- Middle East Technical University   ◆ Department of Computer Engineering

CENG 487

Introduction to Quantum Computing

Fall 2021-2022

Assignment 1

Due date: 02.12.2021, 23:59

1. **The Environment**

   a. You will implement quantum computing programs using real quantum computers on IBM quantum computing environment. We have already enrolled you as collaborators to an educational project on IBM Qantum Computing(quantum-computing.ibm.com). You can create an IBMid account using your metumails and start coding.

   b. The easiest way to create your quantum circuits visually or using OpenQASM 2.0 (an assembly-like language for quantum computing) is IBM Quantum Composer(quantum-computing.ibm.com/composer). You can also use python library Qiskit (v0.3.2.0) on IBM Quantum Lab(https://lab.quantum-computing.ibm.com)

   c. You can get help from the tutorials to start with quantum computing: quantum-computing.ibm.com/docs/

2. **Entanglement**

   At each part, you will implement 2 different quantum circuits(6 in total) and check if measurement works as expected. The only difference between the circuits in each part is an additional Hadamard gate which will help you to check the difference for the expected outcome.
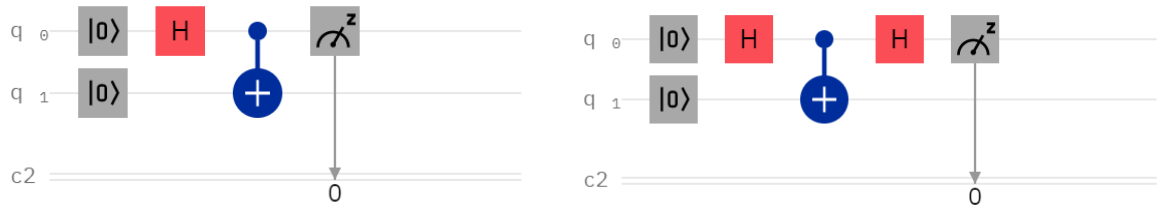
   a. Single qubit – Try to see the effects of Hadamard Gate:

   Implement the two quantum circuits above and run them on a system with shots=1024. For both circuits;
   a.1. What are the expectations for the results to be measured as $|0\rangle$ or $|1\rangle$?
   a.2. What are the real results? (i.e. how many 0's and 1's out of 1024) Is it different than the expected? If it is, what is the reason?
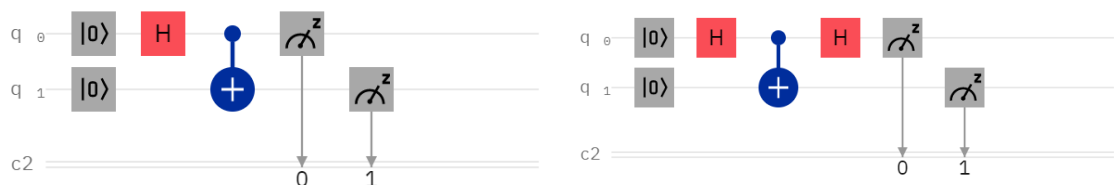
b. Bell(EPR) State – 1-qubit measurement – Try to see the effects of Hadamard Gate:

Implement the two quantum circuits above and run them on a system with shots=1024. For both circuits;

b.1. What are the expectations for the results to be measured as $|00\rangle$, $|01\rangle$, $|10\rangle$ or $|11\rangle$?

b.2. What are the real results? (i.e. how many 00's, 01's, 10's and 11's out of 1024) Is it different than the expeced? If it is, what is the reason?

c. Bell(EPR) State – 2-qubit measurement – Try to see the effects of Hadamard Gate:

Implement the two quantum circuits above and run them on a system with shots=1024. For both circuits;

c.1. What are the expectations for the results to be measured as $|00\rangle$, $|01\rangle$, $|10\rangle$ or $|11\rangle$?

c.2. What are the real results? (i.e. how many 00's, 01's, 10's and 11's out of 1024) Is it different than the expeced? If it is, what is the reason?

3. Submission

a. For your first assignment, we do not expect you to upload any code. The circuits are already given, you will just run them yourself and answer the questions above. You will submit a **pdf** file consisting of your answers, comments and comparisons.

b. Try to finish as early as possible. The sytems to run your work are shared between many different users across the earth. Therefore some systems may have longer queues that can cause for you to wait. (look for systems that have smaller number of jobs on queue).

c. The assignments are for individual work. You work should be done by only you and it should be genuine. We have zero tolerance policy for cheating. People involved in cheating will be punished according to the university regulations and will get zero.