Quantum Information Processing, BME 2019 Spring
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Exercises

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I. EXERCISES

Keywords: quantum Hello World, making graphs in python, fitting an exponential in python.

1. *Quantum Hello World.*
   Do a Hadamard gate and measure the qubit afterwards. Use 10 shots.

   (a) Define the circuit in the composer. Run the simulator. How many times do you measure the state 1?

   (b) Define the circuit in qiskit in a jupyter notebook. Run the circuit in your notebook on your local simulator. How many times do you measure the state 1?

   (c) Homework: Run the circuit on a quantum computer, using the composer.

   (d) Homework: Run the circuit on a quantum computer, using qiskit in a jupyter notebook.

2. *Draw a circuit.*
   Visualize the simple circuit above in qiskit in a jupyter notebook.

3. *Draw a histogram.*
   Plot the histogram of the data obtained above, using qiskit in the jupyter notebook. (counts of 0, counts of 1)

4. *Bell state.*
   Your goal is to prepare the Bell state $\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$ by acting on the first qubit with a Hadamard gate, and acting with a CNOT on the two qubits, and measuring the two qubits. Draw the circuit on a piece of paper. Use 1024 shots in what follows.

   (a) Compose the circuit in the composer. Run the circuit from the composer on the simulator.

   (b) Define the circuit with qiskit in a jupyter notebook. Run the circuit.

   (c) Plot the histogram of the measured data.

5. *Plot a function.*
   Plot the sine function in the $[0, 4\pi]$ interval in a jupyter notebook.

6. *Exponential decay.*
   Generate a noisy exponential decay curve: sample the function $f(t) = e^{-t}$ between the interval $[0, 10]$ in steps 0.1, add a normally distributed random contribution to each data point with a standard deviation of 0.1, and fit an exponential function, $g(t) = Ae^{-t/T_1} + c$, to the noisy data. What are the three values of the parameters A, T_1, c obtaind from the fit? How do they relate to the parameters ($A = 1$, $T_1 = 1$, $c = 0$) of the original $f(t)$ function? Plot the noiseless data set, the noisy data set, and the fitted curve, in the same graph.

7. *Rabi oscillations on the Bloch sphere.*
   The Rabi formula states that the time evolution of the polarization vector of a resonantly driven qubit reads

$$\boldsymbol{p}(t) = \begin{pmatrix} \sin\theta(t)\cos(\phi(t)) \\ \sin\theta(t)\sin(\phi(t)) \\ \cos\theta(t) \end{pmatrix}, \qquad (1)$$

   where $\phi(t) = \omega_L t$ and $\theta(t) = \Omega t$. Plot this time evolution as a 3D parametric plot, with $\Omega = 1$, $\omega_L = 10$, in the time window $t \in [0, \pi]$.