

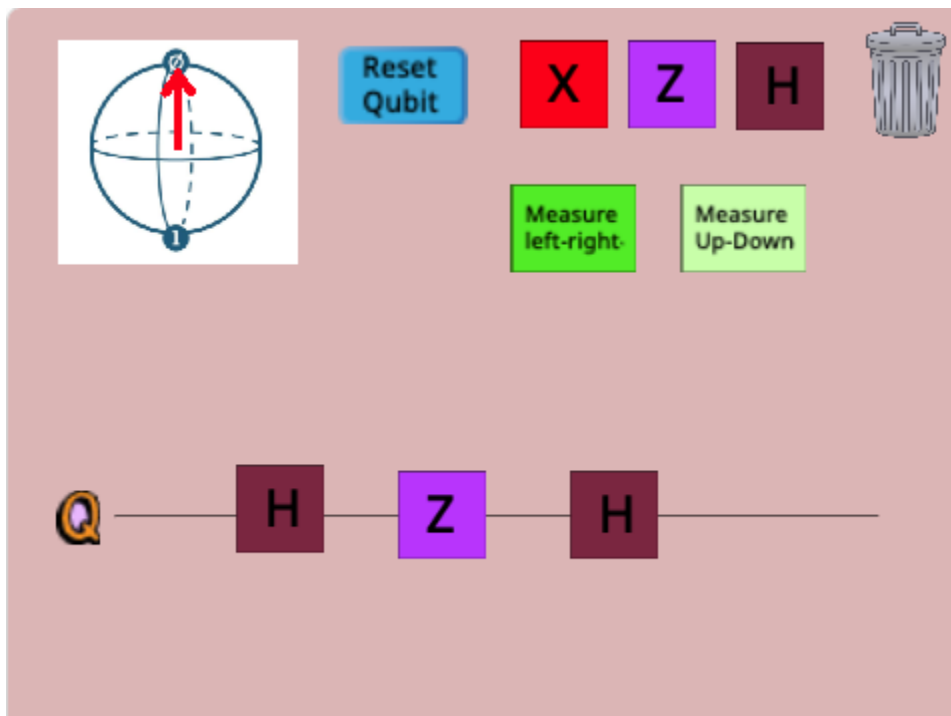


The Quantum Circuit Challenge (solutions):

Note: In many cases several different solutions are possible. We've provided one.

Challenge 1 - Up, down, left, right: Create a quantum circuit that puts the qubit into each of the 4 states up, left, down, right (in any order, look at the picture on the top left to see what state you are in)

Solution:



Challenge 2 - Making randomness: Build a circuit and choose a measurement at the end so that the result of the measurement is random.

This means that when you run the same circuit a few times the measurement at the end will sometimes say "up" and sometimes say "down" OR, sometimes it will say "left" and sometimes say "right".



A quantum circuit interface on a light brown background. At the top left is a Bloch sphere with a red arrow pointing to the top pole. To its right are four buttons: a blue 'Reset Qubit' button, a red 'X' gate, a purple 'Z' gate, and a dark red 'H' gate. Further right is a trash can icon. Below these are two green 'Measure' buttons: 'Measure Up-Down' and 'Measure left-right'. At the bottom, a yellow 'Q' qubit icon is connected by a horizontal line to the 'Measure left-right' button.

Challenge 3 - Doing and undoing: Start your circuit with an X gate. Then, add gates so that the effect of your circuit is to do nothing at all.

A quantum circuit interface on a light brown background, identical to the one above. The Bloch sphere and gate buttons are the same. However, the 'Measure Up-Down' button is now disabled (greyed out). The circuit at the bottom shows a yellow 'Q' qubit icon connected by a horizontal line to two red 'X' gates in sequence.



Challenge 4 - Doing and undoing: Start your circuit with a Z gate and then an H gate. Then, add gates so that the effect of your circuit is to do nothing at all.

The image shows a quantum circuit simulation interface. At the top left is a Bloch sphere with a red arrow pointing to the top pole. To its right is a palette of gates: a blue 'Reset Qubit' button, a red 'X' gate, a purple 'Z' gate, a dark red 'H' gate, a trash can icon, a green 'Measure left-right' button, and a light green 'Measure Up-Down' button. Below the palette is a quantum circuit with a qubit labeled 'Q' on the left. The circuit consists of a sequence of gates: a purple 'Z' gate, a dark red 'H' gate, another dark red 'H' gate, and a final purple 'Z' gate. The circuit line ends with an open connection on the right.

Challenge 5 - Flipping without X gates: Create a circuit that takes in an "up" state and sends out a "down" state, but, create this circuit without ever using an X gate!



The simulator interface includes a Bloch sphere with a red arrow pointing to the top pole. Control buttons include a blue 'Reset Qubit' button, red 'X' gate, purple 'Z' gate, dark red 'H' gate, a trash can icon, a green 'Measure left-right' button, and a light green 'Measure Up-Down' button. The circuit diagram shows a qubit labeled 'Q' followed by three gates: a dark red 'H' gate, a purple 'Z' gate, and another dark red 'H' gate.

Challenge 6 - Useless gates: Create a circuit where the X gate doesn't do anything. you'll need at least one gate before the X gate so that the qubit going into the X gate isn't in the "up" state!

The simulator interface is identical to the one above. The circuit diagram shows a qubit labeled 'Q' followed by four gates: a dark red 'H' gate, followed by three red 'X' gates.



Challenge 7 - XH vs HX: Find two gates which create different circuits when put in a different order.

The interface includes a Bloch sphere with a red arrow pointing to the top pole (state $|0\rangle$). The circuit starts with a qubit Q at the top pole. It then passes through an X gate (red square) and an H gate (dark red square). The available gates are: Reset Qubit (blue), X (red), Z (purple), H (dark red), Measure left-right (green), Measure Up-Down (light green), and a trash can icon.

The interface is identical to the one above. The circuit starts with a qubit Q at the top pole. It then passes through an H gate (dark red square) and an X gate (red square). The available gates are: Reset Qubit (blue), X (red), Z (purple), H (dark red), Measure left-right (green), Measure Up-Down (light green), and a trash can icon.



Challenge 8 - XH vs HX: Find two gates which create the same circuit when put in a different order.

The interface shows a Bloch sphere with a red arrow pointing up. The toolbar contains: a blue 'Reset Qubit' button, a red 'X' gate, a purple 'Z' gate, a dark red 'H' gate, a trash can icon, a green 'Measure left-right' button, and a light green 'Measure Up-Down' button. The circuit diagram shows a qubit labeled 'Q' on the left, followed by an X gate (red square) and a Z gate (purple square) on a horizontal line.

The interface is identical to the one above. The circuit diagram shows a qubit labeled 'Q' on the left, followed by a Z gate (purple square) and an X gate (red square) on a horizontal line.



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Challenge 9 and 10: These are open ended challenges so we can't really provide a "solution". Please contact us though if you have questions!