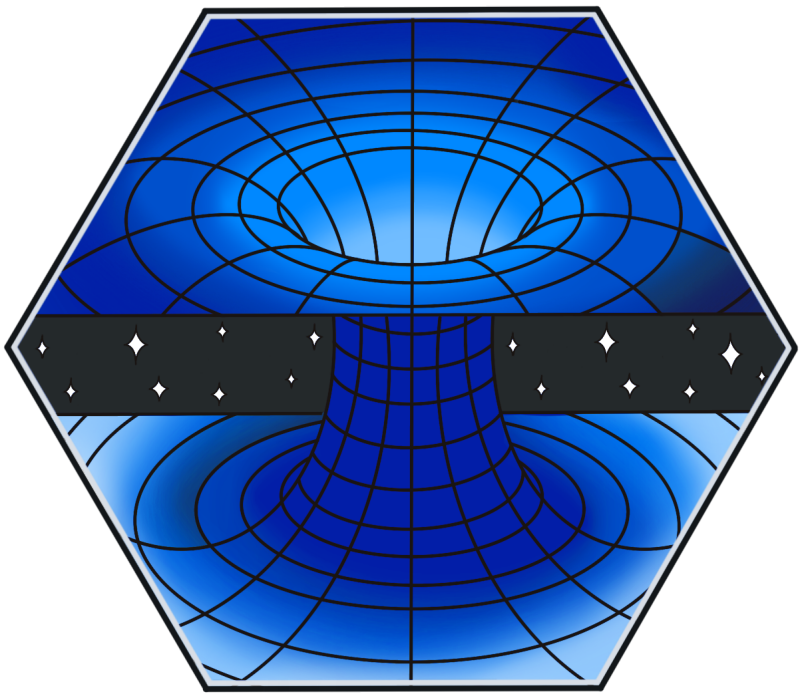
Workbook 2

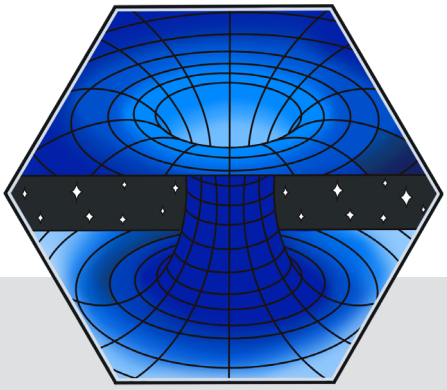
Qiskit | Quantum Explorers

A Self-Paced Quantum Learning Journey



Achievement:
TIME TRAVELER

Quantum Error Correction & Mitigation



QUANTUM ERROR CORRECTION & MITIGATION

Achievement to unlock: Time Traveler
Remember when time went wibbly wobbly? Oh, it hasn't happened yet.

You notice some curious anomalies and apparent glitches aboard your starship. The dessert you saved for later in your private quarters' fridge hasn't been baked yet. According to the ship's Earth history archives, the first moon landing took place in the 18th century. Your cargo is filled with items you were going to collect in two weeks.

Your instruments reveal a noisiness to your timeline, unwanted contributions from neighboring timelines that should be independent from your own. You suspect this must have somehow been caused by that eerie-looking nebula you passed through not too long ago.

(Share the curious and potentially humorous glitches and anomalies you observe aboard your starship in the #space-exploration channel on Discord!)

Complete this learning module to correct your timeline, and gain the rank of Time Traveler.

In this module you will:

- Understand why our current-day quantum computers are noisy (i.e. error-prone).
- Know what quantum error correction and mitigation are and the importance of them.
- Implement basic quantum error correction and mitigation techniques using Qiskit.

SYLLABUS

Checklist of tasks to complete and materials to learn

Warm-up Activities

- [ ] **LIVE EVENT: Badge Kick-off - Quantum Error Correction & Mitigation**

  Date: August 3, 2023 [time] [video link]
  An introductory lecture providing basic and easy-to-understand definitions, along with an explanation of how the content in this syllabus flows.

- [ ] **VIDEO: Noisy Real Hardware - Noise in Quantum Computers - Part 1 [**link**]**

  Introduction to noisy quantum computers and each source type of noise. (Timestamp: 00:00 to 17:35)

- [ ] **ARTICLE: How I Use Quantum Computing to Create Bubble Art [**link**]**

  A fun article visually showing noise in quantum computers while explaining why noise exists in quantum computers.

- [ ] **ARTICLE: What's the difference between error suppression, error mitigation, and error correction? [**link**]**

  Introductory article on error correction and mitigation and the differences between them.

- [ ] **ARTICLE: IBM hopes a new error mitigation technique will help it get to quantum advantage [**link**]**
  An introductory article on why error mitigation is important for nearer-term quantum computing applications.

Online Version of Syllabus

SYLLABUS (CONT'D)

Main Activities

- **VIDEO: Noisy Real Hardware - Noise in Quantum Computers - Part 1 [link]**

  A deeper dive into coherent noise. Watch from timestamp 17:35 to the end of the video. (Note: for 33:24 - 43:43 and 47:18 - 51:02, focus less on understanding the maths and more on the main messages.)

- **VIDEO: Noisy Real Hardware - Noise in Quantum Computers - Part 2 [link]**

  A deeper dive into projection noise. (Note: for 8:56 - 17:20 and 37:46 - 57:14, focus less on completely understanding the maths and more on the main messages.)

- **VIDEO: Noisy Real Hardware - Noise in Quantum Computers - Part 3 [link]**

  More on projection noise, plus a deeper dive into readout error and incoherent error. For 4:41 - 15:00 and 39:49 - 50:41, focus less on completely understanding the maths and more on the main messages.

- **LAB: Circuit Optimization [link]**

  Learn some ideas behind circuit optimization and how this practice can contribute to better quantum algorithm performance. (Hint: reduce num qubits + layers.)

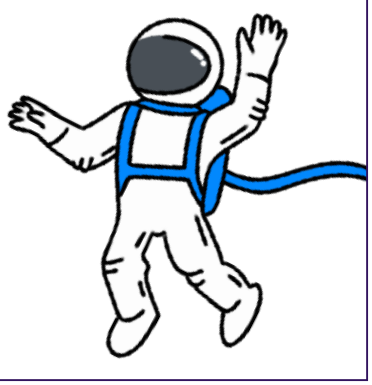
Quantum Error Correction

- **VIDEO: Quantum Error Correction Using Repetition Codes - Part 1 [link]**

  An introduction to Quantum Error Correction and Repetition Codes.

- **TEXT: Introduction to Quantum Error Correction via the Repetition Code [link]**

  Understand the intuition behind quantum error correction. Read from "Introduction" up to "Correcting errors in qubits".



SYLLABUS (CONT'D)

Main Activities

Quantum Error Mitigation

- **ARTICLE: Introducing new Qiskit Runtime capabilities — and how our clients are integrating them into their use cases [link]**

  Learn about error correction and mitigation using Qiskit Runtime.

- **VIDEO: Nick Knows - Dynamical Decoupling [link]**

  Learn about Dynamical Decoupling (DD) and how it can be used to reduce error when the qubits in your quantum circuits or algorithms have a lot of idle time.

- **VIDEO: Nick Knows - Measurement Errors [link]**

  Learn about Matrix-Free Measurement Error Mitigation (M3) and how you can implement it into your quantum programs.

- **LAB: Learn how to use Qiskit Runtime to implement Matrix-Free Error Mitigation (M3) [link]**

  Complete "4.1 Error Mitigation with the Sampler" in Part IV. Check out the extra resources below for help with the Runtime Primitives.

  [Solutions]

ADVANCED SYLLABUS

Optional advanced additional materials

Quantum Error Correction

- **TEXT: Introduction to Quantum Error Correction via the Repetition Code [link]**

  Learn about the Repetition Code with Qiskit. Read from “Correcting errors in qubits” up to “Graph Theoretic Decoding” and ensure you understand the code snippets.

- **ARTICLE: Quantum Error Correction using Qiskit [link]**

  Revise quantum error correction with this article and be introduced to surface codes.

- **VIDEO: Quantum Error Correction Using Repetition Codes - Part 2 [link]**

  A deeper dive into repetition codes, including an explanation of why it isn’t the best method of error correction to implement, and a quick introduction to how surface code works.

- **VIDEO: Quantum Error Correction Using Repetition Codes - Part 3 [link]**

  A deeper dive into surface code.

- **VIDEO: Progress Towards Quantum Error Correction with the Surface Code [link]**

  Learn more about error correction, surface code, and the recent research done in this field with this more advanced seminar.

- **LAB: Quantum Error Correction [link]**

  Complete this lab to practice your understanding of quantum error correction. Feel free to discuss your solutions with your fellow Explorers!

Quantum Error Mitigation

- **LAB: Let’s explore more quantum error mitigation techniques! [link]**

  Learn about other quantum error mitigation techniques including ZNE, T-REX, and PEC, as well as how to implement heavier error mitigation using the Estimator Primitive.

RESOURCES

Supplementary Materials

- **LAB: Qiskit Runtime and Runtime Primitives Tutorial [link]**

  Brush up on your Qiskit Runtime and Runtime Primitives knowledge with this material from the IBM Quantum Challenge Fall 2022. Read and complete Parts I, II, and III, and view here for help. [Solutions]

- **DOCUMENTATION: How to use the Qiskit Runtime Primitives with noisy simulators [link]**

UNLOCK YOUR BADGE

QUIZ

Ready to test your knowledge and unlock your achievement?

Return to the Quantum Explorers portal.

Quantum Explorers Portal

PASSED?

Congratulations!

Download your badge image using the password revealed on passing the quiz.

Then share your achievement in the #level-up channel on Discord.

Badge Download

Keep an eye on the #announcements channel for details about the next modules and Badge achievements.

NOTES