

AEP/ENGRD 2550: Engineering Quantum Information Hardware

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Office hours: Appointments available upon request

Credits: 3 hours

Catalog Description:

This course examines the physical hardware of quantum information processing, quantum communication, and quantum sensing technologies. Topics include an analysis of qubit attributes and an introduction to the operational principles of physical qubits. Specific systems will include photons, superconducting quantum circuits, isolated solid-state spins and quantum dots.

Prerequisites:

MATH 1920, PHYS 1112 or 1116

Corequisites:

MATH 2930, PHYS 2213 or 2217

Textbook(s) and Other Materials:

- “Quantum Processes, Systems, and Information” by Benjamin Schumacher and Michael Westmoreland (ebook available through the Cornell Library Gateway)
- “Quantum Computation and Quantum Information” Michael A. Nielsen and Isaac L. Chuang (ebook available through the Cornell Library Gateway)
- Course notes posted on Canvas

Class Schedule:

Lectures: TR 11:25 – 12:40 am, PSB 120. We typically have a "warm-up" quiz to start each class so being on time is important.

Assignments, Exams:

Homework: Approximately 1 per week. They will be posted on Canvas under "assignments" and "modules." Collaboration between students is encouraged, however, every student is individually responsible for their own work. Unless otherwise stated, homework will be due Thursday midnight to the homework box. Late homework assignments will be accepted by the following Monday at midnight for 85% of the nominal points earned.

Exams: One preliminary exam.

Quizzes: There will be a quiz at the end, and there may be small quizzes throughout the semester.

Message discussion board:

I have set-up an "Ed Discussion" message board to ask questions of instructors and each other. I previously used Piazza for the same purpose, but it seems they are now out. For this course it is very helpful to be able to write notes & questions using Latex,

which Ed Discussion supports. You should see a tab on the right of Canvas. I encourage you to enroll and use it.

COVID-related issues:

Per Cornell policy, the first two weeks of lectures will be over Zoom. The zoom links will appear in the zoom tab of Canvas. Thereafter, I still plan to start a zoom meeting to record the lecture, even though it will be given in person. I expect you come in person unless you have a legitimate illness (in which case you should stay at home, of course). If you are ill, please join class via Zoom if you feel well enough, and watch the recording later if you do not. Recordings seem to be a generally useful resource for students, even though they came to class, but they are not a replacement for attendance. If you must miss class due to COVID quarantine (or any other health-related reason) you should (a) let me know via email and (b) report your illness through proper channels (typically engineering advising or student disability services.) If they agree, they will issue a "request for academic consideration" (I am not a physician, and I do not judge if you are well or not; the university has a mechanism for that.)

You should plan to abide by all university public health requirements found [here](#).

Minimum expectations for in-person classes are:

- Remain fully masked over the nose and mouth at all times during class.
- Only "high-quality" masks. This includes no cloth masks. The university has made vague statements (as of the time of this writing) about providing (K)N95 masks, and I don't know the final situation, so this definition may be updated to be (K)N95 masks.
- No eating or drinking in class. I know it over the noon hour, and its long -- sorry -- but that's where we are. I'll try to take a brief break in the middle of class if you want to step out to get a drink of water or whatever.
- Meeting all COVID testing requirements (you'll lose Canvas access if you don't, which is out of my control).
- I reserve the right to make any changes based on the current COVID situation. My past record has been to teach in person whenever possible, but at least once I went online before the university, which turned out to be the right choice based on the number of positive cases among students a few days later.

Grading:

Attendance and Participation 5%

Homework 25%

Prelim Exam 30%

Final Quiz 10%

Final Paper 30%

Typical Topics Covered:

1. Introduction to quantum information processing, quantum communication, and quantum-enhanced sensing technologies
2. Introduction to qubits and their relation to classical (digital bits)
3. Introduction to a quantum 2-level system and their representation
4. The criteria for a good physical qubit system
5. Qubit state lifetime and coherence lifetime (T_1 and T_2)
6. Introduction to quantum gate operations
7. The operation of selected physical qubits including photons, ions, solid-state spins, and superconducting circuits.
8. Understanding the multidisciplinary and complex problem that needs to be tackled for the continued development of quantum technologies – applied physics, material science, electrical engineering, computer science and more.
9. Developments and future directions for quantum information science and technology

Academic Integrity:

Students expected to abide by the Cornell University Code of Academic Integrity with work submitted for credit representing the student's own work. Discussion of homework assignments is permitted and encouraged, however, any work submitted for academic credit should be the student's own work.

Course materials posted on Canvas are intellectual property belonging to the author. Students are not permitted to buy or sell any course materials without the express permission of the instructor. Such unauthorized behavior will constitute academic misconduct.

Students agree that by taking this course all required papers may be subject to submission for textual similarity review to Turnitin.com for the detection of plagiarism. All submitted papers will be included as source documents in the Turnitin.com reference database solely for the purpose of detecting plagiarism of such papers. Use of Turnitin.com service is subject to the Usage Policy posted on the Turnitin.com site.