QUANTUM INFORMATION

Phys 396 Fall 2018

Instructor: Professor David Collins
Office: WS 228B
Phone: 248-1787
email: dacollin@coloradomesa.edu

Office Hours: M 10 – 11am, M 2 – 3 pm, TW 1 – 2pm, F 9am – 10am

Class Meetings: TTh 2:00pm – 3:15pm, WS 366

Course Website: http://www.coloradomesa.edu/~dacollin/teaching/2018Fall/Phys396/index.html

Required Text: E. Reiffel and W. Polak, *Quantum Computing,* MIT Press (2014).

G. Benenti, G. Casati and G. Strini, *Principles of Quantum Computation and Information,* World Scientific (2004).

Prerequisites: Phys 230 or 231

Overview

Quantum information concerns how quantum systems can be harnessed to do information processing tasks in ways that are not possible for conventional, classical, systems and devices. During the last 25 years a wide variety of theoretical quantum information processing schemes have been developed. These include cryptographic key distribution protocols, algorithms that can factorize numbers efficiently and efficient methods for simulating real quantum systems such as complex molecules. Separately classical information theory has been adapted for quantum systems and used to assess communication and measurement tasks involving quantum systems and even inform our understanding of the foundations of quantum physics.

Although experimental implementations in the field have lagged behind theoretical development, these have reached the stage where commercial cryptography devices are available and it appears likely that in the next few years a quantum device will be able to outperform any classical supercomputer on a specific task.

This course introduces you to the ideas of quantum information. It does not assume any knowledge of formal quantum physics and it will include a development of the key foundational ideas of quantum physics.

The course covers:

1. Basic ideas of classical computing.
2. Fundamentals of quantum physics.

3. Quantum cryptography and teleportation.
4. Quantum computing and algorithms.
5. Experimental implementations of quantum information processing.

Assignments

An undergraduate student should expect to spend on this course a minimum of two hours outside the classroom for every hour in the classroom. The outside hours may vary depending on the number of credit hours or type of course. More details are available from the faculty member or department office and in CMU's Curriculum Policies and Procedures Manual.

1. **Homework:** There will typically be one homework assignment per week. This will be due by 5pm on the date indicated on the assignment. Late homework will be subject to a penalty of a 2% reduction in the maximum possible grade for each hour that the work is late. It is in your best interests to work by yourself on the homework problems but collaboration is acceptable. You can discuss the broad outlines of problem solutions with your colleagues but must write your final solutions independently. You are also encouraged to consult me for help with homework problems.

2. **Term paper:** There will be research/review paper due on Friday 7 December 2018. The term paper will report on a single topic within the realm of quantum information beyond those covered in the lectures. A topic must be selected by 9 November 2018 and must meet with the instructor's approval.

3. **Presentation:** You will be required to give a short presentation on the topic that you have chosen for your term paper. As much as possible, you will present these during the final exam period, at **1:00 pm on Tuesday 11 December 2018**.

Exams and Quizzes

1. **Class Exams:** There will be two exams during class on the following days:

   Exam 1: Tuesday 2 October 2018
   Exam 2: Tuesday 13 November 2018

   Exams will be closed book and closed notes although you will be able to bring a formula sheet. Calculators will be allowed.

Grades

Individual assignments and exams will be graded using suitable scales. In general, to get full credit (100%) for a problem your solution must be correct and well justified. Partial credit will be given for incomplete or partly correct solutions. No credit (0%) will be given for problems not attempted, assignments not turned in or quizzes and exams missed without good reason.

The numerical grades for each component will be totaled and a final numerical grade will be computed according to the following distribution.

Homework	40%
Class Exams	30%
Term Paper	20%
Presentation	10%

The following final numerical scores will guarantee letter grades:

90%	A
80%	B
70%	C
60%	D

Policies

1. **Helpful Resources:** The Tutorial Learning Center (TLC) is a *free* academic service for all CMU students. Tutors are available in Houston Hall 113 on a walk-in basis for many courses. More information is available at www.coloradomesa.edu/tutoring or 248-1392.

   In coordination with Educational Access Services, reasonable accommodations will be provided for qualified students with disabilities. Students must register with the EAS office to receive assistance. Please meet with the instructor the first week of class for information and/or contact Dana VandeBurgt, the Coordinator of Educational Access Services, directly by phone at 248-1801, or in person in Houston Hall, Suite 108.

2. **Withdrawals:** There are several ways to drop this course. The deadline for dropping without penalty is **4 September 2018.** Please consult the MSC academic calendar and catalog for more details about adding and dropping courses.

3. **Attendance:** Attendance policies are described in the CMU catalog. You are expected to attend all the class meetings. In case of illness or other emergencies you must be able to produce the appropriate documentation. There are other circumstances under which you can be excused but you must discuss these with me in advance. If you miss a class or lab for a valid reason, turn in any assignments due before the start of the next class. Assignments turned in beyond your return to class will not be accepted.

   If there is an unavoidable conflict with one of the class exams or the final exam, please discuss it with me as soon as possible. In general I will assume that the final exam will have priority, since you know the dates of the exam.

4. **Academic integrity:** You are expected to present your own work in assignments, exams and quizzes. Fabrication of data, plagiarism, and copying from anyone else, particularly in closed book exams, are serious violation of academic norms. CMU has extensive policies on these matters and penalties for infringement can be severe. For more details, consult the academic integrity policies in the CMU catalog.

Schedule

The following schedule is tentative, except for the dates of the class exams.

Week	Dates	Topic
1	8/21 – 8/23	Classical computing.
2	8/28 – 8/30	Quantum states and measurements, linear algebra.
3	9/4 – 9/6	States of spin-1/2 particles.
4	9/11 – 9/13	Entangled systems, evolution of states.
5	9/18 – 9/20	Evolution of states, matrices in quantum physics.
6	9/25 – 9/27	Evolution of states.
7	10/2 – 10/4	**Exam I**, Cryptography.
8	10/7 – 10/11	Quantum cryptography.
9	10/14 – 10/18	Quantum gates.
10	10/21– 10/25	Quantum gates, classical computing with quantum systems.
11	10/28 – 11/1	Quantum algorithms.
12	11/6 – 11/8	Quantum algorithms.
13	11/13 – 11/15	**Exam II**, Topics in quantum information.
14	11/20 – 11/22	Thanksgiving (no classes).
15	11/27 – 12/1	Experimental quantum information.
16	12/4 – 12/8	Experimental quantum information.