Module 4: Pre_Homework

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1. My IBM instance

d4om5c45fjns73cugdcg

2. Quantum Circuit

Expectations

- **q0:** Input $|0\rangle \xrightarrow{\text{Gate } X}$ Output $|1\rangle$

  X gate acts as a bit-flip operator, which is the quantum equivalent of a classical NOT gate. It flips the input state $|0\rangle$ to $|1\rangle$.

- **q1:** Input $|0\rangle \xrightarrow{\text{Gate } H}$ Output $\frac{|0\rangle+|1\rangle}{\sqrt{2}}$

  H gate is used to create a superposition state. It transforms the computational basis state $|0\rangle$ into an equal superposition of $|0\rangle$ and $|1\rangle$, resulting in the state $\frac{|0\rangle+|1\rangle}{\sqrt{2}}$ (often denoted as $|+\rangle$).

- **q2:** Input $|1\rangle \xrightarrow{\text{Gate CNOT (Control)}}$ Output $|1\rangle$

- **q3:** Input $|0\rangle \xrightarrow{\text{Gate CNOT (Target)}}$ Output $|1\rangle$

  q2 and q3 qubit acts as the Control qubit for the CNOT operation. Since the input state is $|1\rangle$, it triggers the operation to flip the state of the target qubit (q_3). The state of the control qubit itself remains unchanged after the operation. The result is the same as q2 and q3.

Circuit & Simulation Screenshots

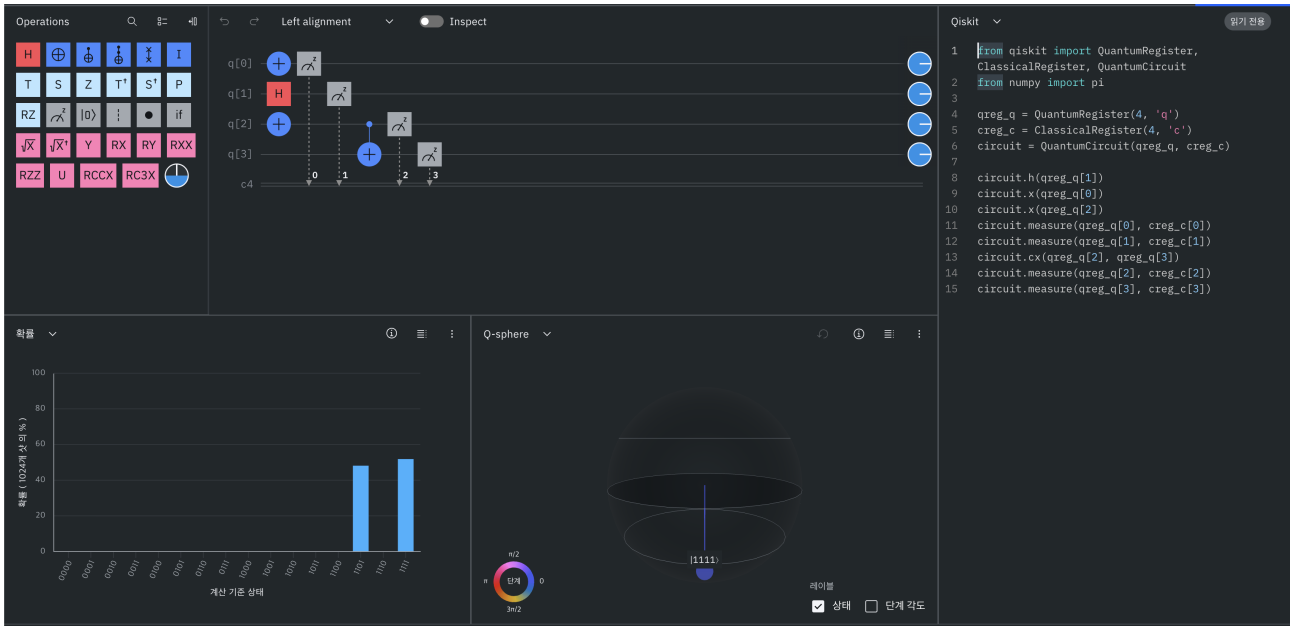

Figure 1: Quantum Circuit Design

Simulation Results Analysis

The simulation results show that our circuit is working as expected:

$$\frac{1}{\sqrt{2}}|1\rangle|0\rangle|1\rangle|1\rangle + \frac{1}{\sqrt{2}}|1\rangle|1\rangle|1\rangle|1\rangle \approx |1\rangle \otimes \left(\frac{|0\rangle + |1\rangle}{\sqrt{2}}\right) \otimes |1\rangle|1\rangle$$

3. Result on Real Device

Device name: ibm_fez

The experiment results closely match the simulation. We observed distinct peaks at 1101 and 1111, confirming that the Hadamard and CNOT gates operated as intended to produce the expected superposition.

Real Device Output (Histogram & Status)

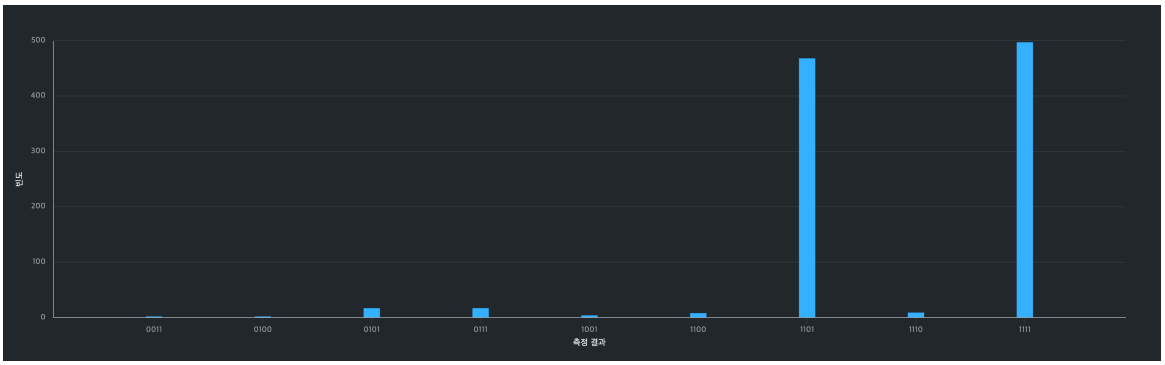

Figure 2: Result Histogram

Figure 3: Job Status Timeline

Job Results Data

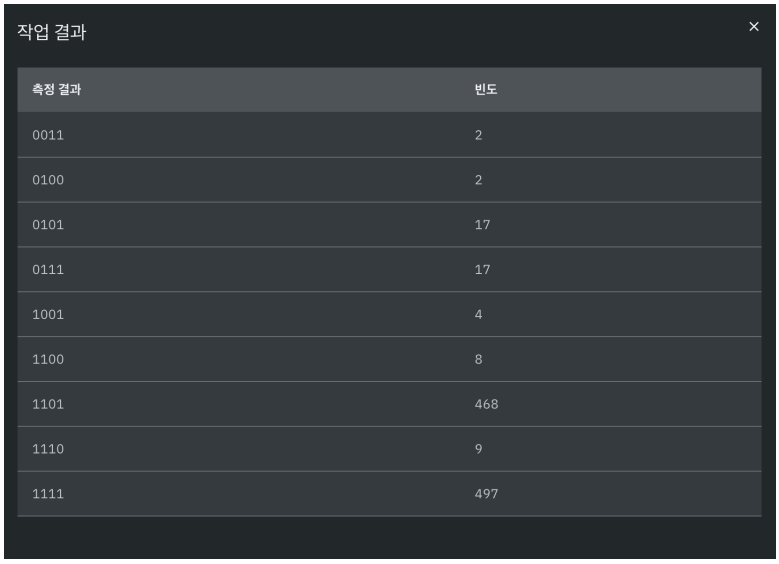

Figure 4: Job Status Timeline