Topics in Quantum Foundations (L16)

Non-Examinable (Graduate Level)

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This course introduces a number of key foundational questions in quantum theory and quantum information, with a focus on the relationship between quantum measurement, nonlocality and relativistic causality.

The course will cover a selection of topics including:

- Overview of basic concepts in quantum theory and quantum information: Hilbert space, pure and mixed states, density matrix, the Schmidt decomposition, entanglement, etc.
- Relationship between quantum theory and relativity: the no-signalling principle.
- The EPR argument, Bell’s theorem and Bell-nonlocality, local hidden variable model, CHSH inequality; relationship between Bell-nonlocality and entanglement; Quantum nonlocality without entanglement.
- Measurement in Quantum Mechanics - the quantum measurement paradigm: definition and formalism (pointers, Born-rule, interaction Hamiltonian, etc.)
- Quantum measurement and Relativity: constraints on measurements of joint properties of several quantum systems separated in space (instantaneous measurements of nonlocal variables).
- Two-vector formalism and weak measurements; Interaction-free measurements.
- Interpretation of measurement in different theories of Quantum Mechanics: Everettian (Many-Worlds) quantum theory and collapse-based versions of quantum theory.

Prerequisites

Familiarity with undergraduate level quantum mechanics is essential. An advanced course on quantum mechanics including Dirac’s ”bra/ket” notation, Heisenberg picture and Heisenberg equations of motion will be very useful for this course. Familiarity with a first course in quantum information theory, such as the Cambridge Part II Quantum Information and Computation course (specifically familiarity with Dirac notation, qubits, entanglement, Pauli operations, no-signalling theorem and quantum teleportation), would be advantageous.

Literature

1. Y. Aharonov and D. Rohrlich, Quantum paradoxes: quantum theory for the perplexed. WILEY-VCH Verlag, 2005: Chapters 3,7,8,10,14 and 16.
3. John Bell, Speakable and Unspeakable in Quantum Mechanics. CUP, 2nd edition: Chapters 1,2 and 22.


8. S. Saunders, J. Barrett, A. Kent, and D. Wallace (eds.), *Many Worlds?: Everett, Quantum Theory, and Reality*. OUP (2010);

**Additional support**

There will be no examples sheets associated with this course, but several worked examples will be discussed. In addition, one or two Part III essays will be offered in conjunction with this course.