CS4670/PH4670, Quantum Computing (4-0)
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Course Description:
This inter-disciplinary survey course explores the evolution and current direction of quantum computing technology. Topics include quantum circuits, quantum algorithms (including factoring and search), and quantum key distribution. You will learn to think critically about the tradeoffs of this evolving technology. Prerequisites: familiarity with basic notions of computing, quantum theory, and linear algebra, consistent with the material covered in CS3000, PH2652, MA3042 or PH3991.

Grading:
Student Project, 60%
Class Participation and Student Presentations, 40%
A student presentation is required on a topic taken from the articles listed at the end the syllabus, or equivalent, with consent of instructor.

Recommended Textbooks:
• Yanofsky, Quantum Computing for Computer Scientists
• Blümel, Foundations of Quantum Mechanics

Learning Objectives:
• Be able to think critically about the tradeoffs of this evolving technology.
• Be able to understand the foundational physics of quantum computing.
• Be able to understand how quantum circuits work.
• Be able to compare different quantum algorithms.
• Be able to apply the concept of quantum parallelism.
• Be able to operate a quantum computer simulator.
• Be able to compare different physical implementations of quantum computers.
• Be able to understand how quantum error correcting codes work.
• Be able to understand why quantum error correction is necessary.
• Be able to apply the concept of quantum computer architecture.
• Be able to contrast quantum computing and quantum key distribution.
• Be able to contrast teleportation and quantum key distribution.

A weekly schedule is on the next page.
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<tr>
<th>Week</th>
<th>Topic</th>
<th>Subtopics/Readings/Labs</th>
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<tr>
<td>1</td>
<td>Introduction</td>
<td>Quantum Computer Science: [Aaronson08] Quantum Information Processing Landauer’s Principle, Maxwell’s Daemon Schrödinger’s Cat, Quantum Bits Superposition, Entanglement, Teleportation Richard Feynman, Peter Shor, David Deutsch</td>
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<td>2</td>
<td>Foundational Physics of Quantum Computing I</td>
<td>History of Light; Photons and Polarization Thomas Young’s Two-Slit Experiment Birefringence: Calcite Crystal Demonstration Wave vs. Particle Experiment: [Grainger86] The No-Cloning Theorem Malus’ Law, Dirac Notation Mach-Zehnder Interferometer, Pockels Cells John Wheeler’s Delayed Choice Experiment Bell’s Inequalities, Bertlmann’s Socks Realism vs. Copenhagen Interpretation Stern-Gerlach Experiment: [Aspect82]</td>
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<td>3</td>
<td>Foundational Physics of Quantum Computing II</td>
<td>Superconductivity; Bardeen, Cooper, and Schrieffer (BCS) Theory; Cooper Pairs, Pauli Principle, Bose-Einstein Condensation; Meissner Effect, Josephson Effect, Aharonov-Bohm Effect; Nuclear Magnetic Resonance (NMR), Larmor Frequency; Ion Traps, Laplace Equation, Earnshaw’s Theorem, Coulombe Force; Linear Optics; Quantum Dots, Heterostructures, Debroglie Wavelength</td>
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<td>4</td>
<td>Quantum Circuits</td>
<td>Quantum Bits and Registers Quantum Gates, Wires, and Circuits Single- vs. Multiple-Qubit Qates Reversible Computing, Complex Numbers</td>
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<td>Quantum Algorithms I</td>
<td>Deutsch’s Algorithm Deutsch-Jozsa Algorithm Grover’s Algorithm: [Grover96]</td>
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<td>6</td>
<td>Quantum Algorithms II</td>
<td>Shor’s Algorithm: [Shor96] Simulation of Quantum Mechanical Systems</td>
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<td>7</td>
<td>Physical Implementations of Quantum Computers I</td>
<td>Superconducting Josephson Junctions Nuclear Magnetic Resonance: [Cory00] [Vandersypen01]</td>
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<td>8</td>
<td>Physical Implementations of Quantum Computers II</td>
<td>Ion Traps, Quantum Dots Linear Optical Quantum Computing</td>
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<td>9</td>
<td>Quantum Error Correction</td>
<td>Bit Flip, Phase Flip, Shor’s [9,1,3] Code</td>
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<td>10</td>
<td>Quantum Computer Architecture</td>
<td>Realization of Large-Scale and Fault-Tolerant Quantum Computers: [Oskin02]</td>
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<td>11</td>
<td>Quantum Key Distribution</td>
<td>[Bennett84] [Ekert91] [Gisin02]</td>
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Bibliography:


