QS3 Quantum Experience Hands-On Activity

General Guidelines

- Work in teams of 2-4. Larger teams should include at least one person whose background is in a field other than physics, if possible. Be sure that everyone participates!
- Most of the projects listed below (all except the ones marked **API Only**) can reasonably be done using either the drag-and-drop GUI on the website or programming through the API. Feel free to use either one or a combination of the two.
- Keep in mind that simulations run faster than real executions, and sometimes give clearer results, so you'll probably want to make liberal use of the simulator at least for debugging.
- Document your findings, especially anything that surprised you, and be prepared to give a quick (2-3 minutes) summary to the whole group at the end of the session.
- Don't forget to check out the user guide on the QX website as well as the example python files and ipython notebooks in the SDK for additional interesting circuits to run.
- *Spend up to 10-15 minutes considering various ideas and deciding what to do. The list below is just a starting point, as are the suggested references; feel free to do anything you find interesting!*

Possible Projects

Quantum physics demonstrations:

1. Make a GHZ state and study its properties (see Full User Guide, Section III.5 on QX website, qiskit-sdk-py/examples/ghz.py, and/or qiskit-sdk-py/tutorial/sections/entanglement_revisited.ipynb)
2. Make a 3-qubit W state a study its properties (https://arxiv.org/pdf/quant-ph/0503096.pdf)
3. Teleportation (see qiskit-sdk-py/examples/teleport.py and/or https://arxiv.org/pdf/1607.02398.pdf)
4. Interaction-free measurement (https://en.wikipedia.org/wiki/Elitzur–Vaidman_bomb_tester)
5. **API Only** CHSH inequality (see qiskit-sdk-py/tutorial/sections/entanglement_revisited.ipynb)

Quantum algorithm building blocks:

6. CNOT behavior in the +/- basis (Exercise 4.20 from Nielsen & Chuang; ask Doug for a photocopy)
7. Toffoli gate (https://arxiv.org/abs/quant-ph/9503016)
8. Quantum Fourier Transform (https://courses.cs.washington.edu/courses/cse599d/06wi/lecturenotes9.pdf)
9. Quantum phase estimation (https://courses.cs.washington.edu/courses/cse599d/06wi/lecturenotes10.pdf)
10. Parity checks for error correction (https://arxiv.org/pdf/1208.0928.pdf)
11. Grover's search (see user guide (Full User Guide Section IV.3))
12. Quantum adder (see qiskit-sdk-py/examples/rippleadd.py)
13. Deferred and implicit measurement (Nielsen & Chuang pp. 186-187; ask Doug for a photocopy)

Performance tests:

14. Crosstalk tests: do control operations and/or measurements affect qubits other than the intended one(s)?
15. **API Only** Randomized Benchmarking (https://arxiv.org/pdf/1203.4550.pdf)
16. **API Only** State/Process Tomography (https://arxiv.org/pdf/quant-ph/9610001.pdf)
17. For a moderately simple circuit(s) of your choice, compare performance of real device to simulation and see if you can figure out the main sources of error. Can you improve the performance by changing which qubits play which roles? Are the coherence times and error rates reported in the most recent calibration consistent with your findings?