

The Quantum Circuit Challenge

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)

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".

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.

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.

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!

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!

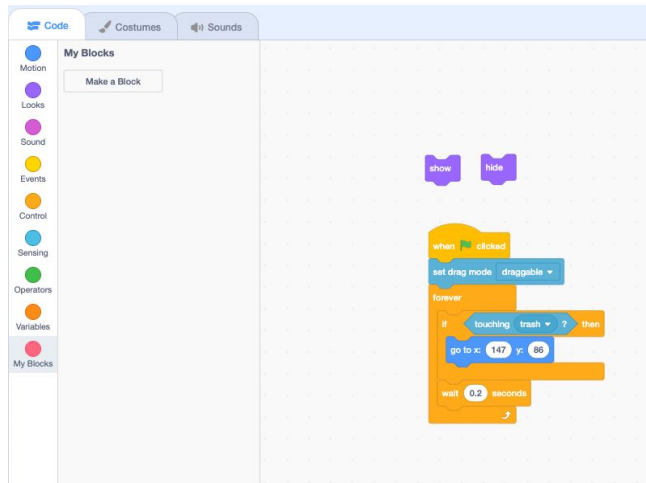
Challenge 7 - XH vs HX: Find two gates which create different circuits when put in a different order.

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

Hint - try a circuit with an X gate then an H gate, and compare this to an H gate and then an X gate. Try this again with X and Z.

Challenge 9 - Create your own gate:

To get started, look for the "my gate" sprite. In the code tab you'll notice a "show" block and a "hide" block. Click the "show" block.



A new sprite will appear in the circuit editor. You can go to the "costumes" tab to change the appearance of your gate (Make sure to keep your gate as a square and don't change the size, or the circuit won't work properly!)

Next go to the Q sprite. You'll need to use an "if" statement so the qubit checks if it is touching the new gate sprite. Then inside the if statement build your quantum gate! You can create a new gate by putting together a few of the existing gates.

Here's an example:

The image shows a Scratch script on a grid background. The script starts with a 'when space key pressed' event block, followed by a 'set drag mode to draggable' block. A 'forever' loop contains several conditional blocks. Each 'if touching color' block is followed by a gate block (XGate, ZGate, HGate) and a 'followWire' block. The colors are red, purple, dark red, white, light green, and green. The green block is followed by 'Measure Up Down' and 'stop this script'. The green block is followed by 'Measure Left Right' and 'stop this script'. The script ends with a 'go to front layer' block. A handwritten note 'new gate' with a bracket is next to the white and light green blocks. A 'Q' icon is in the top right, and search, zoom, and reset icons are in the bottom right.

```
when space key pressed
set drag mode to draggable
forever
  followWire
  if touching color red ? then
    XGate
    followWire
  if touching color purple ? then
    ZGate
    followWire
  if touching color dark red ? then
    HGate
    followWire
  if touching color white ? then
    XGate
    XGate
    followWire
  if touching color light green ? then
    Measure Up Down
    stop this script
  if touching color green ? then
    Measure Left Right
    stop this script
go to front layer
```

new gate

Remember that you can always restart by creating a new remix of the original project: <https://scratch.mit.edu/projects/400546699/>

Challenge 10: Once you've created your own quantum gate, you're ready to share your Scratch project!

Add your project to the "One Qubit Circuit" Scratch studio:

<https://scratch.mit.edu/studios/26808197/>

Next, check out 2-3 other projects in the Scratch studio. Without looking inside their code, can you figure out what their mystery gate is? How is it built out of the X, H, and Z gates? Post your guess in the comments on their Scratch project page.