Middle East Technical University | Department of Computer Engineering

CENG 487

Introduction to Quantum Computing

Fall 2023-2024

Assignment I

Due date: November 12, 23:59

Introduction

This assignment consists of two parts. In the first part, you are supposed to answer some classical questions about quantum gates and qubits. In the second part you will implement some basic quantum circuits and make measurements on them. The circuits will be implemented on IBM Quantum Computing and details are explained in the next section.

The Environment

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 Quantum Computing (*here*). You can create an IBMid account using your mails on OdtuClass.

The easiest way to create your quantum circuits visually is *IBM Quantum Composer*. You can also use python library Qiskit on IBM Quantum Lab. You can get help from the *tutorials*.

Part 1 - Quantum Gates (40 pts)

a)

For the following matrices state whether they can be a quantum gate or not. If they are a well-known quantum gate also indicate what they are called as and what they do.

- $A = \begin{bmatrix} 0 & 0 \\ 1 & 1 \end{bmatrix}$
- $B = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
- $C = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$
- $D = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$
- $E = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$
- $F = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{bmatrix}$
- $G = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$

b)

For each of the single qubit quantum gates above (for those which can be a gate), give the result if the following inputs are given;
$|0\rangle, |1\rangle, |+\rangle, |-\rangle$

Do the same for the 2-qubit gates with;
$|00\rangle, |01\rangle, |10\rangle, |11\rangle$

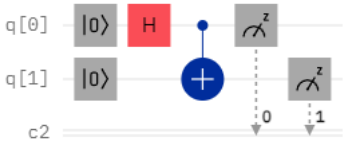
Part 2 - Quantum Circuits (60 pts)

In this part, you will implement quantum circuits and run them on a system with **1024 shots**. For each circuit, give your expectations for the measurement and compare it with the real results. Provide a histogram plot for the results. Each circuit is worth *10 points*.

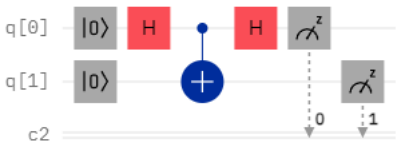
a)

b)

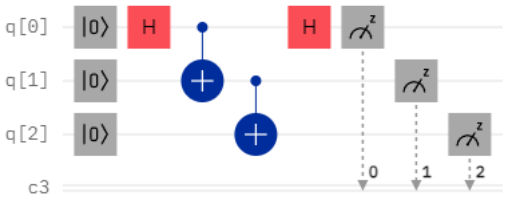
c)



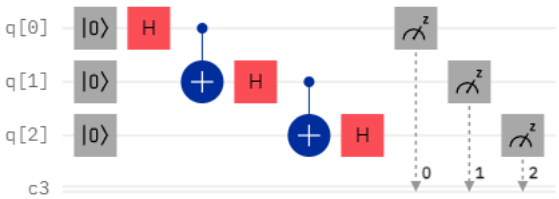
d)



e)



f)



Submission

- For this assignment, we do not expect you to upload any code. Just submit a single **PDF** file named eXXXXXXX.pdf, where XXXXXXX is your student ID.
- Hand-written solutions will **not be accepted**.
- We have a late policy with penalty. The penalty is $10 * day^2$ where day is the amount of days submitted late. After three days, late submissions will not be accepted.
- For the second part, try to start as early as possible. The IBM Quantum systems you work on are shared by many different users across the earth. Therefore some systems may have longer queues that can cause for you to wait.
- The assignments are for individual work. We have zero tolerance policy for cheating. People involved in cheating will be punished according to the university regulations.
- You may ask your questions by sending a mail to "mduymus@ceng.metu.edu.tr".