COURSE: QIC750/ECE676/PHYS768

NOTE: Everything in this course outline is contingent on the continuing state of the ongoing global pandemic. This includes how exams will be administered and the marking scheme for assessment. Everything is subject to change in response to emergency guidance and restrictions from the government and the university. Best efforts will be made to give you as much time as possible to adjust to changes.

COURSE TITLE: **Implementations of Quantum Information Processing**

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DESCRIPTION:
This course gives an introduction to physical implementations of quantum computers with an emphasis on common and connecting themes.

PREREQUISITE: Quantum mechanics, linear algebra, differential equations

SYLLABUS:

1. ***Introduction to quantum computing***
   Origin and elements of quantum computers. Quantum circuit model

2. ***Review of Important Quantum Models***
   Time-evolution and the Hamiltonian. The quantum harmonic oscillator. The 2-level system (spin 1/2). Density matrices. The Bloch Sphere.

3. ***Nuclear Magnetic Resonance Quantum Computing***
   The Rabi problem and RWA. Single- and Two-qubit gates. Noise

4. ***Photonic Quantum Information***
   Optical elements. Polarization, time-bin and dual-rail encoding. Quantum key distribution. Noise

5. ***Trapped-Ion Quantum Computing***
   Trapping ions. Optical and Microwave qubits. Raman transitions. Single- and Two-qubit gates. Noise

6. ***Superconducting Qubits***
   Quantized circuits. Charge and Flux qubits. Circuit Quantum Electrodynamics. Jaynes-Cummings Hamiltonian: Coupling between a harmonic oscillator and two-level system. Noise.

7. ***Special Topics***
   Students will give presentations on topics of interest to themselves drawn from the literature

TEXTBOOK: There will be no required textbook.

COURSE MATERIAL: Lecture notes will be provided on **Learn.**
When in-person lectures are not allowed, online lectures will be offered through MS Teams (most likely) or Zoom.

OTHER REFERENCE: Modern Quantum Mechanics, J.J. Sakurai. Addison-Wesley Publishing, (1994).
OTHER RESOURCES:

- We will use the **LEARN** platform for announcement, submission and grading problem sets.
- We will use the **Piazza** platform for online discussions and questions.

MARKING SCHEME:

- Homework: 30%
- Presentations: 20%
- Final Exam: 50%

The intention is to have a closed-book, in-person final exam. If this is not possible due to the pandemic, we will have an online exam administered through CrowdMark. If this becomes necessary, more details will be provided as soon as is practical.

Plagiarism detection software (Turnitin) will be used to screen assignments in this course, to verify that the use of all materials and sources is documented. If you object to your work being screened by Turnitin, contact Prof. Kim with your concerns within the first 2 weeks of class.

Scenario 1

Week	Date	Topic	Reading	Problem Set
1	Lec. 1: Jan. 11	Introduction to QC	Chap. 1	
	Lec. 2: Jan. 12	Review of QM	Chap. 2.1-2.3	
2	Lec. 3: Jan. 18	Q. Dynamics	Chap. 2.4, 2.5	PS1. Out
	Lec. 4: Jan. 19	QHO	Chap. 2.5	
3	Lec. 5: Jan. 25	NMR Introduction, Single-qubit	Chap. 3.1-3.3	
	Lec. 6: Jan. 26	NMR Two-qubit, Measurement	Chap. 3.4, 3.5	
4	Lec. 7. Feb. 1	NMR Initialization, Noise	Chap. 3.6, 3.7	PS1. Due
	Lec. 8. Feb. 2	Spin-based QC	Chap. 3.6, 3.7	PS2. Out
5	Lec. 9: Feb. 8	Photon Introduction, Single-qubit	Chap. 4.1-4.3	
	Lec. 10: Feb. 9	Photon Two-qubit, measurement	Chap. 4.4,4.5	
6	Lec. 11: Feb. 15	Photon One-way computation	Chap. 4.6	
	Lec. 12: Feb. 16	Photon Continuous Variable QC, Noise	Chap. 4.7, 4.8	PS2. Due
7	Study Break			
8	Lec. 13: Mar. 1	Trapped-Ion Introduction	Chap. 5.1	PS3. Out
	Lec. 14: Mar. 2	Trapped-Ion Qubit, Interaction Processes	Chap. 5.2, 5.3	
9	Lec. 15: Mar. 7	Trapped-Ion Initialization Presentations - I (2 teams)	Chap. 5.4	
	Lec. 16: Mar. 9	Trapped-Ion Qubit Control, Measurement Presentations - II (2 teams)	Chap. 5.4-5.6	
10	Lec. 17: Mar. 14	Trapped-Ion Noise, Summary Presentations - III (2 teams)	Chap. 5.7, 5.8	PS3. Due
	Lec. 18: Mar. 16	Superconducting Introduction Presentations - V (2 teams)	Chap. 6.1	
11	Lec. 19: Mar. 21	Superconducting Qubit Presentations - VI (2 teams)	Chap. 6.2	PS4. Out
	Lec. 20: Mar. 23	Superconducting QED Presentations - VII (2 teams)	Chap. 6.3	
12	Lec. 21: Mar. 28	Superconducting QED, Initialization Presentations - VII (2 teams)	Chap. 6.3, 6.4	
	Lec. 22: Mar. 30	Superconducting Gates Presentations - VIII (2 teams)	Chap. 6.5	
13	Lec. 23: Apr. 4	Superconducting Measurement, Noise Presentations - IX (2 teams)	Chap. 6.7	PS4. Due
	Lec. 24: Apr. 6	Superconducting Noise, Summary Presentations - X (2 teams)	Chap. 6.8	

Scenario 2

Week	Date	Topic	Reading	Problem Set
1	Lec. 1: Jan. 11	Introduction to QC	Chap. 1	
	Lec. 2: Jan. 12	Review of QM	Chap. 2.1-2.3	
2	Lec. 3: Jan. 18	Q. Dynamics	Chap. 2.4, 2.5	PS1. Out
	Lec. 4: Jan. 19	QHO	Chap. 2.5	
3	Lec. 5: Jan. 25	NMR Introduction	Chap. 3.1, 3.2	
	Lec. 6: Jan. 26	NMR Single-qubit	Chap. 3.3	
4	Lec. 7. Feb. 1	NMR Two-qubit, measurement	Chap. 3.4, 3.5	PS1. Due
	Lec. 8. Feb. 2	NMR Initialization, Noise	Chap. 3.6, 3.7	PS2. Out
5	Lec. 9: Feb. 8	Photon Introduction, Single-qubit	Chap. 4.1-4.3	
	Lec. 10: Feb. 9	Photon Two-qubit, measurement	Chap. 4.4, 4.5	
6	Lec. 11: Feb. 15	Photon One-way computation	Chap. 4.6	
	Lec. 12: Feb. 16	Photon CV QC, Noise	Chap. 4.7,4.8	PS2. Due
7	Study Break			
8	Lec. 13: Mar. 1	Trapped-Ion Introduction	Chap. 5.1	PS3. Out
	Lec. 14: Mar. 2	Trapped-Ion Interaction Processes, Initialization	Chap. 5.2-5.4	
9	Lec. 15: Mar. 8	Trapped-Ion Qubit Control, Noise	Chap. 5.5-5.7	
	Lec. 16: Mar. 9	Superconducting Introduction	Chap. 6.1, 6.2	
10	Lec. 17: Mar. 15	Superconducting QED	Chap. 6.3	PS3. Due
	Lec. 18: Mar. 16	Superconducting Gates	Chap. 6.4-6.6	PS4. Out
11	Lec. 19: Mar. 22	Superconducting Measurement, Noise	Chap. 6.7, 6.8	
	Lec. 20: Mar. 23	Summary		
12	Mar. 28	Presentations - I		
	Mar. 30	Presentations - II		PS4. Due
13	Apr. 4	Presentations - III		
	Apr. 6	Presentations - IV		