KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

UNIWERSYTET GDAŃSKI

UNIA EUROPEJSKA
EUROPEJSKI
FUNDUSZ SPOŁECZNY

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Course title **Signatures of non-classicality**	ECTS code 13.2.0419

Name of unit administrating study
Department of Mathematics, Physics and Informatics

Studies

Faculty	Field of study/ phd studies/doctoral school/postgraduate studies	Type	Form
Quantum Information Technology	MSc studies	stationary	

Teaching staff
Dr. Ana Belén Sainz (lectures); Dr. John Selby (recitation classes)

Forms of classes, the realization and number of hours	ECTS credits
A. Forms of classes, in accordance with the UG Rector's regulations **Lecture, auditory exercises** **B. The realization of activities** **classes in the teaching room of the University of Gdańsk** **blended learning** **C. Number of hours** **Lecture: 30, exercises: 30**	**Total: 5 ECTS including:** **30 h of lecture – 1 ECTS point;** **30 h of exercises – 1 ECTS point;** **30 h of consultation – 1 ECTS point;** **60 h of student's own work - 2 ECTS points.**

The academic cycle
According to study program

Type of course	Language of instruction
mandatory	**English**

Teaching methods
problem lecture
lecture with multimedia presentation

discussion
case analysis
problem solving
student's own work (e.g., homework)

Form and method of assessment and basic criteria for evaluation or examination requirements

A. Final evaluation, in accordance with the UG study regulations
Exam
Credit with grade

B. Assessment methods
Lecture: test (oral or written) with closed questions.
Exercises: determination of the final grade based on partial grades received during the semester

C. The basic criteria for evaluation or exam requirements
Exams (Lecture and Exercises): correct answer to at least 60% of the questions.
Evaluation criteria and exams' tentative schedule will be communicated to the students during the first classes.
The students will be assessed primarily on their conceptual understanding, and not on knowledge of intricate mathematical formulae.

D. Method of verification of the established effects of education

established effect of education	exam	activity	tests
W01	+	+	+
W02	-	+	+
W03	+	+	-

U01	-	+	+
U02	-	+	+
U03	+	+	-
U04	+	-	-

Required courses and introductory requirements

A. Formal requirements

None

B. Prerequisites

Basic knowledge of mathematics at high school level is required.

Aims of education

- **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.**

Course contents

The course contents includes presentation of the following concepts (lecture and exercises will be devoted to the same topics):

- **Entanglement theory: bipartite and multipartite entanglement; separability criteria; entanglement distillation and monogamy; applications (e.g., teleportation).**
- **Bell nonclassicality: Bell's theorem; Fine's 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; Spekkens' contextuality; applications.**
- **Steering: bipartite and multipartite steering; steering inequalities; applications.**
- **Network nonclassicality: brief introduction to networks, examples, and applications.**

Bibliography of literature

A. Literature required to pass the course

- **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).**
- **Material provided by the lecturer.**

B. Extracurricular readings

The learning outcomes (for the field of study and specialization) *K_W01*	**Knowledge** W01: Student knows and understands the basic concepts and terminology used in the quantum foundations approach to quantum information. (K_W01) W02

Student has extensive knowledge 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, world cognition and social development *K_W02* *Student has in-depth knowledge of advanced mathematics, mathematical and computer methods necessary to solve physical problems of medium complexity and advanced in the area of quantum information and its technological aspects* *K_W04* *Student knows the advanced methods of theoretical and mathematical physics necessary in creating models of quantum mechanics* *K_U02* *Student can apply mathematical knowledge to formulating, analyzing and solving problems related to information theory*	Student knows the proofs of the main facts such as Asymptotic Equipartition Property, Shanonn's theorem etc., as well as knows basic methods such as compression algorithms (K_W02, KW_04) W03 has a clear understanding of models of classicality and how Nature does not respect them. (K_W01) **Skills** U01 Student is able to compute the classical bounds for Bell and steering inequalities, and respective quantum violations. (K_U02) U02 Student is able to compute and mathematically manipulate correlations and assemblages. (K_U02) U03 Student is able to analyze and interpret nonclassical phenomena for the purpose of quantum information (K_U01, K_U02) U04 Student is able to draw conclusions on the foundations of quantum physics from the studied nonclassical phenomena. (K_U01) **Social competence**
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