Syllabus: Physics 260_2024.docx

Physics 260B/QSE 210B: Introduction to Quantum Information

Introduction to quantum information science and quantum computation. Emphasis on fundamental concepts including qubits and quantum operations, the nature of entanglement and its manipulation, quantum error correction, and various implementation models. Topics include: basics of quantum information, different models of quantum computing, fundamental quantum algorithms, quantum error correction, and fault tolerance; as well as experimental implementations. Recent developments in the field will be discussed.

Lectures: MW, 10:30-11:45 AM

Prerequisites: Physics143A and Math 21a/b or instructorâ€™s permission

Recommended literature

Physics 260 lecture notes: Physics_260_notes.pdf

Preskillâ€™s lecture notes: http://www.theory.caltech.edu/people/preskill/ph229/#lecture

D. Mermin â€œQuantum Computer Scienceâ€

M. Nielsen & I. Chuang â€œQuantum computation and quantum informationâ€

Grading Homework sets and final project. Homework sets will range from problems on quantum foundations to topics based on modern literature. The goal of the final project will be to discuss the research topic from the current literature or to develop realization of quantum algorithms, potentially implementing them in state of the art quantum hardware platforms. Collaborations in small groups are encouraged. Collaborators should be listed on HW sets and title pages of final project presentations.

Tentative plan

1. **Overview of quantum mechanics, quantum bits and operations.** Review of quantum postulates, two-level systems, continuous variables, dynamics, unitary operations, measurements. No-cloning theorem. Tensor products & entangled states. Pure and mixed states, density operator. Generalized evolution and measurements, quantum channels. Quantum control.
2. **Quantum entanglement.** Measures of entanglement. Entanglement and non-locality. Quantum teleportation. Quantum complexity. Entanglement in many body systems, introduction to tensor networks.
3. **Introduction to quantum computation.** Models for quantum computation: gates & circuits, universality, computation by measurement, adiabatic quantum computation. Fundamental quantum algorithms. Introduction to quantum computer science.
4. **Quantum error correction.** Introduction to quantum error correction, stabilizer codes & fault tolerant quantum computation. Quantum operations with logical qubits and resource estimations.
5. **Physical systems and experiments leading to quantum computation.** Leading platforms for implementation of quantum computing. NISQ and fault tolerant systems.
6. **Recent developments & final project.** Recent developments in the field. Programming real-world quantum machines, developing, implementing, simulating and testing quantum algorithms.

Instructor: Mikhail Lukin, Lyman 328, lukin@physics.harvard.edu; **Office hours:** Mondays 3-4pm

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Sections and office hours:

OH: Mondays, 4:30-5:30pm in Lyman 425

Section: Thursdays, 5-6pm in Lyman 425