Uniwersytet Gdański

KAPITAŁ LUDZKI
NARODOWA STRATEGIA SPÓJNOŚCI

Projekt współfinansowany przez Unię Europejską w ramach Europejskiego Funduszu Społecznego

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ SPOŁECZNY

Course title

Signatures of non-classicality

ECTS code

13.2.0513

Name of unit administrating study

null

Studies

faculty	field of study		
Faculty of Mathematics, Physics and Informatics	Quantum Information Technology	type	all
		form	all
		specialty	all
		specialization	all

Teaching staff

dr Ana Sainz; dr John Selby

Forms of classes, the realization and number of hours

Forms of classes

Auditorium classes, Lecture

The realization of activities

classroom instruction, online classes

Number of hours

Auditorium classes: 30 hours, Lecture: 30 hours

ECTS credits

5

lecture 3ECTS

exercises 2ECTS

The academic cycle

2022/2023 summer semester

Type of course

obligatory

Language of instruction

english

Teaching methods

- critical incident (case) analysis
- discussion
- multimedia-based lecture
- problem solving
- problem-focused lecture

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

Final evaluation

- Graded credit
- Examination

Assessment methods

- (mid-term / end-term) test
- written exam (test)

The basic criteria for evaluation

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.

Method of verifying required learning outcomes

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

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

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.
Extracurricular readings

The learning outcomes (for the field of study and specialization)	Knowledge
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 SK_W01 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	W01: Student knows and understands the basic concepts and terminology used in the quantum foundations approach to quantum information. (K_W01) W02 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**

Contact

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