</td></tr>
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