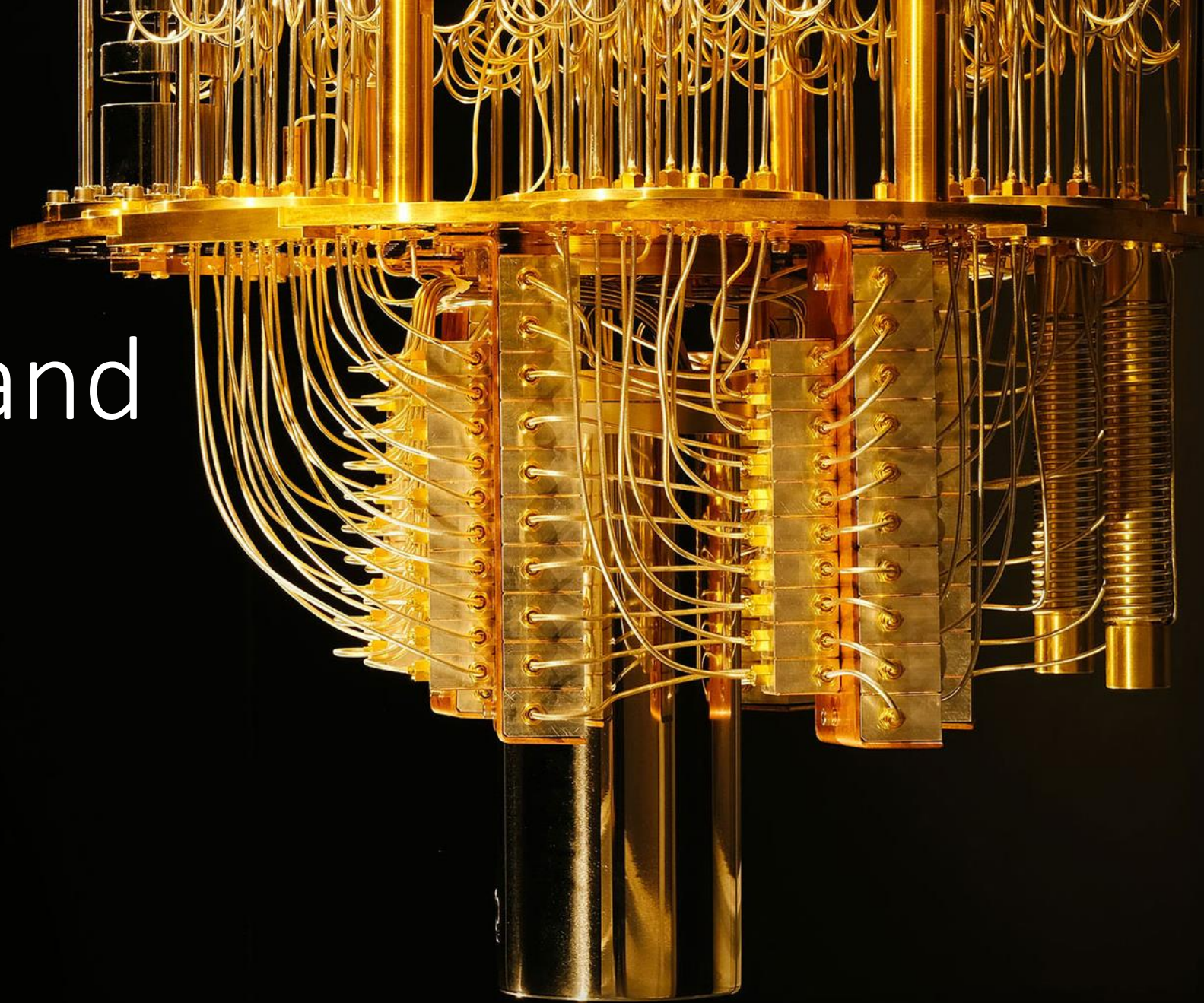


States, Gates and Circuits

Priya Angara, Ulrike Stege

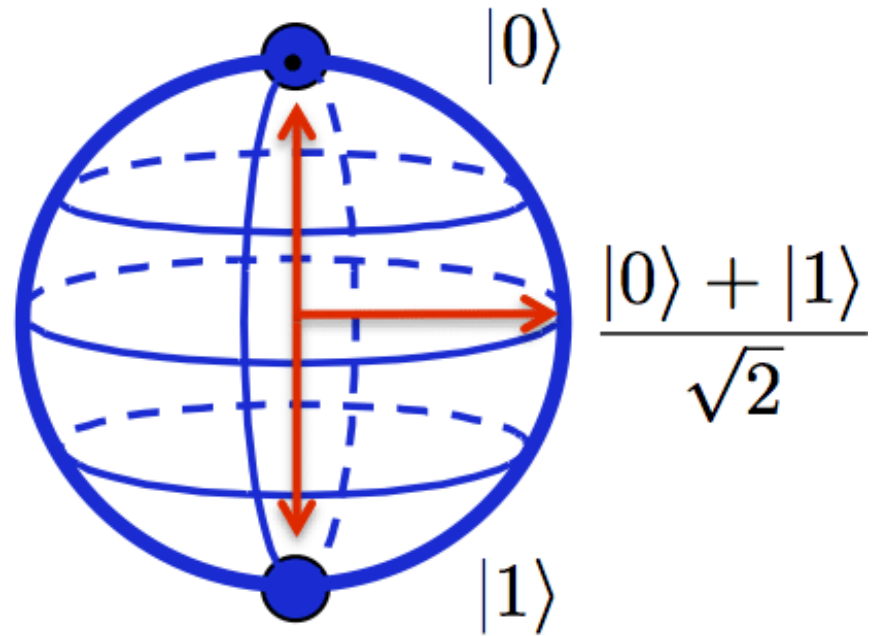


Bits vs Qubits

● 0

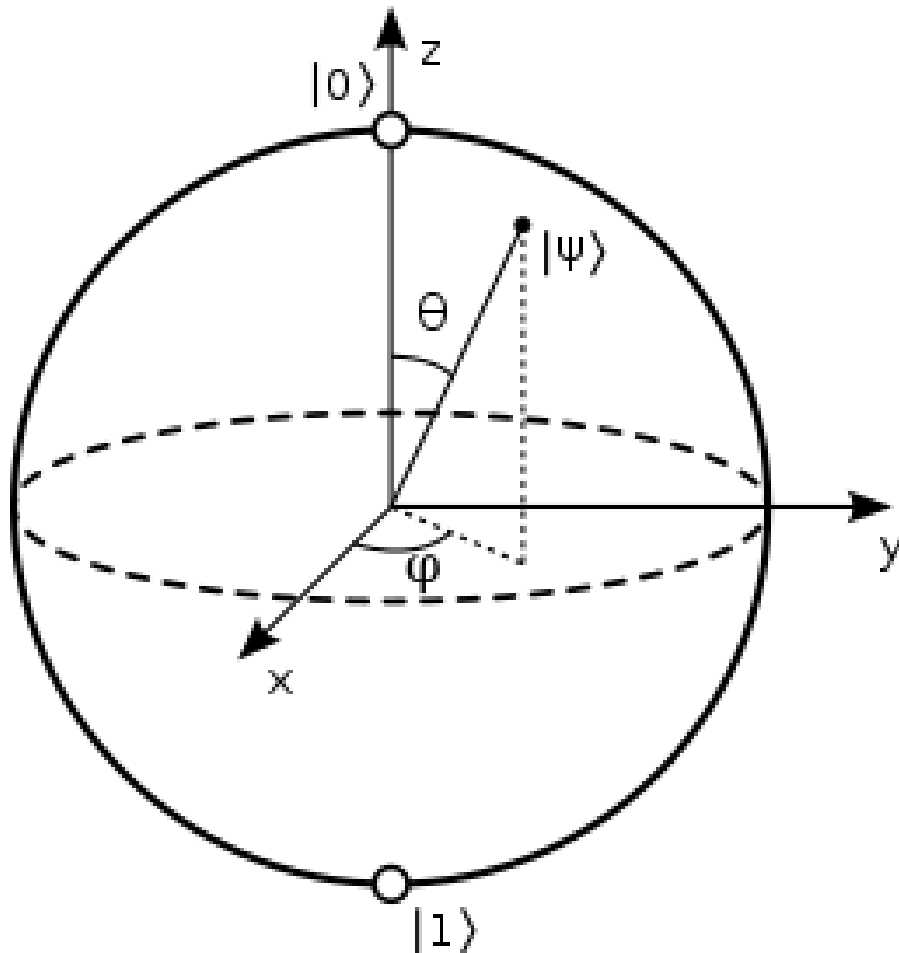
● 1

Classical Bit



Qubit

Qubits: Notation



- This is called the Dirac notation or the bra/ket notation
- $|0\rangle \rightarrow$ this is a Ket
- $\langle 0| \rightarrow$ this is a Bra

They are special symbols that simplify the math for us.

(Bra/Kets simplify vectors and complex conjugates.)

10>



$|1\rangle$

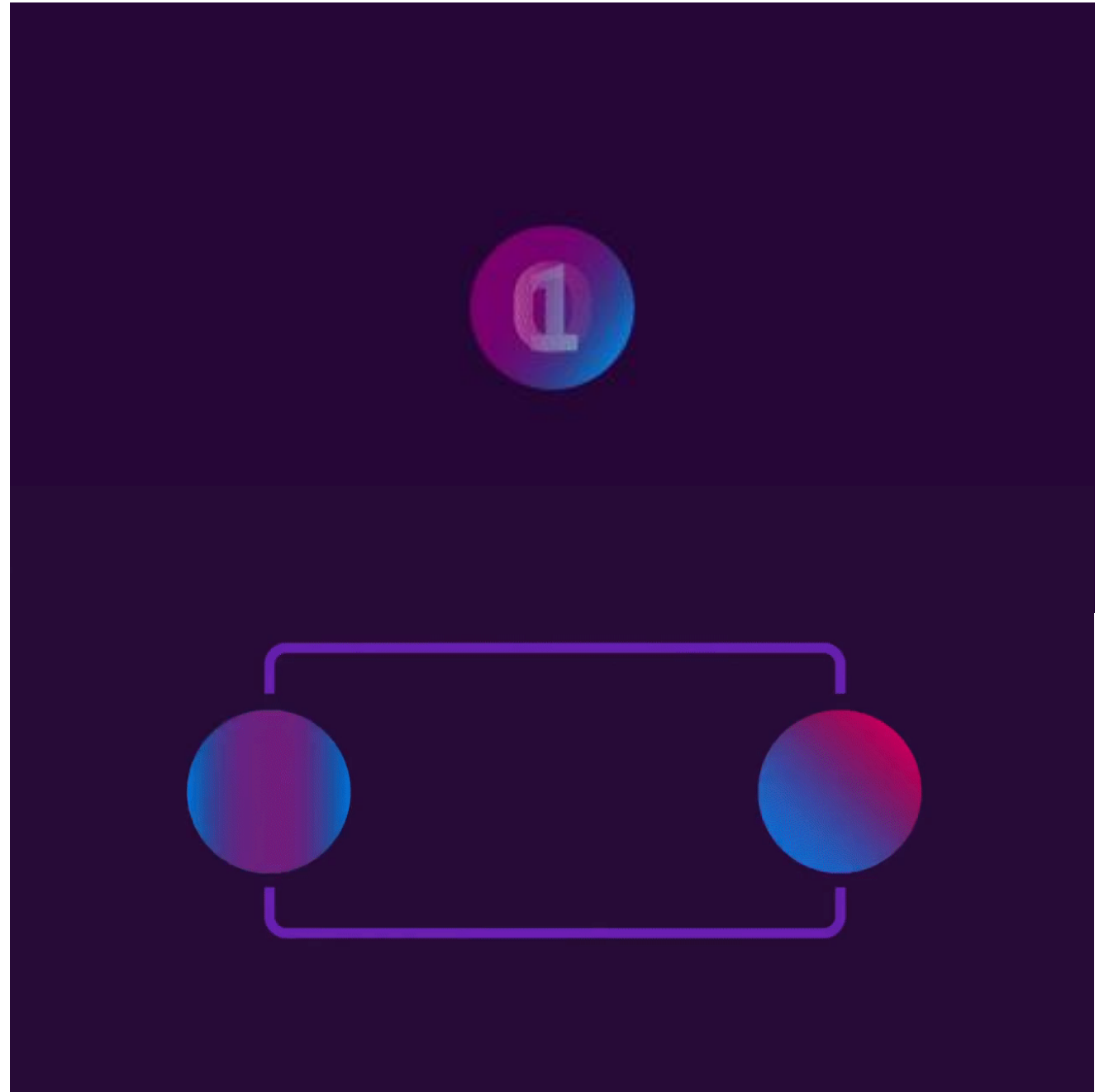


Superposition!



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 ($|\psi\rangle$)



$$|\psi\rangle = \alpha |0\rangle + \beta |1\rangle$$

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

Quantum State ($|\psi\rangle$)

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

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

What is a valid
quantum
state?

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

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

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

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

What is a valid
quantum
state?

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

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



What is a valid
quantum
state?

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

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

What is a valid
quantum
state?

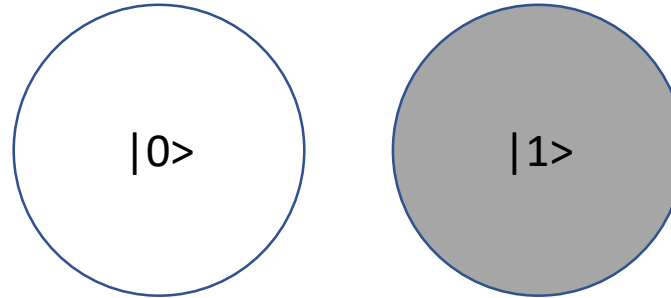
$$|\psi\rangle = \frac{12}{13}|0\rangle + \frac{5}{13}|1\rangle$$

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



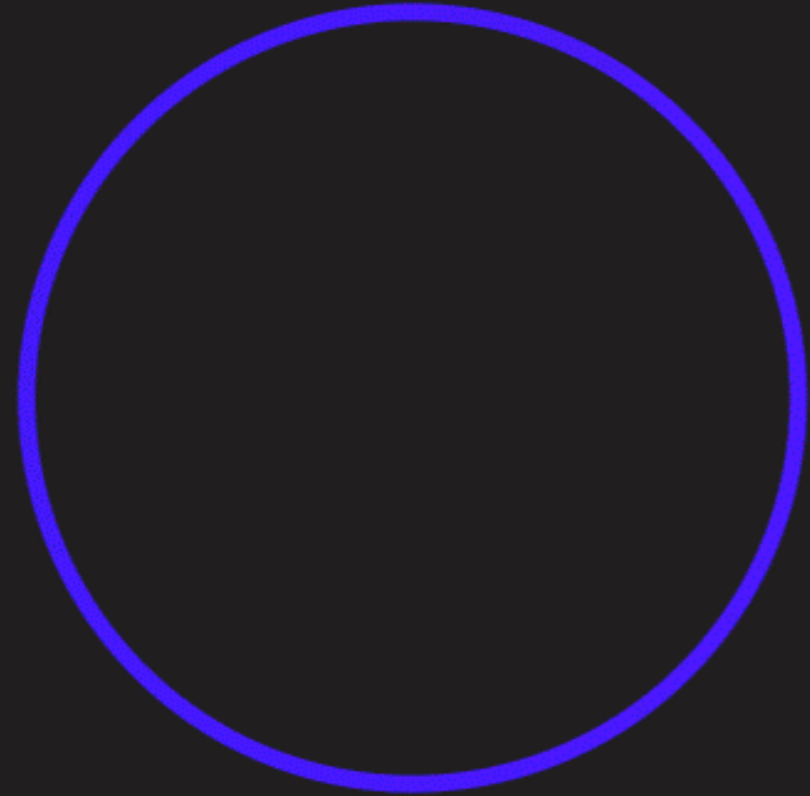
Activity: Find your Quantum Partner!

- Pick a ball

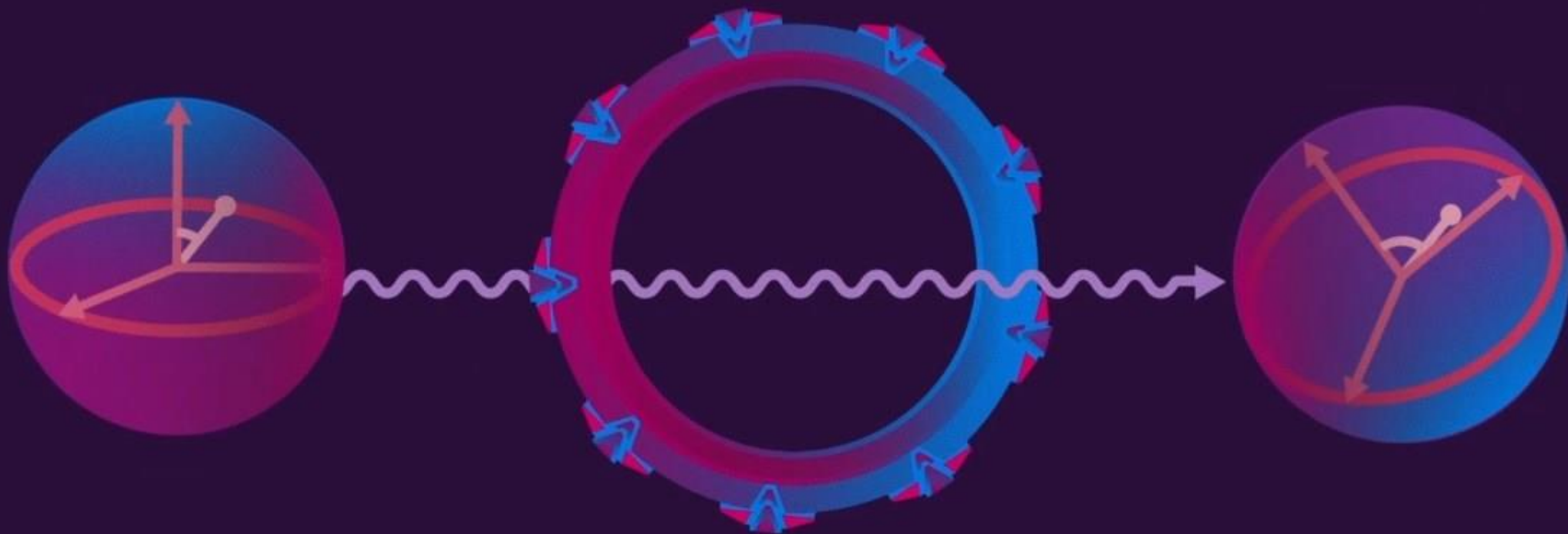


- Find a person with a ball of a color different from yours, and an amplitude that makes your combined state a quantum state.

Molding states using gates



QUANTUM GATE



Identity Gate

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

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

I



NOT Gate

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

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

X



Hadamard Gate



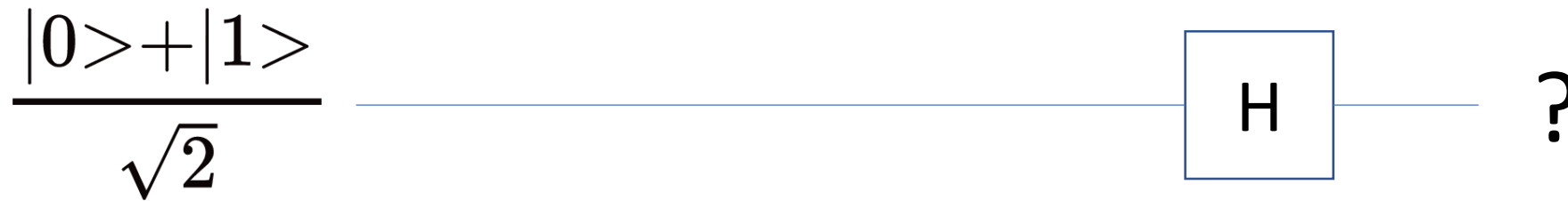
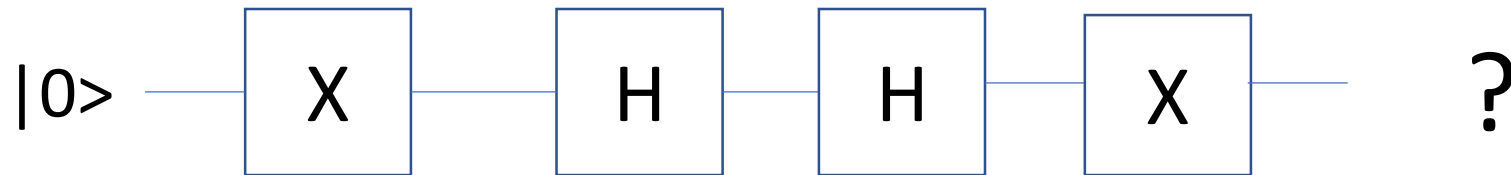
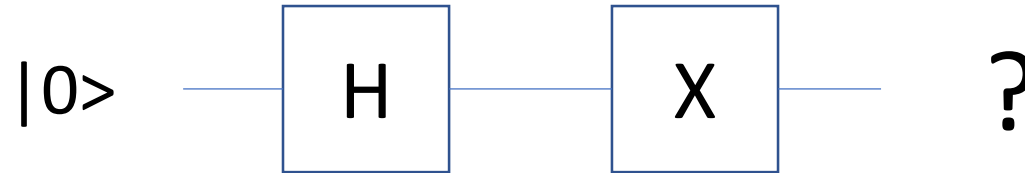
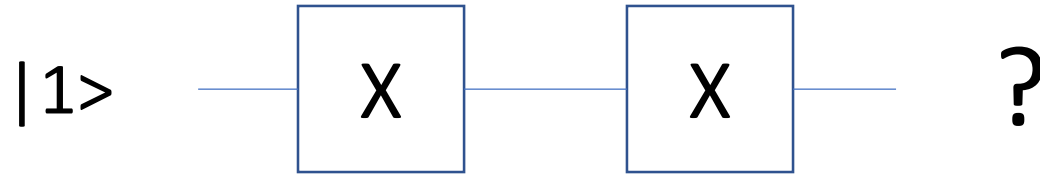
Qubit



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

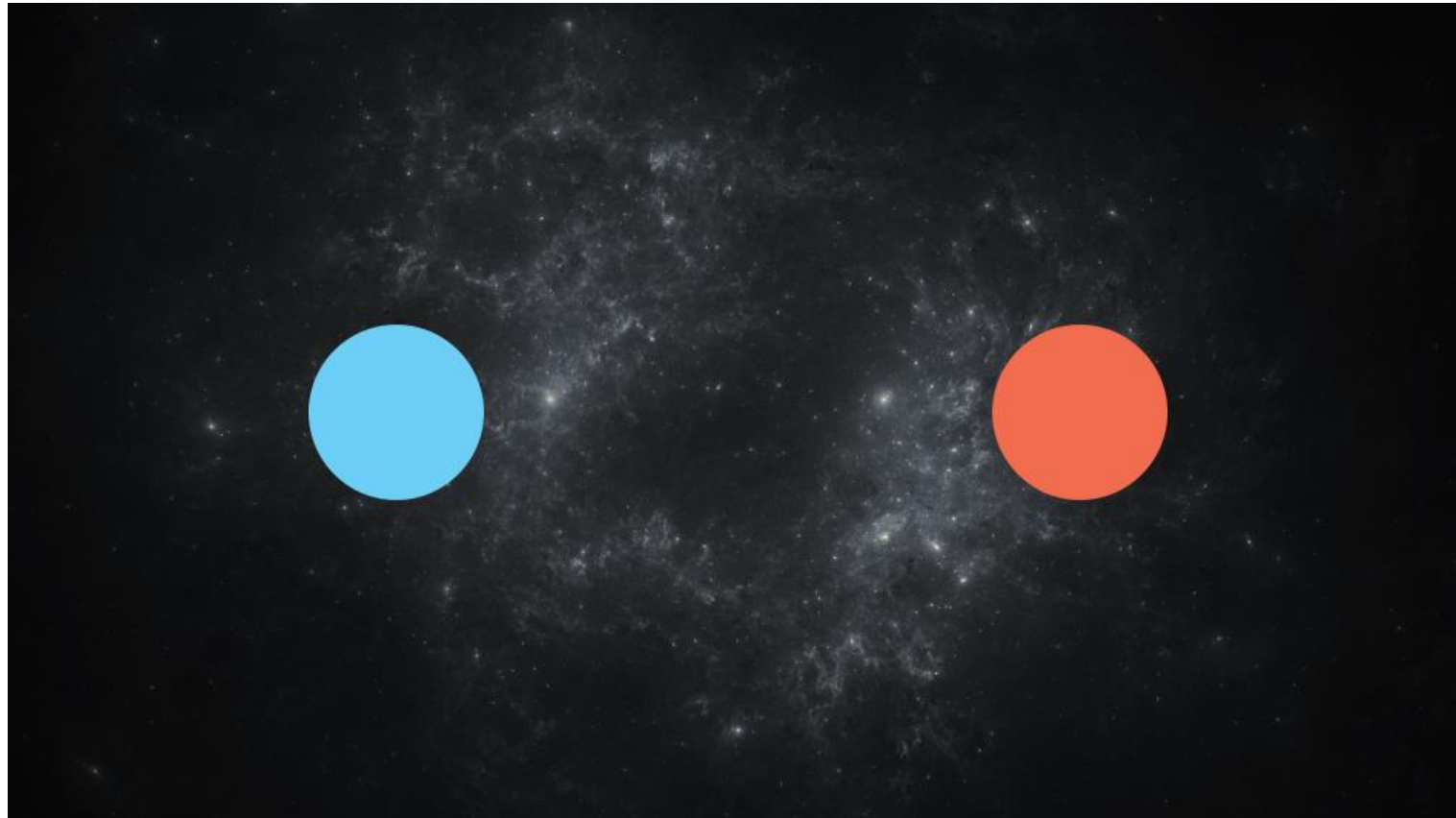
$$|0\rangle \rightarrow \frac{|0\rangle + |1\rangle}{\sqrt{2}}$$

What's the
state after
applying the
gates?

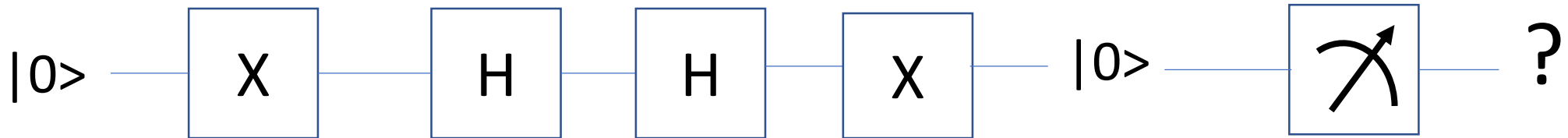
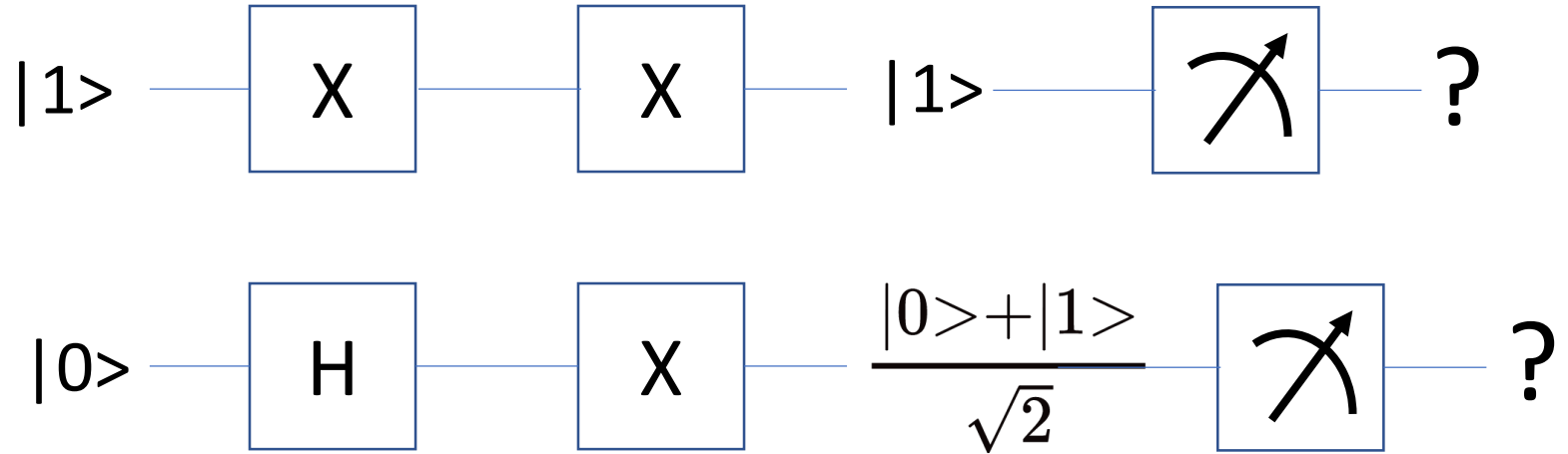


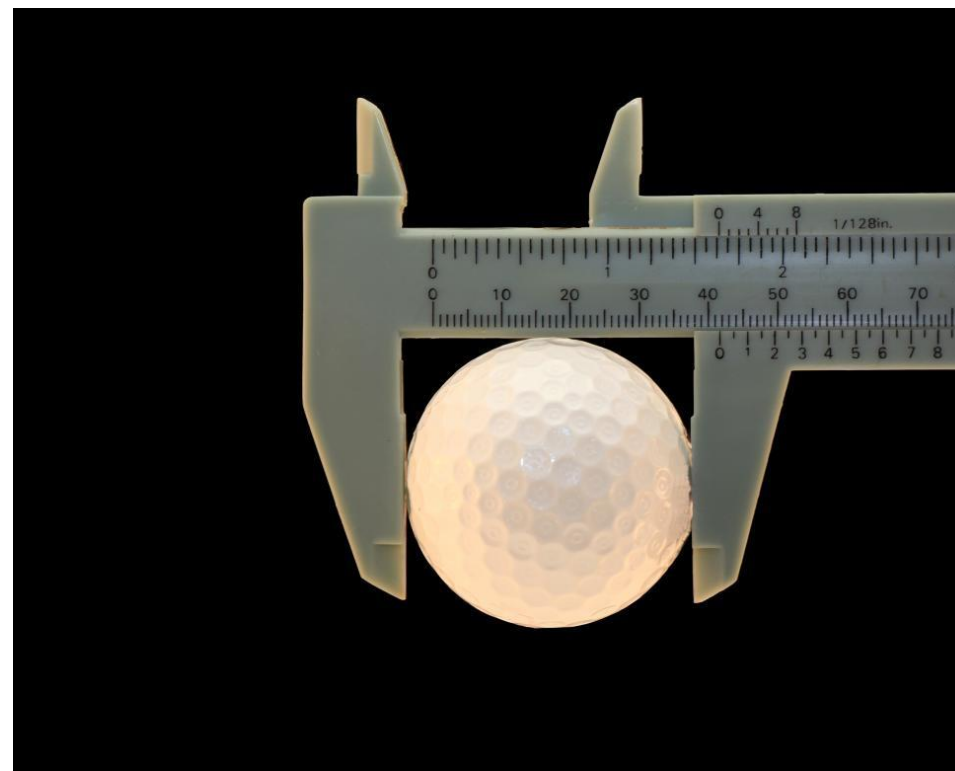
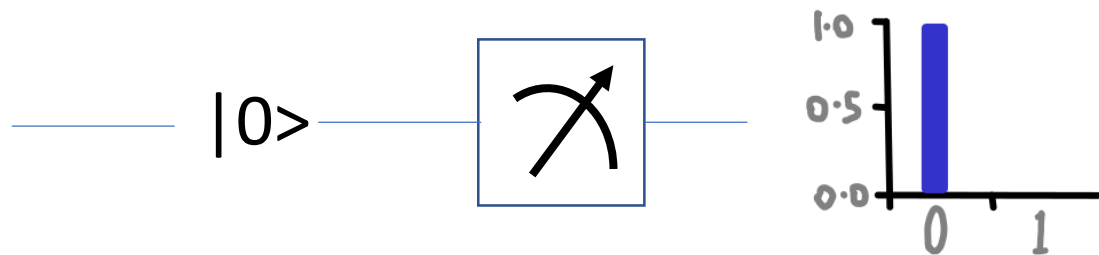
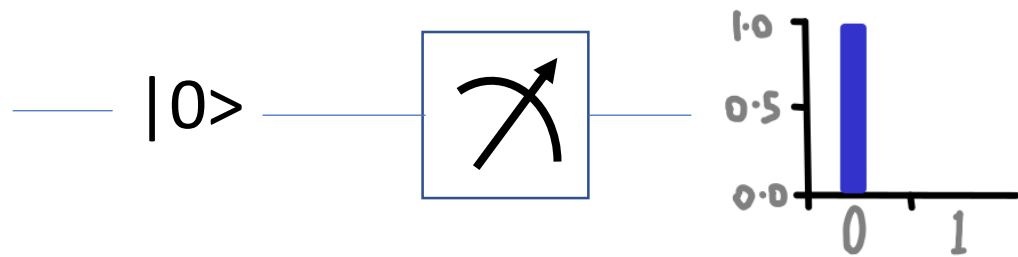
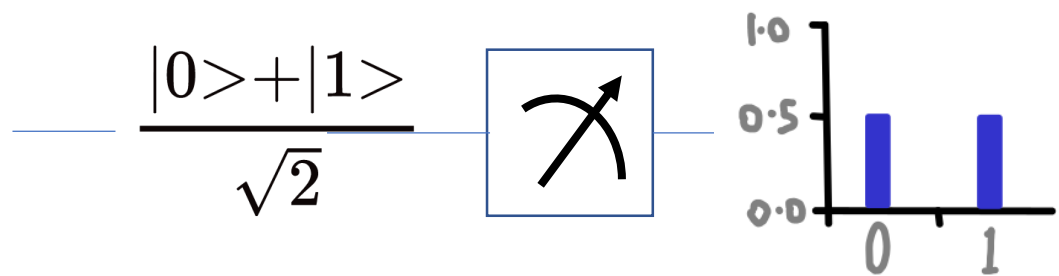
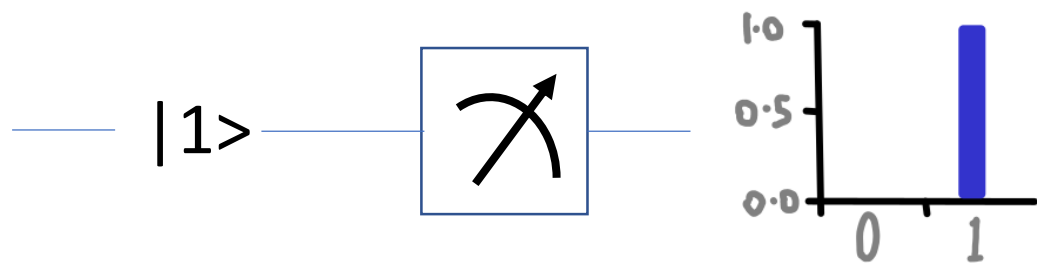
Measurement: Qubits are shy

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



What's the
state after
applying the
gates?





Guessing game

The box has 50 balls colored pink and grey.

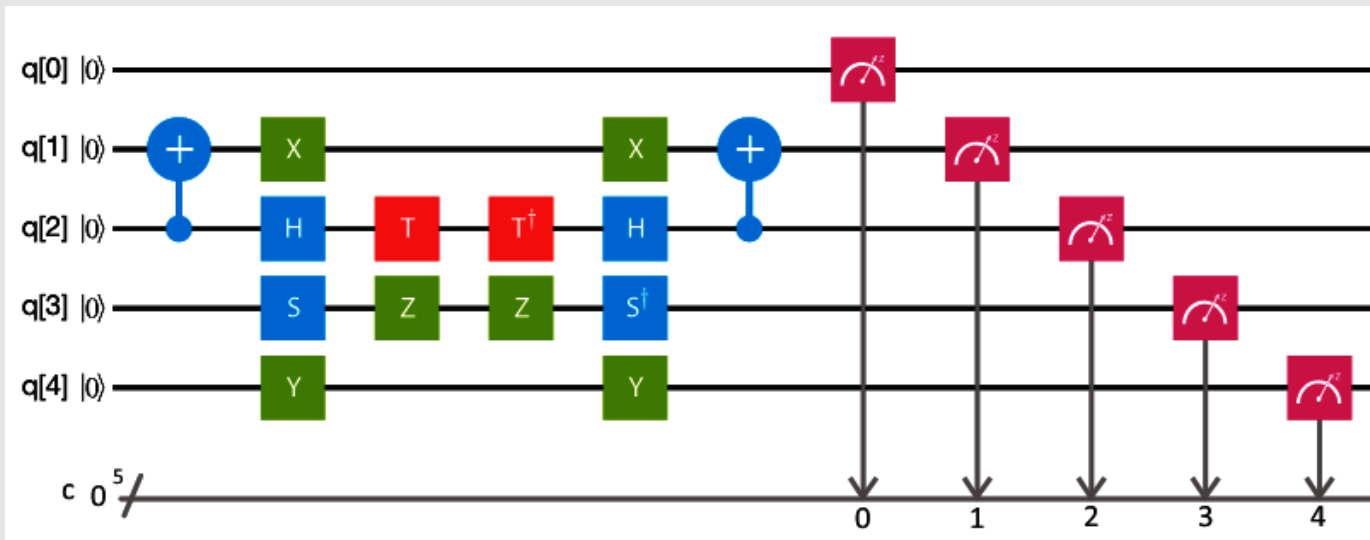
How many of these are pink, and how many are black?

Can you make a guess?

Let's sample from the box and speculate!



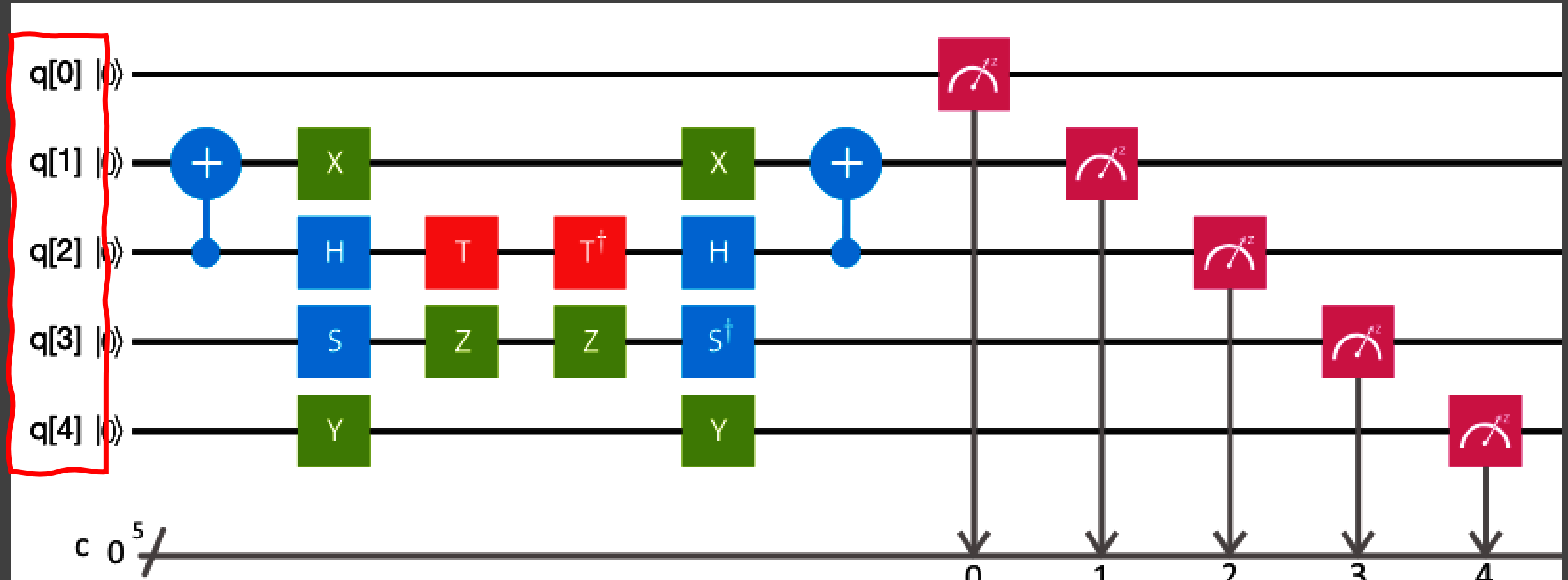
Quantum Circuits



- 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

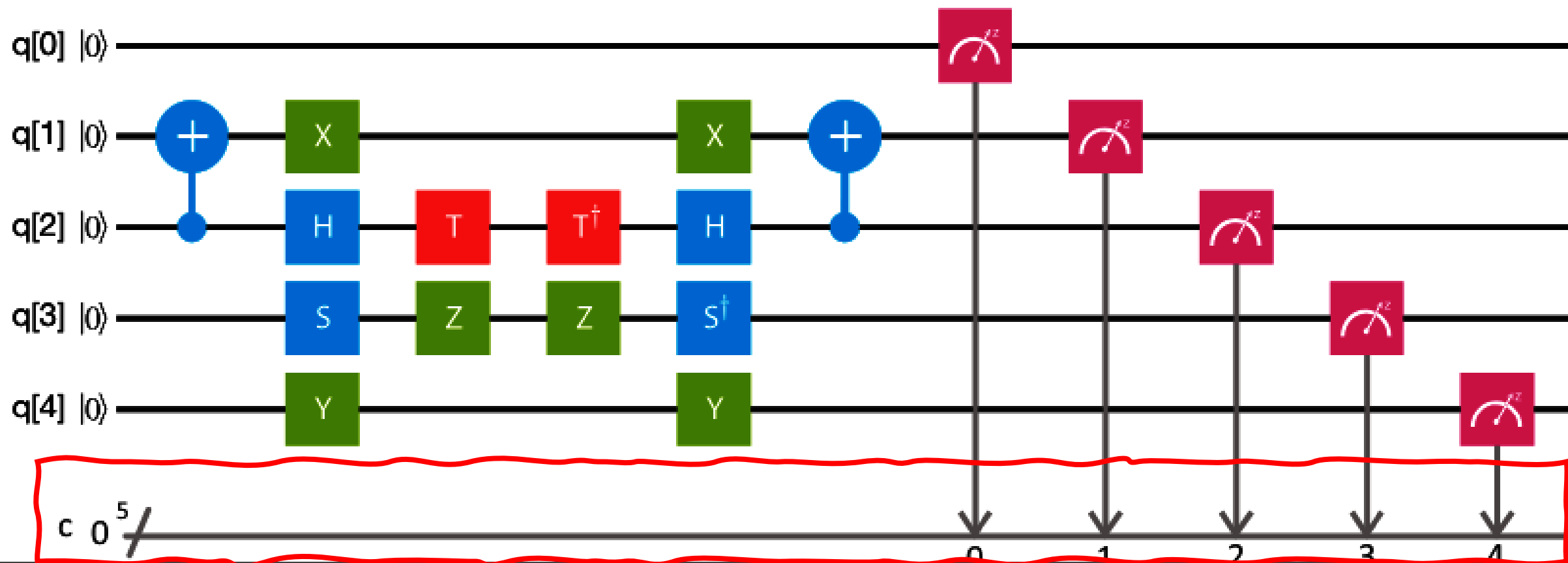
Qubits

`qr = QuantumRegister(5)`



Classical Bits

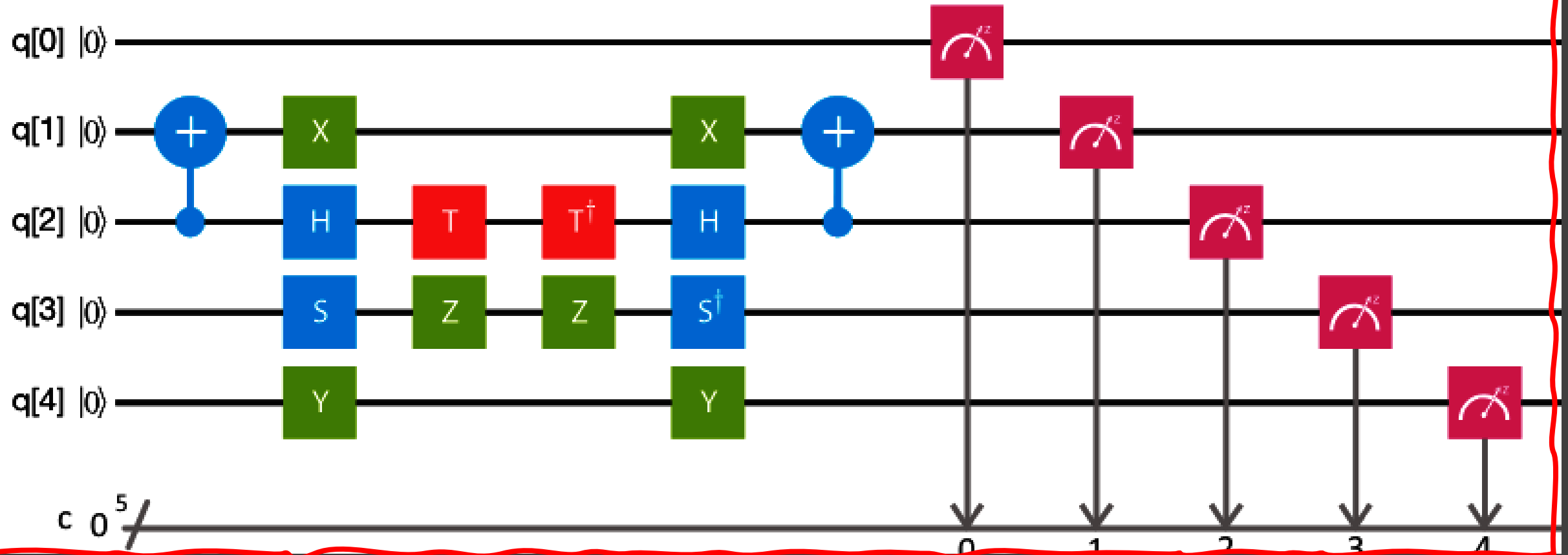
`cr = ClassicalRegister(5)`



Why do we need classical registers?

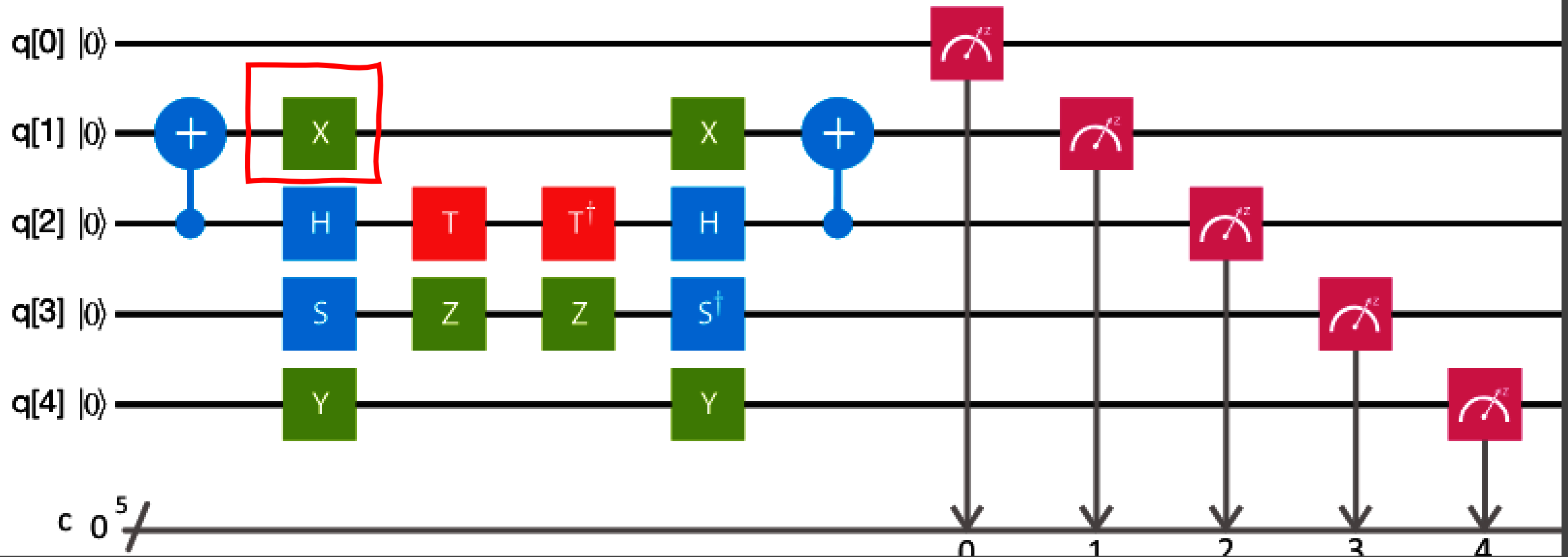
Circuit

`circ = QuantumCircuit(qr,cr)`



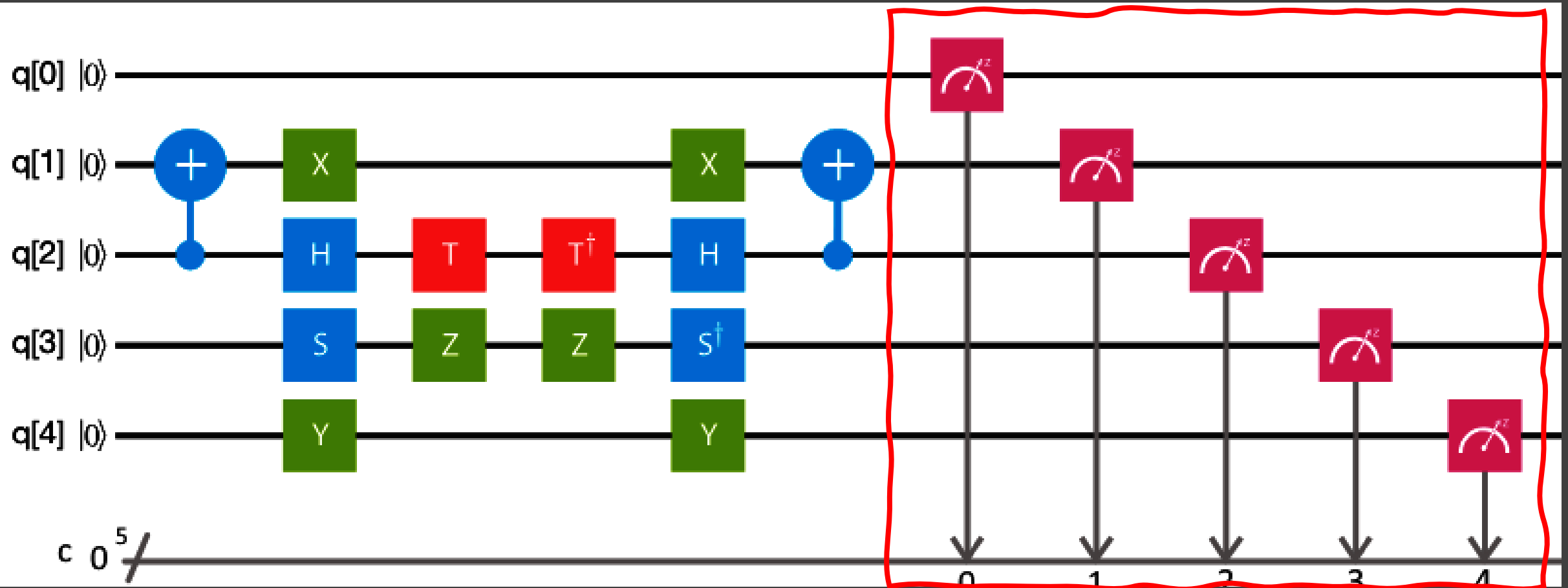
Gates

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)

Circuit Composer

Explore the graphical interface for creating and testing circuits

Create a circuit →

Qiskit Notebooks

Create your first notebook and start using Qiskit

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[See more](#)

Pending results (0)

You have no experiment runs in the queue.


Your backends (9)

Got it!

 maintenance


ibmq_16_melbourne (14 qubits)

████████████████████
Queue: 6 jobs

 online


ibmq_essex (5 qubits)

■■■■■■■■■■■■■■■■■■■■
Queue: 24 jobs

 online

ibmq_burlington (5 qubits)

■■■■■■■■■■■■■■■■■■■■
Queue: 22 jobs

 online

ibmq_london (5 qubits)

■■■■■■■■■■■■■■■■■■■■
Queue: 36 jobs

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[Got it!](#)

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