Programming Assignment I: Quantum Hello World on a Quantum Computer and Simulator with Qiskit

1.1 Install Qiskit either on your local machine or on Colab

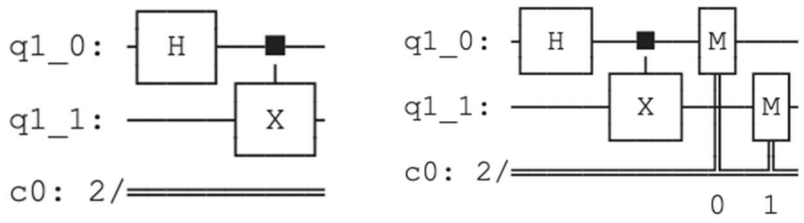
> We as a group decided to start with Colab. All three of us installed qiskit, but different to the tutorial we installed qiskit 1.2.0 and additionally installed qiskit_aer and qiskit-ibm-runtime.

1.2 Create an account on the IBM Quantum experience

> All three of us created an account on IBM Quantum to run the job on the cloud.

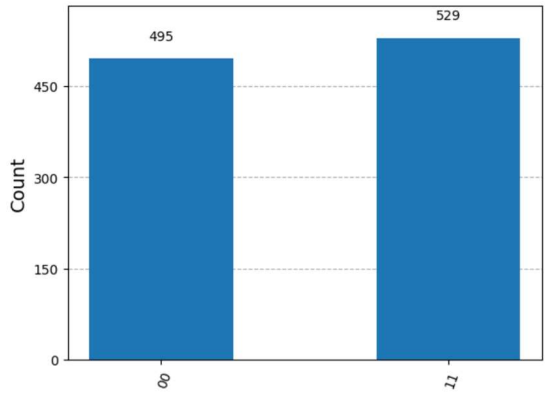
1.3 Using Qiskit, create a two-qubit system to implement the Bell's circuit. For this, follow the instructions in the tutorial.

1.3.1 Plot the circuit diagram



1.4 Run the quantum circuit using the Qiskit Aer quantum simulator backend.

1.4.1 Plot the histogram with the (simulated) measurements



1.5 Check which IBM quantum computers are available via the cloud (see the code in the tutorial).

We had the following quantum computers available:

```
Cloud backends:
ibm_brisbane
ibm_kyiv
ibm_kyoto
ibm_sherbrooke
AerSimulator('aer_simulator')
AerSimulator('aer_simulator_statevector')
AerSimulator('aer_simulator_density_matrix')
AerSimulator('aer_simulator_stabilizer')
AerSimulator('aer_simulator_matrix_product_state')
AerSimulator('aer_simulator_extended_stabilizer')
AerSimulator('aer_simulator_unitary')
AerSimulator('aer_simulator_superop')
QasmSimulator('qasm_simulator')
StatevectorSimulator('statevector_simulator')
UnitarySimulator('unitary_simulator')
```

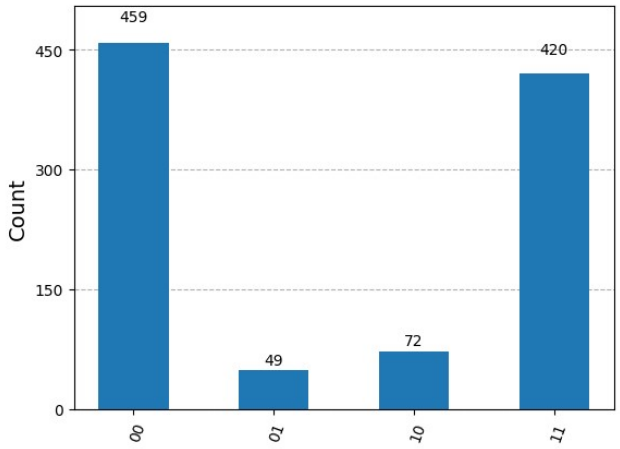
1.5.1 Which quantum technology IBM Quantum computers are based on? Find information about the IBM quantum computers and report the information you could find.

IBM's quantum computers are based on superconducting qubit technology, specifically using fixed-frequency qubits with tunable couplers, as demonstrated in their latest Heron processor. Tunable couplers in quantum computing allow for precise control over the interaction between qubits, which is essential for reducing errors and improving the overall performance of quantum processors by minimizing unwanted cross-talk and enabling more efficient quantum gate operations. Fixed-frequency qubits are a type of superconducting qubit where the qubit's resonant frequency is set during the manufacturing process and remains constant during operation. This contrasts with tunable qubits, whose resonant frequency can be dynamically adjusted during computation. Fixed-frequency qubits are valued for their stability and reduced sensitivity to environmental noise, which helps in minimizing errors. Tunable qubits, on the other hand, offer flexibility in adjusting interactions between qubits, which can be useful for certain types of quantum operations but may introduce more complexity and noise.

1.6. Run the quantum circuit on any IBM quantum machine you can easily run on. Report the name of the IBM quantum computer you used for your experiments.

We used 'ibm_sherbrooke' for our computation, with a wait time of 1 min, actual computation time of 2 seconds, with a total computation time of 4 min.

1.6.1 Plot the histogram with the measurements



1.6.2 Compare the results with the simulated ones.

When running on the real quantum computer, we observed four different measurement outcomes, namely 00, 01, 10 and 11. The states 00 and 11 are the most likely ones, whereas the states 01 and 10 are only observed very rarely. However, in the simulated case only the measurement outcomes 00 and 11 were observed.