

Applied Physics 150a: Introduction to Quantum Devices

(Dated: Fall, 2014)

Instructor:

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Lectures:

Tu,Th 2:30-4:00PM, Rm. 104 Watson

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Course Website:

http://copilot.caltech.edu/classes/APh150_Intro_Quantum_Devices

Course work:

1 HW/week (~ 7 HWs). HW will be given out at the end of Thursday lecture, and due the following Thursday. HWs should be handed in to the "INBOX" box outside Watson 268. You can pick up graded HWs and exams from the "OUTBOX". There will be a mid-term exam (1 hour, take home) and a final "HW" exam. With regard to grading, HW will make up 70% of your grade, mid-term exam 10%, and final exam 20%. Please talk to me if you feel you want to take the course pass/fail.

Policies:

Homework: Limited collaboration allowed; make sure to work out the details of solutions on your own. Use of any texts, any notes, computers, etc. is fine. For MATLAB and Mathematica output please provide brief (but comprehensible) commentary.

Textbooks and References:

No textbook will be used this year. Lecture notes will be made available electronically at the end of each week of lecture.

Recommended for supplemental reading:

Notes from John Preskill's class on Quantum Information Theory [lecture notes link]

"Quantum Computation and Quantum Information," by Michael A. Nielsen and Isaac L. Chuang

"Cavity Quantum Electrodynamics," edited by Paul R. Berman

"A Computation Toolbox for Quantum and Atomic Optics," originally by Sze M. Tan [QuTip]

"Optical Resonance and Two-Level Atoms," by L. Allen and J.H. Eberly

"Quantum Noise," by C. W. Gardiner and P. Zoller

"Quantum Optics," by D. Walls and G. Milburn

Course Outline: The class is intended as an *introduction* to quantum devices, and will be taught accordingly (i.e., very little prior knowledge expected). Specifically, the course will attempt to introduce the physics and applications of those devices which are currently being developed/studied for quantum information processing and quantum metrology. Depending upon the interest of students, this can either be a one term or a two term class, two terms providing more time to delve into the physics behind the devices and the context for their application. Below is a syllabus for a one term class.

1. Introduction to Quantum Information Processing (QIP) [lecture 1,2,3]

from classical information to quantum information; the qubit, one and two qubit gates, qubit measurements, the density operator and mixed quantum states; quantum network elements and pictorial representations of quantum algorithms; introduction to Shor's factoring algorithm, the phase-estimation algorithm, and Grover's unstructured quantum search algorithm

2. Introduction to Quantum Communication (QC) [lecture 4]

quantum teleportation; quantum cryptography and the BB84 protocol; quantum repeaters and quantum networking

3. Quantum Mechanics Primer [lecture 5,6]

Schroedinger, Heisenberg, and density matrix pictures of quantum mechanics; the quantum harmonic oscillator, intro to the “Quantum Optics” toolbox software

4. **Atom-Cavity Systems** [lecture 7,8]
basic physics of a two-level atom coupled to a single-mode cavity (cavity-QED); on-demand single photon source; quantum state transfer between stationary atom-cavity quantum nodes via flying photon qubits
5. **Quantum Optical Memories**[lecture 9,10]
electromagnetically induced transparency (EIT); single photon storage and read-out in an atomic ensemble; solid-state quantum optical memories
6. **Superconducting Quantum Circuits** [lecture 11,12,13]
basic physics and circuit representation of the Josephson Junction (JJ); JJ-qubits: phase, flux, and charge qubits; circuit-QED with JJ-qubits; quantum computing outlook
7. **Trapped Ions** [lecture 14,15]
ion trapping physics and resolved-sideband laser cooling; ion trap geometries and hardware; ion trap quantum computing; ion trap precision clocks
8. **Mechanical Quantum Systems** [lecture 15,16,17]
cavity-optomechanical systems: from LIGO to a microchip; precision displacement sensing and the standard quantum limit (SQL); quantum nondemolition measurements of photons and phonons; optomechanical crystals; quantum information processing with cavity-optomechanics
9. **Topological Phases of Matter and Quantum Computing** [lecture 18,19(?)]
intro to topological order of quantum matter; non-Abelian anyon quasiparticles and braiding statistics; fraction Quantum Hall states; topological quantum computing