

Lab 2 Basics of quantum computer simulation.

- we will be using [a quantum simulator](#) by Joanna Patrzyk and Bartłomiej Patrzyk
- NOTE: Please install simulator directly from zip
- [Issue tracker](#)

Exercise T1 THEORY:

Get familiar with H gate. Calculate $H|0\rangle$ $H|1\rangle$

Exercise T2 THEORY

Get familiar with idea of control gates: CNOT gate, Toffoli gate. Find the matrix representation for Toffoli.

Exercise Q1 : Playing with the QUIDE - simple example

1. Open the [example1.cs](#) file showing how to create a single register and how to use the Hadamard (H) gate in the simulator. The code of the algorithm should appear in the top left part of the window
2. Generate visual quantum circuit from the code using "Build Circuit" button. The circuit should appear in the bottom left part of the window
3. Execute circuit step by step by pushing right arrow button "step forward".
4. The output will be shown in the output window in the top right part of the window .
5. Run the file by pushing "Run in a console" button. Instead of the quantum circuit you'll get console output.
6. Check the simulator results with mathematical calculations.

Exercise Q2 QUIDE

Add a second q-bit to a circuit and apply the H gate to it. Observe the changes in the probability panel. Check the simulator results with mathematical calculations.

Exercise Q3 QUIDE

Check in the simulator the operations of the X, Y, Z, SQRT(X). Check the simulator results with mathematical calculations.

Exercise Q4 QUIDE

Check in the simulator that $\text{SQRT}(X) * \text{SQRT}(X) = X$

Exercise Q5 QUIDE

CNOT(i,j) gate is the 2-qbit controlled-NOT gate that has a control bit (i) and a target bit (j). CNOT gate is defined to act as the identity if a control bit is 0 and as NOT on a target bit if a control bit is 1.

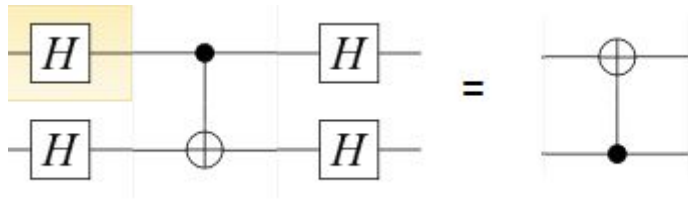
Check in the simulator the operation of CNOT. Observe the behaviour of the control and target bits.

Exercise Q6 QUIDE

Build and test other control gates in the simulator (e.g. Ctr -Z, Ctr-Y, Ctr-H)

Exercise Q7 GUIDE

Hadamard “sandwiching”. Check by experiment that:



Exercise Q8 GUIDE

Construct the SWAP gate from the CNOT gates $S(i,j)=CNOT(i,j)CNOT(j,i)CNOT(i,j)$

Exercise Q9 GUIDE

Toffoli gate is the 3-qbit controlled-controlled-NOT gate $T(i,j,k)$ that has two control bits (i and j) and a target bit (k). Toffoli gate is defined to act as the identity for control bits in states 00,01 or 10 and as NOT on a target bit if a control bits are in a state 11.

Build and test Toffoli's gate in the simulator. How to find the matrix representation for Toffoli?

Exercise I1 IBM-Q

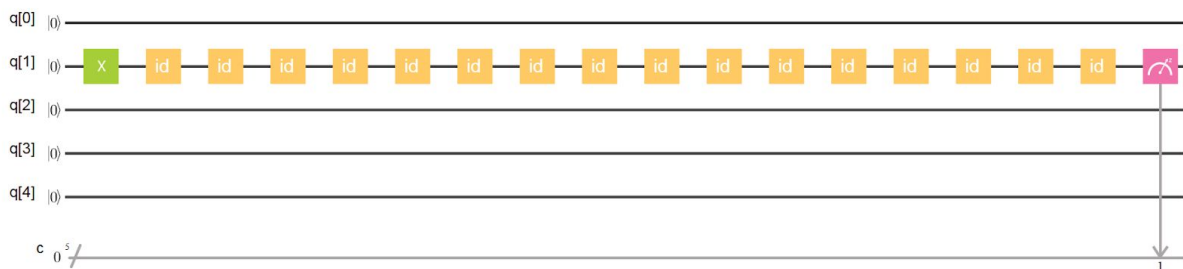
Register and login to IBM quantum experience

<https://quantumexperience.ng.bluemix.net/qx/editor>

Try X, Y, Z, H, gates on IBM simulator and real device

Exercise I2 IBM-Q

Check decoherence using the following circuit. Compare runs on real IBM device with IBM simulator.



Exercise I3 IBM-Q

Try to execute CNOT between arbitrary qubits. Use trick from Exercise Q6.

Exercise I4 IBM-Q

Build SWAP Gate between arbitrary qubits. Use solution from exercise Q8 and I3

Exercise T3 THEORY

Explain how to build Ctr-U gate from Ctr-X gates, if there exists a matrix W such that $WXW^{\dagger}=U$

Exercise I5 IBM - Custom controlled gates

Using control gates in QUIDE simulator is simple as every gate is actually a matrix in a memory of a classical computer. On IBM, gates are implemented to act on physical quantum device, so one has to deal with building complex control gates from basic ones.

The general rules how to do this with examples are described [here](#)

Knowing that $HXH=Z$ build Ctrl-Z gate

Knowing that $SXS^{\dagger}=Y$ build Ctrl-Y gate