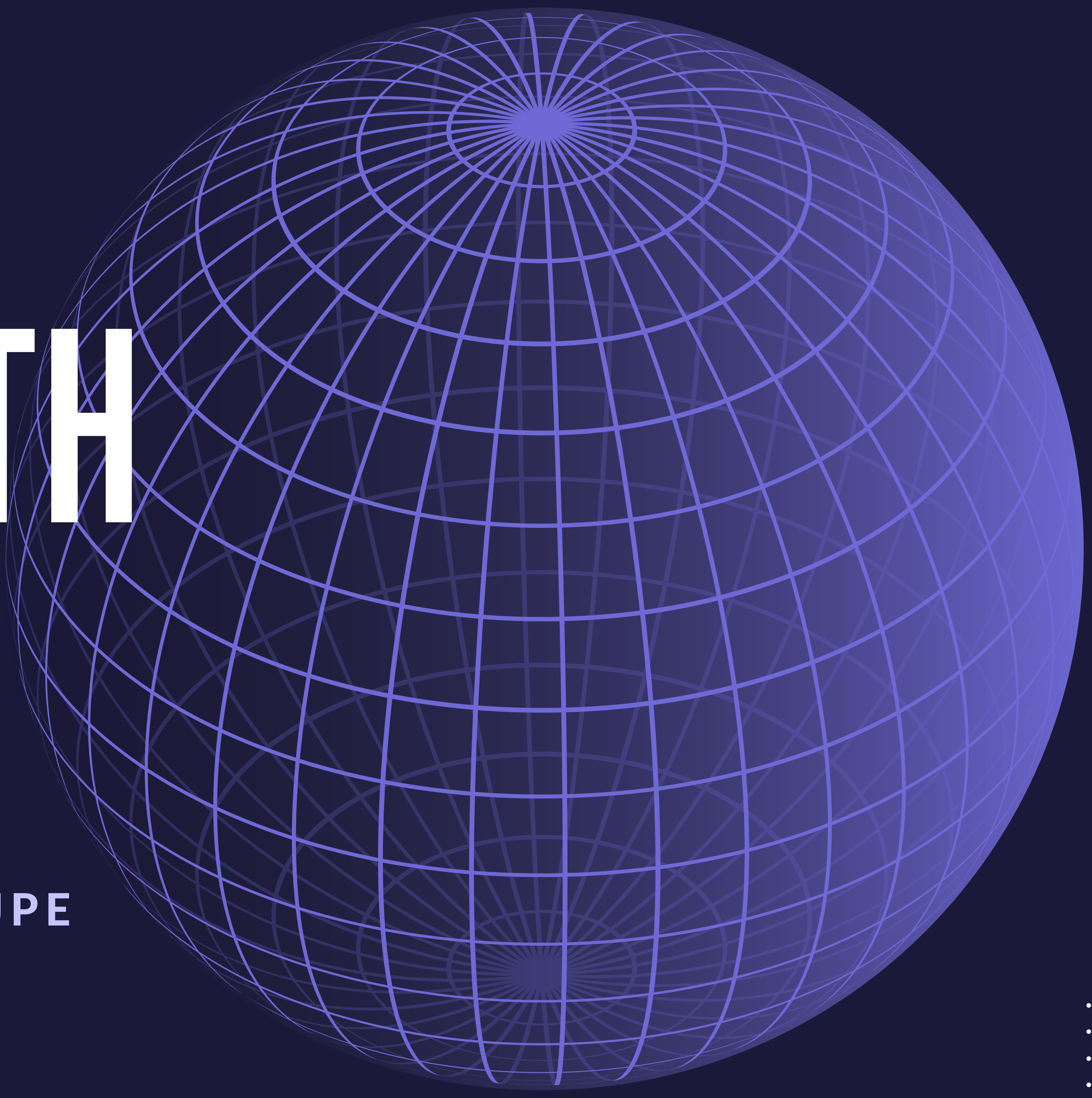
001

CODING WITH QISKIT



- VISHAL SHARATHCHANDRA BAJPE

QTANGLE | QBASICS WORKSHOP - JUNE 27 2021

WELCOME TO CLASS!

Today's Agenda

- Learning
  - Custom Rotation Gates
  - Controlled Gates
  - Importing Composer to Notebook
  - Backends
- Coding
  - Mini demonstation on Quantum Rock-Paper-Scissiors
  - Mini Demonstration on Quantum Teleportation

LEARNING

Lets go!

CUSTOM ROTATION GATES

RX - GATE

Single Qubit parameterized rotation along X axis

Pauli X = Rx (π)

$$RX(\theta) = exp(-i\frac{\theta}{2}X) = \begin{pmatrix} \cos\frac{\theta}{2} & -i\sin\frac{\theta}{2} \\ -i\sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix}$$

RY - GATE

Single Qubit parameterized rotation along Y axis

Pauli Y = Ry (π)

Hadamard = Ry (π/2) + Rx (π)

$$RY(\theta) = exp(-i\frac{\theta}{2}Y) = \begin{pmatrix} \cos\frac{\theta}{2} & -\sin\frac{\theta}{2} \\ \sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix}$$

RZ - GATE

Single Qubit parameterized rotation along Z axis

Pauli Z = Rz (π)

S gate = Rz (π/2)

T gate = Rz (π/4)

Hadamard =Ry (π/2) + Rz (π)

$$RZ(\lambda) = exp(-i\frac{\lambda}{2}Z) = \begin{pmatrix} e^{-i\frac{\lambda}{2}} & 0 \\ 0 & e^{i\frac{\lambda}{2}} \end{pmatrix}$$

THE U GATE

Generic single-qubit rotation gate with 3 Euler angles.

If theta = π, phi = -π/2 and lambda = π/2 => X gate

If theta = π, phi = 0 and lambda = 0 => Y gate

if theta = 0, phi = 0 and labda = π => Z gate

$$U(\theta, \phi, \lambda) = \begin{pmatrix} \cos(\frac{\theta}{2}) & -e^{i\lambda}\sin(\frac{\theta}{2}) \\ e^{i\phi}\sin(\frac{\theta}{2}) & e^{i(\phi+\lambda)}\cos(\frac{\theta}{2}) \end{pmatrix}$$

Additionally, it can also be proved that there exist angles α, β and γ such that U ≡ RZ (α) RY (β) RZ (γ)

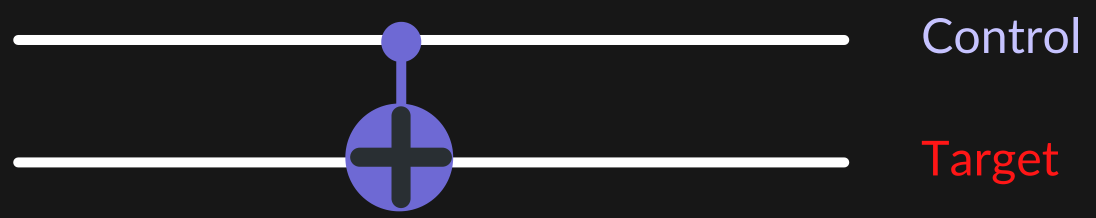
CONTROLLED GATES

CONCEPT OF "CONTROL" AND "TARGET"

The gate specified on the "Target" qubit is only applied when the "Control" qubits are in the state |1>. Any gate can be converted to a control gate in Qiskit

Lets look at this with an example on a Controlled X gate or a CNOT gate.

THE CNOT GATE

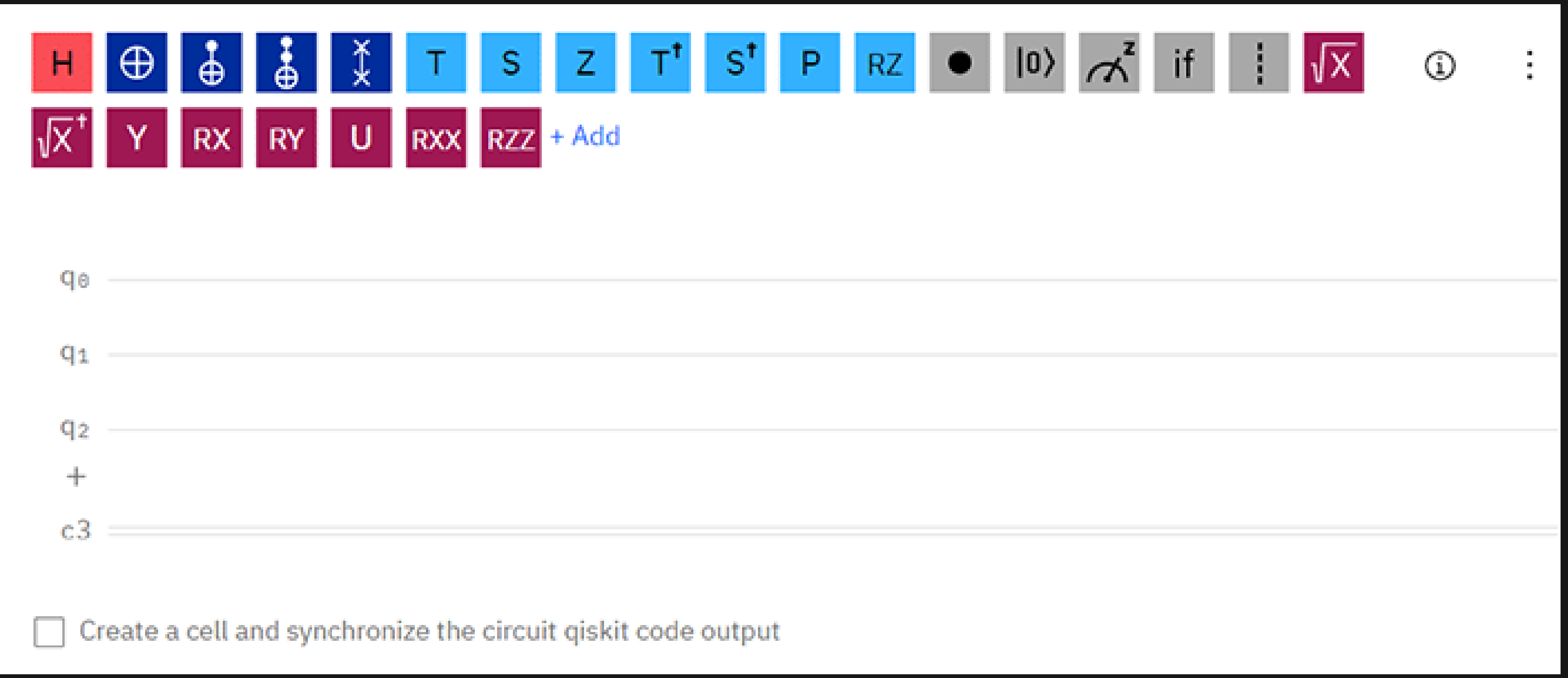


Input (Target, Control): 00 01 10 11

Output (Target, Control): 00 11 10 01

IMPORTING THE COMPOSER

Yes! You can have the qiskit composer in the notebook!



You can have the composer generate code for you while you drag and drop the gates. Bear in mind the code will follow a specific naming convention which may need to be changed to adapt to your use case.

BACKENDS

Running your circuits on Simulators or acutal Quantum hardware

SIMULATORS

QASM SIMULATOR

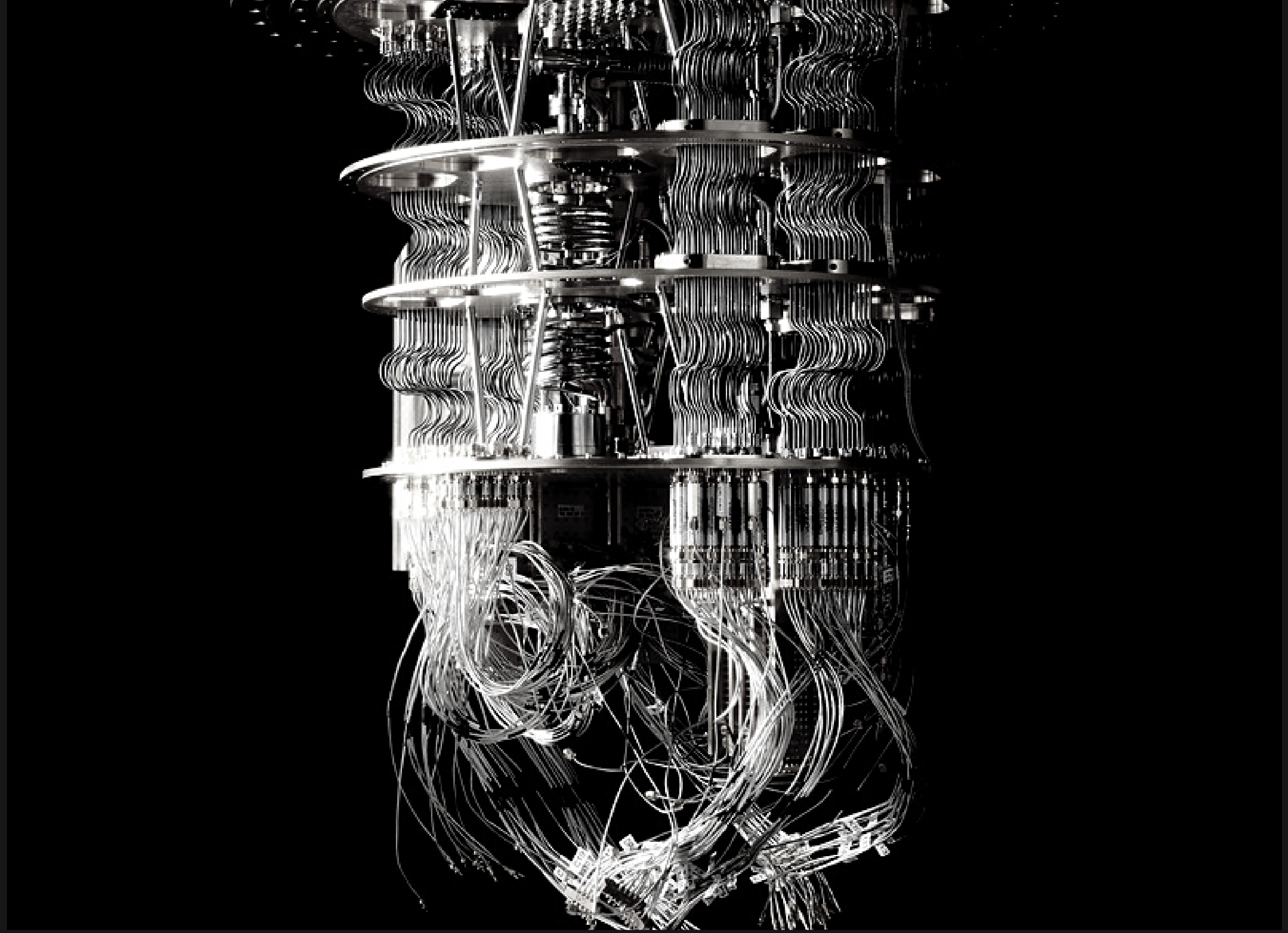
- Simulates the circuit as if it was run on a perfect quantum computer with randomness
- Provision to add in noise models to simulate real quantum backends

STATEVECTOR SIMULATOR

- Returns the state vector that describes the state of the circuit
- Function wont work on real quantum devices or even the qasm simulator

UNITARY SIMULATOR

- Returns the unitary matrix of the resulting circuit
- Function wont work on a real quantum computer.

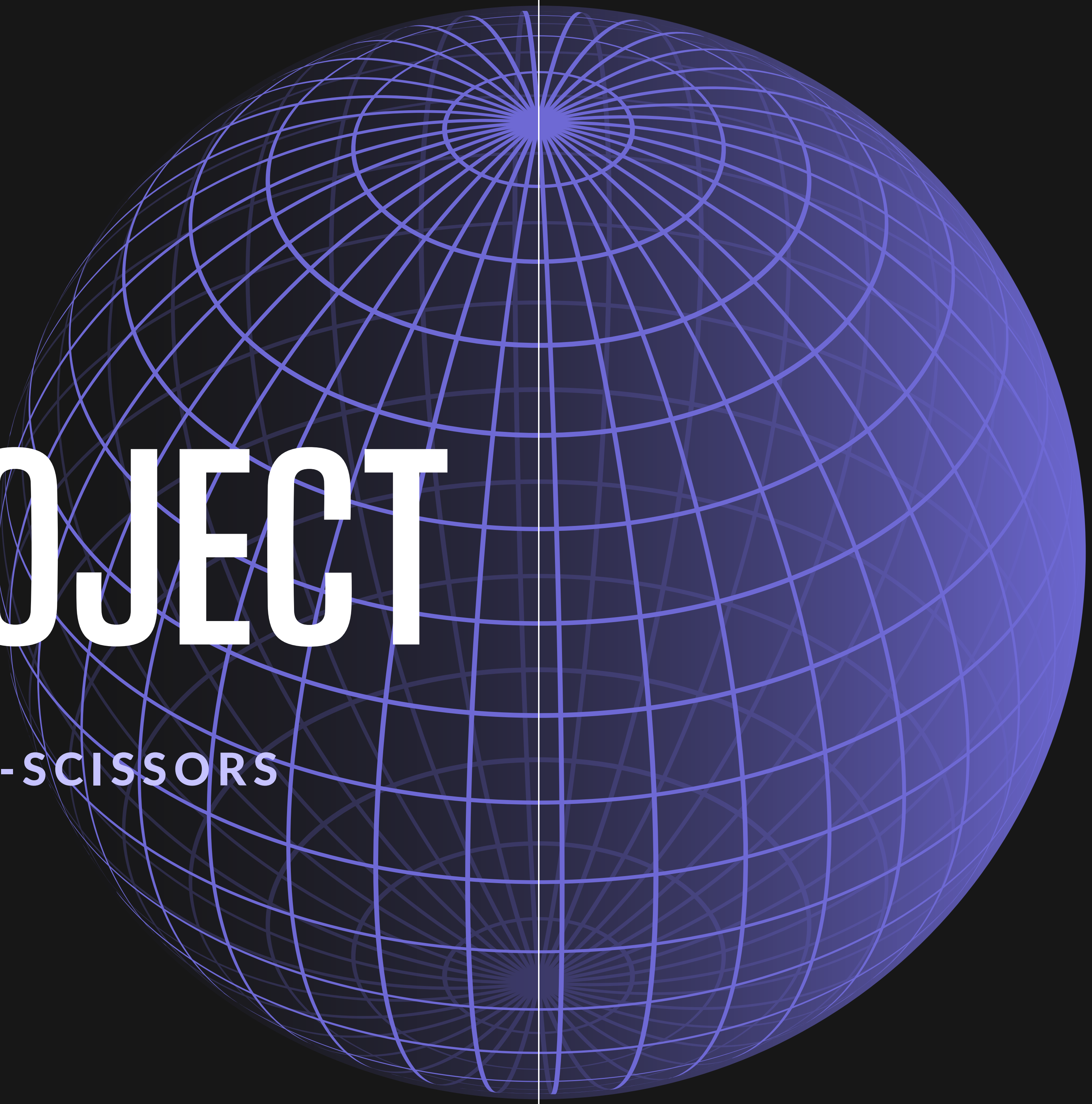


RUNNING ON A REAL QUANTUM BACKEND

IBM Quantum has a few openly accecible backends with which you can examine the results of a circuit running on a real quantum computer. We shall look at a short example in the notebook.

MINI PROJECT

QUANTUM ROCK-PAPER-SCISSORS



TRUE RANDOMNESS

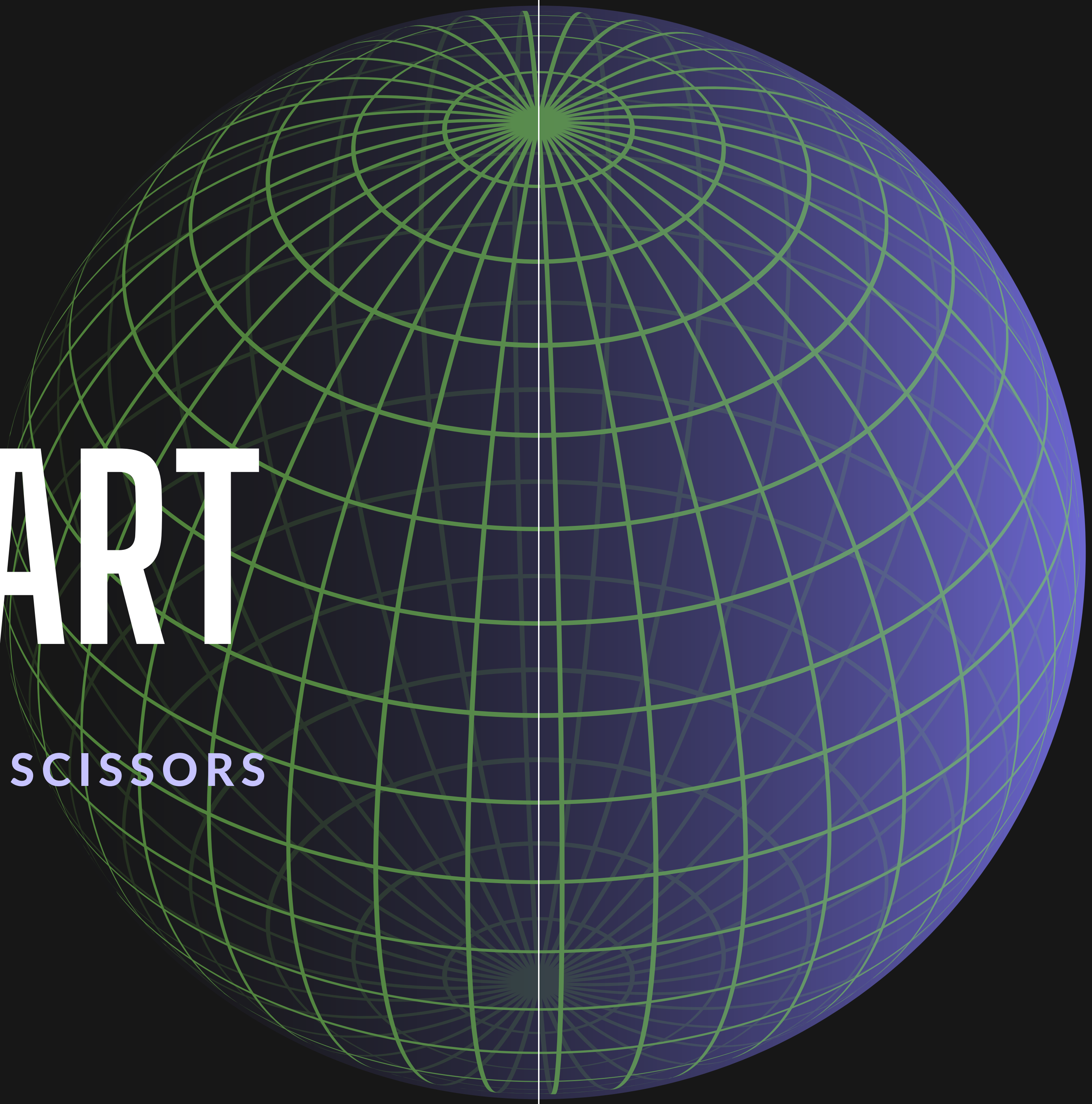
Why does it matter?

Pseudo-random numbers are an approximation of random numbers generated on software. It depends on seed factor

A truly random generator use physical unpredictable phenomenom to get numbers mapped on to it.

LETS START

QUANTUM ROCK PAPER SCISSORS



MINI PROJECT

QUANTUM TELEPORTATION

QUANTUM TELEPORTATION

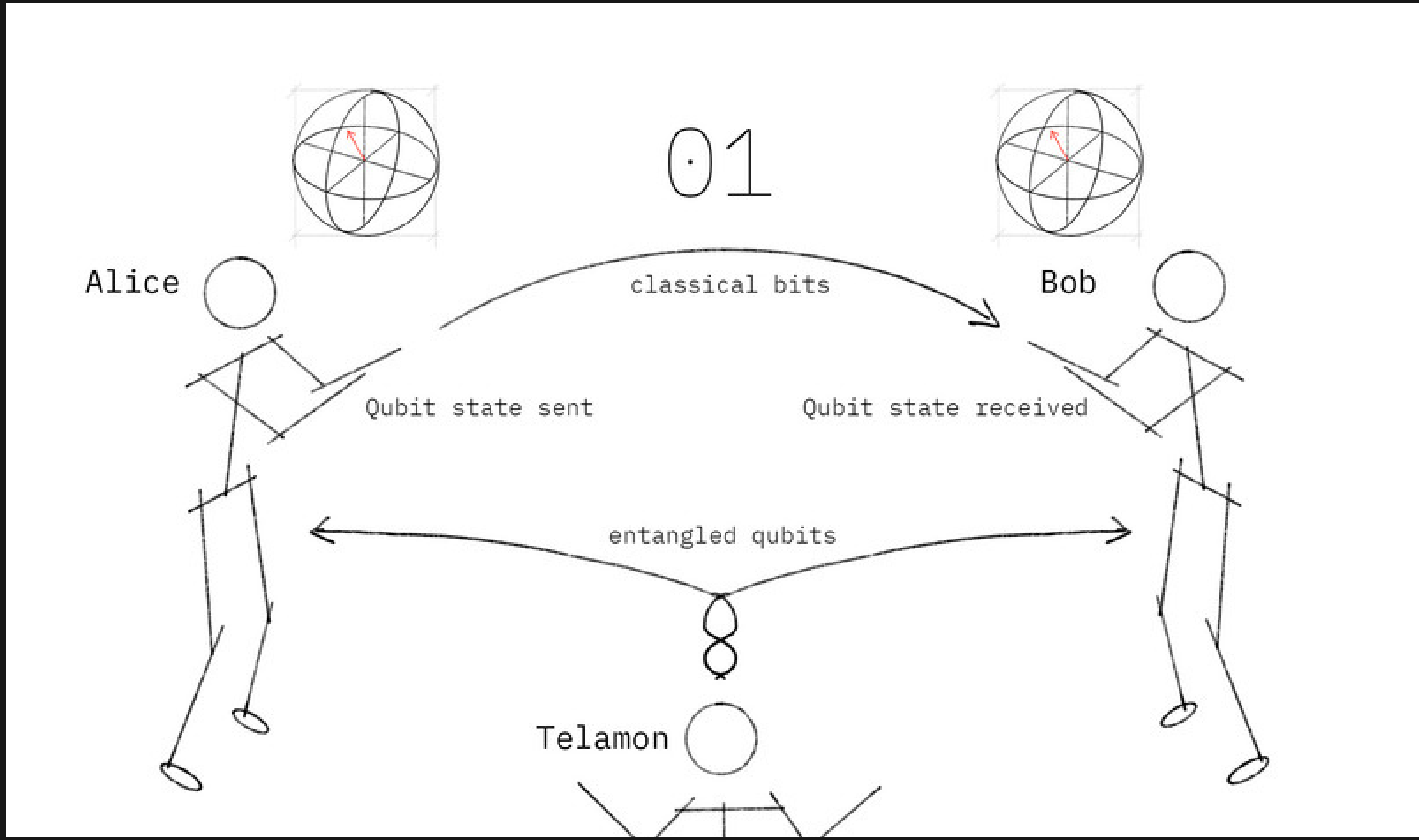
No, we cant "Scotty beam me up" yet

TELEPORTING INFORMATION STATES

Transfer quantum information from a sender at one location to a receiver some distance away.

ALICE AND BOB

The teleportation tale



QUANTUM TELEPORTATION

PROTOCOL

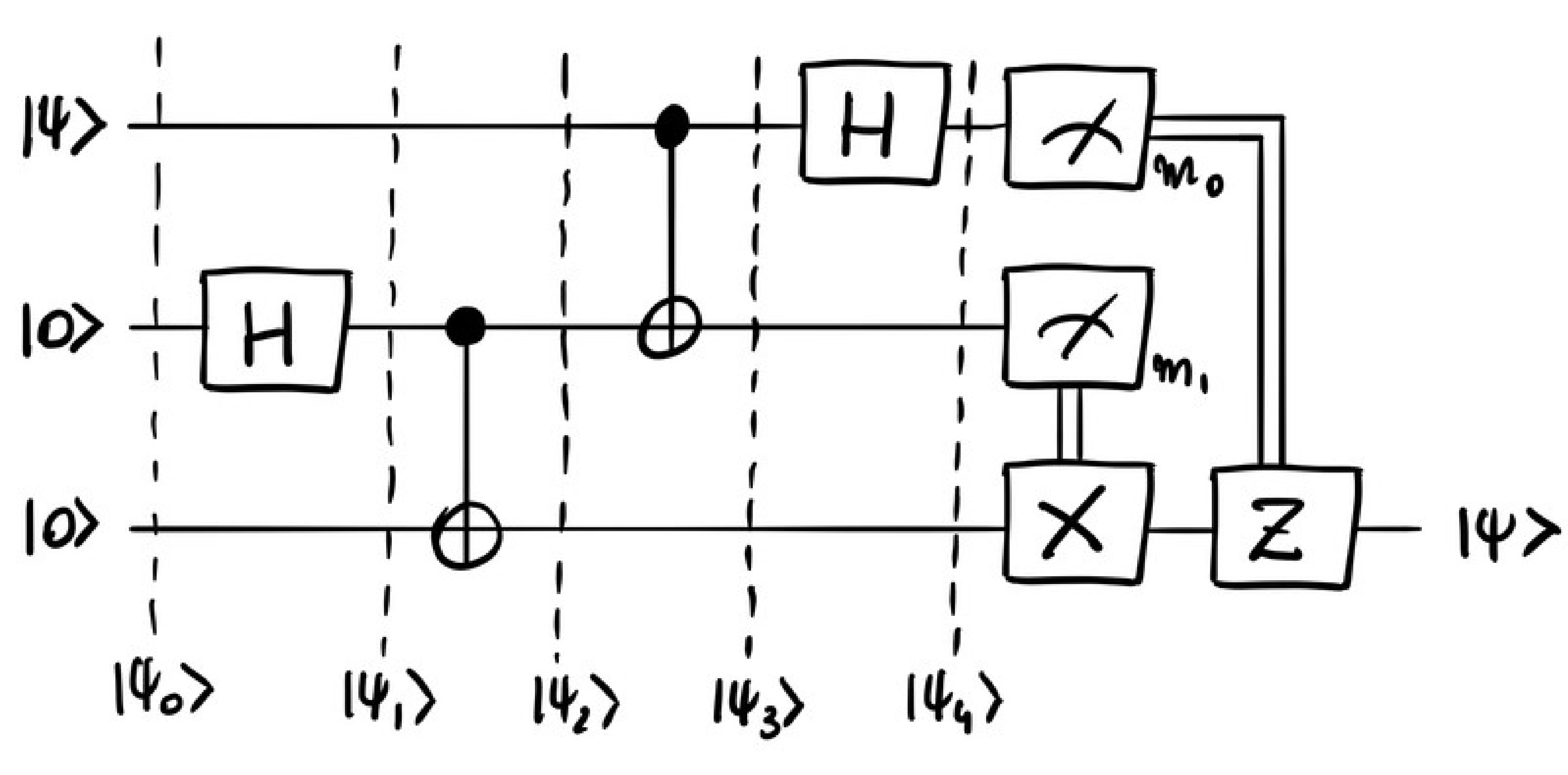
The idea is if you entangle two qubits, and perform a bell basis measurement with one of the qubits and pass on the classical information and apply conditional X and Z depending on your classical output, you essentially teleport the state to the second entagled qubit

GATES TO BE APPLIED

Bob's State	Bits Received	Gate Applied
$(\alpha\|0\rangle + \beta\|1\rangle)$	00	I
$(\alpha\|1\rangle + \beta\|0\rangle)$	01	X
$(\alpha\|0\rangle - \beta\|1\rangle)$	10	Z
$(\alpha\|1\rangle - \beta\|0\rangle)$	11	ZX

QUANTUM TELEPORTATION

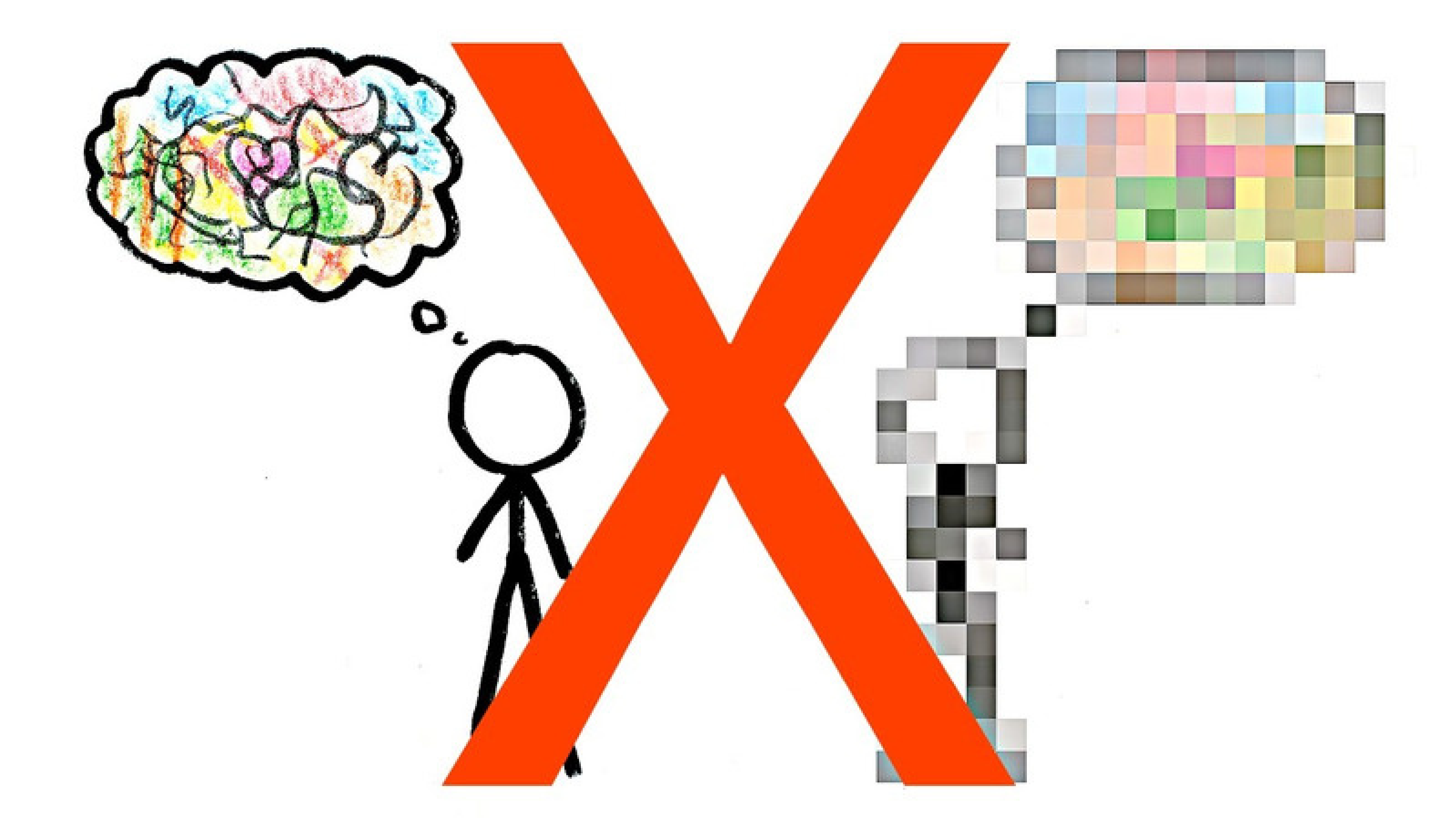
CIRCUIT REPRESENTATION OF THE TELEPORATION PROTOCOL



The No-cloning theorem

The no-cloning theorem states that it is impossible to create an independent and identical copy of an arbitrary unknown quantum state,

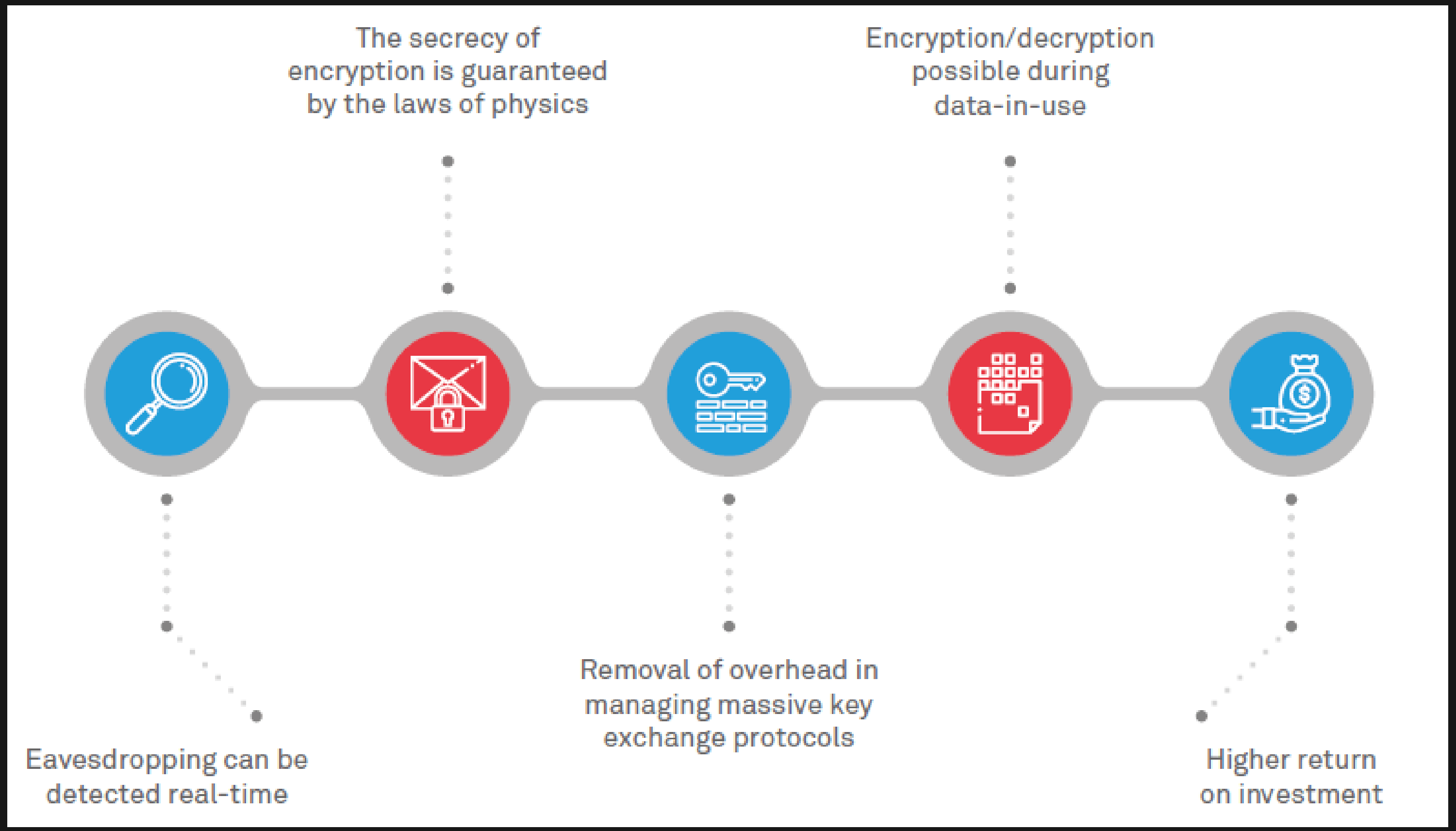
TL:DR: You cannot Ctrl + C and Ctrl + V on a quantum state



Quantum Cryptography

Quantum cryptography, or quantum key distribution (QKD) for safe transmission of data from one location to another over a fiber optic cable.

Comparing measurements of the properties of a fraction of these photons, the two endpoints can determine what the key is and if it is safe to use. Any interventions can be monitored



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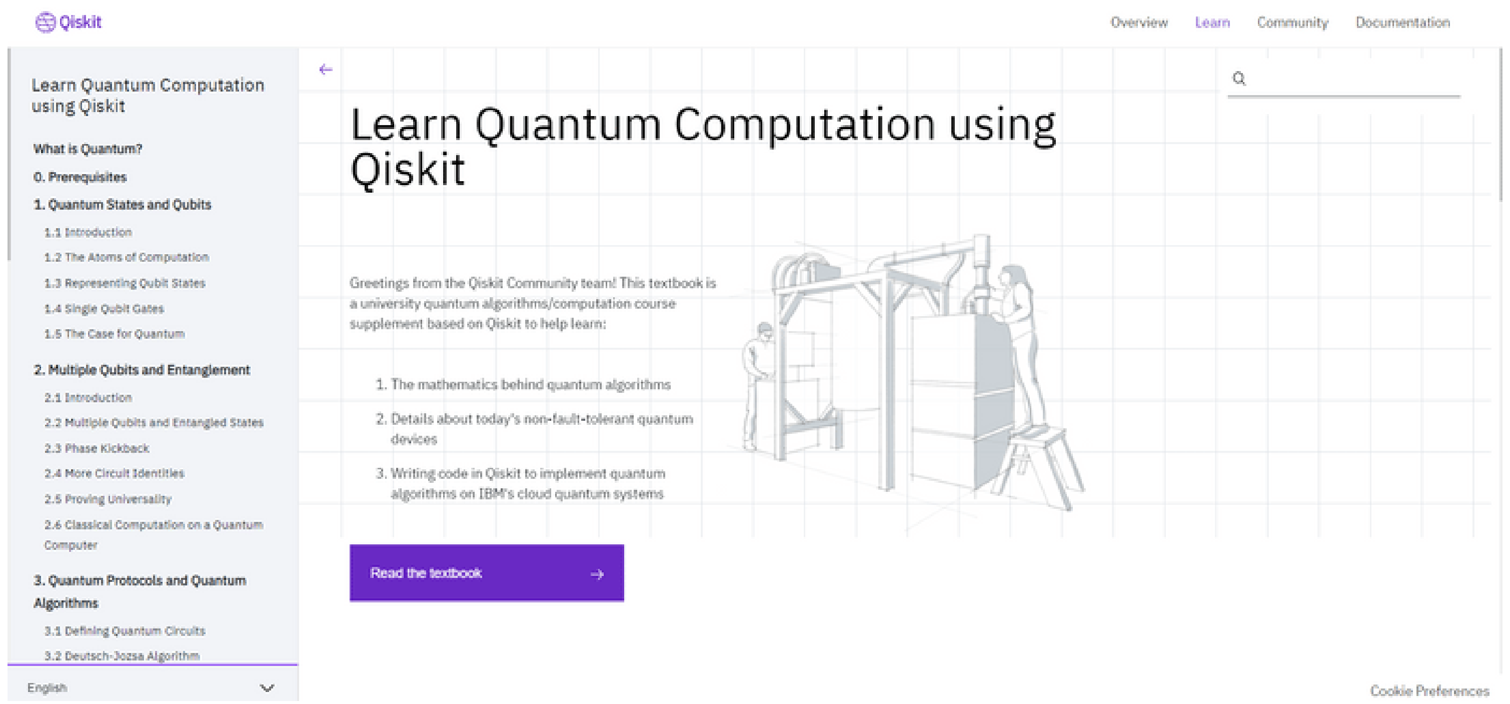
Qiskit Textbook

- Great starting point to quench your curiosity!
- Segregated material
- Suitable for any background
- Code samples
- Regularly updated with new added sections

Prerequisite: Linear Algebra



https://qiskit.org/textbook/preface.html

QBronze | QWorld

- No major prerequisites!
- Based on Qiskit
- Segregated material with a gentle introduction to the world of quantum computing
- Mentor support for live questions during the workshop
- Certificate of Diploma on completion!

https://qworld.net/qbronze62-qzimbabwe/

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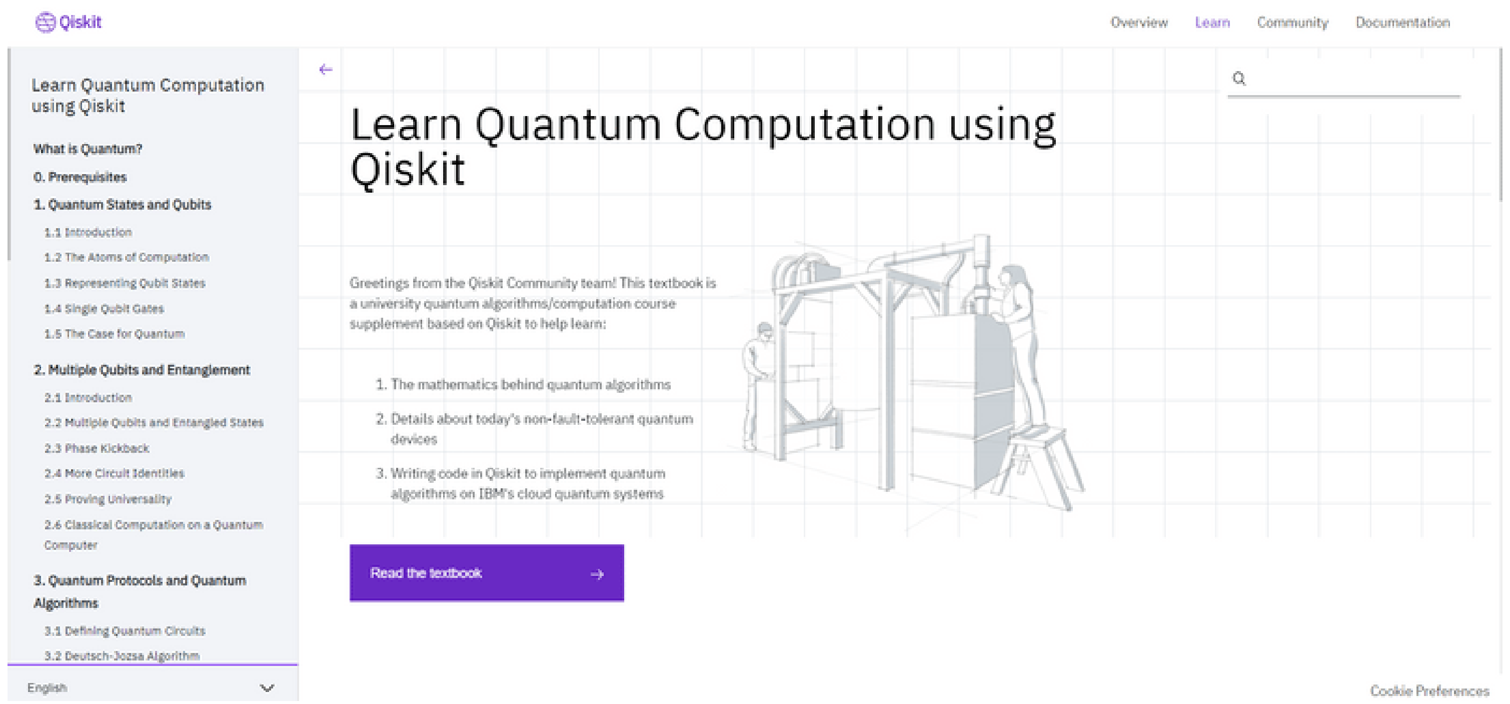

https://qiskit.org/textbook/preface.html

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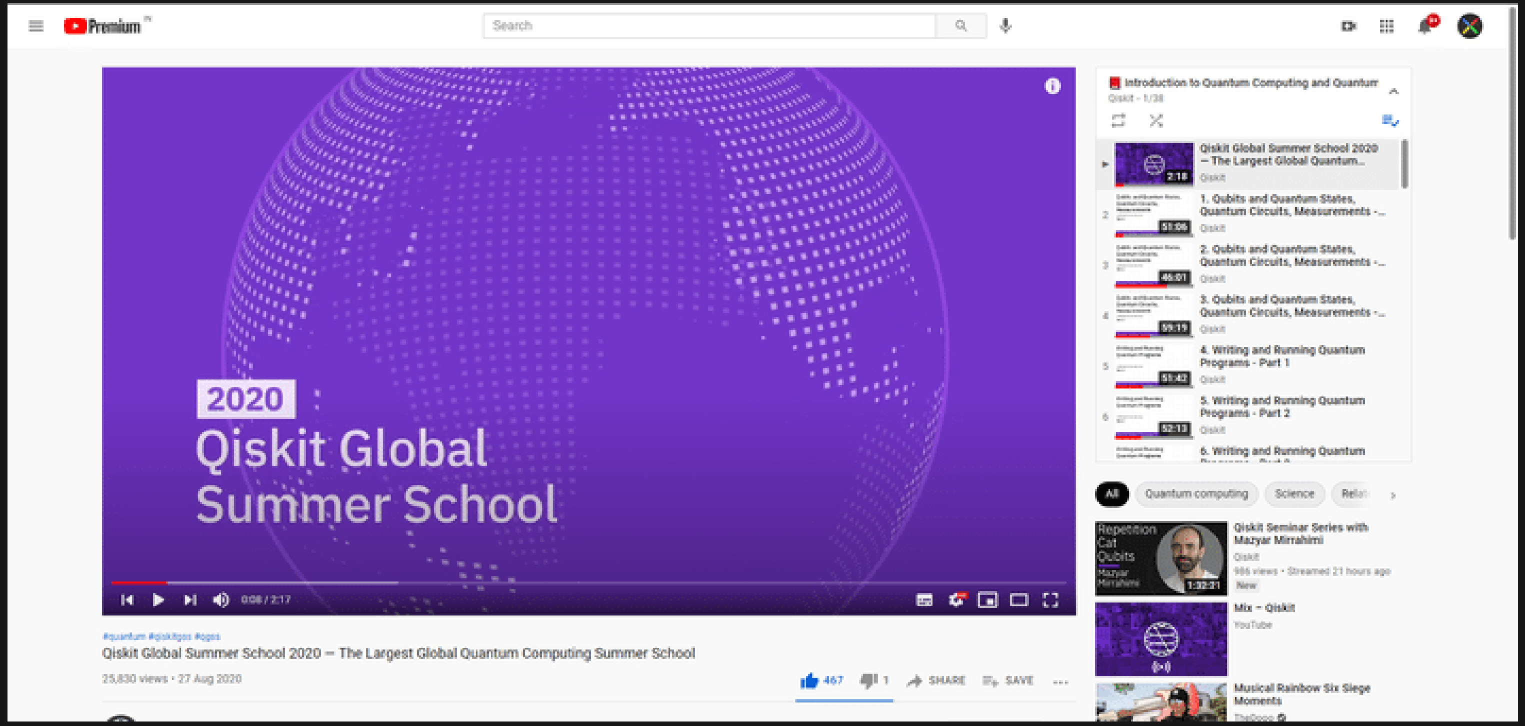
Qiskit Summer School 2020 Playlist

- Rigourous material spanning across lots of domains
- Hands on labs with great introductory exercises
- Self Paced visual material

Qiskit | Global Summer School

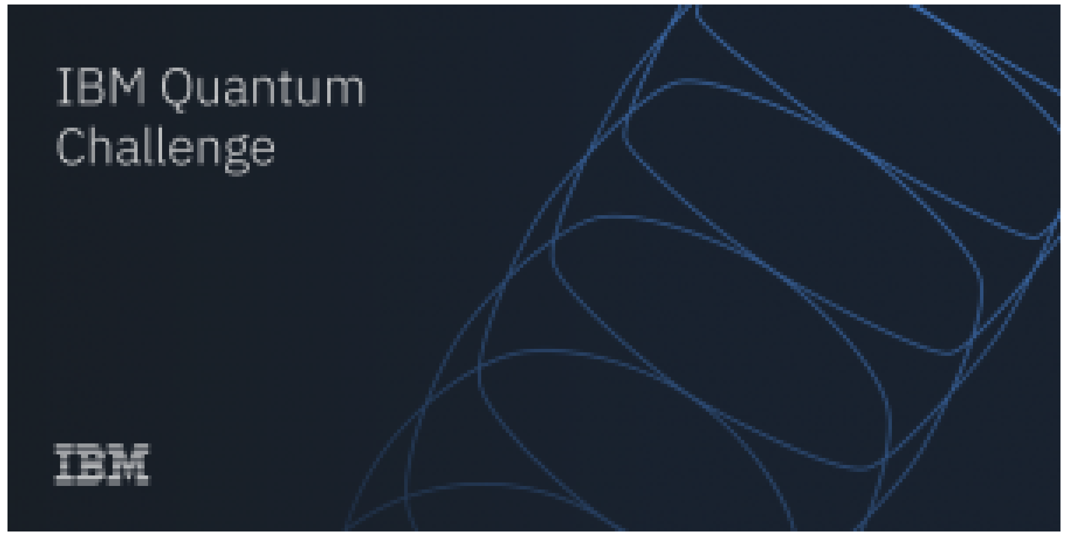


https://www.youtube.com/watch?v=Rs2TzarBX5I&list=PLOFEBzvs-VvrXTMy5Y2IqmSaUjfnhvBHR

https://qiskit.org/learn/intro-qc-qh

Quantum Challenges!

- IBM Quantum Challenge 2020
- IBM Quantum Challenge Fall 2020
- IBM ICPC Quantum Challenge 2021
- IBM Quantum Challenge 2021



icpc | university commons

https://github.com/qiskit-community/may4_challenge_exercises
https://github.com/qiskit-community/IBMQuantumChallenge2020
https://github.com/qiskit-community/ICPC-Quantum-Challenge-2021
https://github.com/qiskit-community/ibm-quantum-challenge-2021

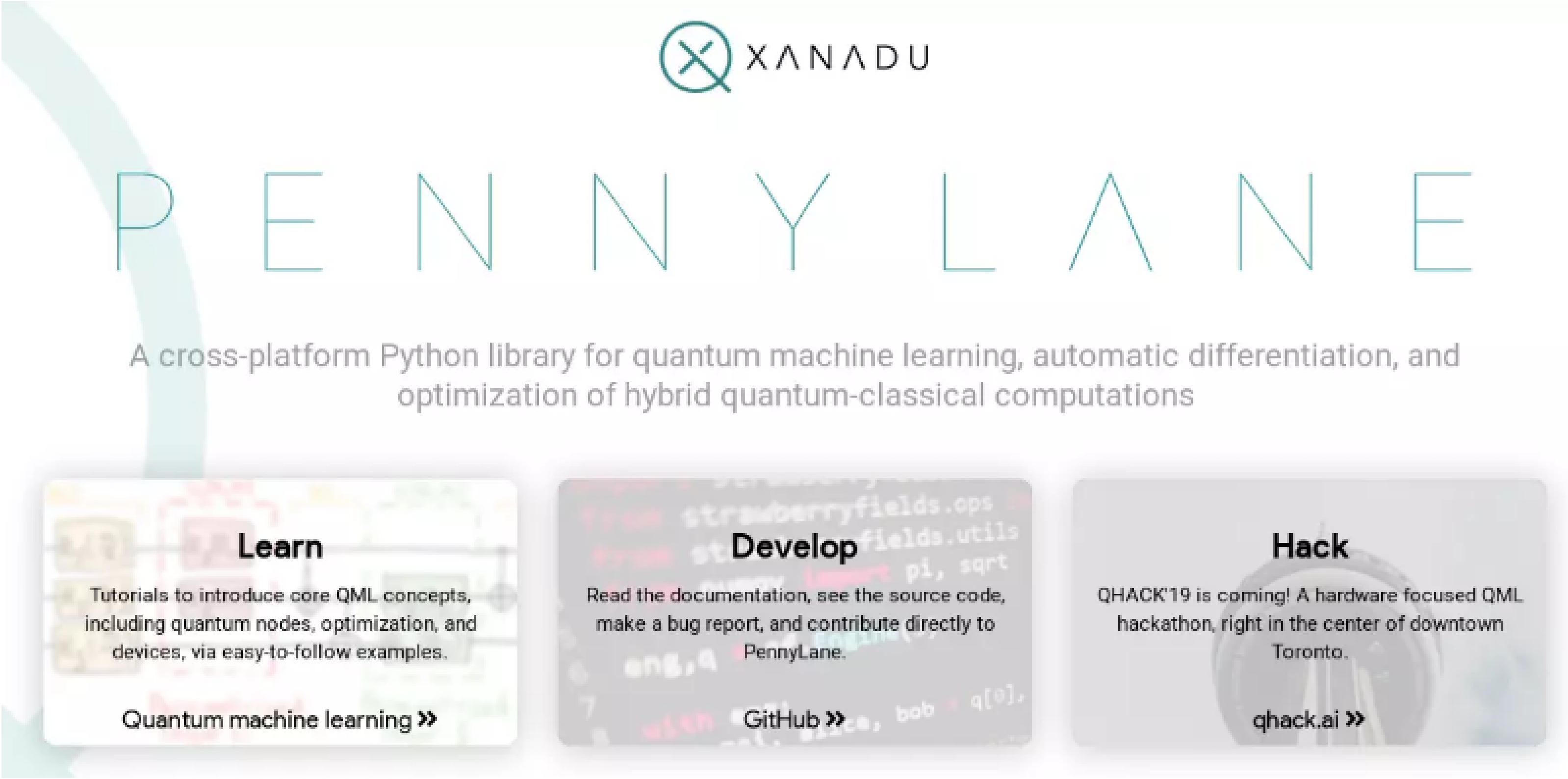
Explore!

Hackathons!

Keep an eye out for hackathons by:
- IBM : Qiskit Global Hackathons
- MIT : iQuHack
- Xannadu : Qhack
- Stanform x Yale : QC Hack
- Q-munity : Q-Munity Hack

Pennylane - Xanadu

- Cross platform QML integration
- Tutorials scaling from beginners to advanced concpets
- Python based library with integration with Qiskit



PennyLane

A Python library for quantum machine learning, automatic differentiation, and optimization of hybrid quantum-classical computations. Use multiple hardware devices, alongside TensorFlow or PyTorch, in a single computation.

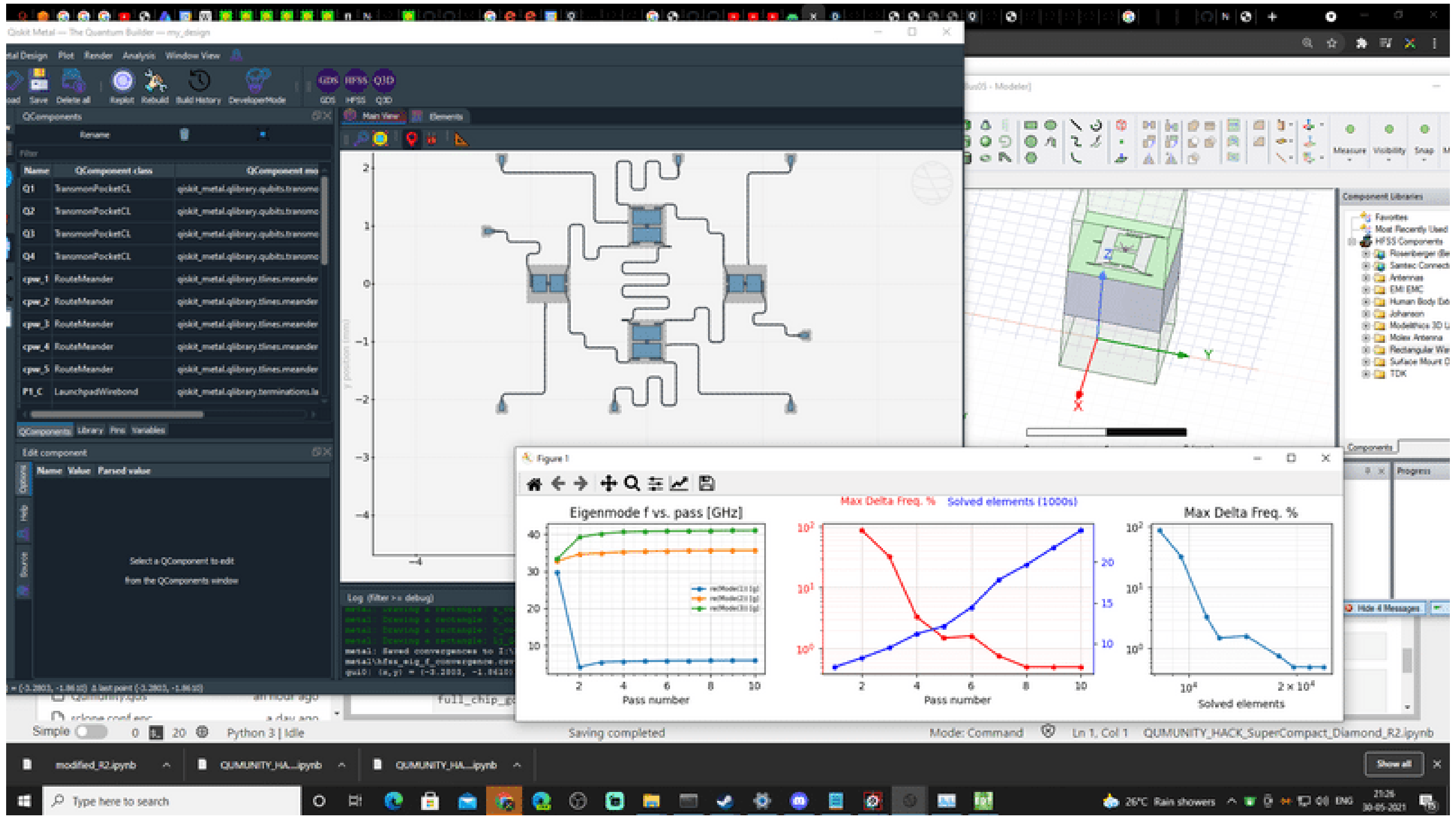
pennylane.ai

https://pennylane.ai/

Qiskit | quantum device design

Qiskit - Metal

- Open source Quantum Chip development
- Designed for Superconducting quantum devices
- Integration with analysis softwares and easy deployment pathways for fabrication

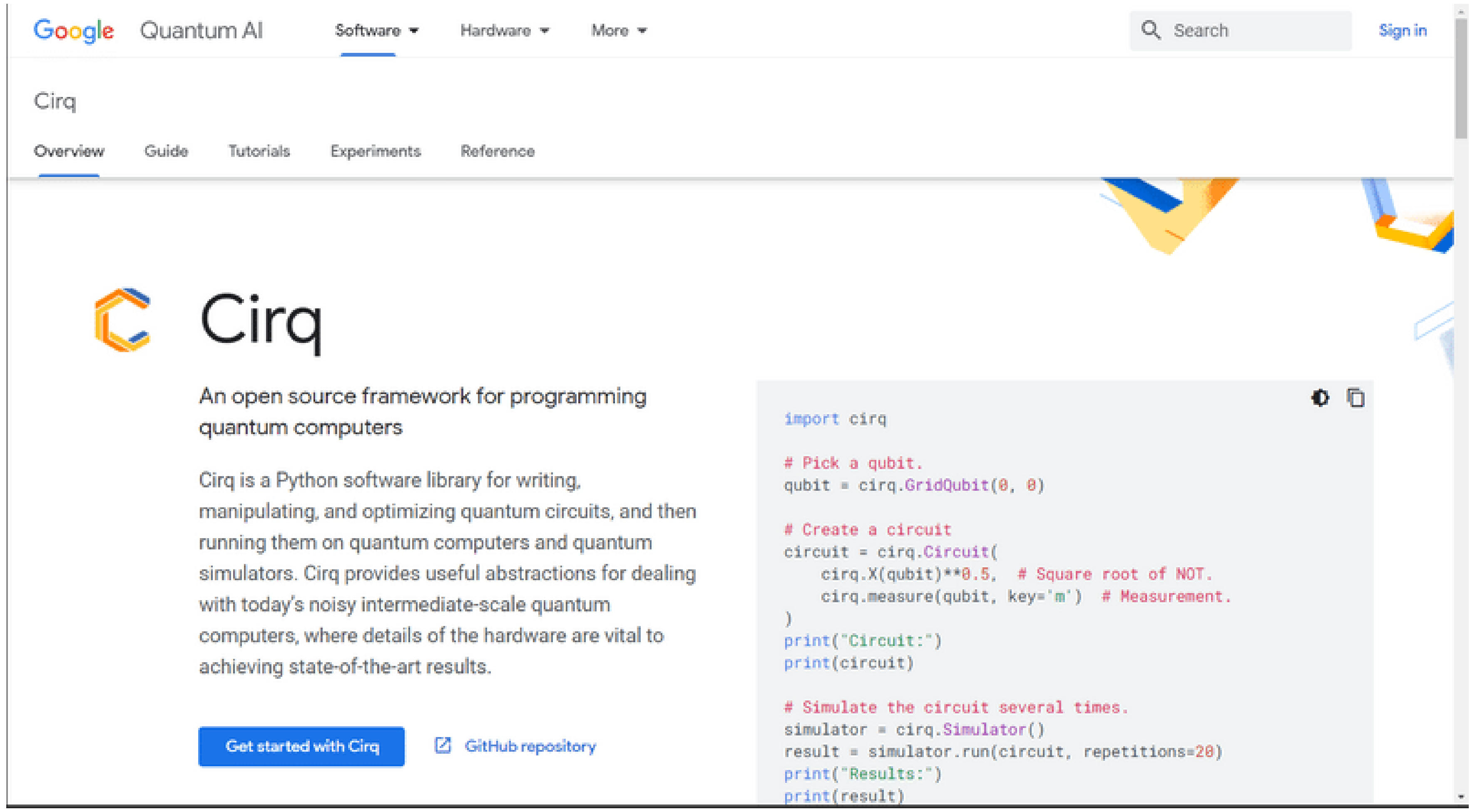


https://qiskit.org/metal/

https://qiskit.org/documentation/metal/tut/index.html

Cirq

- Maintained by Google
- Focused towards NISQ era and research oriented approach
- Core team directly approachable with feature requests
- Has a slightly steeper learning slope
- Based on Python

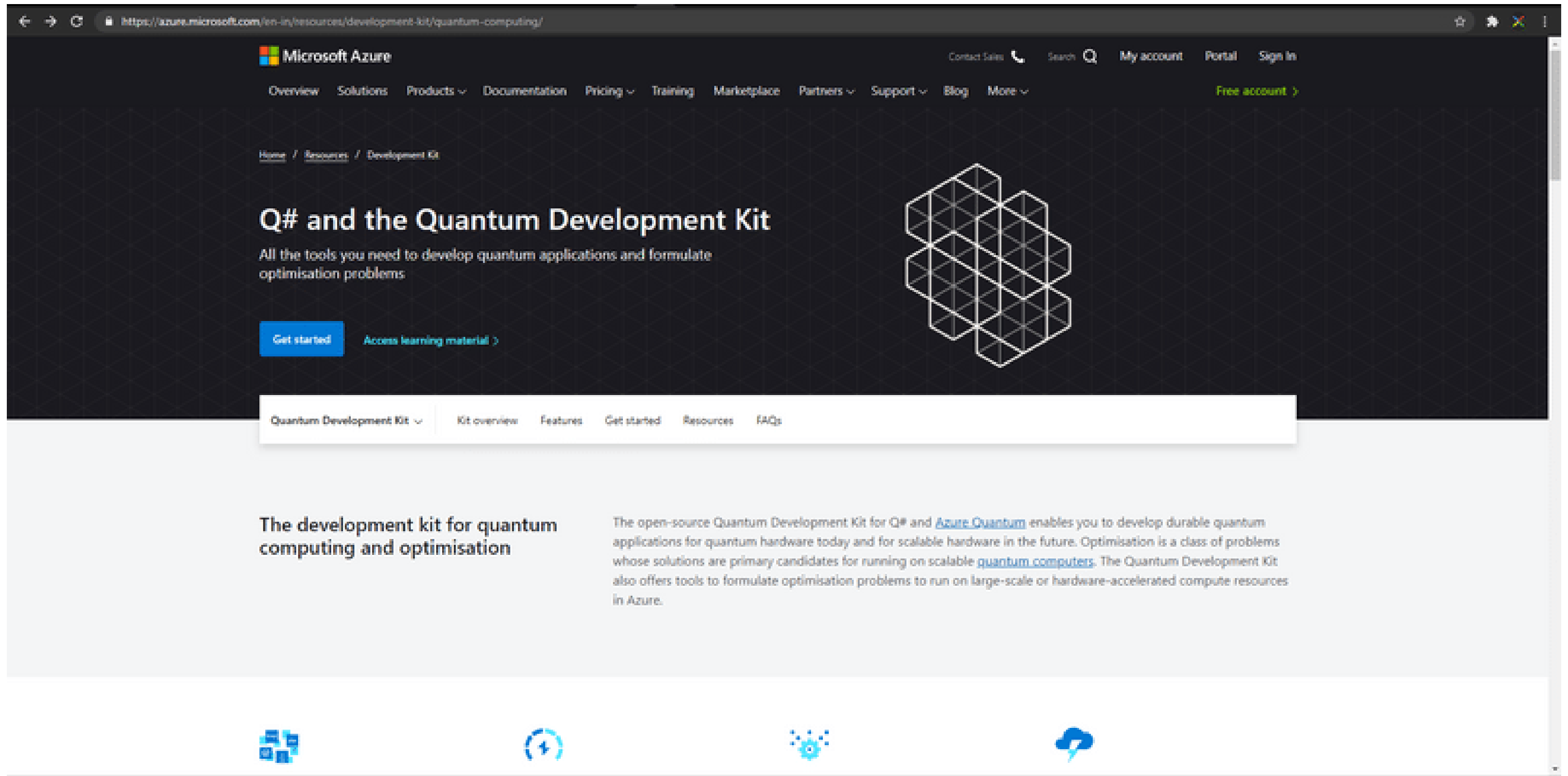


https://quantumai.google/cirq

https://quantumai.google/cirq/tutorials

Microsoft Q#

- Developed and maintained by Microsoft
- QDK with a full stack solution based approach
- C# Based coding paradigm
- Has a slightly steeper learning slope
- Lots of tutorials with more being currently added
- Can be interfaced with backends using Azure Quantum

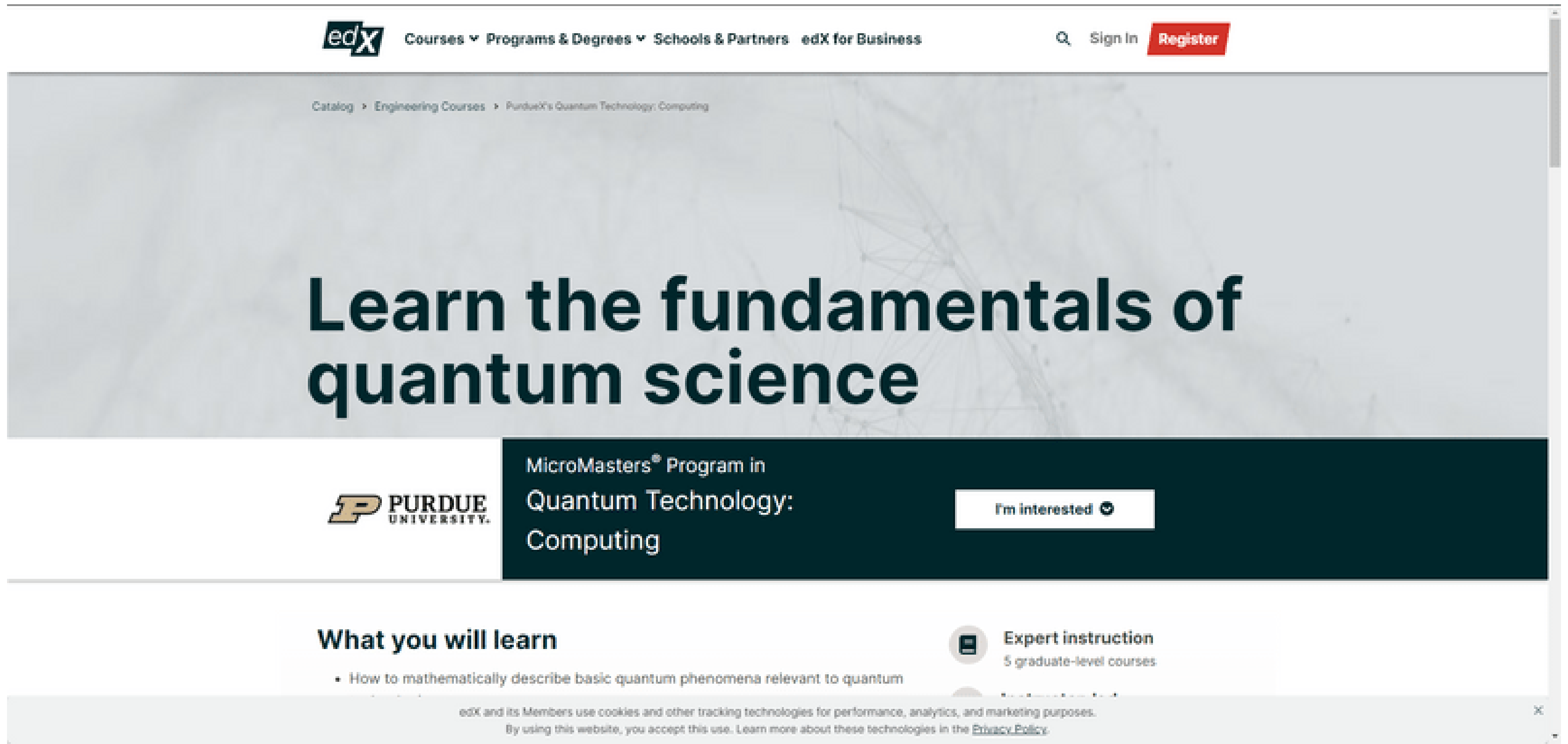


https://azure.microsoft.com/en-in/resources/development-kit/quantum-computing/

https://docs.microsoft.com/en-gb/learn/paths/quantum-computing-fundamentals/

Quantum Technologies: Computing Micromasters

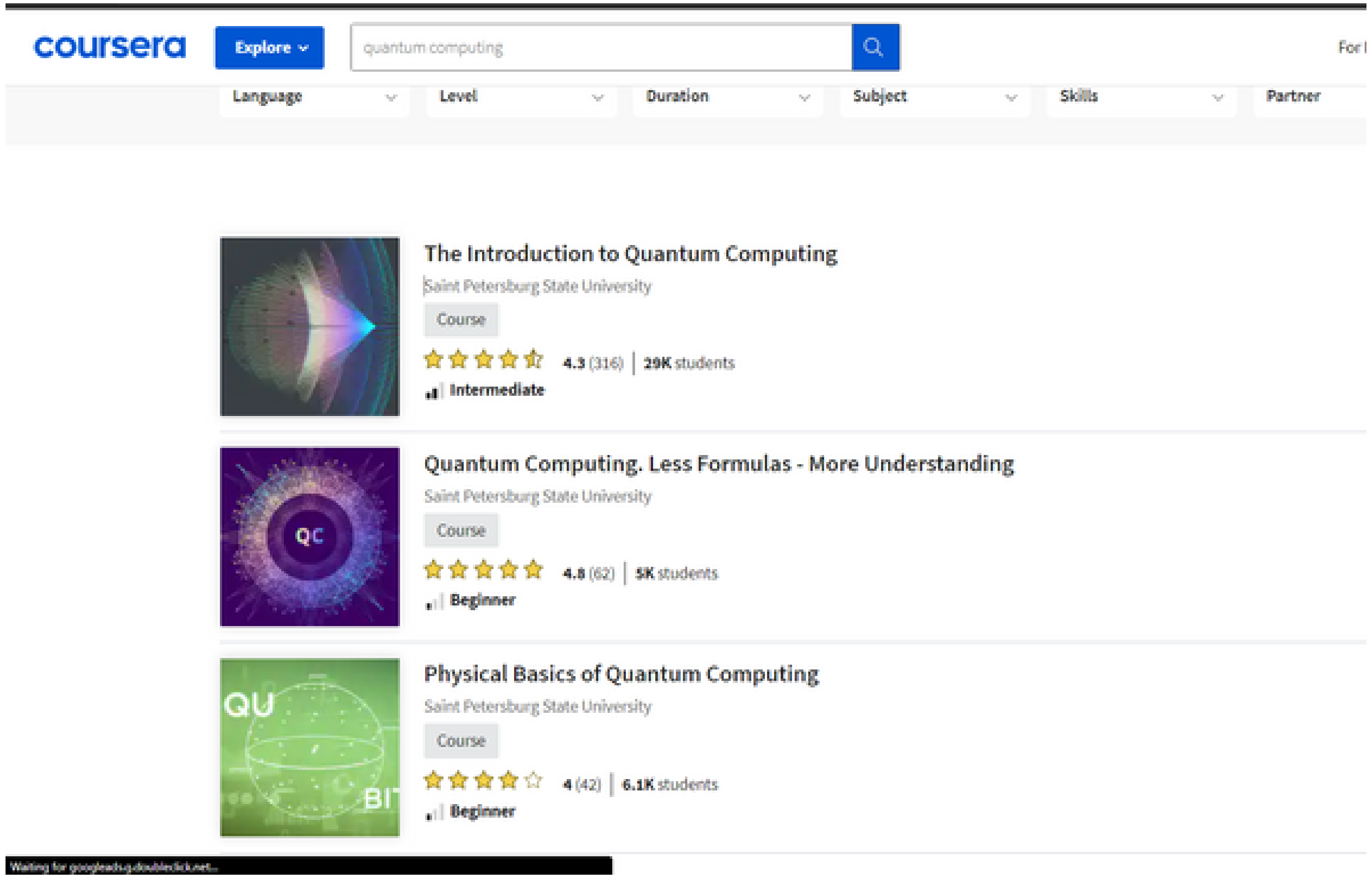
- In depth, rigorous and more lower level coverage of Quantum Technologies
- Covers basics of Quantum mechanics fundamentals, Hardware and Software
- Fast tracked learning with access to on campus purdue university lecturers
- Option for 90% Financial Aid for students (Material is totally free of cost for everyone, only certification will be paid)



Coursera:

- Quantum Computing. Less Formulas - More Understanding
- The Introduction to Quantum Computing
- Physical Basics of Quantum Computing

- Start with the order above
- Great introduction, but very mathematically rigorous and expects a lot of prerequisites
- Material free and full financial aid available for certification



Thank You for your time!

Feel free to ask any questions!

Feel free to contact me at: vishal.bajpe@gmail.com