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Exercise: Quantum Computing
Problem set 3 (to be discussed in week of November 14, 2020)

Problem 1 Matrix Representation of Quantum Fourier Transform

In the lecture we discuss the Quantum Fourier Transform defined through its action

$$|x\rangle \to \frac{1}{\sqrt{2^N}} \sum_{k=0}^{2^N-1} e^{2\pi i x k/2^N} |k\rangle$$

on the basis states $|x\rangle \in \{|0\rangle, \ldots, |2^N - 1\rangle\}$ with number of qubits N. Give a matrix representation for $N = 3$.

Problem 2 Quantum Fourier Transform and Elementary Gates

We have established previously how to relate a general gate operation to only the single-qubit H, R_ϕ, and the two-qubit CNOT gates. How many H, R_ϕ, and CNOT gates, respectively, are required to implement the Quantum Fourier Transform circuit given in the lecture?

Problem 3 Quantum Fourier Transform is Unitary

Show that the Quantum Fourier Transform is unitary.

Problem 4 Inverse Quantum Fourier Transform

In the lecture we give a quantum circuit to perform the Quantum Fourier Transform. Give a circuit to perform its inverse operation.

Problem 5 Simulation of Quantum Fourier Transform

Implement the Quantum Fourier Transform for general N in the simulator http://github.com/lehner/sqc. Using this implementation, perform the Quantum Fourier Transform for $N = 3$ on all basis vectors.