PHYS 340: Quantum Information Science (Spring 2017)

Instructor: Dr. Justin Dressel
Email: dressel@chapman.edu

Course Time: MW 4pm-5:15pm
Course Location: 220B Hashinger Science Center

Office: 110 Hashinger Science Center
Office Hours: MW 1pm-3pm or by appointment

Course Webpage: https://blackboard.chapman.edu

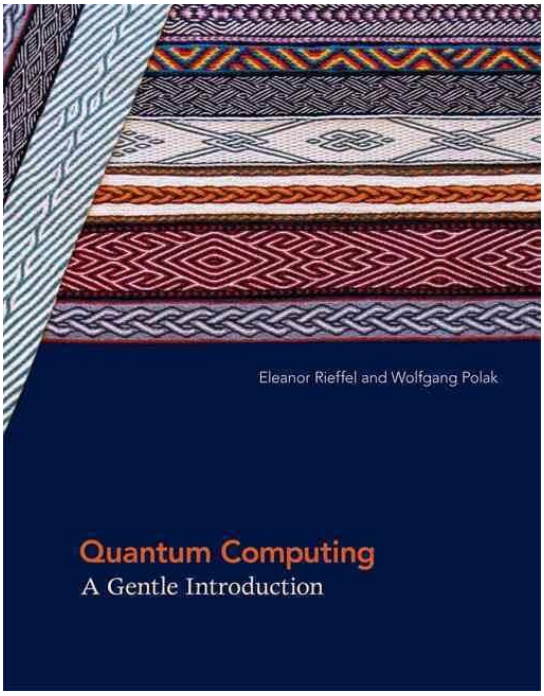
In-Class Participation: https://b.socrative.com/login/student/ Channel: SCSTPHYS340

Slack Discussion: https://scststudents.slack.com/ Channel: #phys340-17s

Course Description:
(Same as CPSC 320.) Prerequisites, MATH 211, CPSC 230. This multi-disciplinary course introduces the study of finite-dimensional collections of quantum bits. Using the circuit model of quantum computation, the course illustrates concrete algorithms that show an advantage over classical methods, including those discovered by Deutch-Josza, Simon, Grover, and Shor, along with basic error correction. (Offered spring semester.) 3 credits.

Course Textbook:

Quantum Computing : A Gentle Introduction
By Eleanor Rieffel and Wolfgang Polak
Publisher: MIT Press. 2014. (Paperback edition)



Instructional Methods/Strategies:

The class is primarily lecture-based, with some in-class activities, and a mid-semester programming exercise. The material can get abstract, so it is recommend that students **read the textbook to familiarize themselves with the material BEFORE coming to class, to facilitate more productive discussion.**

Methods of Evaluation:

In addition to in-class assessment of abilities, students will be challenged by a combination of regular written homework, a mid-term exam, and a final exam.

Student Assessment:

Class Participation and Attendance	10%
Homework	40%
Midterm Exam	25%
Final Exam	25%

Course Objectives and Learning Outcomes:

After completing this course students will be able to:

1. Recall the postulates of finite-dimensional quantum theory and identify universal gate sets for quantum and classical reversible computing.
2. Calculate the outcome probabilities for quantum circuits using complex state vectors, unitary matrices, and Dirac notation.
3. Analyze and create circuit-based algorithms for systems of quantum bits.

4. Explain the differences between classical and quantum computing, including problems for which quantum computers are thought to offer an advantage over classical computers, and the challenges involved in building a quantum computer.
5. Design and implement computer simulations of quantum circuits with one and two quantum bits in Python.

Physics Program Objectives and Learning Outcomes

1. Demonstrate knowledge and understanding of basic mathematics and physical principles used to model natural phenomena.
2. Demonstrate ability to convey physical concepts with mathematical expressions and/or computation, and effectively derive quantitative predictions from a model through mathematical/computational analysis.
3. Demonstrate competency in using computer tools.
4. Demonstrate the ability to apply knowledge of advanced mechanics, electromagnetism, thermodynamics and quantum physics to the solution of problems in physics.
5. Demonstrate the ability to effectively communicate information, scientific or otherwise, in both written and verbal form.
6. Demonstrate the ability to write clear, organized and illustrated technical reports with proper references to previous work in the area.
7. Demonstrate the skills and motivation for continued self-education.

Supplemental Bibliography:

Quantum computing is an active and rapidly evolving field, so students are encouraged to read broadly for different perspectives on the material. The following textbooks are also generally recommended, but not required for the course:

Principles of Quantum Computation and Information, Volumes I and II
Giuliano Benenti, Giulio Casati, and Giuliano Strini
World Scientific, 2004.

An Introduction to Quantum Computing
Kaye, Laflamme, and Mosca
Oxford University Press, 2007.

Quantum Computation and Quantum Information, 10th Anniversary Edition
Nielsen and Chuang
Cambridge University Press, 2011.

Blackboard:

Grades will be posted on Blackboard. Updated course schedules and announcements will be posted on Blackboard.

Slack:

Group discussion and contact with the professor will be facilitated by Slack, at http://scststudents.slack.com . Ensure that you have an account. Please notify the instructor if you

need to be invited. The channel for this course will be **#phys340-17s** and is set to auto-notify the instructor. Note that this is a public forum, but private chats are also available as required.

Collaboration Policy:

I encourage you to discuss and study course material together. However, all work you submit for this course must be your own. Any incidents of academic misconduct will be dealt with severely in accordance with the Chapman University Academic Integrity policy (see below).

Chapman University's Academic Integrity Policy:

"Chapman University is a community of scholars that emphasizes the mutual responsibility of all members to seek knowledge honestly and in good faith. Students are responsible for doing their own work and academic dishonesty of any kind will be subject to sanction by the instructor/administrator and referral to the university Academic Integrity Committee, which may impose additional sanctions including expulsion. Please see the full description of Chapman University's policy on Academic Integrity at http://www.chapman.edu/academics/academicintegrity/index.aspx."

Chapman University's Students with Disabilities Policy

"In compliance with ADA guidelines, students who have any condition, either permanent or temporary, that might affect their ability to perform in this class are encouraged to contact the Disability Services Office. If you will need to utilize your approved accommodations in this class, please follow the proper notification procedure for informing your professor(s). This notification process must occur more than a week before any accommodation can be utilized. Please contact Disability Services at (714) 516–4520 or visit www.chapman.edu/students/student-health-services/disability-services if you have questions regarding this procedure or for information or to make an appointment to discuss and/or request potential accommodations based on documentation of your disability. Once formal approval of your need for an accommodation has been granted, you are encouraged to talk with your professor(s) about your accommodation options. The granting of any accommodation will not be retroactive and cannot jeopardize the academic standards or integrity of the course."

Chapman University's Equity and Diversity Policy

"Chapman University is committed to ensuring equality and valuing diversity. Students and professors are reminded to show respect at all times as outlined in Chapman's Harassment and Discrimination Policy. Please see the full description of this policy at http://www.chapman.edu/faculty-staff/human-resources/eoo.aspx. Any violations of this policy should be discussed with the professor, the dean of students and/or otherwise reported in accordance with this policy."

Student Support at Chapman University

Over the course of the semester, you may experience a range of challenges that interfere with your learning, such as problems with friend, family, and or significant other relationships; substance use; concerns about personal adequacy; feeling overwhelmed; or feeling sad or anxious without knowing why. These mental health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. You can learn more about

the resources available through Chapman University's Student Psychological Counseling Services here:
https://www.chapman.edu/students/health-and-safety/psychological-counseling/
Fostering a community of care that supports the success of students is essential to the values of Chapman University. Occasionally, you may come across a student whose personal behavior concerns or worries you, either for the student's well-being or yours. In these instances, you are encouraged to contact the Chapman University Student Concern Intervention Team who can respond to these concerns and offer assistance:
https://www.chapman.edu/students/health-and-safety/student-concern/index.aspx
While it is preferred that you include your contact information so this team can follow up with you, you can submit a report anonymously. 24-hour emergency help is also available through Public Safety at 714-997-6763.

Tentative Course Schedule:

Week	Monday	Wednesday
1 - 1/30	Classical Computation: Turing Machines and Circuits (Benenti, Casati, Strini: 1.1 -- 1.2)	Classical Computation: Information, Erasure, and Reversibility (Benenti, Casati, Strini: 1.5 -- 1.6)
2 - 2/6	Ch 2 : Single Quantum Bits Concepts and Complex State Vectors	Ch 2 : Single Quantum Bits Geometry and the Bloch Sphere
3 - 2/13	Ch 3 : Multiple Quantum Bits Direct Sums and Products	Ch 3 : Multiple Quantum Bits Entanglement
4 - 2/20	Ch 4 : Measurement Operators and Collapse	Ch 4 : Measurement EPR-Bell Theorem
5 - 2/27	Ch 5 : Quantum Transformations Reversible (Unitary) Gates	Ch 5 : Quantum Transformations Quantum Circuit Model
6 - 3/6	Ch 6 : Quantum Classical Computation Reimplementing Classical Gates	**Midterm** **Ch 1-5**
7 - 3/17	Python Coding Project	Python Coding Project
8 - 3/20	**Spring Break**	**Spring Break**
9 - 3/27	Ch 7 : Quantum Algorithms Deutch-Jozsa's and Simon's Problems	Ch 7 : Quantum Algorithms Quantum Fourier Transforms
10 - 4/3	Ch 8 : Shor's Factoring Algorithm	Ch 8 : Shor's Factoring Algorithm
11 - 4/10	Ch 9 : Grover's Search Algorithm	Ch 9 : Grover's Search Algorithm
12 - 4/17	Ch 10 : Subsystems Mixed States and Density Operators	Ch 10 : Subsystems Classifying Entanglement
13 - 4/24	Ch 10 : Subsystems General Transformations	Ch 11 : Error Correction Bit, Phase, and Bit-Phase Flips
14 - 5/1	Ch 11 : Error Correction Syndromes and Error Models	Ch 11 : Error Correction Stabilizer Formalism
15 - 5/8	Ch 13 : Further Topics Experimental Implementations	Ch 13 : Further Topics Surface Codes and Outlook
16 - 5/15	**Final : 4:15pm-6:45pm** **Ch 7-11**	

Chapters refer to the primary text by Rieffel and Polak unless otherwise specified.