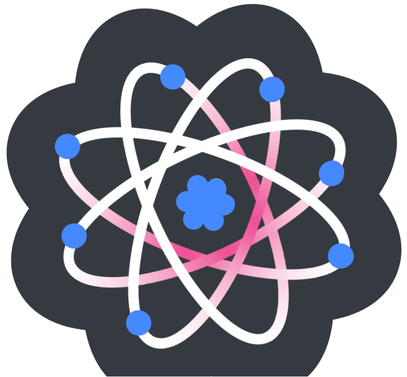
Fall Fest 2025, Halfway There!

Century of Quantum



Natalie Hawkins
Qiskit Advocate, Tier 1
Seattle Quantum Computing Meetup, Founder

Today’s Agenda

- SQCM’s FF25 Materials

https://github.com/SeattleQuantumComputingMeetup/qiskit_fall_fest_2025/tree/main

- Who else is hosting?

https://www.ibm.com/quantum/events/fall-fest-2025

- What is the International Year of Quantum Science and Technology (IYQ)?

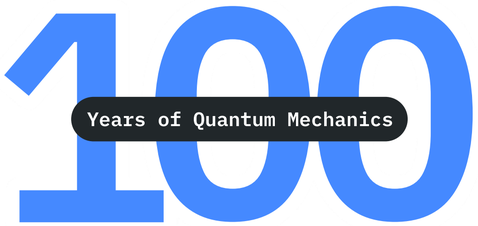
- Why does this Year's Nobel Prize in Physics Matter for Quantum Computing?

- Real world interactions: HowTo with Qiskit and Quantum Computers

International Year of Quantum Science and Technology, IYQ

- Declared by the UN
- year-long, world-wide initiative
- will “be observed through activities at all levels aimed at increasing public awareness of the importance of quantum science and applications”.
- 1925: significant progress was made in quantum mechanics, with Wolfgang Pauli announcing the exclusion principle and Werner Heisenberg developing matrix mechanics (Google AI Overview)

https://quantum2025.org/



Nobel Prize in Physics, 2025

Clarke, Devoret, Martinis

"for the discovery of macroscopic quantum mechanical tunnelling & energy quantisation in an electric circuit"

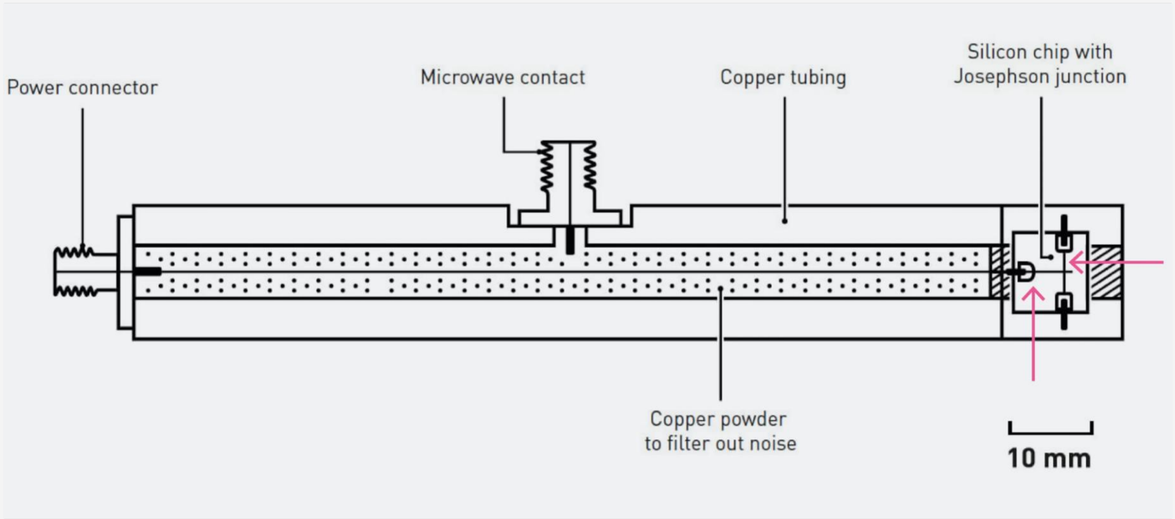
Why This Year's Nobel Prize Matters for Quantum Computing,

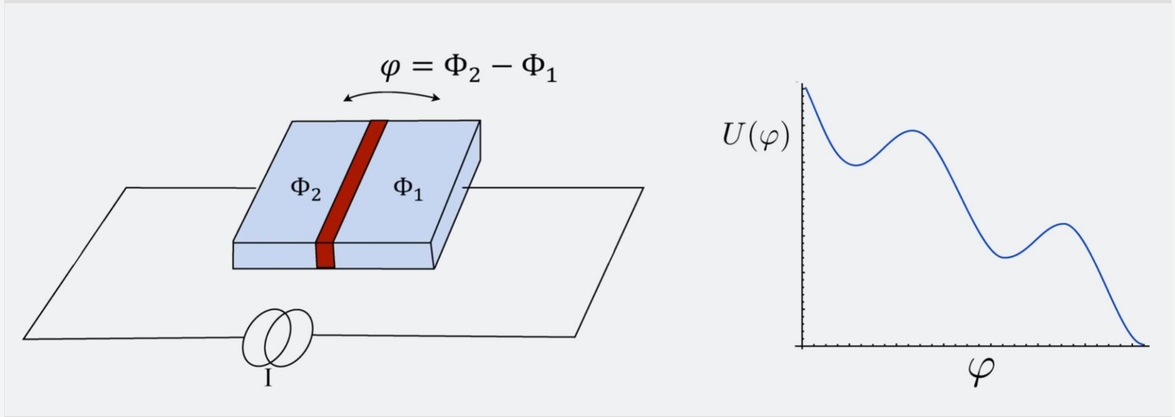
Qiskit Channel, Christopher Porter

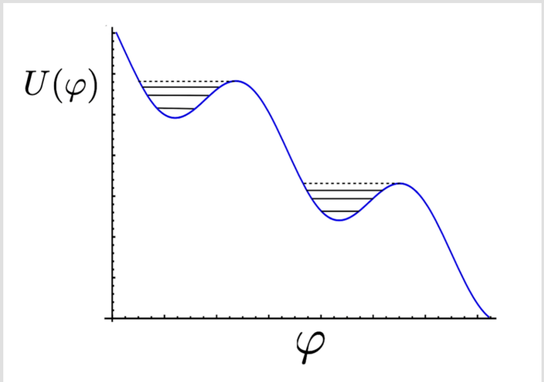
https://www.youtube.com/watch?v=N4zxJ5iJRhg

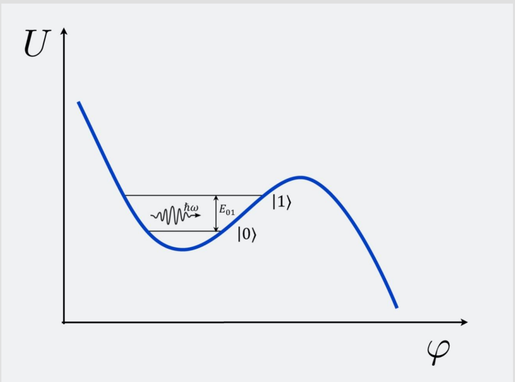
Macroscopic Tunnelling, Energy Quantization in an Electric Circuit

- Josephson Junction = 2 superconductors separated by a thin barrier (red), and the current going through it can be controlled; i.e. biased; each superconductor is a macroscopic superfluid (of Cooper pair electrons)
- Energy – curve of the junction is a function of the phase difference, phi, of the phases of the two superconductors
- Valley – of the energy curve represents a qubit; when the bias current is below a critical value and at zero temp, the system sits in a valley; energy quantization of electrical circuits is observed in the valley, and energy can tunnel out of the valley
- Application = superconducting qubits, which are engineered to maximize coherence, minimize noise, and allow precise control, such as the ones used by IBM Quantum
- We can design the energy gap between |0> and |1>, and use microwaves to control their quantum state on demand









Why This Year's Nobel Prize Matters for Quantum Computing
https://www.youtube.com/watch?v=N4zxJ5iJRhg

Nobel Prize in Physics, 2025

Clarke, Devoret, Martinis

Resource: Google AI Overview

Josephson Junctions

- use tunneling to create the non-linear inductance needed to make the qubit's energy levels quantized and distinct, allowing it to hold quantum information in a superposition of states.
- tunneling is also a source of problems, as unwanted quasiparticle tunneling and tunneling two-level systems (TLS) can cause decoherence and errors.

How Tunneling is used:

- Josephson junctions:
Superconducting qubits are built with Josephson junctions, which consist of two superconductors separated by a very thin insulating layer.

- Cooper pair tunneling:
Quantum tunneling allows pairs of electrons (Cooper pairs) to tunnel across this insulating barrier, creating a supercurrent.

- Qubit control:

This tunneling creates a nonlinear inductance, which is essential for creating an anharmonic oscillator. This ensures that the energy levels are not equally spaced, allowing the qubit to be controlled to operate between just the lowest two levels

Nobel Prize in Physics, 2025

Clarke, Devoret, Martinis

How tunneling is a challenge

Quasiparticle tunneling:
Unwanted quasiparticles (individual electrons with broken pairs) can tunnel across the junction, leading to qubit decay and dephasing.

Tunneling two-level systems (TLS):
Defects in the insulating layers or other parts of the qubit can act as TLS, where particles can tunnel between different energy states. This can introduce noise and cause the qubit to lose its quantum state.

Decoherence:
Both quasiparticle tunneling and TLS are major sources of decoherence, which limits the performance and coherence time of the qubit.

Mitigation efforts:
Researchers are actively working to reduce these detrimental tunneling effects by engineering the materials and the qubit structure itself to suppress unwanted tunneling.

Quantum Computing Hardware

Resources

Book:

Building Quantum Computers, A Practical Introduction by Shayan Majidy, Christopher Wilson, Raymond Laflamme

Company Websites:

have articles explaining their hardware

Real World Interactions w/Quantum Computing

Parts of Qiskit

https://www.ibm.com/quantum/qiskit#ecosystem

Open Source Software Development

Extend the Power of Qiskit - the Qiskit ecosystem is a collection of tools created by researchers and developers who use Qiskit every day.

https://www.ibm.com/quantum/ecosystem

Tools for heterogeneous orchestration

- Qiskit quantum hardware plugins, backend-agnostic
- QRMI: Quantum resource management interface
- Slurm workload manager
- Qiskit Serverless for multi-cloud and supercomputer use cases

Tools for algorithm development

- Qiskit Addons – combine to build algorithms; exist for mapping, optimizing and post-processing steps
- Qiskit Function templates – realistic code examples utilizing Qiskit and Qiskit Addons

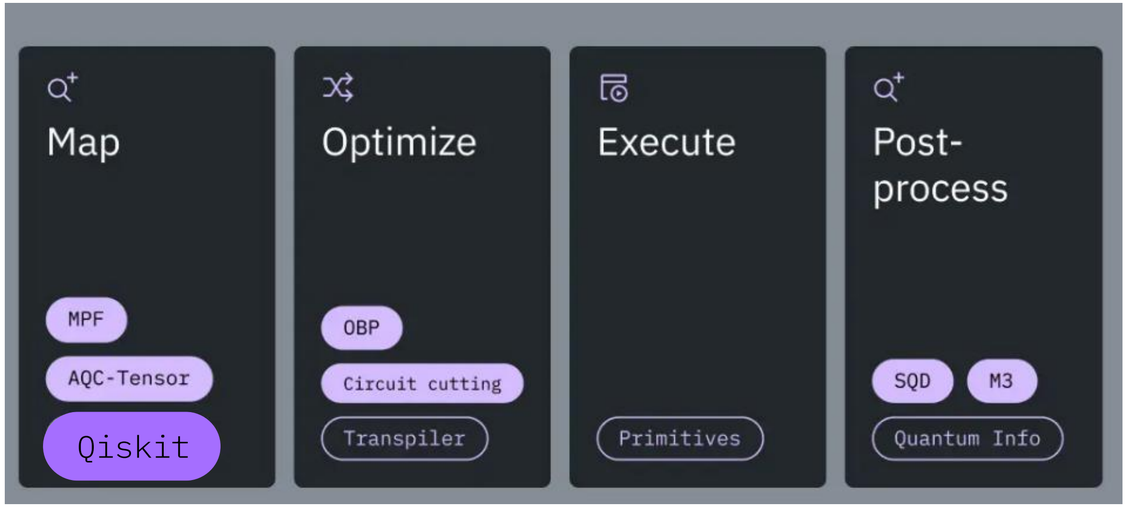
Use Cases

- Optimization: combinatorial problems
- Simulate complex systems in nature across physics and chemistry domains
- Quantum Machine Learning, leverage quantum kernels
- Partial differential equations, simulate nonlinear dynamical systems

Some Examples

Qiskit Tutorials

https://quantum.cloud.ibm.com/docs/en/tutorials



1

Combine addons to build an algorithm – as in the graphic above for a Hamiltonian simulation. The addons used are: MPF (multi-product formulas), AQC-Tensor, OBP, Circuit cutting, SQD, and M3.

2

Create your own addon. One example, could be an addon for loading classical data into the quantum computer.

3

Create a game.

Examples:

- *Qpong*, https://kirais.itch.io/qpong
- *DOOM*, https://github.com/Lumorti/Quandoom

4

Use the QAOA algorithm to solve an optimization problem.

Thanks for coming!!

Century of Quantum

Join the Discord: invite link is under the About tab on the Seattle Quantum Computing Meetup page

Submissions Due: Nov 3, 10 am, PT

Next Event(s):
- Possibly a Zoom
- Possibly a Speaker on the UW Campus