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 directly go to exercise 2-c-d.

Exercise 1 Single qubit manipulations (use ibmqx2)

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

(b) Consider the operations: |output⟩ = XX|0⟩, XXXX|0⟩, XXXXXX|0⟩ 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: |output⟩ = HXH|0⟩ followed by a measurement. "simulate" and "run" and compare histograms. Same questions with double and triple interferometers. 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 $\frac{1}{\sqrt{2}}(|0⟩ \otimes |0⟩ + |1⟩ \otimes |1⟩)$ 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.