Assignment: Quantum Error Correcting Codes

In this assignment, you will implement quantum error correction codes using Qiskit. You will encode a qubit, introduce an error, and then apply error correction to recover the original quantum state.

Part A

- Implement the 3 bit Repetition Code that we discussed in Class for both bit and phase errors
- Theory Questions which should be answered in the context of Part A
    - What are the limitations of the bit-flip code?
    - We showed that the Algorithm corrects errors with the inner block doing bit flip and the outer block doing phase flip. Can you interchange phase-flip and bit-flip modules?
    - Why is fault tolerance important in practical quantum computers?

Part B

- Implement and simulate the Shor Code (9-qubit QECC) to protect against bit-flip and phase-flip errors.
- Extend your implementation to a Calderbank-Shor-Steane (CSS) Code or the Steane Code (7-qubit QECC).
- Analyze the performance of your error correction schemes under different noise models.
- Theory Questions which should be answered in the context of Part A
    - What is a stabilizer code, and how does it relate to the Shor and Steane codes?
    - Compare the Shor Code and the Steane Code. What are the advantages and disadvantages of each?

Part C

- Implement a quantum decoder using Machine Learning

Submission

For each part, submit a different Python Notebook (.ipynb) with

- Explanation and code for each part.
- Simulation results and visualizations.
- Answers to the theoretical questions.