Course Overview

2020-2021 Qubit by Qubit Introduction to Quantum Computing with IBM Quantum

Course Hours

Students enrolled in this course will spend approximately 130 hours on course material over the course of the year, which comes out to approximately 5 hours a week. The actual time required will vary depending on students' skill level and aptitude.

Weekly Requirements

Each week, there are three requirements:

1. Lecture
2. Lab
3. Homework

Note: The course is entirely virtual, including lectures and labs.

Lecture

Every Sunday from 2-4pm EST, there is a 2-hour lab lecture. On average, there will be 1-hour of lecture and 1-hour of tutorial. The lectures will be co-led by Amir Karamlou and Francisca Vasconcelos. Recordings will be available for those unable to attend the live sessions. Closed captioning will also be made available in the recordings.

Lab

Labs are 1-hour long, in which a Teaching Assistant (TA) will go over students' questions, practice problems similar to the homework, and the previous weeks' homework assignments.

Homework

Each week, there will be a homework assignment related to the lecture. The homework, on average, should take students around 1 hour to complete. Homework will be released following the lecture, and they will be required to submit the homework by 2:59am EST the following Sunday. Prior to the submission deadline, students will have unlimited homework submissions. Solutions will be released following this at 3:01 am EST on Sunday.

Attendance

In terms of attendance, students are expected to attend the live lectures and lab sessions. Students are required to submit a weekly attendance quiz via Canvas in order to verify their attendance.

COURSE SYLLABUS

For a weekly breakdown of the topics that will be covered in this course, see the calendar (below).

Semester 1 focuses on the foundational math, programming, and physics concepts required to learn quantum computing. For some, this may be a review. We aim to relate as much of the content to quantum computing as possible. Topics include:

- Classical Computing
- Quantum Computing in the Abstract
- Math: Introduction to Vectors and Complex Numbers, Probability
- Math for Quantum Mechanics
- Introduction to Python Programming

Semester 2 focuses on quantum mechanics, quantum information, and quantum algorithms. Topics include:

- Quantum Mechanics
- The Qubit and Bloch Sphere
- Gates, Measurements and Quantum Circuits
- Quantum Key Distribution
- Superdense Coding + Quantum Teleportation
- Classic Algorithms
- Deutsch-Jozsa Algorithm, Grover's Algorithm, VQE & QAOA
- Experimental Metrics and Implementation

CALENDAR

Week		Date + Time	Event
Week 0: 10/11-10/17	**Orientation**	10/11/20: 2-4pm EST	Lecture
		10/17/20: 12-1pm EST	Panel Discussion with TAs
Week 1: 10/18-10/24	Classical Computing	10/18/20: : 2-4pm EST	Lecture
		Various times	Lab
Week 2 10/25-31	Quantum Computing in the Abstract	10/25/20: 2-4pm EST	Lecture
		Various times	Lab
Week 3 11/1-11/7	Intro to Vectors + Complex Numbers	11/1/20: 2-4pm EST	Lecture
		Various times	Lab
Week 4 11/8-11/14	More Vectors + Matrices	11/8/20: : 2-4pm EST	Lecture
		Various times	Lab
Week 5 11/15-11/21	Intro to Probability + Mathematics for Quantum Mechanics Pt. 1	11/15/20: 2-4pm EST	Lecture
		Various times	Lab
Week 6 11/22-11/28	Introduction to Python (Part 1)	11/22/20: 2-4pm EST	*Optional Lecture**
		No Lab (Thanksgiving)	
Week 7 11/29-12/5	Introduction to Python (Part 2)	11/28: 2-4pm EST	*Optional Lecture**
		Various times	Lab
Week 8 12/6-12/12	Mathematics for Quantum Mechanics Pt. 2	12/6/20: 2-4pm EST	Lecture
			Lab
Week 9 12/13-12/19	Mathematics for Quantum Mechanics Pt.	12/13/20: 2-4pm EST	Lecture

	3 + Second Semester Overview	Various times	Lab
WINTER BREAK: 12/20/20 - 1/9/21			
Week 10 1/10-1/16	Math for Quantum Mechanics Review	1/10/21: 2-4pm EST	Lecture + IBM Quantum Panel
		Various times	Lab
Week 11 1/17-1/23	Quantum Mechanics (Part 1)	1/17/21: 2-4pm EST	Lecture
		Various times	Lab
Week 12 1/24-1/30	Quantum Mechanics (Part 2)	1/24/21: 2-4pm EST	Lecture
		Various times	Lab
Week 13 1/31-2/6	Quantum Mechanics (Part 3)	1/31/21: 2-4pm EST	Lecture
		Various times	Lab
Week 14 2/7-2/13	The Qubit & Bloch Sphere	2/7/21: 2-4pm EST	Lecture
		Various times	Lab
Week 15 2/14-2/20	Qiskit Intensive	2/14/21: 2-4pm EST	Lecture
		Various times	Lab
Week 16 2/21-2/27	Gates, Measurement, & Quantum Circuits Pt 1	2/21/21: 2-4pm EST	Lecture
		Various times	Lab
Week 17 2/28-3/6	Gates, Measurement, & Quantum Circuits Pt 2	2/28/21: 2-4pm EST	Lecture
		Various times	Lab
Week 18 3/7-3/13	Quantum Key Distribution (BB84) + Final Project Introduction	3/7/21: 2-4pm EST	Lecture
		Various times	Lab
Week 19 3/14-3/20	Superdense Coding + Quantum Teleportation	3/14/21: 2-4pm EST	Lecture

		Various times	Lab
Week 20 3/21-3/27	Classic Algorithms Overview + Deutsch-Jozsa Algorithm	3/21/21: 2-4pm EST	Lecture
		Various times	Lab
Week 21 3/28-4/3	Experimental Metrics & Implementations Pt 1 [Metrics - T1, T2]	3/28/21: 2-4pm EST	Lecture
		Various times	Lab
SPRING BREAK: 4/4/21 - 4/17/21			
Week 22 4/18-4/24	Experimental Metrics & Implementations Pt 2	4/18/21: 2-4pm EST	Guest Lecture
		Various times	Lab
Week 23 4/25-5/1	Grover's Algorithm	4/25/21: 2-4pm EST	Lecture
		Various times	Lab
Week 24 5/2-5/8	VQE & QAOA	5/2/21: 2-4pm EST	Lecture
		Various times	Lab
Week 25 5/9	Course Wrap Up	5/9/21: 2-4pm EST	Faculty/Industry Panel
		No Lab	

**These lectures are optional if you have previous coding experience in Python through foundational programming concepts and basic data structures. Topics you must be well-versed in include: variables, loops, functions, and lists.*

PEOPLE

Qubit by Qubit (QxQ)

QxQ is an initiative by The Coding School (TCS), a 501(c)(3) tech education nonprofit dedicated to preparing students with the technical skills for the future of work. To learn more about TCS, visit: www.codeconnects.org

Administrators

Kiera Peltz (she/her/hers), Executive Director
Kiera is the founder of The Coding School and executive director of Qubit by Qubit. She is a Gates-Cambridge and Schwarzman Scholar and holds an MPhil in Sociology and MMSc in Economics and Business from the University of Cambridge and Tsinghua University, respectively. She graduated magna cum laude from Brown University.

Rachel Zuckerman (she/her/hers), Program Director
Rachel is the Director of The Coding School's Qubit by Qubit quantum initiative. She's interested in using technology to improve government services and increase social mobility. Previously, Rachel worked at the Michigan Department of Health and Human Services, focused on behavioral health policy and then COVID-19 response in her home state. In addition, she worked in workforce development for the City of Detroit, helping eliminate barriers to employment for Detroiters. Rachel earned her undergraduate degree from the University of Iowa, where she had the privilege of serving as Student Body President, and her master's degree in Beijing, China, representing the United States as a Schwarzman Scholar.

Kiley Foster (she/her/hers), Program Manager
Kiley is the Program Manager for Qubit by Qubit, and has worked for The Coding School's development/fundraising team. She holds an MA in Near Eastern Studies from Cornell, where she will also receive her PhD in December 2020. At Cornell, she led courses and workshops on writing, history, and pedagogy. She graduated Phi Beta Kappa from the University of Oklahoma.

Instructors

Francisca Vasconcelos (she/her/hers)
Francisca Vasconcelos is currently pursuing an MSc in Statistical Sciences at the University of Oxford, through the Rhodes Scholarship. She graduated from MIT in 2020 with a BS in Electrical Engineering, Computer Science, and Physics. Through undergraduate research in the MIT Engineering Quantum Systems group as well as internships at Rigetti Computing and Microsoft Research Quantum, Francisca has worked on quantum measurement of superconducting devices, statistical learning for error mitigation, machine learning for quantum, and radiation studies. Furthermore, Francisca is very interested in education, serving as a

course instructor for MIT's winter-term Intro to Quantum Computing course for two years and leading The Coding School's QxQ academic team.

Amir Karamlou (he/him/his)
Amir is a graduate fellow in the EECS department at MIT. He graduated from MIT with a B.S. in Physics and Electrical Engineering and Computer Science and an M.Eng in Electrical Engineering and Computer Science in 2018. His research motivation is to use quantum mechanics to gain an advantage over current technology and protocols. As an undergraduate he worked with Dirk Englund on control and high fidelity readout of NV centers in diamond.

Head TA

Akshay Agarwal (he/him/his)
Akshay is a postdoctoral researcher in the Research Laboratory for Electronics at MIT. In his research, he applies principles of quantum mechanics to improve the efficiency of electron microscopy and make the technique applicable to live biological samples. Akshay obtained his PhD. in Electrical Engineering and Computer Science from MIT in September 2020, and his B. Tech. and M. Tech. in Electrical Engineering from IIT Bombay in 2014. Outside of his research, Akshay enjoys teaching, writing, and playing the violin.

Advisors

Clarice Aiello

UCLA ECE Faculty

James Whitfield

Dartmouth Physics Faculty

Scott Aaronson

UT Austin CS Faculty

Spiros Michalakis

Caltech IQIM Researcher

Ray Laflamme

UWaterloo IQC Director

Umesh Vazirani

UC Berkeley BQIC Director

William Oliver

MIT CQE Director

Abraham Asfaw
Global Lead, Quantum Education & Open Science at IBM Quantum