Quantum Information Theory

Titulaire
Stefano PIRONIO (Coordonnateur)

Mnémonique du cours
PHYS-F509

Crédits ECTS
5 crédits

Langue(s) d'enseignement
Anglais

Période du cours
Premier quadrimestre

Campus
Plaine

Contenu du cours

Quantum Information is the study of how the principles of quantum mechanics can be harnessed to process, transmit, and store information in fundamentally different ways from classical systems. By utilizing uniquely quantum phenomena such as superposition and entanglement, Quantum Information allows for tasks like faster computation and more secure communication, offering capabilities that are impossible in the classical world. The field bridges foundational questions about quantum theory with practical applications in technology, making it both a theoretical and applied science.

While other courses at ULB (INFO-H514 and INFO-H517) primarily focus on "how" quantum effects can be exploited to perform computational or information tasks, this course focuses on the "why" of quantum information, examining the underlying principles that allow quantum theory to achieve such effects. It is geared toward physicists who seek a deeper understanding of the fundamental aspects of quantum theory, rather than just its applications in computation or cryptography.

Historically, there has been a rich and fruitful interplay between the foundations of quantum theory and quantum information science. In this course, we will dive into some of the foundational questions and puzzles that have shaped both fields. We will review key quantum phenomena such as interference, the no-cloning theorem, quantum teleportation, and non-locality and present important no-go theorems such as Bell's theorem and the PBR theorem. We will also introduce the major interpretations of quantum mechanics, including many-worlds, de Broglie-Bohm theory, and collapse models, as well as the operational perspective of quantum mechanics, framing it in the context of generalized probabilistic theories.

A central focus of the course is entanglement, a resource that underpins many of the advantages of quantum information processing. We will introduce the resource theory of entanglement, examine its role in quantum computation and many-body physics, and discuss how systems with low entanglement can be efficiently simulated using tensor-network states. Additionally, we will explore Bell's non-locality and its role in self-testing and device-independent quantum information theory.

Although this course can be taken independently of INFO-H514, students interested in quantum information are encouraged to take both courses for a more comprehensive understanding of the field.

Objectifs (et/ou acquis d'apprentissages spécifiques)

The objective of this course is to provide students with a deeper understanding of the foundational principles of quantum mechanics and their role in quantum information theory. Students will explore key concepts like entanglement, non-locality, and quantum interpretations, gaining insight into the theoretical underpinnings that make quantum information possible.

Pré-requis et co-requis

Connaissances et compétences pré-requises

Quantum theory, Dirac notation, Linear Algebra (vector spaces, eigenvalues, eigenvectors, matrix operations), probability theory.

Méthodes d'enseignement et activités d'apprentissages

Lectures at the blackboard and/or using projected presentations.

Contribution au profil d'enseignement

This course enhances the teaching profile by offering an in-depth exploration of the foundational aspects of quantum theory and quantum information, complementing more application-focused courses. It broadens the curriculum by addressing key concepts like entanglement and non-locality.

Références, bibliographie et lectures recommandées

See page of the course on Université Virtuelle.

Autres renseignements

Lieu(x) d'enseignement

Plaine

Contact(s)

Stefano Pironio (stefano.pironio@ulb.be)

Méthode(s) d'évaluation

Présentation orale et Examen oral

Examen oral

Examen à livre ouvert et Examen avec préparation

Langue(s) d'évaluation principale(s)

Anglais

Programmes

Programmes proposant ce cours à la faculté des Sciences

MA-PHYS | Master en sciences physiques | finalité Approfondie/bloc 1 et finalité Didactique/bloc 1