Syllabus:
Phys 467
Fall 2022

8/1/2022

Instructor:
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Course Time and Location: Tu-Th 9:30-10:45 AM, Toll Physics 1204

Course overview: Phys 467 is a senior-level elective course whose objective is to introduce students to the language and concepts of modern quantum technologies and many of the leading hardware platforms in development today.

The course will consist of two parts. First, a review of quantum mechanics with an emphasis on concepts, methods, and terminology needed to understand quantum devices and qubit technologies. Second, an introduction to many of the leading hardware platforms.

Prerequisites: All students in the course are expected to have prior experience with complex numbers, linear algebra, one-variable calculus, and some knowledge of quantum mechanics, either through PHYS 401/402 or an appropriate short course.
All students must have taken MATH 141 and MAT 240, or equivalent.

Textbooks:
Phys 467 will use one required textbook:

"**Exploring the Quantum** Atoms, Cavities, and Photons"
Haroche and Raimond
1st Edition
Oxford University Press

Additional recommended texts are:

"Quantum Mechanics"
Griffiths

"Quantum Mechanics"
Sakurai

"Quantum Computation and Quantum Information"
Nielsen and Chuang

"An Introduction to Quantum Computing"
Kaye, LaFlamme, Mosca

Course Collaboration Policy: Phys 467 is an advanced elective course and collaboration and discussion between students is strongly encouraged. However, all students must turn in their own solutions to all assignments. Direct copies, whether copied out by hand or copy-pasted by computer are not allowed.

Working on problems together, discussing possible answers, and talking through references together are excellent ways to make progress and help fellow students. **Supplying another student with copies of your completed work for them to work off of directly is not allowed and will be considered a direct violation of the UMD academic honesty regulations. Receiving and making use of such material is also a violation.**

Here is a link to the University of Maryland's course-related policies, including the University academic dishonesty regulations.
http://www.ugst.umd.edu/courserelatedpolicies.html

Course Components: Final grads in Phys 467 will be based on the following course components.

HWs : 20%
Quiz 1: 20%
Quiz 2: 20%
Final Project: 40%

Quiz 1: Will take place during class on Thursday October 4th.

Quiz 2: Will take place during class on Thursday November 17th.

HW assignments: HW assignments will be assigned weekly during part 1 of the course (review of quantum mechanics) and less frequently during part 2 of the course (introduction to quantum hardware platforms). They will be due electronically on elms prior to the start of class on Tuesday mornings. *No late homeworks will be accepted*. The lowest homework score will be dropped.

Final Project: In place of a final exam, Phys 467 will have a final project. Students will choose a scientific paper and must write a review paper (maximum 5 pages, not including references) describing the context of the paper and the main results at a level suitable for senior undergraduates. Papers must be in size 12 font. LaTex single-column single-spaced reprint format preferred. (Do not use AMS article-sized pages. These are significantly smaller, with much larger margins, than APS standard physical review style.)

- A set of appropriate scientific papers from which students can choose will be provided. Students may also select other papers, but suitability of alternative papers must be confirmed by the instructor.
- All paper choices must be submitted by Wednesday Nov 16th.
- Final projects will be due Wednesday Dec 14th at 5 pm.

Grades for the final project will be assessed based on the quality, accuracy, and readability of the presentation. A more detailed rubric will be available on elms.

Late final projects will receive an immediate 10% grading penalty, followed by an additional 10% per day late.

Tentative Course Schedule:

Week 1: (ETQ 2.1) The mathematics of quantum mechanics (complex functions and complex-valued linear algebra) and review of quantum states and two-level systems.

Week2: (ETQ 2.2) Quantum measurement, time evolution, and interference.

Week 3: (ETQ 2.4) Quantum entanglement: the effect of the environment and density matrices, Bell states, and the EPR paradox.

Week 4: (ETQ 2.5 and 2.6-2.6.3) The quantum-classical boundary and decoherence, quantum communication protocols.

Week 5: (ETQ 2.6.4) Qubits, single and multi-qubit gates, quantum circuit notation.

Week 6: Review session and Quiz 1

Week 7: (ETQ 3.4, 4.5.1) Methods of qubit characterization, quantum description of light and light-matter interactions, creation and annihilation operators, harmonic oscillator.

Week 8: Superconducting qubits.

Week 9: Photonic qubits.

Week 10: (ETQ 8) Ion traps.

Week 11: Nitrogen vacancy centers and quantum sensing.

Week 12: Reviews session and Quiz 2.

Week 13: Special topic, thanksgiving.

Week 14: Optical tweezers and Rydberg atoms.

Week 15: (ETQ 2.3.6, 9) Ultracold atoms and Bose-Einstein condensation.