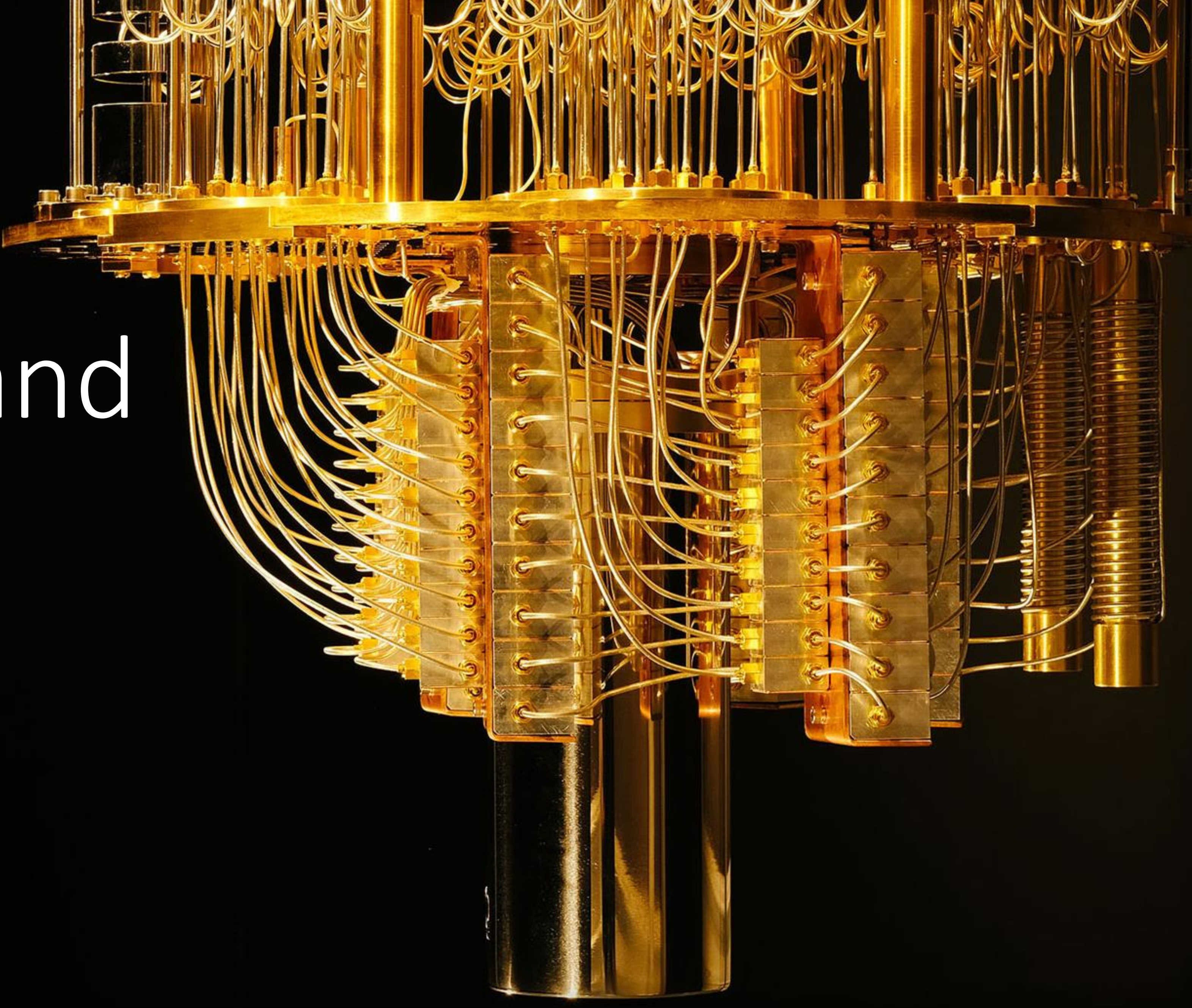
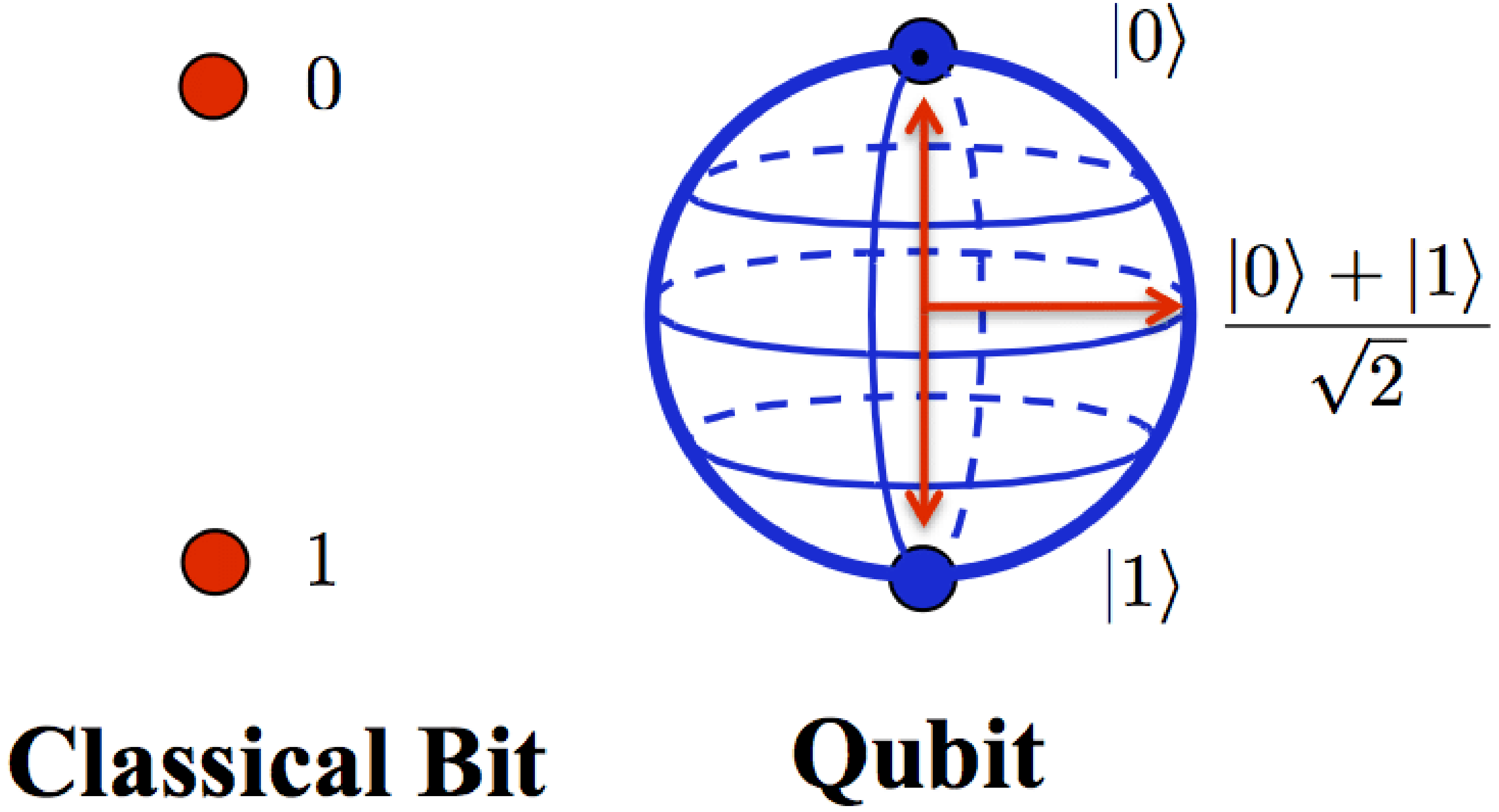
States, Gates and Circuits

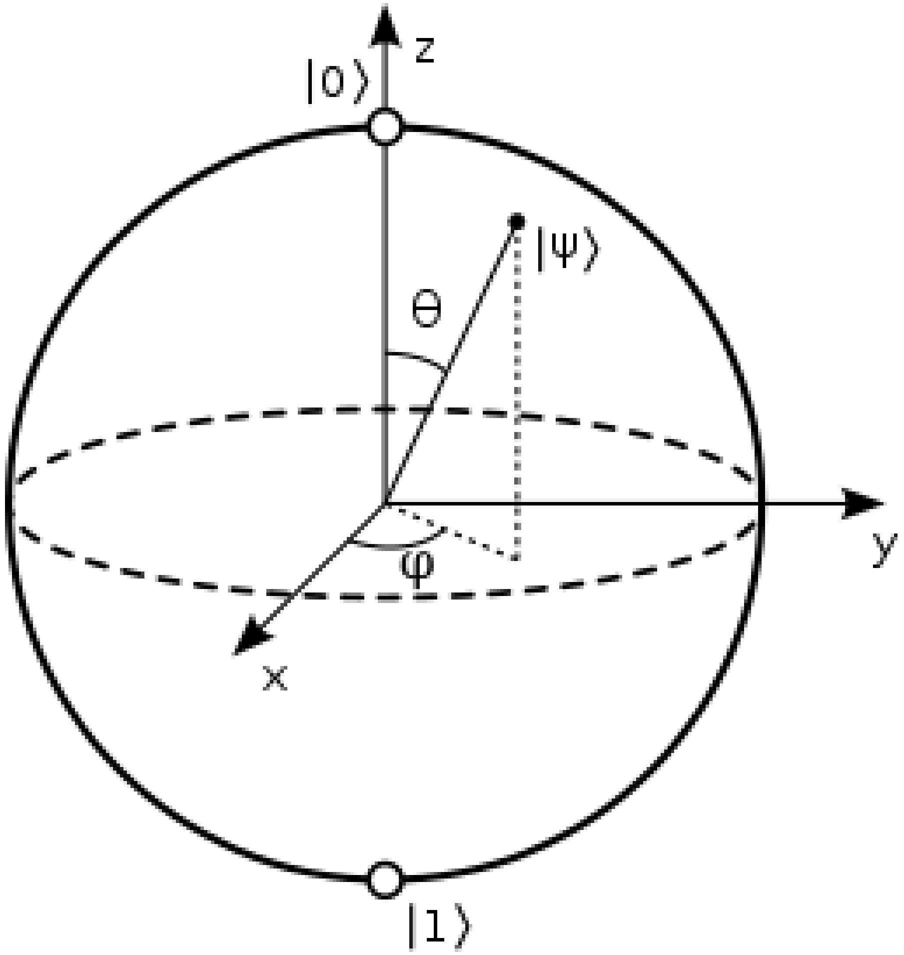


Priya Angara, Ulrike Stege

Bits vs Qubits



Qubits: Notation



- This is the called the dirac notation or the bra/ket notation
- |0> -> this is a Ket
- <0| -> this is a Bra

They are special symbols that simplify the math for us.

(Bra/Kets simplify vectors and complex conjugates.)

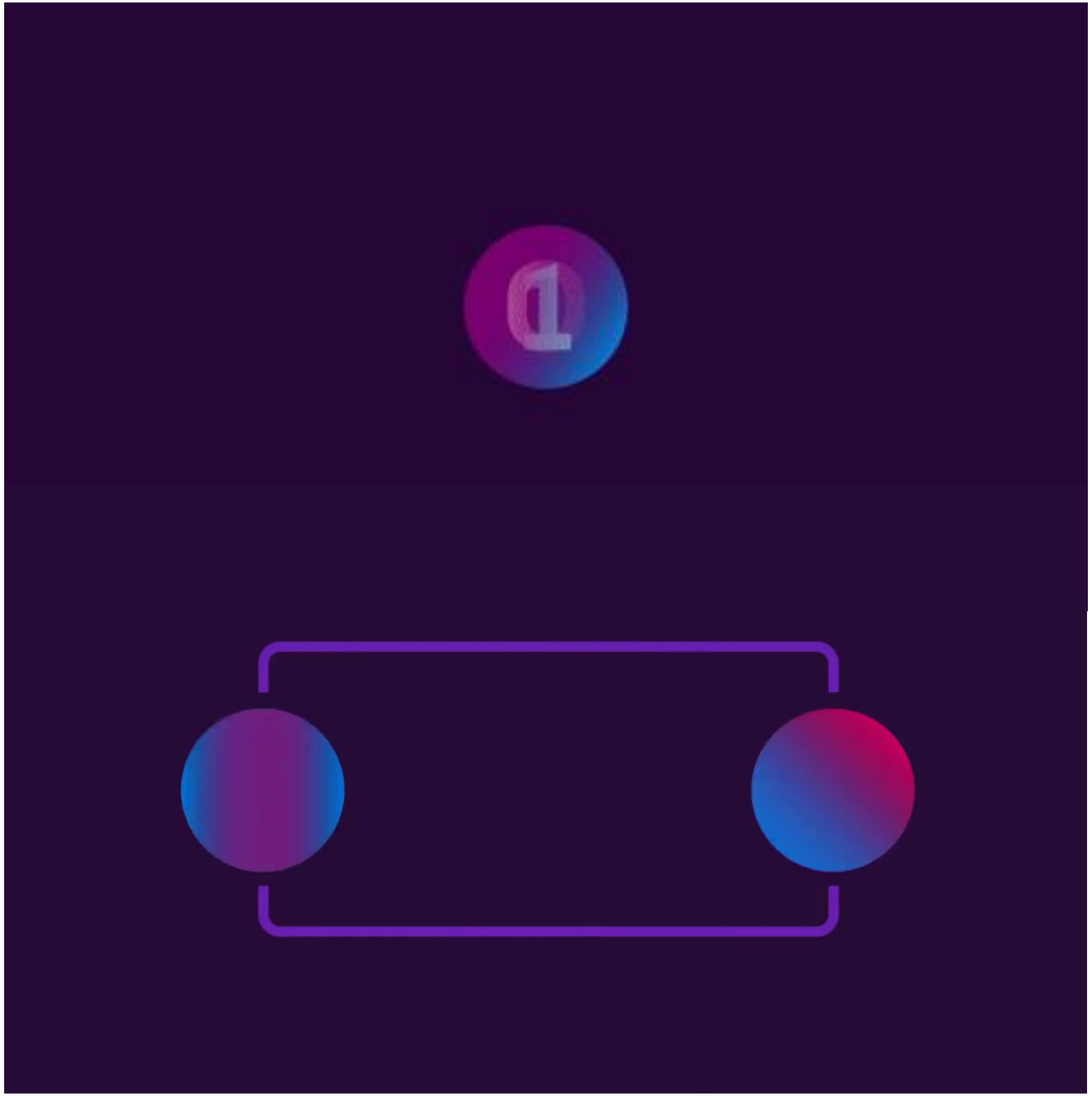
$|0\rangle$

|1>

Superposition!

Superposition

- Think of a state being the spinning donut.
- How plain/pink is our state?
- As soon as the state is *measured*, it will be either plain or pink



The Quantum State (|Ψ >)

$$|\psi > \quad = \alpha\,|0 > + \,\beta\,|1 >$$

$$|\alpha|^2 + |\beta|^2 = 1$$

Quantum State (|Ψ >)

$$|\psi > \quad = \boxed{\alpha}|0> + \boxed{\beta}|1>$$

$$\boxed{|\alpha|^2} + \boxed{|\beta|^2} = 1$$

What is a valid quantum state?

$$|\psi> \ = \frac{1}{\sqrt{2}}|0> + \frac{1}{\sqrt{2}}|1>$$

$$|\psi> \ = \frac{1}{4}|0> + \frac{3}{4}|1>$$

$$|\psi> \ = \frac{12}{13}|0> + \frac{5}{13}|1>$$

$$|\psi> \ = \frac{4}{5}|0> + \frac{2}{5}|1>$$

What is a valid quantum state?

$$|\psi > \quad = \boxed{\frac{1}{\sqrt{2}}}|0 > + \boxed{\frac{1}{\sqrt{2}}}|1 >$$

$$\boxed{(\frac{1}{\sqrt{2}})^2} + \boxed{(\frac{1}{\sqrt{2}})^2} = \frac{1}{2} + \frac{1}{2} = 1$$

What is a valid quantum state?

$$|\psi> \quad = \boxed{\frac{1}{4}}|0> + \boxed{\frac{3}{4}}|1>$$

$$\boxed{(\frac{1}{4})^2} + \boxed{(\frac{3}{4})^2} = \frac{1}{16} + \frac{9}{16} = \frac{10}{16}$$

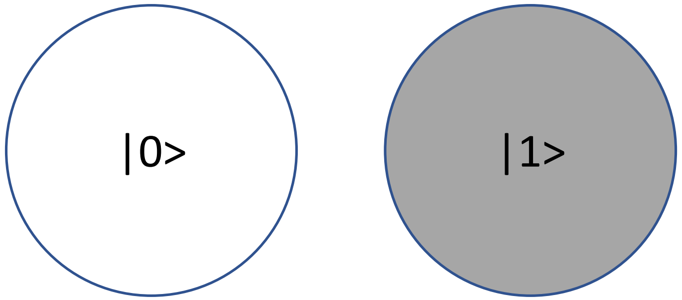
What is a valid quantum state?

$$|\psi> \quad = \boxed{\frac{12}{13}}|0> + \boxed{\frac{5}{13}}|1>$$

$$\boxed{(\frac{12}{13})^2} + \boxed{(\frac{5}{13})^2} = \frac{144}{169} + \frac{25}{169} = \frac{169}{169} = 1$$

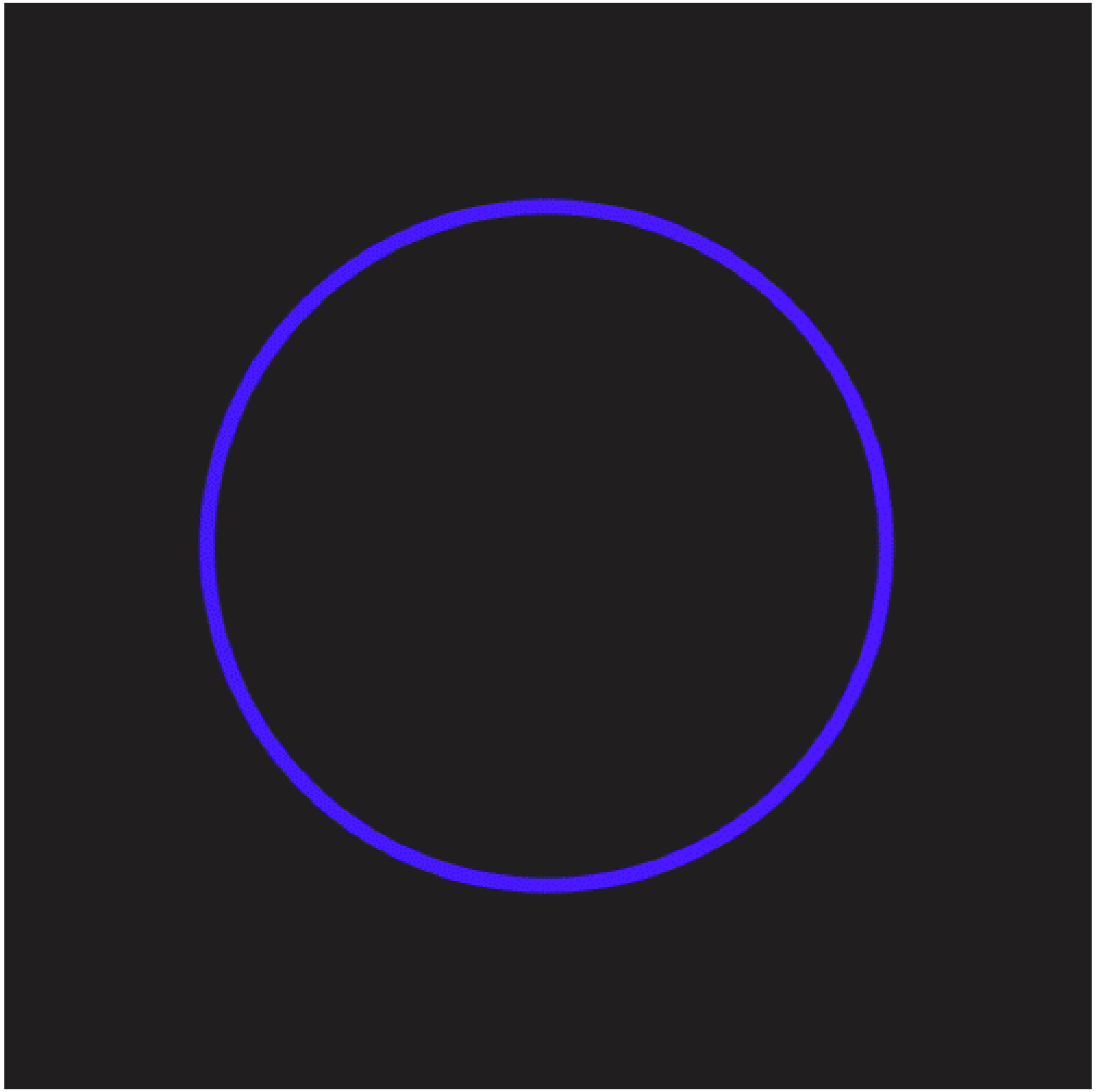
Activity: Find your Quantum Partner!

- Pick a ball

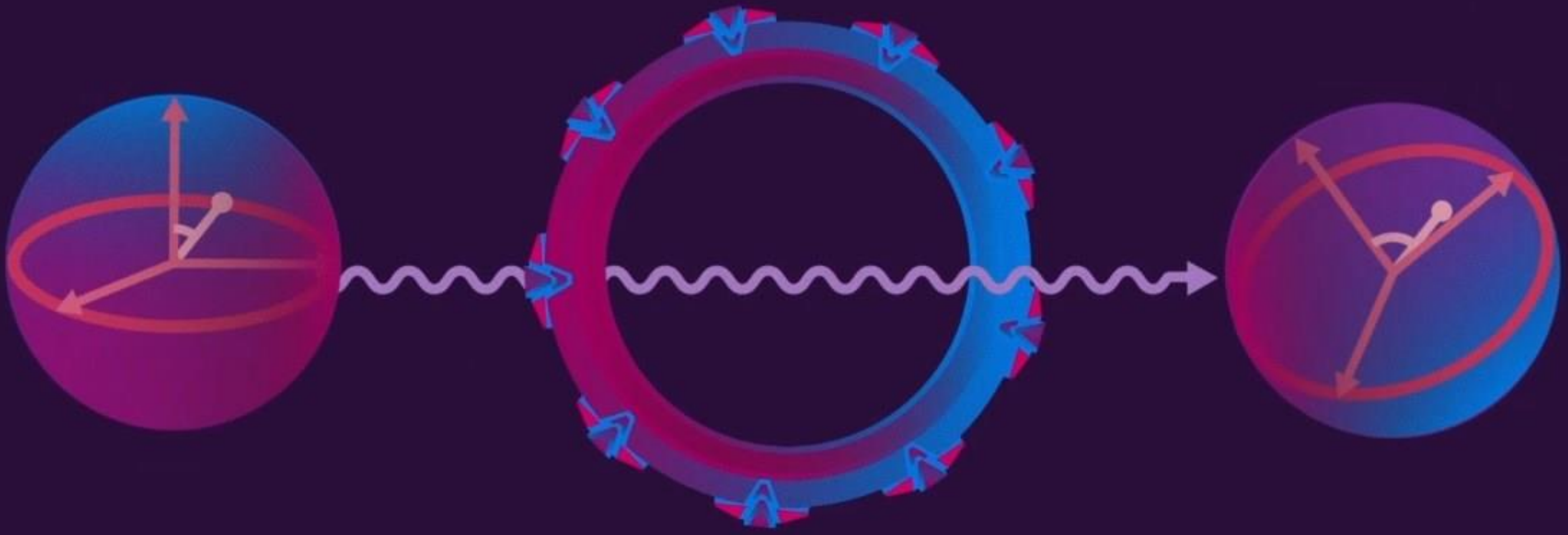


- Find a person with a ball of a color different from yours, and an amplitude that makes your combined state a quantum state.

Molding states using gates



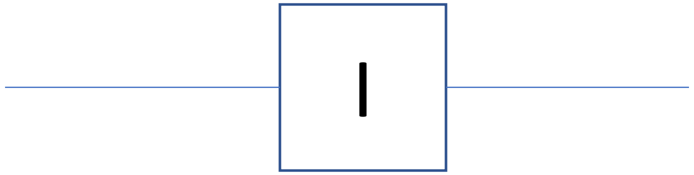
QUANTUM GATE



Identity Gate

$|0\rangle \rightarrow |0\rangle$

$|1\rangle \rightarrow |1\rangle$



NOT Gate

$|0\rangle \rightarrow |1\rangle$

$|1\rangle \rightarrow |0\rangle$

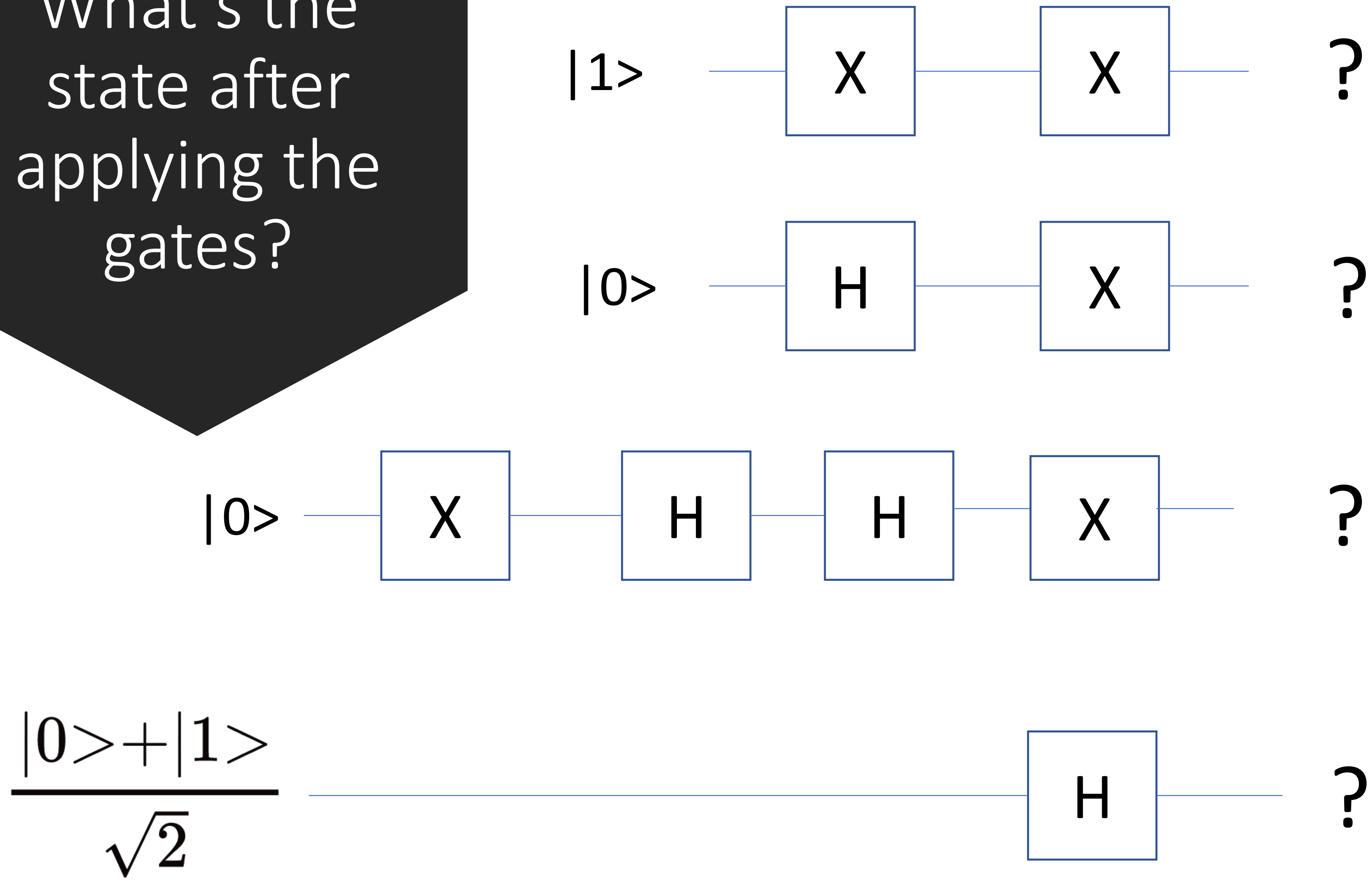
$-\boxed{X}-$

Hadamard Gate

$$|1> \rightarrow \frac{|0>-|1>}{\sqrt{2}}$$

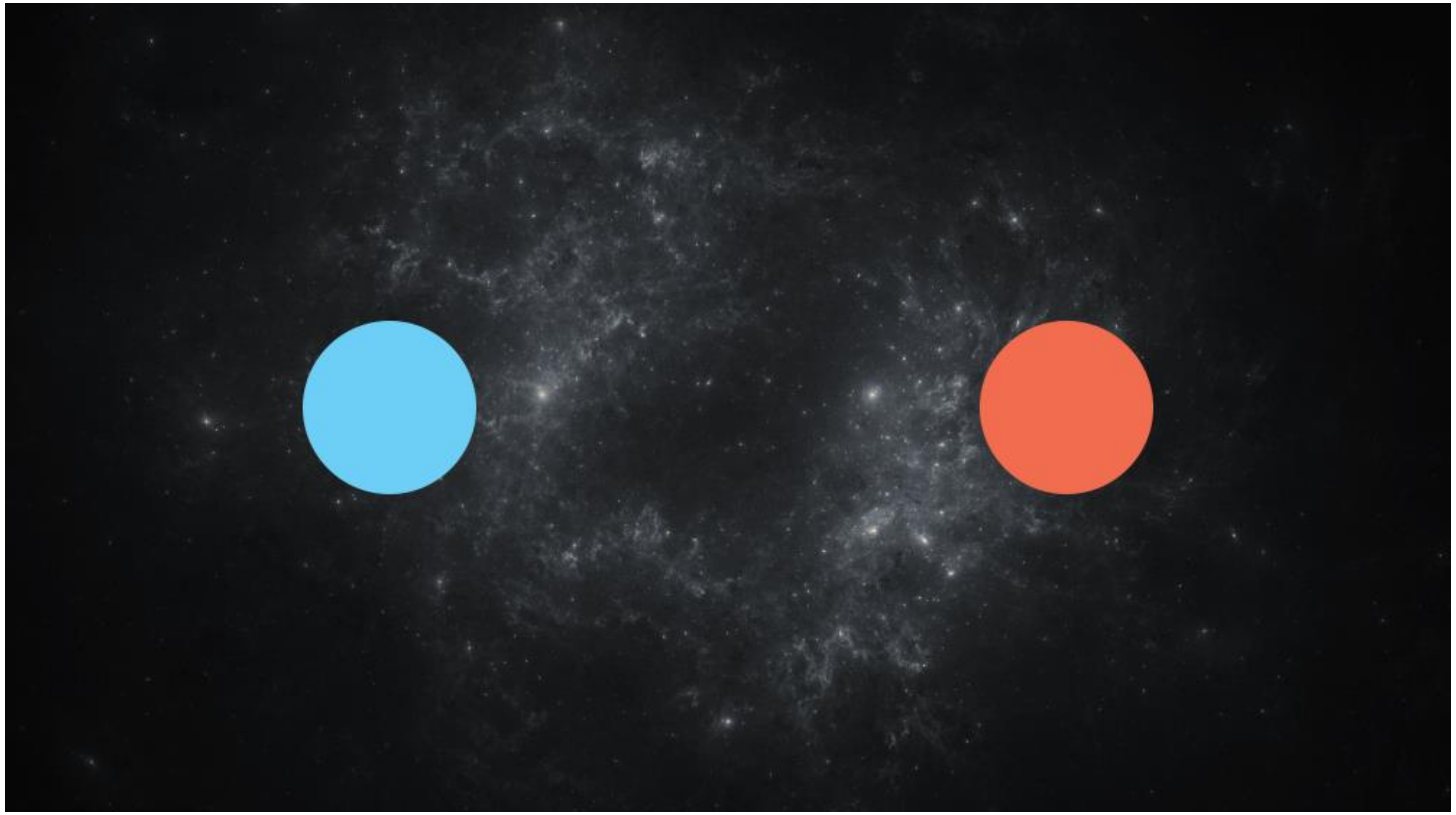
$$|0> \rightarrow \frac{|0>+|1>}{\sqrt{2}}$$

What's the state after applying the gates?

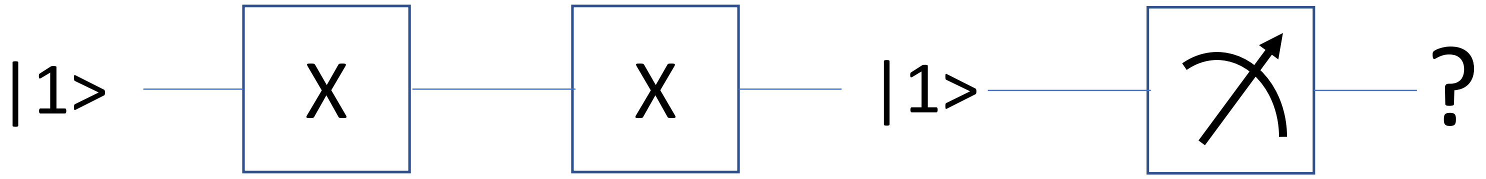


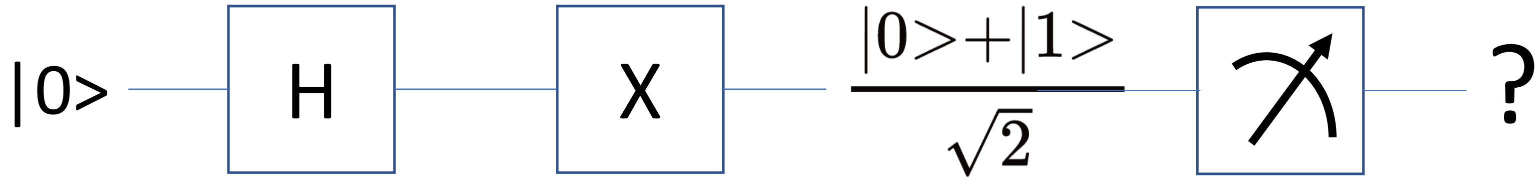
Measurement: Qubits are shy

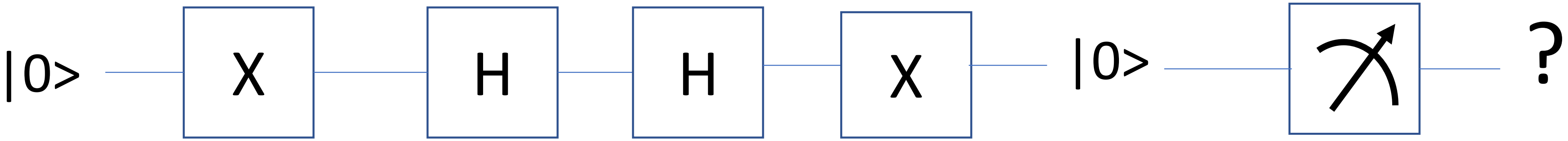
Whatever state qubits are in, they resolve to 0 or 1 on measurement

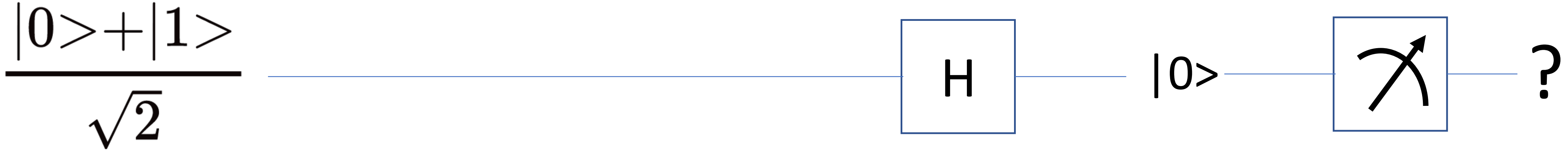


What’s the state after applying the gates?

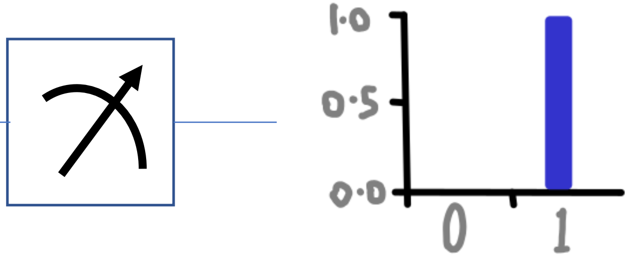




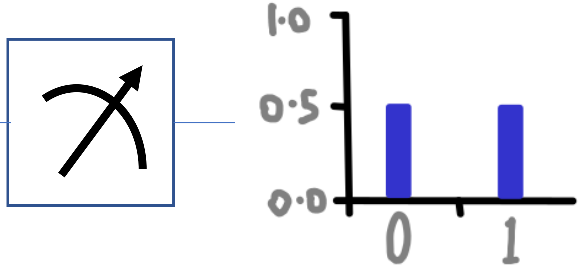




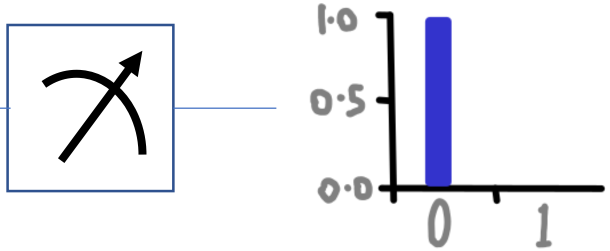
$|1>$



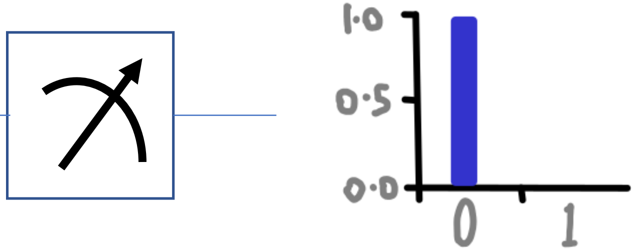
$$\frac{|0>+|1>}{\sqrt{2}}$$



$|0>$



$|0>$



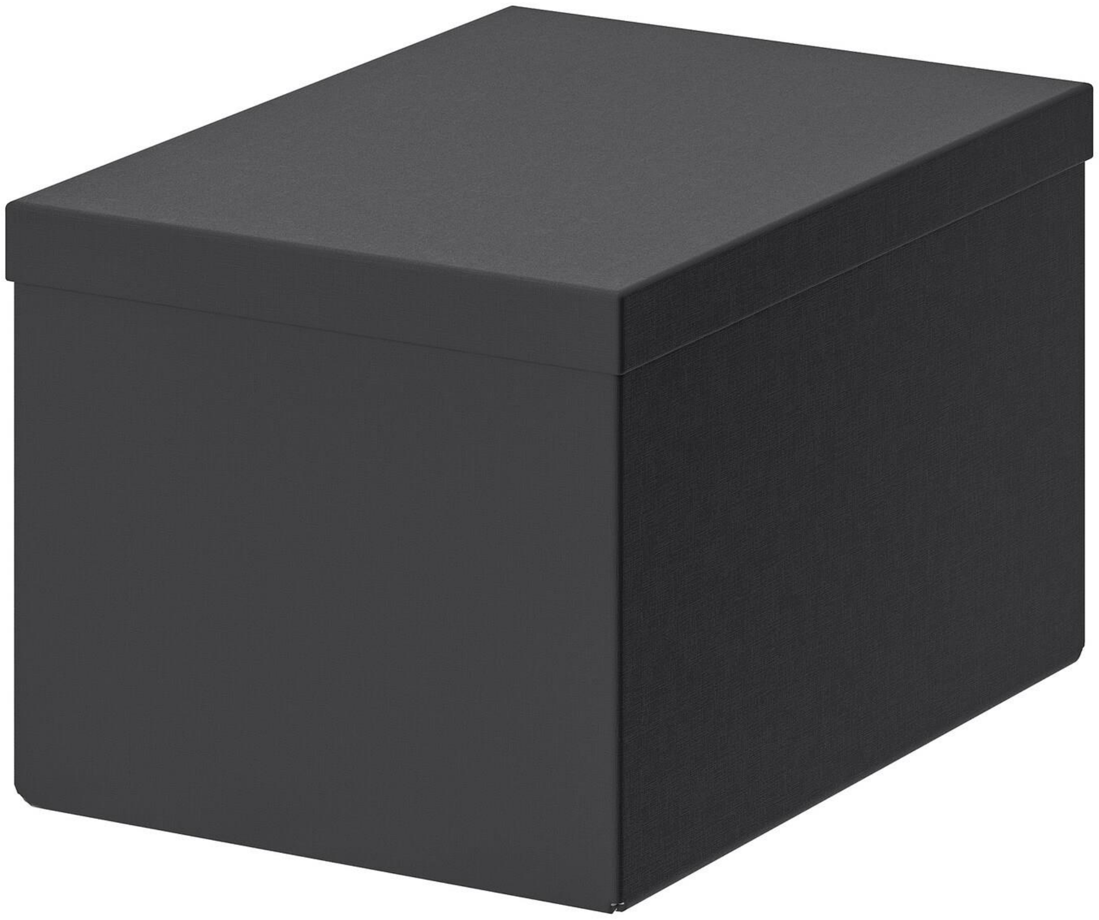
Guessing game

The box has 50 balls colored pink and grey.

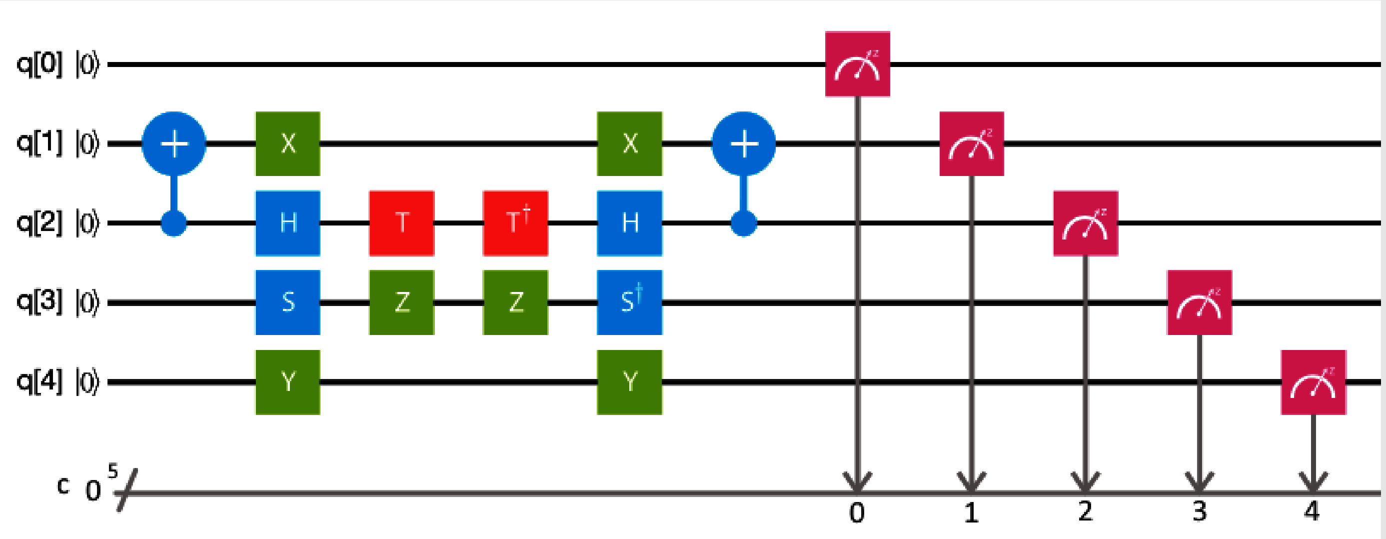
How many of these are pink, and how many are black?

Can you make a guess?

Let’s sample from the box and speculate!



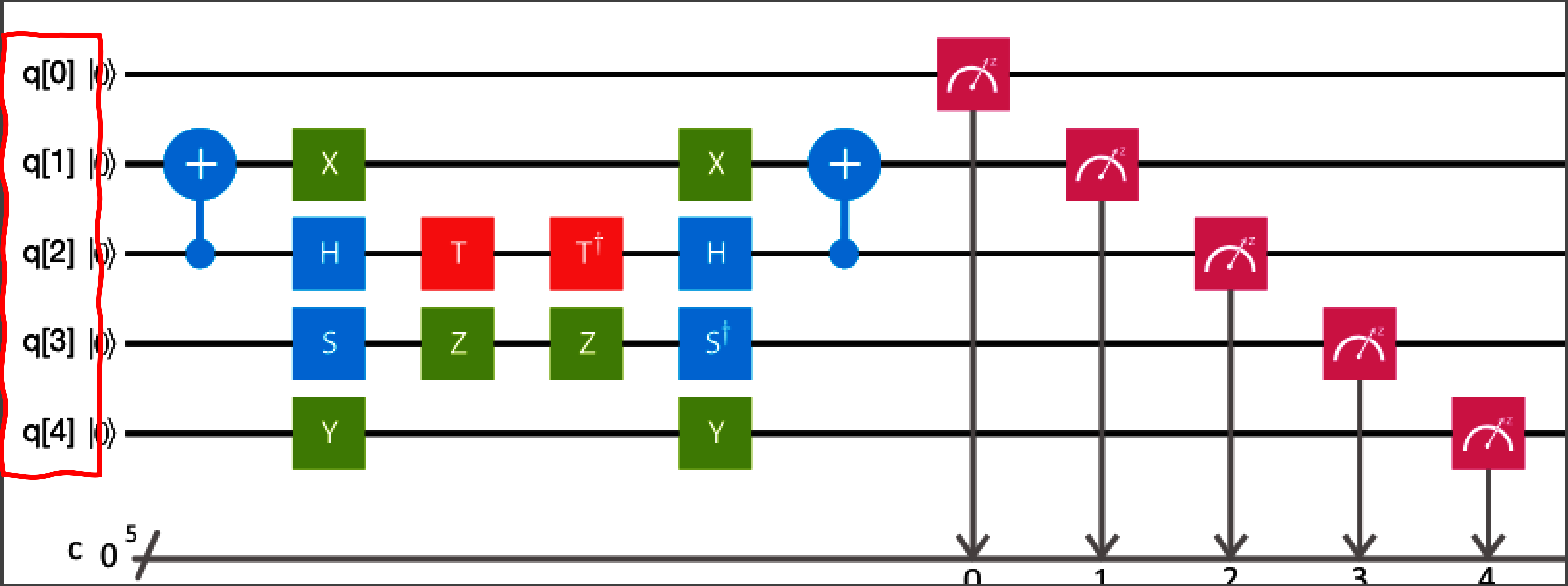
Quantum Circuits



- A sequence of gates that performs a specific task.
- There can be multiple qubits involved in a quantum system
- Basic elements: qubits, classical bits, gates, measurement

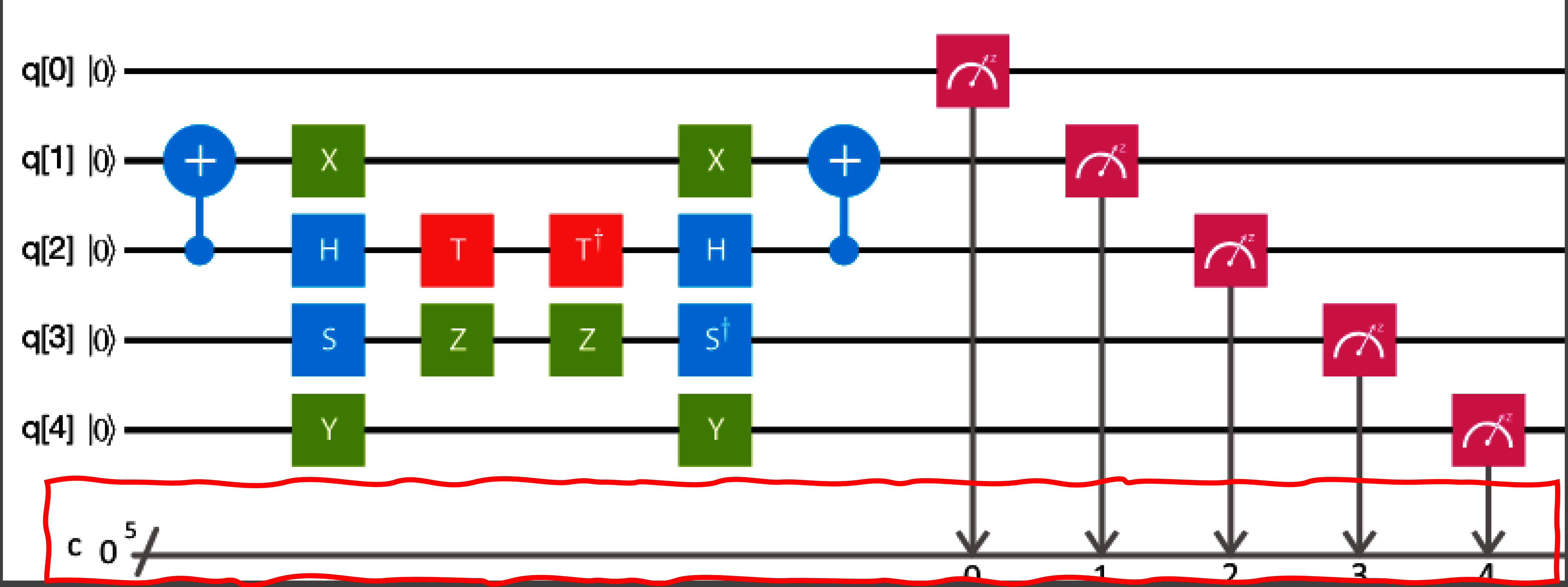
Qubits

qr = QuantumRegister(5)



Classical Bits

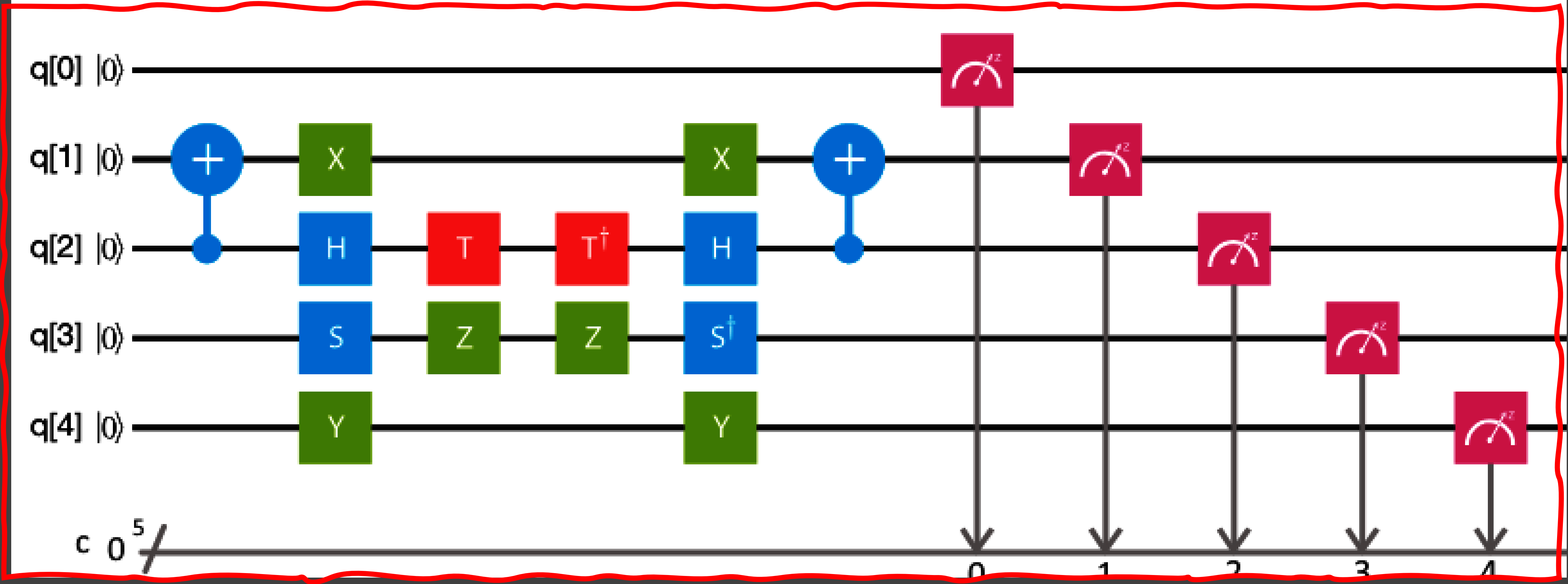
cr = ClassicalRegister(5)



Why do we need classical registers?

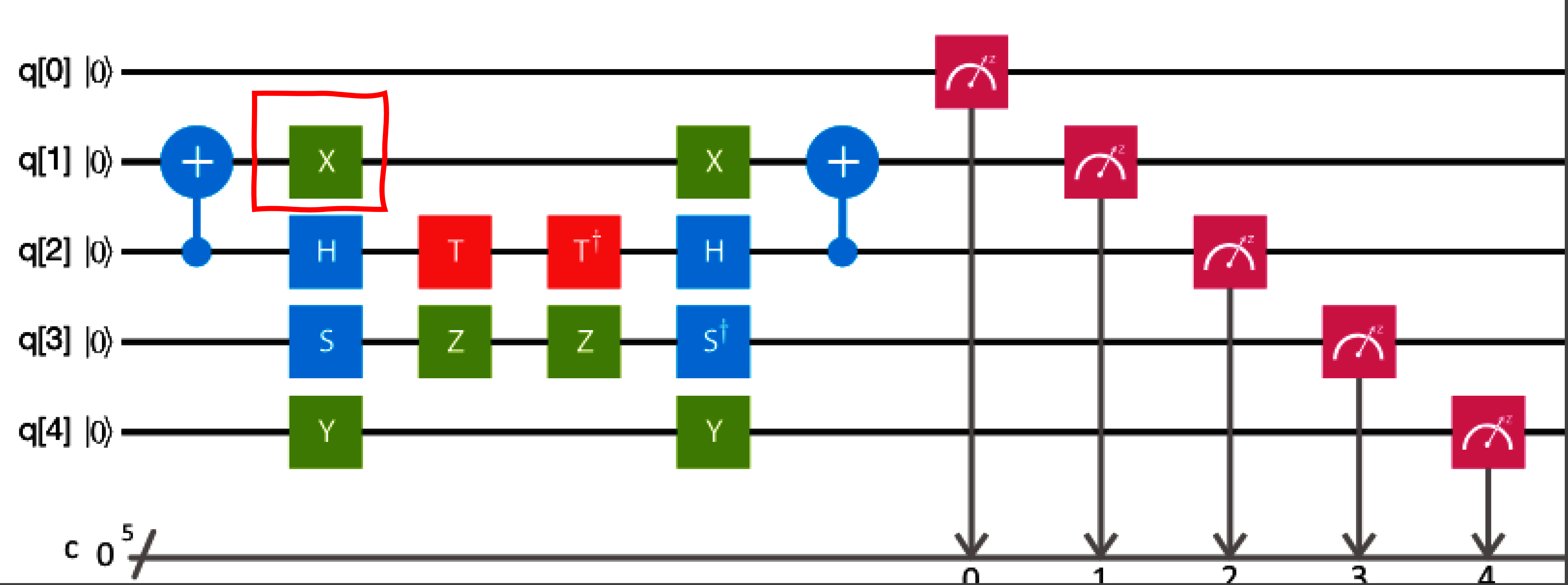
Circuit

circ = QuantumCircuit(qr,cr)



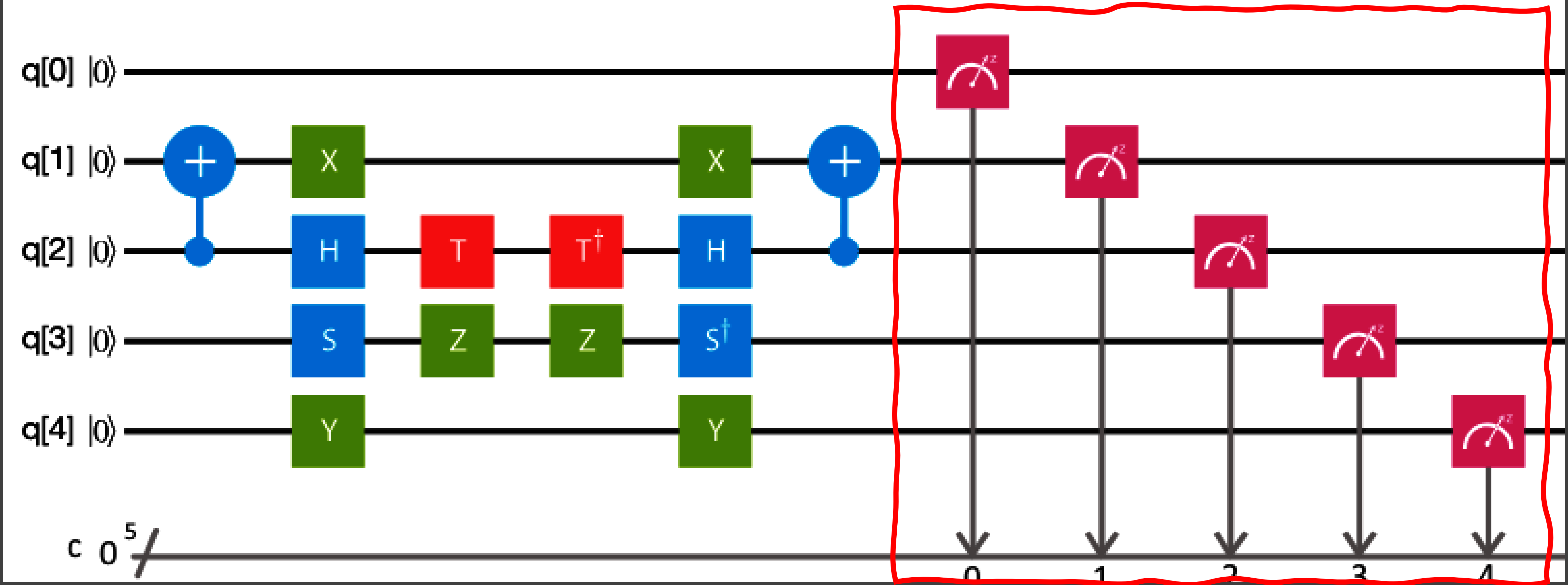
Gates

circ.x (1)



Measurement

```
circuit.measure(qr, cr)
```



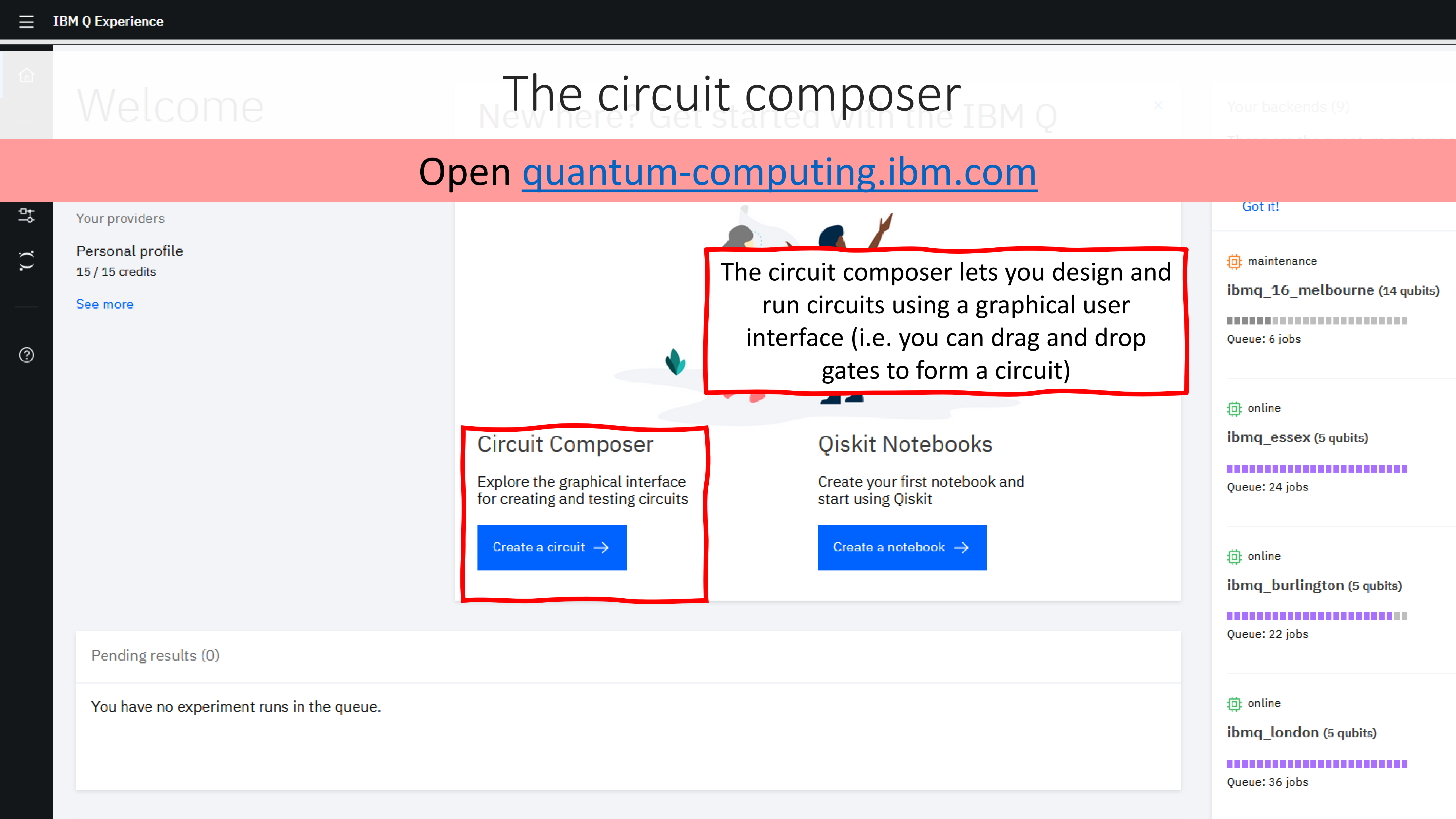
Plot the histogram

- We cannot really do much with one measurement

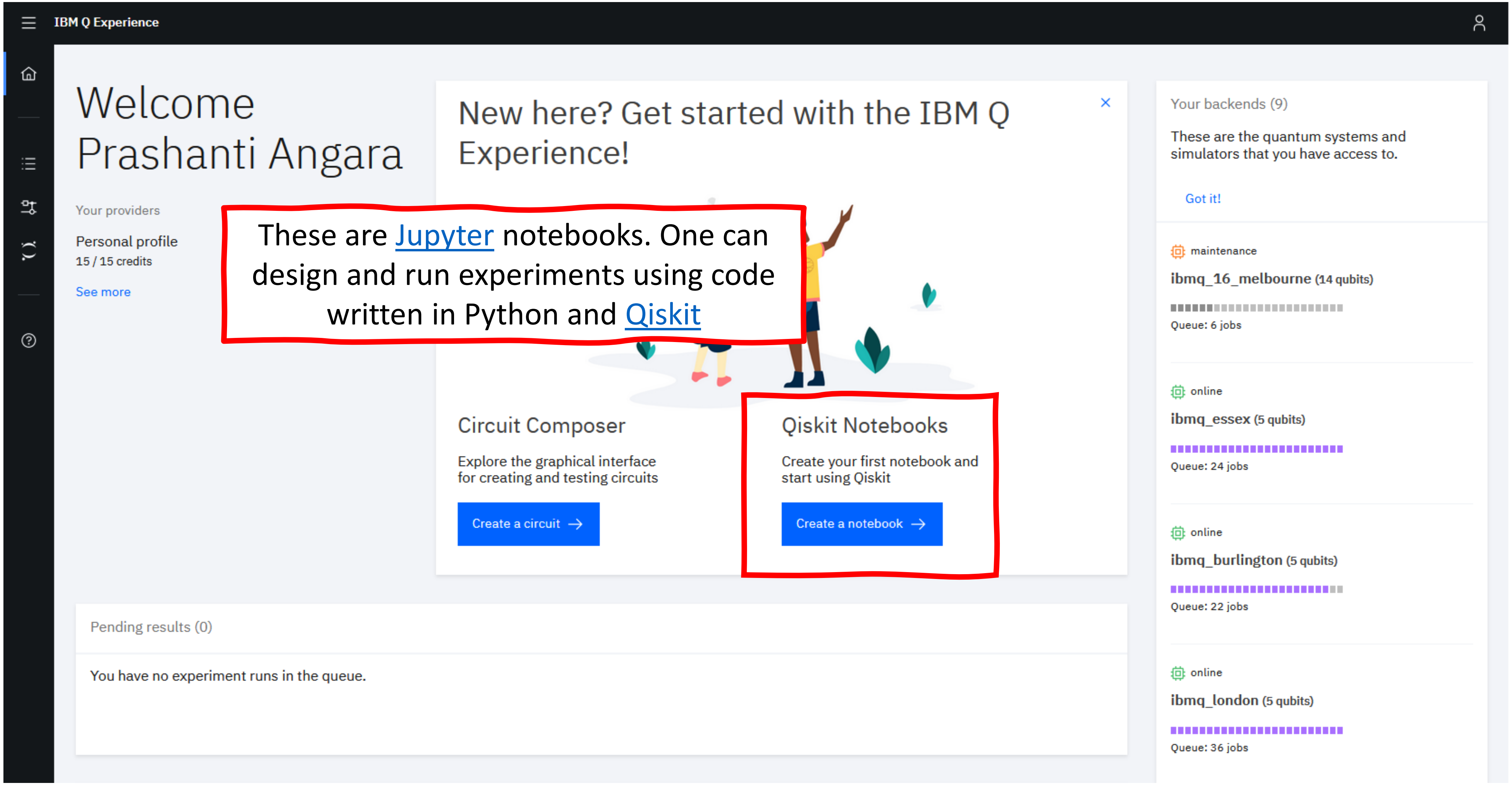
The circuit composer

Open quantum-computing.ibm.com

The circuit composer lets you design and run circuits using a graphical user interface (i.e. you can drag and drop gates to form a circuit)



Qiskit Notebooks



Let’s Qode!