IBM Q practice 1 : March 7, 2019
Hmw Quantum Computation

The goal of this first practice set is to get acquainted with **composer** (graphical interface) in the IBM Q experience. You will take into account geometrical constraints of the device in exercise 2. You are asked to : (i) first solve with pencil and paper, (ii) think carefully about your implementation on the composer, (iii) use the **simulate** button to reproduce pencil and paper results, (iv) use the **run** button to obtain an experimental (noisy) result. When you "run" in order not to spend credit units and/or wait in a queue you can **choose the cache option** which gives results of previously realised experiments when possible. **Those that already have some familiarity can direclty go to exercise 2-c-d.**

Exercise 1 *Single qubit manipulations (use ibmqx2)*

(a) Consider the following elementary single qubit operations : $|\text{output}\rangle = X|0\rangle$, $|\text{output}\rangle = H|0\rangle$, followed by a measurement operation in the computational basis. "simulate" and "run" and compare the histograms.

(b) Consider the operations : $|\text{output}\rangle = XX|0\rangle$, $XXXX|0\rangle$, $XXXXXX|0\rangle$ followed by a measurement operation in the computational basis. "simulate" and "run" and compare the histograms. For qubit 1 on ibmqx2 you find results in the cache.

(c) Consider the "Mach-Zehnder interferometer" operations : $|\text{output}\rangle = HXH|0\rangle$ followed by a measurement. "simulate" and "run" and compare histograms. Same questions with double and triple interfereometers. Use qubit 0 for cache results.

Exercise 2 *Two qubit manipulations (use ibmqx4)*

(a) For the 5 qubit devices the CNOT gates are directional and denoted CX_{i-j} where i is the control and j the target bit. Get familiar with the CNOT gates : choose two qubits 1 and 0 and apply the CX_{1-0} gate. Simulate and run and compare histograms. For 1024 shots you should find cache results.

(b) Think of a small circuit involving H and the directed CX_{1-0} gate to realize a CNOT where 0 is the *control* and 1 the *target* bit. First find such a circuit with pencil and paper. Then, simulate, run, compare histograms. For 1024 shots you should find cache results.

(c) Choose the qubits 1 and 0 that are *connected* by a directed edge and realize the Bell state $\frac{1}{\sqrt{2}}(|0\rangle \otimes |0\rangle + |1\rangle \otimes |1\rangle)$ using the gates H and CX_{1-0}. Observe the histograms when you simulate and run. How would you proceed if 0 is the control bit and 1 the target bit ?

(d) Now try to entangle qubits 0 and 3 (i.e., create a Bell pair) that are *not directly connected* by an edge. Involve only bits 0, 2, 3 in your circuit. You should first think carefully of a circuit design with pencil and paper. Then, simulate, run, produce histograms. Compare the quality of such Bell pairs with those in (c). If you use only bits 0, 2, 3 you might find the results in the cache.