PHYS 370 Syllabus
Fall 2023, UIUC

Title: Introduction to Quantum Information and Computing

Credit Hours: 3 cr.

Description: Introduction to quantum information and computing for sophomores, juniors and seniors from any major. Self-contained description of quantum states and qubits, operators, measurements, tensor products, density matrices, quantum gates and circuits, and quantum computing/simulation algorithms. One of the key points of departure from classical physics, quantum entanglement, is threaded throughout all these topics including a dedicated discussion of Bell's theorem. Students will apply these basic aspects of quantum mechanics to program online quantum computers (e.g., IBM cloud) to gain insight into canonical algorithms such as Deutsch-Jozsa, Shor, and/or Grover as well as standard protocols such as teleportation and entanglement swapping. Course Information: Prerequisite: PHYS 214.

The course schedule can be found below.

When: Mon/Wed 10:00-11:20am

Where: 1047 Sidney Lu Mech Engr Bldg

Who:
Prof. Jake Covey
327 Loomis
jcovey@illinois.edu
320-223-0373
Office Hours: Friday, 2-4pm

Tahereh Mozafarishamsi (HW)
271 Loomis
tahereh2@illinois.edu
Office Hours:

Course website:
https://sites.google.com/view/coveylab/teaching (the teaching tab on my group website: coveylab.com)

Course Material:
Lecture notes, homeworks, homework solutions, and exam solutions and be available from the course website.

We will also use the *gradebook* to keep track of scores.

Lecture participation:
We will not use iClicker.

Lecture attendance will be 5% of your grade. Attendance will be recorded with a sign-in sheet. Participation is not strictly required, but it is highly encouraged and is the intent of the attendance points. You will have four drops throughout the semester.

Class forum:

We will use Campuswire to ask and answer questions outside of class time: I encourage you to do both! You will receive an invitation email close to the start of the semester.

Homework:
Homework will be due every Wednesday by 10am. I prefer to take an "old school" approach where you will turn in a paper copy of your homework at the beginning of the Wednesday lecture. We will hand out a paper copy of the next homework during the Wednesday lecture. Homeworks and their solutions can also be found on the course website.

Homeworks can be turned in up to one week late for 80% credit, or before the final course deadline (whichever is sooner). Accordingly, the homework solutions will not be available until one week after their (100% credit) due date.

Exams:
Exams for this course will be in-class/in-person. Dates are on the schedule below. The two midterm exams will be 80 min; the final exam will be 180 min.

Grading:
The course will comprise weekly homework (40%), class attendance (5%), two midterm exams (15% each), and one final exam (25%). Exams may be curved; final course grades will not be curved. The (lower) grade boundaries will be A+ (97), A (94), A- (91), B+ (88), B (85), B- (82), C+ (78), C (74), C- (70), D+ (66), D (62), D- (58), F (54)

Text:
D. McMahon, Quantum Computing Explained, 1st Edition, 2008 (required).
M. Nielsen and I. Chuang, Quantum Computation and Quantum Information, 10th Anniversary Edition available electronically (reference)

Class responsibilities:
See here: https://courses.physics.illinois.edu/phys370/sp2023/Class%20responsibilities.html

Diversity, equity, and inclusion responsibilities:
The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors directly through the Office of the Vice Chancellor for Diversity Equity and Inclusion (https://diversity.illinois.edu/diversity-campus-culture/belonging-resources). Based on your report, members of the OVCDEI will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Academic Integrity:

All activities in this course, including documentation submitted for petition for an excused absence, are subject to the Academic Integrity rules as described in Article 1, Part 4, Academic Integrity, of the Student Code: https://studentcode.illinois.edu/article1/part4/1-401/

In case of emergency:
Here is a list of emergency resources: https://publish.illinois.edu/illinistudentresources/?page_id=46

References on reserve at the Grainger Library:

- Wilde, Mark; Quantum Information Theory (2017) available online
- Holik, Federico, et al; What is Quantum Information (2017) available online
- Marinescu, Dan & Marinescu, Gabriela; Classical and Quantum Information (2012) available online
- Hayashi, Masahito; Introduction to quantum information science (2014) available online
- Benatti, Fabio; Quantum Information, Computation and Cryptography: An Introductory Survey of Theory, Technology and Experiments (2010) available online
- Hidary, Jack; Quantum Computing: An Applied Approach (2019) available online
- Bernhardt, Chris; Quantum Computing for Everyone (2019) available online
- Fujii, Keisuke, Quantum Computation with Topological Codes: From Qubits to Fault-Tolerance (2015) available online
- Pathak, Anirban; Elements of Quantum Computation and Quantum Communication (2013) available online
- Bera, Rajendra; The Amazing World of Quantum Computing (2020) available online
- Motodi, Tzvetan, et al.; Quantum Computing for Computer Architects (2011) available online
- Mermin, David; Quantum Computer Science: An Introduction (2007) available online

Lecture	Date	Title	Source material
		Unit 1: Single qubits	
1	M, 08/21	Introduction to quantum systems: Infinite Square Well and electron spin	PHYS 214 recap, Accompanying notes
2	W, 08/23	Qubits and the Bloch sphere	MM: Ch. 2, pp. 11-19 Ref: N&C: sec. 1.2
3	M, 08/28	Matrices and operators	MM: Ch. 2, pp. 19-26, 28-31; Ch. 3, pp. 39-49
4	W, 08/30	Manipulating and preserving qubits	Accompanying notes
5	W, 09/06	Expectation values, unitary transformations, HUP, postulates of QM	MM: Ch. 3, pp. 57-62, 66-69, 70-71
6	M, 09/11	The density operator, mixed states, Fidelity	MM: Ch. 5, pp. 86-90, 91-108, 115-117
7	W, 09/13	Quantum measurements	MM: Ch. 3, 62-66; Ch. 6, pp. 121-132, 139-146
8	M, 09/18	Single-qubit gates; towards quantum circuits	MM: Ch. 8, pp. 176-186, Ch. 9, pp. 197-204
		Unit 2: Two qubits	
9	W, 09/20	Tensor products of states and operators	MM: Ch. 4, pp. 73-84
10	M, 09/25	Exam 1 – Unit 1	
11	W, 09/27	Entanglement	MM: Ch. 7, pp. 157-162
12	M, 10/02	Bell's theorem	MM: Ch. 7, pp. 147-155
13	W, 10/04	Partial trace, density operator, mixed states, and measurements	MM: Ch. 5, pp. 111-115; Ch. 6, pp. 132-139 Accompanying notes
14	M, 10/09	Quantum gates and circuits	MM: Ch. 8, pp. 186-195
15	W, 10/11	No cloning theorem, teleportation, quantum repeater	MM: Ch. 13, pp. 279-280, Ch. 10, 225-228 Ref: N&C: secs. 1.3.5. 1.3.7, Box 12.1
		Unit 3: Quantum hardware platforms	
16	M, 10/16	Harmonic oscillators: phonons and photons	Accompanying notes
17	W, 10/18	Neutral atoms	Accompanying notes
18	M, 10/23	Trapped ions	Accompanying notes
19	W, 10/25	Spins in solids	Accompanying notes
20	M, 10/30	Superconducting circuits	Accompanying notes
21	W, 11/01	QED and QAD (not covered on exams)	Accompanying notes
22	M, 11/06	Exam 2 – Units 2 and 3	
		Unit 4: Many qubits and algorithms	
23	W, 11/08	Deutsch (-Jozsa) algorithm	MM: Ch. 9, pp. 203-210 Ref: N&C: secs. 1.4.3, 1.4.4
24	M, 11/13	Fourier transform on a quantum computer	MM: Ch. 9, pp. 211-213 Ref: N&C: sec. 5.1
25	W, 11/15	Phase estimation and Shor's algorithm	Phase estimation: N&C: sec. 5.2, pp. 221-223 Shor's algorithm: MM: Ch. 9, pp. 216-218; Ref: N&C: sec. 5.3
26	M, 11/27	Grover's search algorithm	MM: Ch. 9, pp. 218-221 Ref: N&C: sec. 6.1
27	W, 11/29	QEC – nine qubit Shor code	
28	M, 12/04	Quantum approximate optimization algorithms	Accompanying notes
29	W, 12/06	Final Review	