CUDA-Q Resource List for Quantum Information Science and Quantum Computing Courses

This document is intended to assist faculty in selecting CUDA-Q resources that align with their syllabus and topic list for undergraduate or graduate courses in Quantum Information Science or Quantum Computing. CUDA-Q provides a variety of practical resources that can be seamlessly incorporated into these courses:

- **Jupyter Notebooks:** Self-paced modules, available for self hosting or on platforms such as qBraid Lab or Google Colab, offer hands-on learning experiences on topics the Quantum Approximate Optimization Algorithm (QAOA).
- **Visualization Tools:** These tools help students grasp abstract concepts by visualizing quantum circuits and Bloch spheres, making the learning process more intuitive.
- **Hybrid Programming Examples:** Code snippets demonstrate how to develop hybrid quantum-classical applications using CUDA-Q's kernel-based programming model, supporting both Python and C++ for flexible integration.

The CUDA-Q resources are categorized by topic. The list of topics below combines key concepts identified by the Quantum Information Science Learning: Future Pathways workshop, competencies from the Quantum Computing and Simulation section of the European Competence Framework for Quantum Technologies report, relevant high performance computing competencies, and topics common in the table of contents of several textbooks on quantum computing. This document will be updated with additional resources as they become available.

CUDA-Q Resources

1. Overview of Quantum Information Science and Quantum Computing
    a. Motivation and vision for accelerating quantum supercomputing (blog and video)
    b. Quick Start to Quantum Computing course (A link to a full course under development that covers all fo these topics is here and short code samples that individually address the topics are linked in the items below)
        i. Quantum states and gates
        ii. Quantum Measurement
        iii. Qubits: Qubit visualization on the Bloch sphere
        iv. Entanglement
        v. Quantum circuits and kernels structure, sampling, and expectation value computation
    c. Overview of fault tolerant computation and NISQ
    d. Computational Complexity
2. Quantum algorithms and applications
    a. Quantum teleportation
    b. Deutsch-Josza

    c. Bernstein-Vazirani
    d. Grover’s
    e. QPE
    f. QFT
    g. Shor’s Factoring Algorithm
3. Variational hybrid algorithms and applications
    a. General structure of a variational hybrid algorithm
    b. Variational quantum eigensolver
    c. QAOA for max cut - code only and course materials with exercises, video explanations, etc
    d. Hybrid neural networks basic code and application blog for solar energy research
4. Quantum Computation
    a. Classical Simulation of Quantum Algorithms
    b. Quantum Computers
        i. Quantum Communication
        ii. Coherence and Types of Noise
    c. Error mitigation and error correction
5. Further topics in Applications and Algorithm Design
    a. Circuit cutting (introduction to circuit cutting through QAOA max cut example)
    b. GPT-QE blog
    c. Divisive clustering code and blog