University of Chicago · Molecular Engineering · Spring 2025

MENG 37100: Quantum Processors

Lecture: TuTh 9:30-10:50 am KPTC 101
Instructor: Prof. A. N. Cleland
Discussion (led by TA): F 9:30-10:20 KPTC 103
TAs: Andy Chu & Xuntao Wu

Instructor:
Prof. Andrew N. Cleland <anc@uchicago.edu>
Office: 235 Eckhardt Research Center
Office Hours: TuTh 11 am-noon (in person or by Zoom; see Canvas for Zoom link)

Teaching assistants:
Andy Chu <ctchu@uchicago.edu>
Xuntao Wu <xtwu@uchicago.edu>
Office hours will be held in 305 KPTC M & F 1:30-2:30pm
TAs will alternate by week who runs discussion, is available for office hours, writes pset solutions and grades psets

Optional textbooks available through Amazon or other on-line resources:
Recommended: M. Nielsen and I. Chuang, *Quantum Computation and Quantum Information* (Cambridge University Press)
N. David Mermin, *Quantum Computer Science: An Introduction* (Cambridge University Press)
J. R. Johansson, P. D. Nation, *Quantum Toolbox in Python - QuTiP*, download from http://qutip.org/

Lecture notes:
Available as a PDF download from Canvas. Notes will be generated and posted as the course proceeds.

Course outline and recommended reading:
This course is a one-quarter class in quantum processors. You should have completed a rigorous course covering quantum mechanics, preferably at a graduate level; a prior class in quantum computation will help but is not required. Topics will focus on different hardware systems being exploited for quantum information applications, focusing on quantum computation and simulation.

A general introduction to quantum mechanics in physics can be found in D.J. Griffiths, *Introduction to Quantum Mechanics* (2nd edition; Pearson). More advanced texts include R. Shankar, *Principles of Quantum Mechanics* (2nd edition; Springer) and Sakurai & Napolitano, *Modern Quantum Mechanics* (3rd edition; Cambridge).

Grading:
Grades are based on problem sets (60%), the final presentation (30%) and class participation (10%).

Problem sets: There will be seven problem sets. While you may work in groups, the assignment you turn in must be your own work. Problem sets will be posted on Canvas on Tuesdays. Your solutions must be submitted before the end of class (10:50am) the Tuesday following. Problem sets will include python

exercises using QuTip (see reference above). Late submissions will be marked down 25% before solutions are posted; after solutions are posted submissions will not be graded.

Final presentations: You will work in groups of two to prepare a "mini-lecture" on a research paper or special (advanced) topic related to the class. Possible topics will be provided via Canvas. Presentations will be approximately 20 minutes, and will be given from 5-8pm on May 22 and 23 in W. Eckhardt Research Center 301B. You must participate in a presentation to pass the class.

Approximate schedule:

A. Week 1: A brief history of classical computing, and a quick overview of quantum computing
B. Week 2: Some basic QC algorithms, DiVincenzo criteria for physical qubits
C. Week 3: Spin qubits & NMR
D. Week 4. Spins in solids: quantum dots and NV centers
E. Week 5. Atomic systems: Cold atoms
F. Week 6: Atomic systems: Trapped ions
G. Week 7-8: Superconducting qubits
H. Week 8-9: Photonic qubits
I. Week 9: Final presentations

AI tools: *In this course, we will be developing skills and knowledge that are important to discover and practice on your own. Students are not allowed to use any AI tools, such as ChatGPT. Students are expected to present work that is their own without assistance from others, including automated tools. If you are unclear if something is an AI tool, please check with your instructor. Using AI tools in this course will violate the University's academic integrity policy. I treat potential academic integrity violations by interview possibly followed by a failing grade and/or a report to the Dean of Students.*

The University of Chicago is committed to fostering a safe, productive learning environment. Title IX and University policy prohibits discrimination on the basis of sex. Sexual misconduct — including harassment, domestic and dating violence, sexual assault, and stalking — is prohibited at the University. The University encourages anyone experiencing sexual misconduct to talk to someone, so they can get the support they need and the University can respond appropriately. If you wish to speak confidentially about an incident of sexual misconduct, want more information about filing a report, or have questions about school policies and procedures, please contact the University Title IX Coordinator, who can be found on the University website. The University is legally obligated to investigate reports of sexual misconduct after a formal complaint is filed or signed by the Title IX Coordinator, but a request for confidentiality will be respected to the extent possible. The University of Chicago is committed to ensuring equitable access to our academic programs and services. Students with disabilities who have been approved for the use of academic accommodations by Student Disability Services (SDS) and need a reasonable accommodation(s) to participate fully in this course should follow the procedures established by SDS for using accommodations. Timely notifications are required in order to ensure that your accommodations can be implemented. Please meet with me to discuss your access needs in this course after you have completed the SDS procedures for requesting accommodations.