Preliminary Syllabus:
Phys 467
Fall 2023
8/28/2023

Instructor:
Professor Alicia Kollár
Email: akollar@umd.edu
Office: PSC 2112
Office hours: Thursday 11-12

TA:
Xingxin Liu
Email: xxxl1111@umd.edu
Office hours, location: Toll Physics 2211
Office hours, time: 6:30-7:30 pm

Course Time and Location: Tu-Th 9:30-10:45 AM, Toll Physics 1402

Problem Session: Mon 6:30-8:00 pm, Toll Physics 2211

Course overview: Phys 467 is an interdisciplinary 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 must have passed MATH 141 and MAT 240, or equivalent. All students in the course are expected to have prior experience with complex numbers, linear algebra, and one-variable calculus.

While quantum mechanics is not a prerequisite for PHYS 467, some knowledge of quantum mechanics, either through PHYS 401/402 or an appropriate short course is highly recommended. For students with no prior knowledge of quantum mechanics, significant working knowledge in linear algebra is *essential*.

Textbooks:

Phys 467 will use one required textbook:

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

Students without prior quantum mechanics/quantum computing knowledge should consider the following two references.

1) "Quantum Mechanics: A Paradigms Approach"
   By McIntyre
   This book provides a linear-algebra based introduction to quantum mechanics and is the text currently used in PHYS 401. Most other quantum mechanics textbooks start with a calculus-based approach and only get to the linear-algebra-based approach which is more natural for qubits much later on.
2) "Introduction to Classical and Quantum Computing"
   By Thomas Wong
   This book provides an intro to both classical and quantum computing assuming only knowledge of trigonometry. It provides a basic intro to classical logic for students without a background in classical computer science and uses trigonometry and 3D geometry to describe qubits and quantum gates. A free electronic copy is available at thomaswong.net

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 and Academic Integrity 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, or plagiarized with only minor rephrasing, 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 grades 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 September 28th.

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

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*.

Since PHYS 467 is an interdisciplinary course with students from many different majors, the first HW will be a diagnostic assignment on mathematical prerequisite material. The goal of this assignment is to help students determine if their preparation is sufficient for success in PHYS 467. This course will use complex-valued linear algebra to describe and teach the basic principles of quantum mechanics, and the diagnostic HW will highlight the concepts and types of linear-algebra problems which will be most commonly used. Students with no prior experience in quantum mechanics should pay particularly close attention to the diagnostic HW. A score of under 90% will be a strong indication of preparation which is insufficient for success in PHYS 467.

With the exception of the first diagnostic homework, 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 15th.
- Final projects will be due Wednesday Dec 13th 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. All late penalties will be applied as a fraction of the total available points, rather than of points earned.

University Policies: Students in this course must adhere to all of the University of Maryland's course-related policies for academic and personal conduct. These policies can be found at the following link:
http://www.ugst.umd.edu/courserelatedpolicies.html

Notice of Mandatory Reporting: As a faculty member, I am designated as a "Responsible University Employee," and I must report all disclosures of sexual assault, sexual harassment, interpersonal violence, and stalking to UMD's Title IX Coordinator per University Policy on Sexual Harassment and Other Sexual Misconduct.

If you wish to speak with someone confidentially, please contact one of UMD's confidential resources, such as CARE to Stop Violence (located on the Ground Floor of the Health Center) at 301-741-3442 or the Counseling Center (located at the Shoemaker Building) at 301-314-7651.

You may also seek assistance or supportive measures from UMD's Title IX Coordinator, Angela Nastase, by calling 301-405-1142, or emailing titleIXcoordinator@umd.edu.

To view further information on the above, please visit the Office of Civil Rights and Sexual Misconduct's website at ocrsm.umd.edu**.**

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.

Week 4: (ETQ 2.5) Bell states, and the EPR paradox, the quantum-classical boundary.

Week 5: Review session and Quiz 1

Week 6: (ETQ 2.6 - 2.6.4) Quantum communication protocols, single qubits, the Bloch sphere.

Week 7: Multi-qubit gates, quantum circuit notation, quantum parallelism.

Week 8: Methods of qubit characterization, where to look for qubit systems

Week 9: Superconducting qubits.

Week 10: Reviews session and Quiz 2.

Week 11: (ETQ 8) Ion traps.

Week 12: Rydberg atoms

Week 13: Thanksgiving

Week 14: Quantum sensing and nitrogen vacancy centers

Week 15: Photonic quantum computing