PH 5840 Quantum Computation and Quantum Information

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Class: Slot G
Classroom: ESB 207A (to be shifted to ESB 350 from Aug 1st, 2013)
Textbook: An Introduction to Quantum Computing by Kaye, Laflamme, Mosca (KLM)
References: Quantum Computation and Quantum Information by Nielsen and Chuang (NC)

Outline: This is an introductory course on quantum computation and quantum information. I assume a basic knowledge of linear algebra and probability. We will cover most of the chapters in the textbook (KLM) with a few additional topics on quantum information theory taken from the book by Nielsen and Chuang (NC). A few more topics will be covered if there is time.

1. Introduction
   — Turing machines, Church-Turing thesis, Physics and computation.
2. Review of linear algebra
   — Vectors, Dirac notation, linear independence, vector spaces, inner product, linear operators, Pauli matrices, Hilbert space, unitary matrices, tensor products, eigenvalues, eigenvectors, spectral theorem, Hermitian operators, projectors.
3. Introduction to quantum mechanics.
   — Postulates of quantum mechanics, quantum states, pure states, entangled states, evolution of quantum systems, composite quantum systems, measurement, Born rule, observables, Heisenberg picture vs Schrondinger picture, density operator, mixed states, reduced density operator, Schmidt decomposition, EPR and Bell inequality, classical vs quantum mechanics.
4. Circuit model of quantum computation
   — Quantum bits, Bloch sphere, single qubit gates, multiple qubit gates, universal set of quantum gates, Solovay-Kitaev theorem.
5. Simple quantum protocols
   — Super dense coding, teleportation, quantum key distribution.
6. Simple quantum algorithms
   — Deutsch's algorithm, Deutsch-Jozsa algorithm, Bernstein-Vazirini's problem, Simon's problem.
7. Fast quantum algorithms
   — Shor's algorithm, discrete log, hidden subgroup problem.
   — Grover's algorithm, Amplitude amplification.
8. Introduction to quantum complexity theory
   — Complexity classes, techniques for lower and upper bounds.
9. Quantum information theory
   — Shannon entropy, von Neumann entropy, entropic inequalities, quantum channels, Schumacher's compression theorem, quantum communication, capacities of quantum channels.
10. Quantum error correction
    — Quantum noise, simple quantum codes—Shor's code, Steane's code, stabilizer codes, encoding and decoding quantum codes, fault tolerance, threshold theorem.
11. Additional topics (Time permitting)
    — Quantum walks.
    — Measurement based quantum computing.
    — Quantum cryptography.

Grading:
Homework and quizzes—35% (There will be about 10 homeworks)
Project—35% (Report+presentation. Topics will be put up towards mid course.)
Endsem—30% (Will cover the entire semester material)