PHYS 612: Quantum Information Physics
MW 2:00 – 3:15 PM, PAHB 123

Instructor: Dr. Jason Kestner
Pre-reqs: PHYS 601
Office: Physics 316
Office Hour: Friday 2-3pm, or email for an appointment.
Email: jkestner@umbc.edu
Textbook: *Quantum Computation and Quantum Information*, Nielsen & Chuang
Resources: Preskill's lectures (www.theory.caltech.edu/people/preskill/ph229)
Quantum Computer Science: An Introduction, Mermin
Explorations in Quantum Computing, Williams
IBM Q Experience (www.research.ibm.com/ibm-q/)

Course Description

This course gives an introduction to the fundamental concepts of quantum information processing with an emphasis on the physics of its implementation. The focus is on the nascent field of quantum computing, with some results in quantum communication discussed as well.

The structure of this course is still evolving, and your input is welcome throughout the semester. The class sessions will not be strictly lecture-based, but will require your active participation, with me as your expert (or in any case, fearless) guide. In order for you to benefit, it is **imperative** for you to **read** the assigned sections of the textbook before each class. I am counting on you to do so. We will generally follow the classic textbook of Nielsen & Chuang, though for some sessions we may toggle over to Preskill or another reference.

Academic Objectives

By the semester's end you should be able to demonstrate understanding of:

- How a quantum computer is expected to provide exponential improvement over a classical computer.
- Basic quantum algorithms, such as Deutsch-Josza, Grover, and Shor.
- The basic idea of quantum error correction.

- The physics of the various types of qubits currently being researched.
- Basic ideas of quantum cryptography.
- Outstanding physics challenges that must be overcome to realize the quantum technology revolution.

Assignments

Extensive readings will be assigned before each class. It is essential that you actually do read them and work to understand them. This will take a serious time commitment – probably 2-3 hours for each class meeting – and must be done *prior* to the class meeting. To help motivate this, there will be accompanying short questions due for credit at the beginning of each class.

In addition, homeworks will be assigned semi-regularly. The work you turn in must be self-contained, logical, and neat.

Individual study is absolutely key to internalizing concepts, but consulting others (classmates, me, the internet) is also an essential part of scholarly practice and is a good way to overcome roadblocks. However, all submitted work must be your own. Copied or paraphrased work is unacceptable. It is fine to use somebody else's idea in your solution, but you must cite them.

You may use Mathematica or other software freely. When you do so, attach a printout to your homework.

Final Project

Each student will choose a final project topic in consultation with the instructor. Topic selections are due before spring break. A written paper will be due at the end of the semester, as well as a 30-minute oral presentation to the class in lieu of a final exam.

Overall Grades

Your course grade will be determined by the following components:

Homework	35%
Reading questions	35%
Final project oral	10%
Final project written	20%

This course will not be graded on a curve. Total scores translate to grades in the following way:

Score	Grade
90–100	A
88–90	A-
85–88	B+
81–85	B
78–81	B-
75–78	C+
71–75	C
68–71	C-
65–68	D
0–65	F

Course schedule (subject to change)

Idea and algorithms	
Meetings 1-2	Overview, Deutsch-Josza algorithm, and complexity classes (Chap. 1)
Meetings 3-5	Quantum gates and universality (Chap. 4)
Meetings 6-8	Quantum Fourier Transform and its applications (Chap. 5)
Meetings 9-10	Grover's algorithm and its applications (Chap. 6)
Fault tolerance	
Meetings 11-12	Schmidt decomposition, purification, and Bell's inequality (Chap. 2)
Meetings 13-14	Quantum noise and superoperators (Chap. 8)
Meetings 15-18	Fault-tolerant error-correcting codes (Chap. 10)
Physical implementations	
Meetings 19-20	Photonic qubits (Chap. 7 + supplemental material)
Meetings 21-22	Superconducting qubits (Chap. 7 + supplemental material)
Meeting 23	Trapped ion qubits (Chap. 7 + supplemental material)
Meeting 24	Spin qubits (supplemental material)
Meeting 25	Majorana qubits (supplemental material)
Meeting 26	Quantum annealers (supplemental material)
Other topics	
Meeting 27	Quantum cryptography (Chap. 12)
Meetings 28-29	TBD