

Quantum Errors and Noise

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What is Quantum Noise?

- ▶ Disturbances in the state of qubits that lead to errors in quantum computation
- ▶ One of the current major challenges enterprise-scale quantum computing (one of the others being scalability)
- ▶ **Decoherence**: Happens when a qubit loses its set quantum state.

Creating an IBMid and Accessing API Token

- ▶ Create an account on <https://quantum.ibm.com>
- ▶ On the homepage once your log in there is an API Token in the upper right
 - ▶ This token will allow you to interface directly with IBM hardware (for a limited amount of time)
- ▶ Note that you can also find a list of all IBM quantum computers (QPUs)

Noiseless Simulation

```
simulator = AerSimulator()
results = simulator.run(circuit).result().get_counts()
```

Simulating Real Quantum Noise

```
provider = QiskitRuntimeService(channel="ibm_quantum", token="  
backend = provider.get_backend("ibm_brisbane")  
aersim_backend = AerSimulator.from_backend(backend)  
results = aersim_backend.run(circuit).result().get_counts()
```

Example: Creating a Bell State

To Jupyter!

Types of Quantum Noise (Not All Inclusive)

- ▶ Bit Flip: The state of the qubit flips entirely ($|\uparrow\rangle \rightarrow |\downarrow\rangle$ or $|\downarrow\rangle \rightarrow |\uparrow\rangle$)
- ▶ Phase Flip: Introduces a phase (-) to a qubit
- ▶ Depolarizing: Qubits loss all information it was storing and decays into a random mixture of basis states
- ▶ Amplitude Dampening: The amplitude of certain qubits is lessened
- ▶ Can happen to single qubits and groups of entangled qubits. Quantum errors can break entanglements (as seen in the Bell State example)

Causes of Quantum Noise (Not All Inclusive)

- ▶ Thermal Fluctuations
- ▶ Electromagnetic Interference
- ▶ Imperfections in Construction

Discussion

- ▶ Consider the following algorithms we have covered in class:
 - ▶ Quantum Phase Estimation
 - ▶ Grover's Search Algorithm
 - ▶ Quantum Key Distribution
- ▶ How could each of the errors change the results? Try simulating the algorithms and creating the results histogram, with and without noise.
- ▶ Note that modern noise is relatively small, but consider the worst case scenario where the noise is quite large.