King Fahd University of Petroleum and Minerals

College of Computing and Mathematics

Information and Computer Science Department

ICS 560: Foundations of Quantum Computing

Semester 251

Course information

- Instructor: Dr Alawi A. Al-Saggaf
- Lectures: Sun, Tue. 17:20 -18:35
- Location: Building #22-Room 120
- Email: alawi@kfupm.edu.sa
- Course site: Blackboard
- Office hour: Monday and Wednesday 10:00 to 11:50 (or by Appointment by send on Teams and I will try to accommodate your Qs online).

Course Description

Complex numbers and complex vector space, Hilbert Space, Number theory, Integer representation, Modular arithmetic, Primes, Deterministic and probabilistic Systems, Quantum Systems. Quantum States. Reversible and Quantum Gates. Super dense coding, Deutsch Algorithm, Deutsch-Josza Algorithm, Quantum Programing Languages, Quantum Functions Implementation.

Prerequisites Graduate standing

Course Objectives

- Introduce the foundations of quantum computing from computer science perspective.
- Introduce fundamental quantum computing algorithms and tools..

Learning Outcomes

After taking this course, students will have the ability to

1. Explain the difference between classical and quantum computing.
2. Explain quantum gates and circuits.
3. Use quantum computing programming to implement basic quantum algorithms.
4. Search and utilize information on topics in modern and quantum cryptography from a variety of sources

Textbook

o Yanofsky, N., & Mannucci, M. (2008). Quantum Computing for Computer Scientists. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511813887.

References

1. Hiu Yung Wong, Introduction to Quantum Computing: From a Layperson to a Programmer in 30 Steps, Springer Cham, Sep. 2023.
2. Alan B. Marcovitz , Introduction to Logic Design, Third Edition, McGraw-Hill, 2010.
3. Johnson, Eric R., Nic Harrigan, and Mercedes Gimeno Segovia. Programming Quantum Computers: Essential Algorithms and Code Samples. O'Reilly Media, Incorporated, 2019.
4. Quantum Computation and Quantum Information: 10th Anniversary Edition by Michael A. Nielsen and Isaac L. Chuang Publisher: Cambridge University Press
5. Scott Aaronson. 2013. Quantum Computing since Democritus. Cambridge University Press, USA.
6. N. David Mermin. 2007. Quantum Computer Science: An Introduction. Cambridge University Press, USA.
7. Bertels, K. O. E. N., Aritra Sarkar, Thomas Hubregtsen, M. Serrao, Abid A. Mouedenne, Amitabh Yadav, A. Krol, and Imran Ashraf. "Quantum computer architecture: Towards full-stack quantum accelerators." In 2020 Design, Automation & Test in Europe Conference & Exhibition (DATE), pp. 1-6. IEEE, 2020.
8. Ferrari, Davide, Angela Sara Cacciapuoti, Michele Amoretti, and Marcello Caleffi. "Compiler Design for Distributed Quantum Computing." arXiv preprint arXiv:2012.09680 (2020).
9. Heim, B., Soeken, M., Marshall, S. et al. Quantum programming languages. Nat Rev Phys 2, 709–722 (2020). https://doi.org/10.1038/s42254-020-00245-7.

Evaluation (Tentative)

Homework	15%
Quizzes	15%
Term project	20%
Midterm Exam	20% (Week 8)
Final Exam	30% (Date TBD by registrar)

List of Topics

The following schedule is tentative and subject to changes. More details will be announced in the class and course website/Blackboard

Content Outlines	
Week #	**Topic**
1	Review of complex numbers.
2-3	Complex vector space and Hilbert space.
4-5	Number theory, Integer representation, Modular arithmetic, Primes, Fermat theorem
5-6	Deterministic and probabilistic systems, Probabilistic primality test.
7-8	Quantum systems, Quantum states, Reversible and quantum gates.
Midterm Exam	**Saturday – 18 October 2025**
9-10	Quantum Circuits Simulators and Quantum programming languages (Quirk, Qiskit),
11	Classical and quantum oracles, Quantum speedup
12-13	Deutsch algorithm, Deutsch-Josza algorithm, Quantum function implementation.
14-15	Information Entropy, Super Dense Coding.
16	Revision
Final Exam	**Date will be announced by the registrar's office**