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# Quantum Computing

Program Next-Gen Computers for Hard, Real-World Applications

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The  
Pragmatic  
Programmers

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Hard, Real-World Applications



Nihal Mehta, Ph.D.  
*edited by Brian MacDonald*



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## Try Your Hand

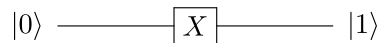
Solutions to these exercises are given in [Quantum Superposition Solutions, on page ?](#).

These exercises demonstrate that by judiciously wiring up quantum gates, it's possible to orchestrate the collapse of qubits and that they don't just gyrate uncontrollably.

For any code listing in the exercises, assume the following header lines:

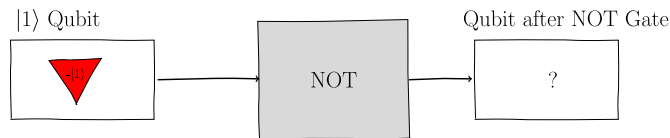
```
OPENQASM 2.0;
include "qelib1.inc";
```

1. The NOT gate operates on a  $|0\rangle$  qubit as shown in this quantum circuit:

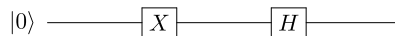


Show the operation of the NOT gate in terms of qubelets.

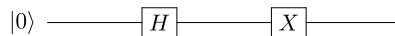
2. An inverted triangle  $|1\rangle$  qubelet is operated on by a NOT gate:



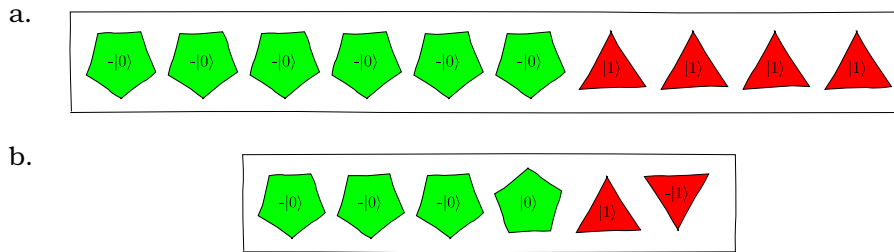
- a. How is this qubelet affected by the NOT gate?
  - b. If you measure the qubit after it's operated on by the NOT gate, what binary state would be logged in the classical register?
3. a. Draw the qubelets for the  $|0\rangle$  qubit after it's been operated on by the H and X gates, as shown in the following quantum circuit:



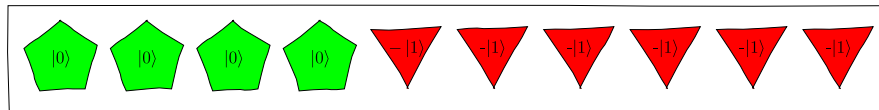
- b. Compare the qubelets against the following quantum circuit:



- c. If you measure the qubit after it's been operated on by both gates in the previous circuits, would you notice any statistical difference in the output?
4. Simplify the following qubits.

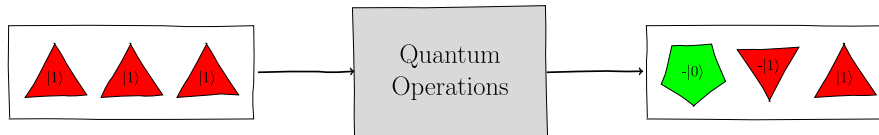


5. Consider the following quantum state of a qubit:



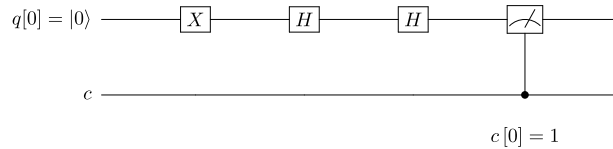
Compare the likelihoods of the qubit collapsing to  $|0\rangle$  versus  $|1\rangle$ .

6. Describe the quantum operations, if any, you can apply to convert the quantum state of the qubit on the left to the quantum state on the right in the following figure:

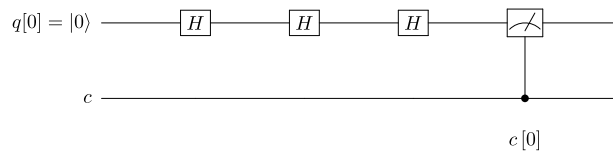


Hint: Consider the quantum operations such as switching and inverting qubelets listed in [Basic Operations, on page ?](#). (In [Quantum Circuit Synthesis, or Guess the Gate, on page ?](#), you'll learn to design the quantum circuit that implements the quantum operations taking the quantum state on the left qubit to the one on the right.)

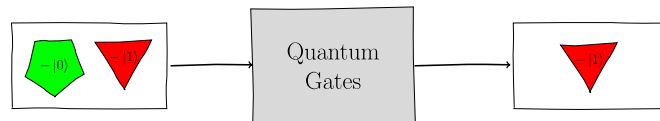
7. a. Draw a quantum circuit and write the quantum program that simulates a coin toss on the real IBM computer.
- b. How many shots would you specify for this program?
8. In the following circuit, back-to-back H gates are applied to a  $|1\rangle$  qubit. Using qubelet diagrams, what is the quantum state of the qubit after it's operated on by both H gates?



9. Consider the following quantum circuit with three back-to-back  $H$  gates, shown as follows:



- Draw the qubelets in the qubit after it's been acted upon by all three gates.
  - Write the quantum program for this circuit.
  - Execute this program and examine the output. What strikes you?
10. When writing quantum programs, it's crucial that you understand how to transform quantum states to ones that increase the likelihood of collapsing to states that solve your computational task. For example, what quantum gates should be performed on the qubit on the left to take it to the state on the right in the following quantum circuit:



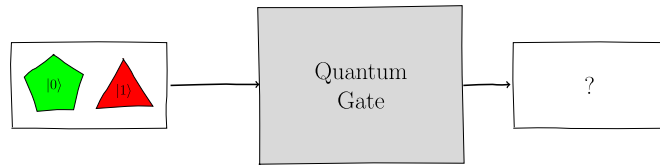
That is, the quantum gates should remove the inverted pentagon  $|0\rangle$  qubelet from the quantum state.

11. Consider a gate that operates as follows:

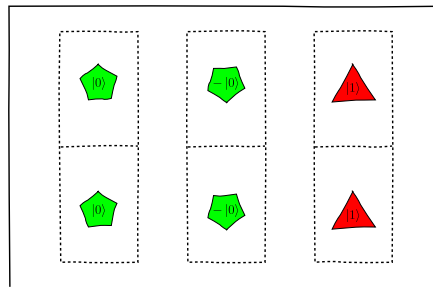
- Doesn't affect the pentagon  $|0\rangle$  qubelets.
- Inverts the triangle  $|1\rangle$  qubelets.

How will this gate transform the following qubit:





12. The following mega-qubit is the result of being operated on by quantum gates. If you measure the qubits making up the mega-qubit, which classical state is it most likely to be recorded as in the classical register?



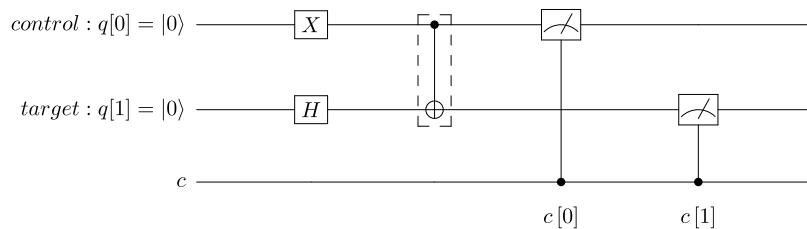
13. Draw the mega-qubit for the following quantum circuit [shown on page 8](#).

$q[0] = |0\rangle$  ———  $[H]$  ———

$q[1] = |0\rangle$  ———  $[H]$  ———

$q[2] = |0\rangle$  ———  $[H]$  ———

14. Consider the following quantum circuit:



- Draw the mega-qubit before it's fed to the CNOT gate.
- Draw the mega-qubit after it's operated on by the CNOT gate.

- c. List the states, and their probabilities, that are recorded in the classical register when the mega-qubit collapses.
  - d. If you just measure the bottom qubit and it happens to be 0, what can you say about the top qubit?
  - e. Write a quantum program for this circuit and compare the output with the mega-qubit you drew earlier.
15. Consider the quantum circuit that models the Aladdin Constraints as outlined in [Logic Expressions to Quantum Circuit, on page ?](#).
- a. Where would you place the H gates?
  - b. Run the quantum program. What can you say about the states shown in the output?
16. Draw the quantum circuit corresponding to the code listing shown here:

```
h q[1];
h q[0];
x q[0];
ccx q[0],q[1],q[2];
```