Obtaining School Credit

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

Updated: January 21, 2021

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SUMMARY

- Qubit by Qubit is an introductory college-level quantum computing course taught by MIT and Oxford quantum scientists in collaboration with IBM Quantum.

- It runs from October 2020-May 2021 and consists of weekly lectures, labs, and homework assignments. These will total 140+ hours.

- This is a University of California (UC) A-G approved course for high school transcript credit. It has been approved with a “G” rating which means it is approved by the UC system as a College Preparatory Course.

- We are currently in the process of obtaining accreditation through the Western Association of Schools and Colleges (WASC). Results will be available in late January 2021. If accreditation is approved, it will be applied retroactively to when the process began (September 2020).

- Upon completion of the course, we will provide students with a Certificate of Completion. We can also offer a transcript/grade report.

- We are not a degree-granting institution and cannot provide credit for the course ourselves: whether or not to grant course credit is the decision of a student’s school.

- By default, the course is graded pass/fail. If students are receiving credit through their school, however, we can allow a special option to receive a letter grade instead.

CONTACT INFORMATION

We are happy to speak with you personally about Qubit by Qubit and offering course credit. Please contact us at one of the below email addresses, or at the office phone number.

NAME	CONTACT INFO
Qubit by Qubit Office Phone	424-310-8999
Qubit by Qubit Office Email	quantum@the-cs.org
Kiley Foster (Program Manager)	kiley@the-cs.org

STUDENT GUIDE: OBTAINING COURSE CREDIT

If you are a student seeking high school credit for Qubit by Qubit, please follow the steps below. Note: The Coding School (TCS) cannot guarantee that your school will agree to provide you course credit. The decision is ultimately up to your high school.

Steps:

1. **Contact your school:** Talk to a school official about obtaining school credit for outside courses. If you are unsure who to talk to, we recommend starting with your guidance counselor.

2. Bring this informational packet with you. It contains most of the course information that is commonly requested by high schools.

3. If you or your school needs additional information from us, please contact our program manager, Kiley (kiley@the-cs.org). You can also call the Qubit by Qubit office at 424-310-8999.

4. If your school agrees to provide you with course credit, please fill out this form: https://airtable.com/shrybP74wyJ9KgfFt

5. Here are some additional questions you should discuss with your school:
    a. In order to get course credit, do I need to take this course for a letter grade? Or can I take it pass/fail?
    b. How and when should course grades be sent to you? Can I give you a TCS transcript, or does the TCS office need to send it to you through an official email address?

SCHOOL GUIDE: GRANTING COURSE CREDIT

If you are considering granting your student course credit for completion of Qubit by Qubit, please follow the steps below.

Steps:

1. Review the information presented in this packet.

2. Upon completion of this course, we will provide your student with a certificate of completion. We can also provide a transcript/grade report (see below).

3. If you need additional information from us, please contact our program manager, Kiley (kiley@the-cs.org). You can also call the main Qubit by Qubit office at 424-310-8999.

4. If you are able to provide your student with course credit, please have them fill out the following form: https://airtable.com/shrybP74wyJ9KgfFt

5. The form asks for the following information:
    a. Student name and contact information
    b. Student's Qubit by Qubit ID number (provided earlier to the student by us)
    c. School official's name and contact information
    d. Documents that you need us to provide you with (certificate of completion and/or transcript).
    e. Where we should send the above information
    f. When course information needs to be sent (either at the end of each semester or the end of the year).
    g. Grading basis (pass/fail or letter grade). For a detailed grading breakdown, see the below section on Grades.

School Partnerships

In addition to making these resources available so that individual students can obtain credit through their school, Qubit by Qubit offers official school partnerships. Our partner schools have enrolled multiple students in the course (either as an afterschool activity or as for-credit class). Each school also provides an advisor for this course to help facilitate students' learning and ensure accountability. If you are an educator and interested in learning more about these partnerships, please contact Kiley (kiley@the-cs.org) and/or fill out this form to be added to our mailing list. We will send you updates on informational sessions, teacher professional development opportunities, and enrollment information for the course in 2021-2022.

COURSE OVERVIEW

About The Coding School

Qubit by Qubit is the quantum computing education initiative of **The Coding School**, a 501(c)(3) organization that aims to empower the next generation through computer science education. Founded by a Brown University undergraduate in 2014, The Coding School has grown into an international organization with 800+ instructors and tens of thousands of students from over 100 countries participating in our programs. To ensure our programming and teaching is of the highest quality, we're partnered with a number of internationally- renowned educational institutions, including: Brown University, Middlebury, UCLA, USC Viterbi School of Engineering, and Villanova University.

About the Course

The Coding School's Qubit by Qubit's *2020-2021 Introduction to Quantum Computing* is offered in partnership with IBM Quantum. This is a first-of-its-kind course aimed to make quantum computing accessible to students as young as high school. Up until now, quantum computing is often taught at the university, if not graduate school, level. Because of the increasingly important role quantum computing will play over the next decade and beyond, we believe it's critical early access to quantum computing education is widely available, which is why we created this course.

This year-long course is the equivalent of a one-semester college-level quantum computing course. In Semester 1, students will learn the foundational math and programming concepts necessary for quantum computing, including important linear algebra concepts. Once these are taught, Semester 2 will focus on quantum mechanics, quantum information and computation, and quantum algorithms. Students will use Qiskit and IBM Quantum Experience to run quantum simulations on real quantum hardware. By the end of the course, students will have foundational knowledge in quantum computing at the collegiate-level. Through this course, students will have the opportunity to attend panel discussions by leading quantum researchers, engage with future quantum leaders, and run simulations on real quantum computers.

Objectives

Train the future diverse quantum workforce

- Introduce students to the field of quantum computing
- Develop foundational skills, including math, computer science, and physics, necessary to pursue quantum computing
- Prepare students with tangible and real-world skills
- Deepen understanding of quantum applications
- Learn about career opportunities in quantum

- Increase diversity in the field
- Introduce students to industry and academic leaders in quantum
- Form a global cohort of future quantum leaders

Prerequisites

This course is intended to be accessible to anyone with knowledge of trigonometry. More advanced knowledge will still be required, but it is our aim to teach students everything beyond this that they need to know.

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-Josza 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 Overiew + Deutsch-Josza 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.*

COURSE ACCREDITATION

University of California A-G approved course for high school transcript credit.

More information can be found: https://hs-articulation.ucop.edu/guide/

In summary, the UC A-G accreditation process is to certify a course is worthy of being designated as official high school credit and credit that the University of California system will accept as valid high school transcript credit. The Quantum Computing Course Qubit by Qubit has been approved with a “G” rating which means it is approved by the UC system as a College Preparatory Course.

Now that the course is UC A-G approved, a student who takes the course may ask their CA high school* to receive transcript credit for this course. The process is simple. The high school would need to:

1. Add the course to their A-G list; OR
2. Grant the student Principal Certification for the course.

The high school can model their request after the Glendale Unified School District (GUSD), which is the first school district to approve the course through the UC A-G process. GUSD’s submission to UC A-G for this course is made public, so it is easy for future high schools to model after.[1] The course will encompass 90 hours of instruction and an additional 60-120 hours of anticipated homework for a total of 150 - 270 hours of learning. A student would be eligible to receive between 5-10 transcript credits (1 - 2 semesters) - at the high school’s discretion. GUSD is giving their students 5 credits (1 semester) of high school credit.

*UC A-G accreditation is for California high schools and online high schools that serve California students.

The Accrediting Commision for Schools Western Association of Schools and Colleges (WASC).

TCS organization is in the process of becoming accredited by WASC. This would mean all courses TCS teaches would qualify for students to receive K-12 transcript credit. More information can be found here: https://www.acswasc.org. Upon completing one of TCS’s courses, a student would simply ask their school to provide transcript credit for the accredited course. We will know in January 2021 and accreditation is retroactive to any course that a

[1] For GUSD’s course model, please visit: https://hs-articulation.ucop.edu/agcourselist/. Select ‘courses' and search for “INTRODUCTION TO QUANTUM COMPUTATION”.

student has been taking since the process began (Sept 2020). We have been encouraged that WASC accreditation for TCS is likely especially with the UC A-G accreditation in place.

In January, once the WASC accreditation has been approved, the WASC team will work with high schools, providing additional information and how a school can offer credit to their students for TCS courses.

Note: If approval will only be granted once we receive WASC accreditation, please note that on the form above.

GRADES

The course is graded Pass/Fail, but if schools require a letter grade, they are available at the end of each semester or at the end of the year. Fall semester grades are available to be sent to schools in January, and spring semester grades will be sent in May.

TCS Principles for Grading:

- The course is Pass/Fail.[2] A score of 60% is a passing grade. Grades will be determined each semester.
- TCS recognizes that remote learning presents unique challenges. Likewise, we know that some students may have barriers to accessing stable internet, lack stable housing, or face other challenges that impede their learning. Increasing diversity in STEM is a core part of our mission, and we will work with students to the greatest extent possible.
- Our grading policy is flexible and subject to change based on student performance.
- Most importantly, we want our students to succeed!

Components of Your Final Grade

Homework	50%
Lab Attendance	40%
Complete required course evaluations (completion grade)	10%

- **Homework**: Based on the breakdown, students must, on average, score 20% on the homework to pass the course, assuming they complete the course evaluations and attend the labs. Students are excused for one homework assignment per semester.
- **Lab attendance:** Unless you have noted that you are unable to attend the weekly lab, attendance at the labs is mandatory. There will be a check-in and check-out process each week. You will only need to be marked for one or the other. *If you are not able to attend any session, we will provide instructions to follow in the recording each week.*
- **Course evaluations:** There will be a pre-course evaluation, mid-course evaluation (in December 2020), and end-of-course evaluation in May 2021. These are completion grades - we're looking for feedback and to see how the course went!

[2] *Except for students receiving letter grades through their school. If this is the case, school partners need to communicate the information with us.*

GRADE REPORT

In addition to a Certificate of Completion, we can provide students seeking credit from their schools with the below transcript/grade report issued by The Coding School. The Coding School is not a degree-granting institution, and students seeking course credit must receive it from their own school. The information provided in this report is intended to help the student's school decide the type and quantity of credit to award at their discretion.

GRADE REPORT

PERSONAL INFORMATION

Surname	
Forename(s)	
Grade	
School	
Advisor	

COURSE INFORMATION

Name of accredited institution	**The Coding School**
Course Name	**Qubit by Qubit's Introduction to Quantum Computing with IBM Quantum**
Course Description	
Official Length of Course	
Instructors	
TA	

GRADES

Semester	Grade Mode	Grade
Fall 2020		
Spring 2021		

STUDENT EXPECTATIONS & RESPONSIBILITIES

Weekly Commitments & Academic Year Commitments

Students in this course have committed to attending and completing the entirety of the course, which finishes in May 2021. It is highly encouraged students attend the live lectures and labs. Each week, at a minimum, students must watch the lecture and lab, as well as complete the readings and homework assignment. Throughout the course, there will be three course evaluations, which students are required to complete.

Group Work & Plagiarism Policy:

We encourage students to work together to learn course material. We believe in a collaborative and supportive community where students learn from one another. Students are encouraged to form study groups and use online tools, like Piazza, to complete assignments. However, plagiarism will not be tolerated. Students should not share answers to assignments with one another and should not copy from their classmates. Plagiarism violations will be taken seriously and may be grounds for removal from the course.

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.

Sponsor

We are grateful for the support of our sponsor and collaborator, IBM Quantum, who has helped make this course possible and make it accessible to 5,000 students.

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.

FAQ

1. What should I do to get college credit instead of high school credit?
    - The process is the same as outlined above in this informational packet. First, you need to talk to a college official (probably your guidance counselor). They will be able to tell you if they can provide you with course credit, and will guide you through the steps you need to take. Note that this year-long course is the equivalent of a single-semester college course.

2. What if I'm outside the US?
    - Some of the information in this packet might not be as relevant to you, such as accreditation details. However, you still need to speak to your school in order to find out what they would need to give you course credit.

3. Are other schools offering course credits to their students?
    - Yes. We currently have students who will be receiving credit through several dozen schools (from multiple US states as well as schools in India and Taiwan).

4. Who issues the course transcript/grade report?
    - The grade report is issued by The Coding School, Qubit by Qubit's parent organization.

5. My school won't give me credit, but I would still like a copy of the grade report. Is this possible?
    - All students will receive a Certificate of Completion at the end of the course (in May). Due to the size of the course, we are unable to guarantee grade reports for all students. However, if this is something that would be helpful for you, please get in touch with us in May and we will see what we can do.