IBM Q practice 1 : Spring 2020
Hmw Quantum Computation

The goal of this first practice set is to get acquainted with **composer** (graphical interface) in the IBM Q experience. Register yourself with your email and generate an API token.

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.

Those that already have some familiarity can directly go to exercise 2-c-d.

Exercise 1 *Single qubit manipulations (use a five qubit machine with small current queue. Typically you can take 1024 shots, but you may also play around by varying this number)*

(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 : $|\text{output}\rangle = XX|0\rangle$, $|\text{output}\rangle = HH|0\rangle$, $|\text{output}\rangle = XXXX|0\rangle$, $|\text{output}\rangle = XXXXXX|0\rangle$ followed by a measurement operation in the computational basis. ”simulate” and ”run” and compare the histograms.

(c) Consider the ”Mach-Zehnder interferometer” operations : $|\text{output}\rangle = HXH|0\rangle$ followed by a measurement in the computational basis. ”simulate” and ”run” and compare histograms. Same questions with double and triple interfereometers.

Exercise 2 *Two qubit manipulations (typically use five qubit machines with small queues and 1024 shots)*

(a) For the 5 qubit devices the CNOT gates are denoted CX_{i-j} where i is the control and j the target bit. Get familiar with the CNOT gates : choose two connected qubits and apply the CX_{i-j} gate. Simulate and run and compare histograms.

(b) Think of a small circuit involving H and a CX_{i-j} gate to realize a CNOT where i is the *control* and j the *target* bit. First find such a circuit with pencil and paper. Then, simulate, run, compare histograms.

(c) Choose your two favorite qubits i and j that *are connected* by an 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_{i-j}. Observe the histograms when you simulate and run.

(d) Now try to entangle two qubits (i.e., create a Bell pair) which are *not directly connected* by an edge. You may choose two qubits seprated by one qubit or two qubits that are more distant (separated by more than one qubit). 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 (b).