AEP3100/5310: Introductory Quantum Computing

INSTRUCTOR:
Prof. P. McMahon
E-mail: pmcmahon@cornell.edu Office hours: Clark 217, Fridays 3:30-4:30 pm
(Please write "AEP3100: " in your e-mail subject line so that I can prioritize your e-mail!)

PREREQUISITES: MATH 2940 (or equivalent exposure to linear algebra) & CS 1110 (or equivalent exposure to Python).

You should be comfortable with the concepts of complex numbers, matrices, eigenvectors, eigenvalues, vector spaces, inner and outer products, matrix decompositions (such as the singular-value decomposition), and differential equations. If you are lacking any background mathematical knowledge, the book *Introduction to Linear Algebra* (5^{th} or 6^{th} Edition) by Gilbert Strang is a good reference.

You should be comfortable with Python programming, including installing Python packages, using Numpy to perform matrix computations (such as matrix-vector multiplications and eigensolving), and using matplotlib to make plots.

TEXTBOOK:
Quantum Computation and Quantum Information, by Michael Nielsen & Isaac Chuang, Cambridge University Press, 2010

Since quantum computing is a fast-moving field, some of the material we will cover in this course does not appear in the textbook nor in any of the readings below – for that material, the lectures will serve as the primary reference.

Optional readings (in no particular order)
An Introduction to Quantum Computing, by Phillip Kaye, Raymond Laflamme, and Michele Mosca
Quantum Computer Science: An Introduction, by David Mermin
Introduction to Quantum Information Science Lecture Notes, by Scott Aaronson [link]
Quantum Computing Since Democritus, by Scott Aaronson [link]
Quantum Computation Lecture Notes, by John Preskill [link]
Quantum Computation Lecture Notes, by John Watrous [link]
Quantum Computing Lecture Notes, by Ronald de Wolf [link]
Lecture Notes on Quantum Algorithms, by Andrew Childs [link]
Why now is the right time to study quantum computing, by Aram Harrow [link]
IBM Qiskit Book [link]
Mini-Library on Quantum Information and Computation, by Xiaodi Wu [link] – a compendium of many more books, lecture notes, etc.

COMPUTING/SOFTWARE REQUIREMENTS:

Some homework problems will involve programming in Python (version >=3.7) using the Numpy and Qiskit (version >= 0.39) libraries, so you need to have access to a computing environment with this software.

Canvas has a link to a guide to using Qiskit in Google's Colab environment, which is probably the easiest way to set up and run Qiskit from any computer.

Optional software: Quirk is a web-based tool for exploring quantum circuits; it may be useful for gaining intuition about how quantum circuits work [link]

COURSE WEB SITE: https://canvas.cornell.edu/courses/62950

TEACHING ASSISTANTS and TA OFFICE HOURS:
Tianyu Huang th678@cornell.edu Clark 218, Tuesdays 2-3 pm

LECTURES: Tuesday, Thursday 11:40 am - 12:55 pm, venue: PSB 120

The criteria upon which your grades will be based:

Examinations: There will be one in-class prelim (date: 14 March 2024; time: 11:40 am - 12:55 pm; venue: PSB 120) and one final exam (date: TBA; time: TBA; venue: TBA) [see https://registrar.cornell.edu/exams/spring-final-exam-schedule for any updates].

Homework: There will be approximately 6 homework sets. No credit will be given for late homework, but one assignment may be missed totally without penalty. Students are encouraged to work together on problem sets; however, each student must hand in an independent write-up. The use of AI assistants, such as ChatGPT, is not permitted (just as asking a person on an internet forum to do your homework for you is not permitted).

Homework is to be submitted via Canvas. The solutions for a single homework set should be submitted as a single .pdf file.

For homework questions that involve programming, please include both your source code and the output given by Python when executing your source code. The output should be sufficiently detailed that the correctness of your solution can be verified by looking at the output. All of this should be included in your single .pdf submission.

Additional work for students enrolled in AEP 5310: the State of New York requires that students enrolled in a higher-course-number version of a class be given additional requirements. Students enrolled in AEP 5310 should complete the following assignment: Identify an aspect of quantum computing that you learned about in this course that is not well-explained in Wikipedia. Edit the relevant Wikipedia page to improve its explanation, including potentially adding helpful worked examples. If the topic does not yet have a suitable Wikipedia page, you can create the page. Do *not* use ChatGPT for any part of this assignment. *What to submit to Canvas*: a PDF "printout" of the Wikipedia page before your edits and a PDF "printout" of the Wikipedia page after your edits, with your edits highlighted in yellow. The expected amount of new material you should add is between 1 and 5 pages of U.S.-Letter-sized original text and diagrams. (Just 1 page of added material can still receive the maximum grade if it is good material - we don't want to make Wikipedia unnecessarily verbose. But pick a topic to edit/add to that needs 1 extra page of material, not just a couple of tweaks.)

Grade Distribution (AEP 3100): Prelim (mid-term exam): 30%; Final exam: 40%; Homework: 30%

Grade Distribution (AEP 5310): Prelim (mid-term exam): 30%; Final exam: 40%; Homework: 25%; Wikipedia assignment: 5%