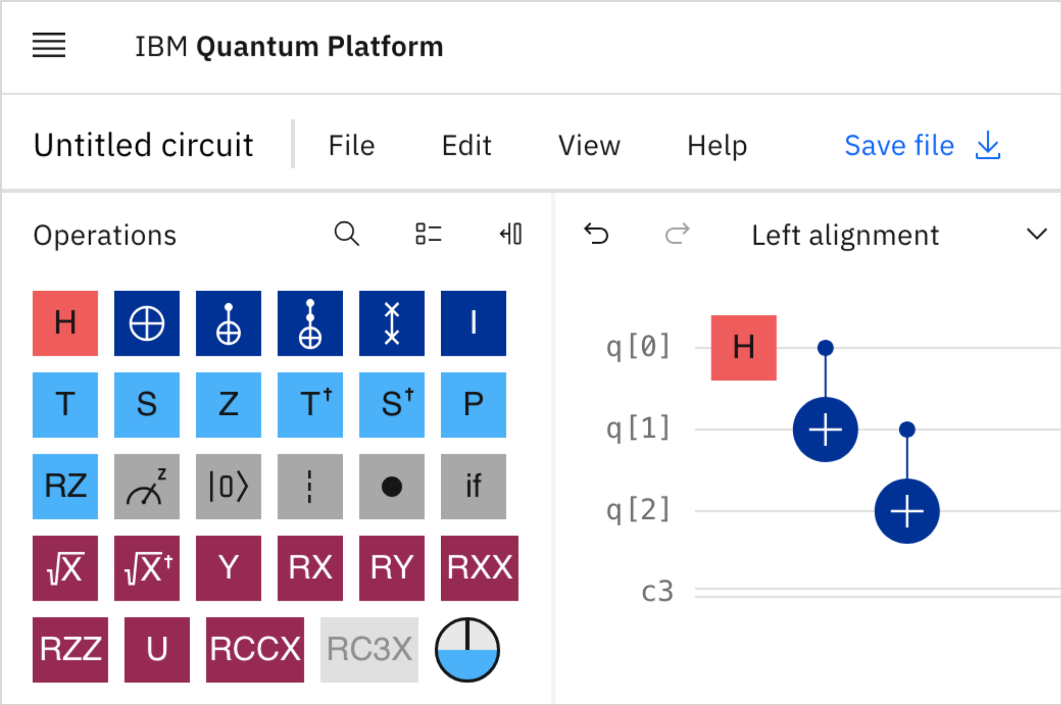
Introduction of Quantum Computing



Nov 18, 2025

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IBM **Quantum**

Kifumi Numata

Qiskit

Qiskit Advocate, APAC Workforce and Education, IBM Quantum

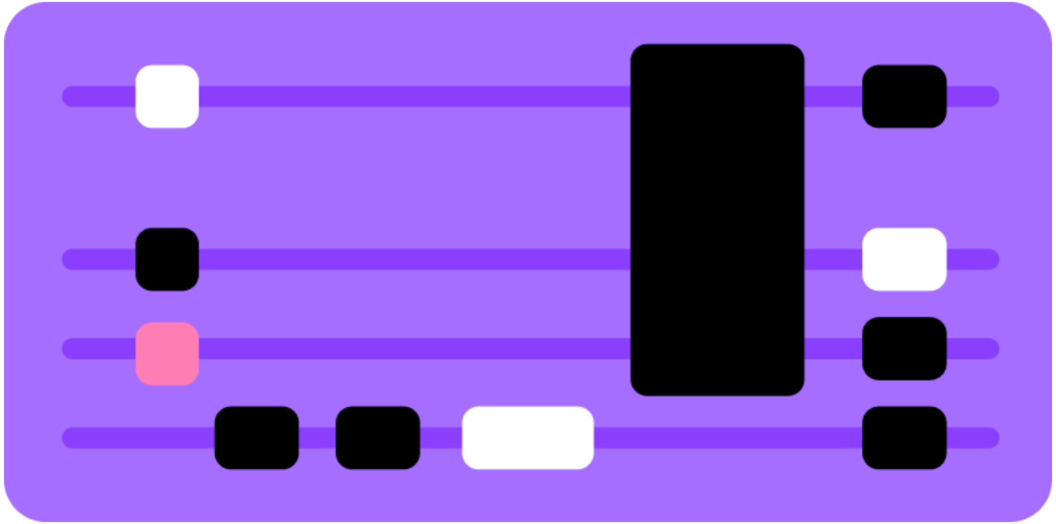
Recent Activity:

- Lectures at the University of Tokyo, etc.
- Lab creation of Qiskit Global Summer School, IBM Quantum Challenge
- Quantum Tokyo:
    - Local quantum community in Japan since 2020
- NICT Quantum Camp – Qiskit workshop since 2020
- Kawasaki Quantum Summer Camp since 2022

Introduction of Quantum Computing

- Qubits and quantum gates
- IBM Quantum Composer
- Introduction of Qiskit

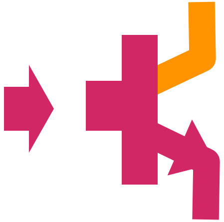
Qubits and quantum gates

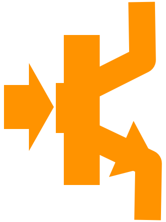


IBM **Quantum**

Computers perform calculations using bits.

Switch



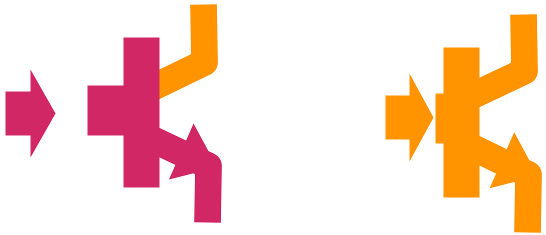


Off On

Bit **0** **1**

Character string	Bit string
7	111
A	0100 0001

The bits in the computers
we always use are



either **0** or **1**

The bits in the computers we always use are

either **0** or **1**

The qubits in the quantum computers use

both **0** and **1**

in superposition

The bits in the computers we always use are

either 0 or 1

coin

Head

coin

Tail

The qubits in the quantum computers use

both 0 and 1

in superposition

The bits in the computers we always use are

either 0 or 1

coin

Head

coin

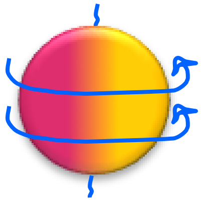
Tail

The qubits in the quantum computers use

both 0 and 1

in superposition

Spinning coin (image)



When a measurement is made,
the state becomes either 0 or 1.

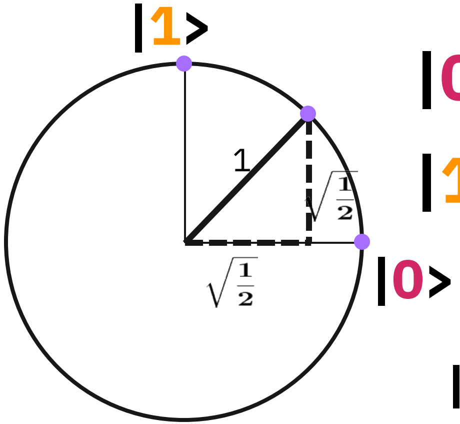
The bits in the computers we always use are

either 0 or 1

The qubits in the quantum computers use

$$\alpha \times |0\rangle + \beta \times |1\rangle$$

"superposition" of $|0\rangle$ and $|1\rangle$.



$$|0\rangle = 1 \times |0\rangle + 0 \times |1\rangle$$

$$|1\rangle = 0 \times |0\rangle + 1 \times |1\rangle$$

| > represents qubit.

The typical calculations in quantum computing

$$|0\rangle \Rightarrow \boxed{X} \Rightarrow |1\rangle$$

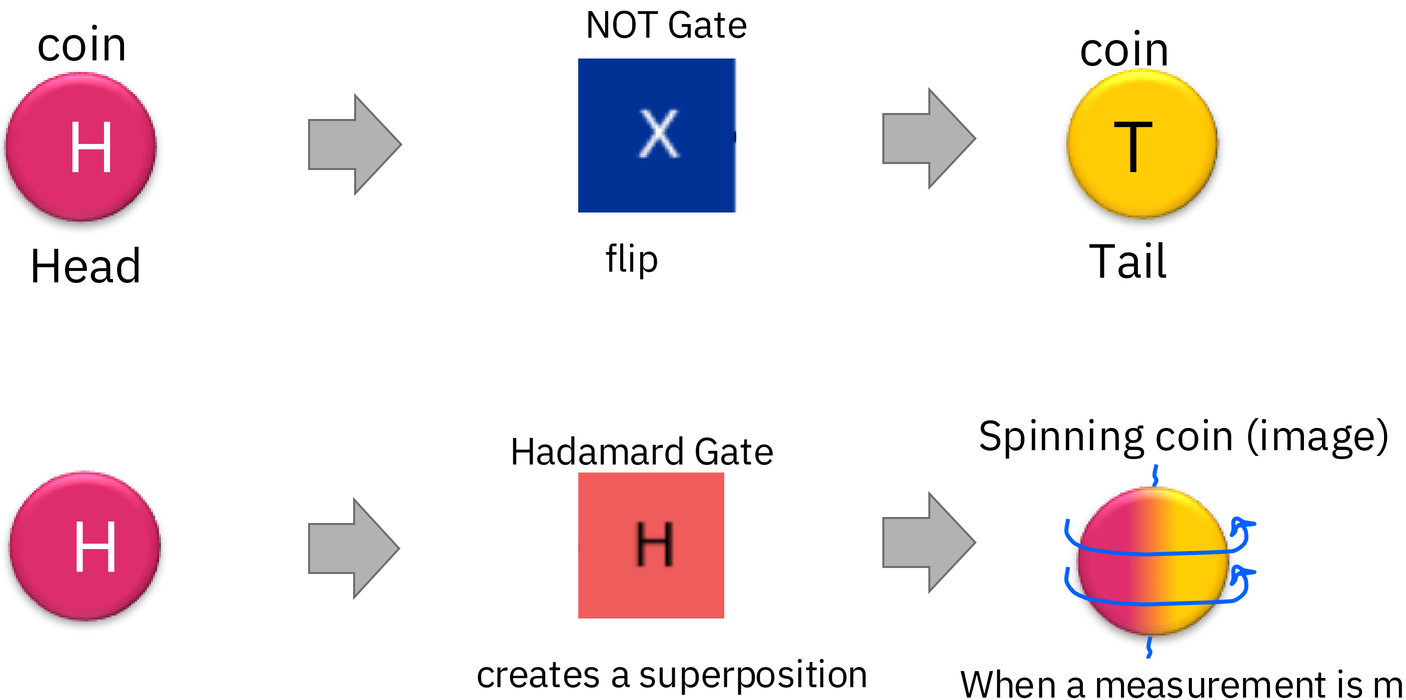
NOT Gate

Hadamard Gate

$$|0\rangle \Rightarrow \boxed{H} \Rightarrow \sqrt{\frac{1}{2}} \times |0\rangle + \sqrt{\frac{1}{2}} \times |1\rangle$$

Creates a superposition

The typical calculations in quantum computing



When a measurement is made,
the state becomes either 0 or 1.

Quantum Computers and its Mathematics

	Quantum computers	Mathematics	Computational representation
Data	Quantum states	Vector	$\begin{pmatrix} v_1 \\ \vdots \\ v_n \end{pmatrix}$: Colum vector
Operation	Quantum gates (Quantum operators)	Matrix	$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$

Single-qubit quantum state

An arbitrary quantum state can be represented as a linear combination of $|0\rangle$ and $|1\rangle$.

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

where α and β are complex numbers such that $|\alpha|^2 + |\beta|^2 = 1$.

$|0\rangle = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ and $|1\rangle = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$

Therefore, the arbitrary quantum state is also represented as

$$|\psi\rangle = \alpha\begin{bmatrix} 1 \\ 0 \end{bmatrix} + \beta\begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} \alpha \\ \beta \end{bmatrix}.$$

$|\psi\rangle = \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$ is also called the state vector.

Quantum Operators

Quantum states are transferred by the unitary operator U: $|\psi'\rangle = U|\psi\rangle$

NOT Gate

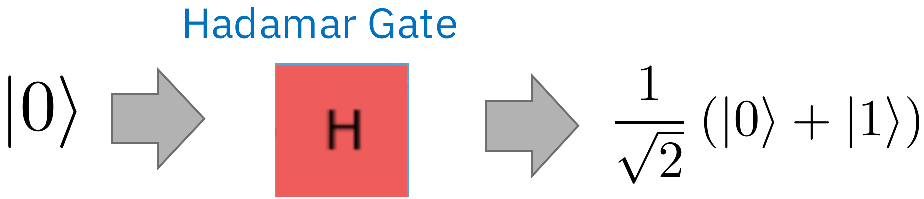
$$|0\rangle \Rightarrow \boxed{X} \Rightarrow |1\rangle$$

$$X = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix},$$

$$X\,|0\rangle = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \end{bmatrix} = |1\rangle$$

Quantum Operators

Quantum states are transferred by the unitary operator U : $|\psi'\rangle = U|\psi\rangle$



$$H = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix},$$

$$H\,|0\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix} = \frac{1}{\sqrt{2}}\left(\begin{bmatrix} 1 \\ 0 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}\right) = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

$|0\rangle$ and $|1\rangle$ are measured with a 1/2 chance

The typical calculations in quantum computing

$$|0\rangle \Rightarrow \boxed{X} \Rightarrow |1\rangle$$

Not Gate

Hadamard Gate

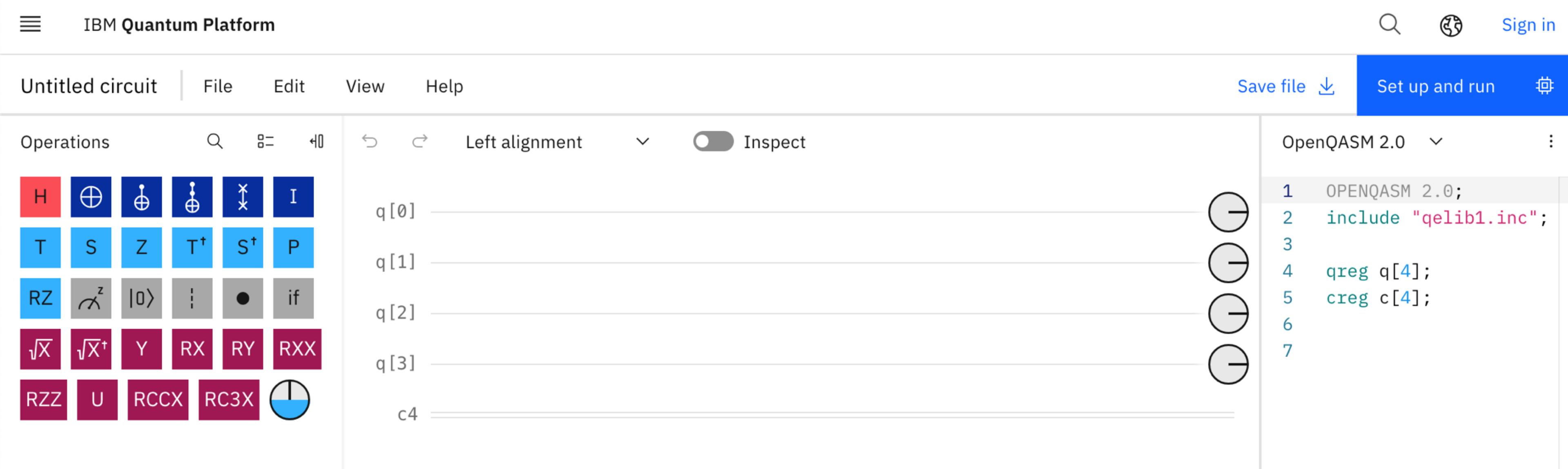
$$|0\rangle \Rightarrow \boxed{H} \Rightarrow \sqrt{\frac{1}{2}} \times |0\rangle + \sqrt{\frac{1}{2}} \times |1\rangle$$

Creates a superposition

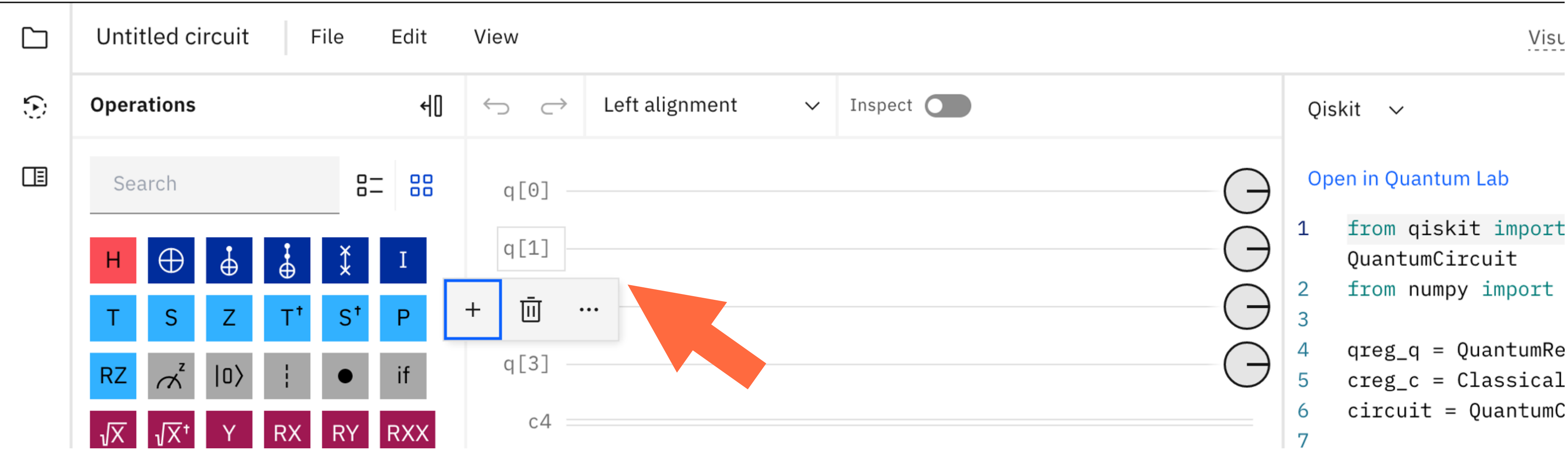
Hands-on: IBM Quantum Composer

https://quantum.cloud.ibm.com/composer

Short URL: **ibm.biz/cmpsr25**

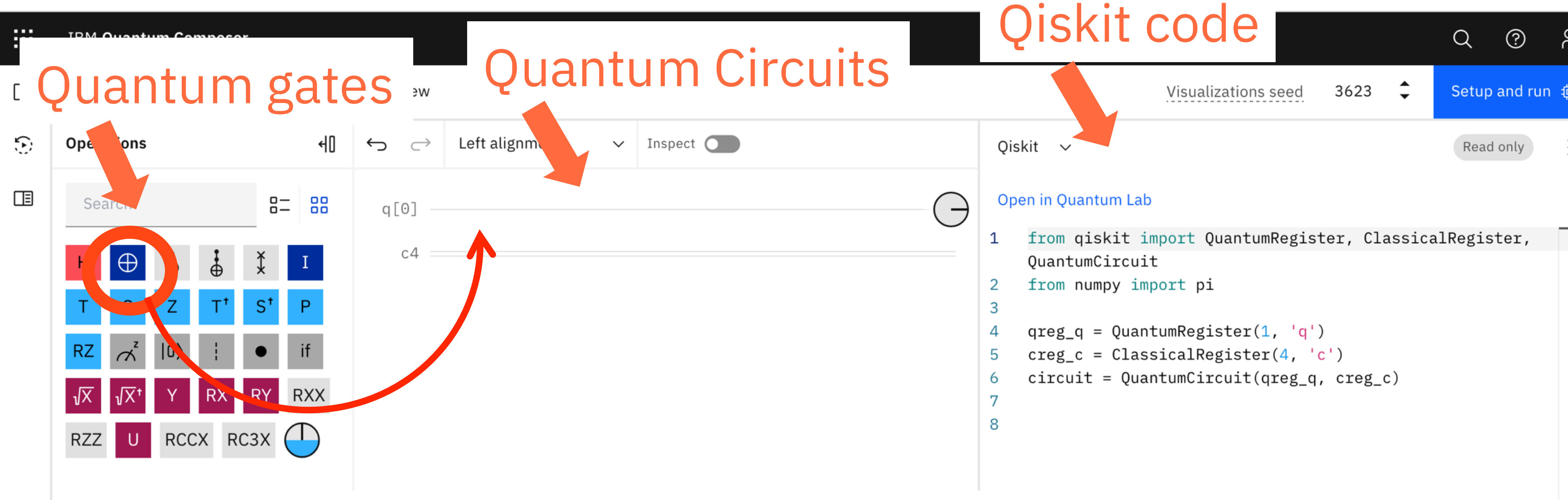


Single-qubit circuit



1. Click q[1] and click a trash icon to clear it.
2. Repeat that to leave only q[0] to prepare a single qubit circuit.

Single-qubit circuit



Drag and drop the quantum gate with your mouse to create a quantum circuit.
On the right side, the code for Qiskit is auto-generated.

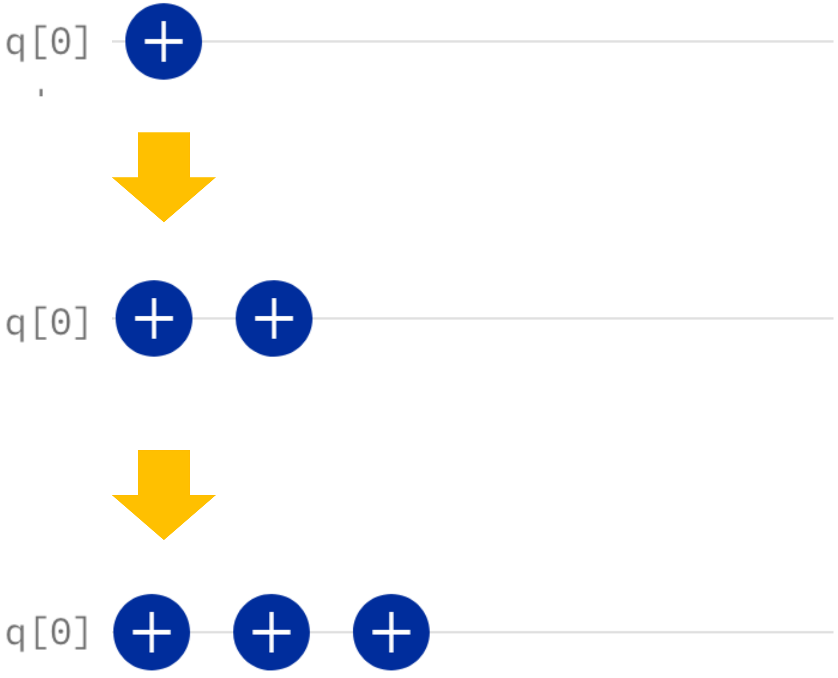
1. X gate (NOT gate)

Try to build the circuits shown below.
And, let's check the changes in the bar graph.

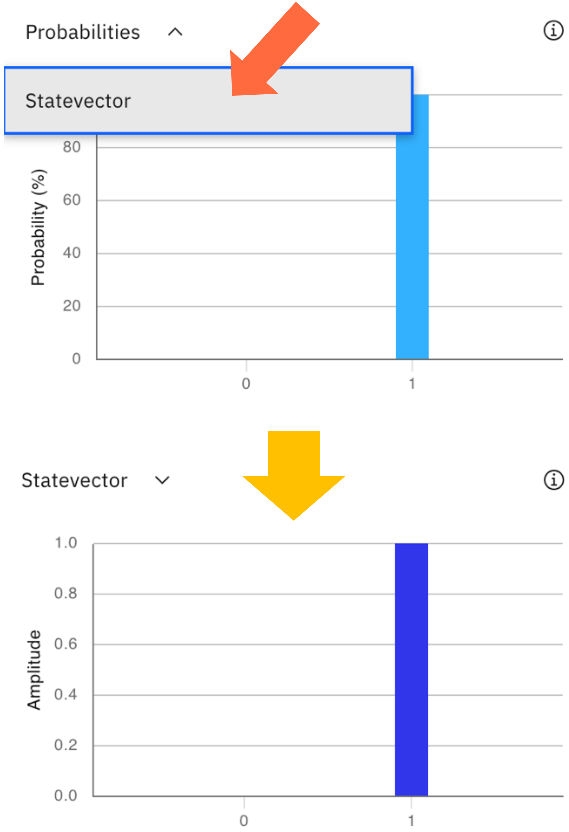
1-1)

1-2)

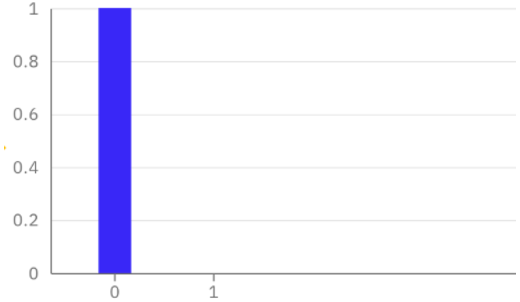
1-3)



Set the lower left graph to “Statevector” of blue bar.



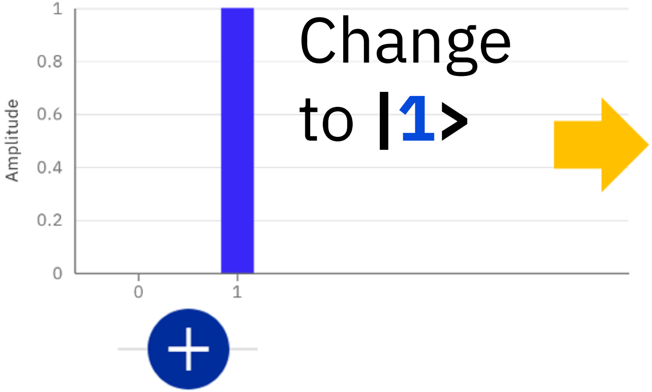
The initial state is $|0\rangle$



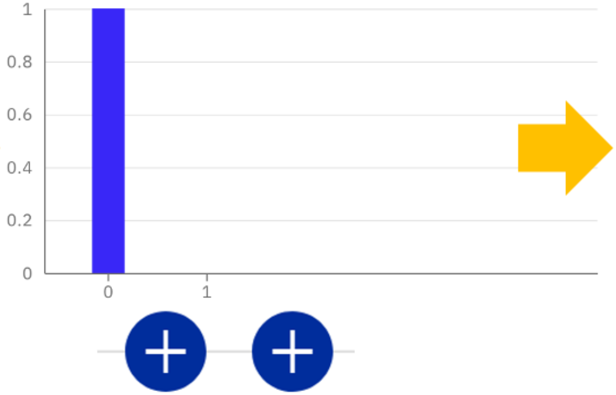
The bars in a statevector graph are the value of α and β, probability amplitude, of a quantum state, $\alpha|0\rangle + \beta|1\rangle$.

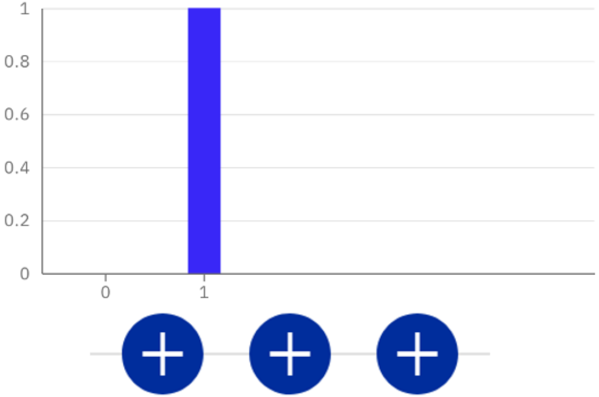
$$|0\rangle = 1 \times |0\rangle + 0 \times |1\rangle$$

$$|1\rangle = 0 \times |0\rangle + 1 \times |1\rangle$$

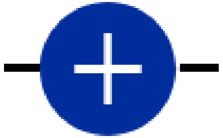


Change to $|1\rangle$



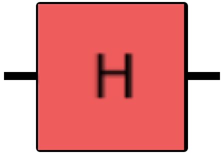


The typical calculations in quantum computing

$|0\rangle \Rightarrow$  $\Rightarrow |1\rangle$

Not Gate

Hadamard Gate

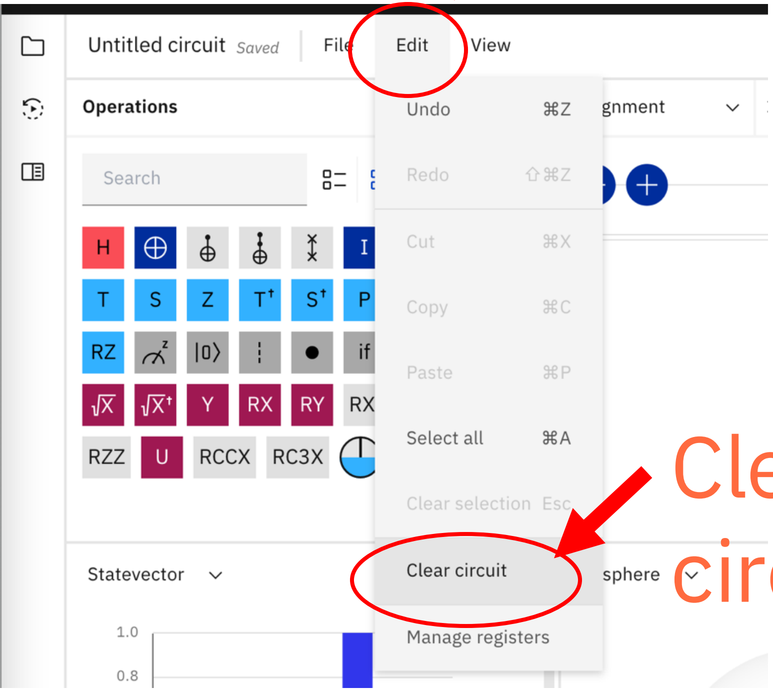
$|0\rangle \Rightarrow$ 

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

Creates a superposition

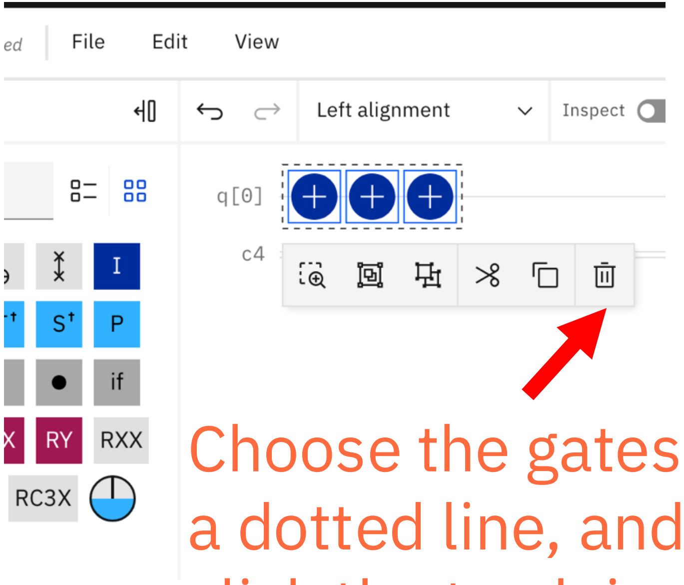
Remove the gates you put

Edit



Clear circuit

OR

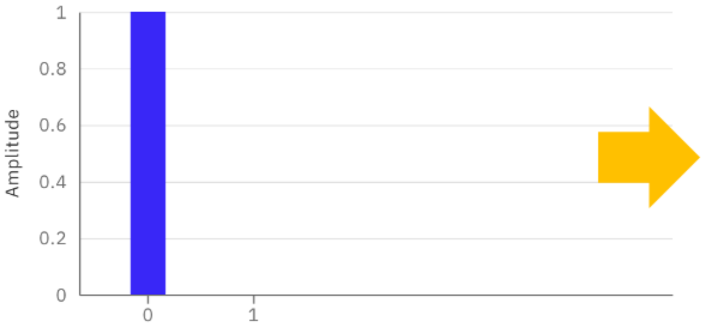


Choose the gates with a dotted line, and click the trash icon.

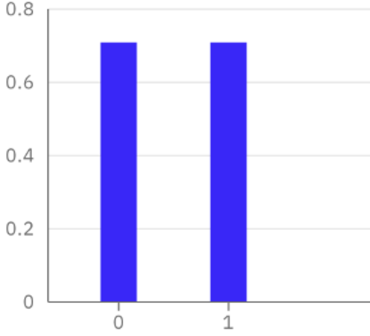
2. H gate

Try to build the circuits shown below. Let's check the changes in the bar graph.

2-1)



Superposition



For example, if you create the same state 1000 times and measure them, you will observe 0 about 500 times and 1 about 500 times.

$$|0\rangle = 1 \times |0\rangle + 0 \times |1\rangle$$

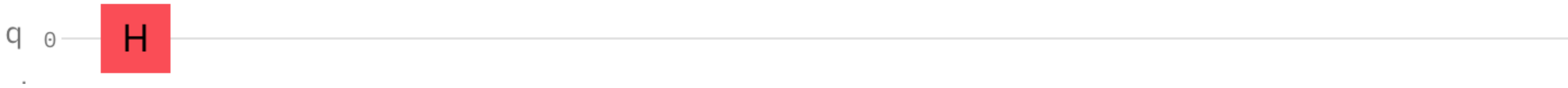
$$0.707 \times |0\rangle + 0.707 \times |1\rangle$$

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

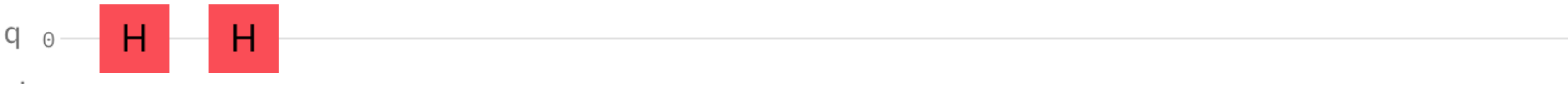
2. H gate

Try to build the circuits shown below. Let's check the changes in the bar graph.

2-1)

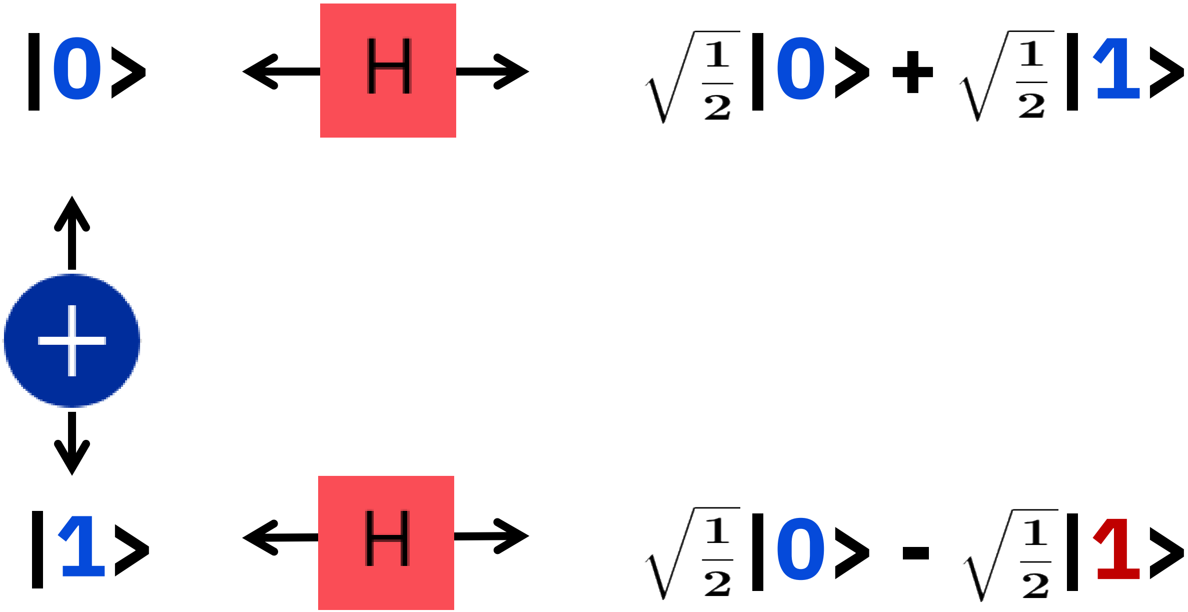


2-2)

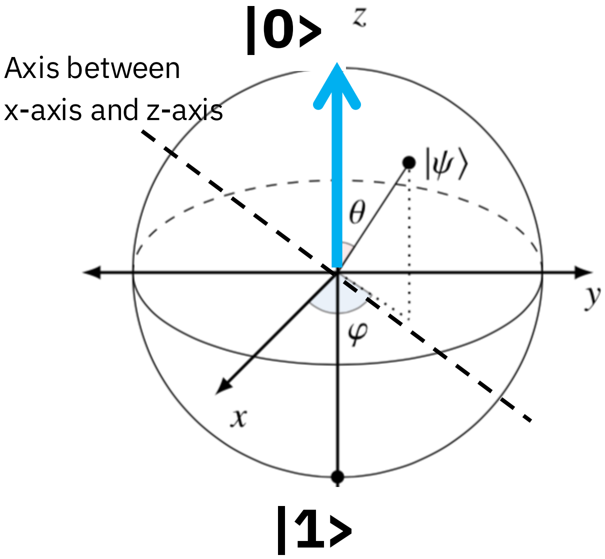


2-3)

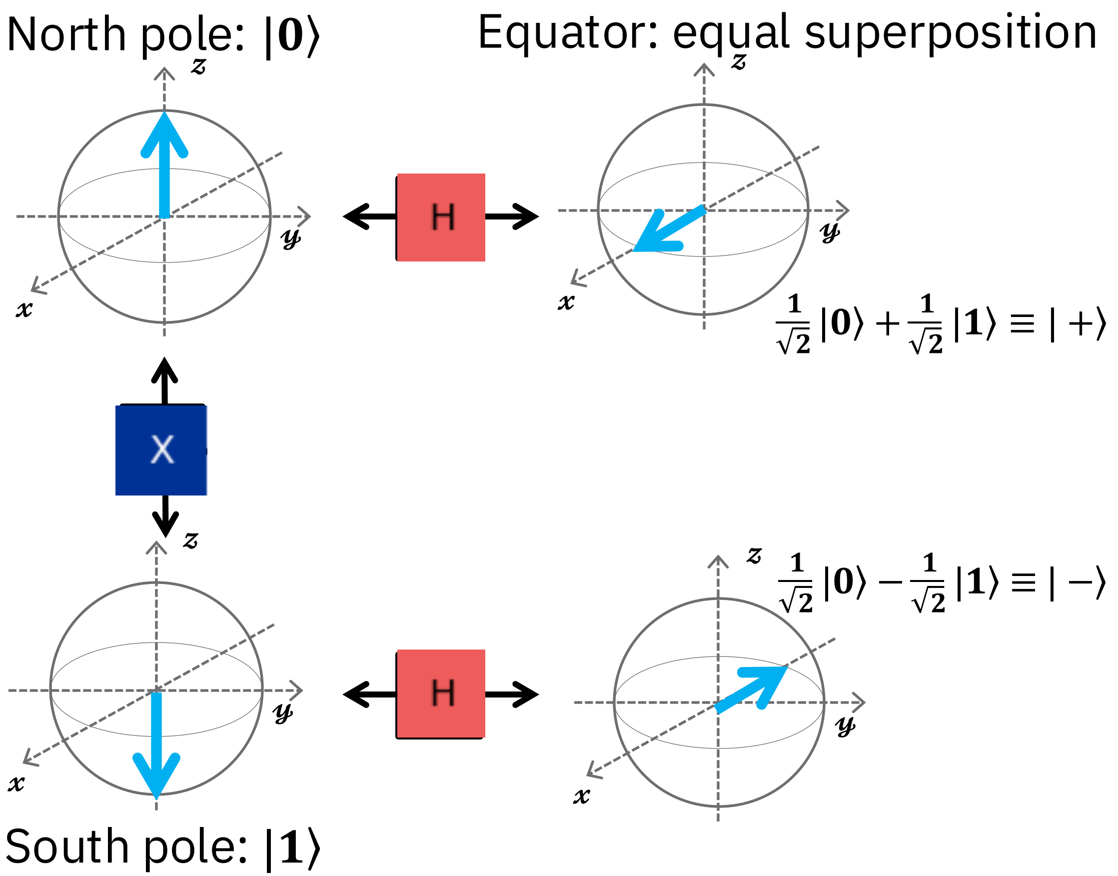
The typical calculations in quantum computing



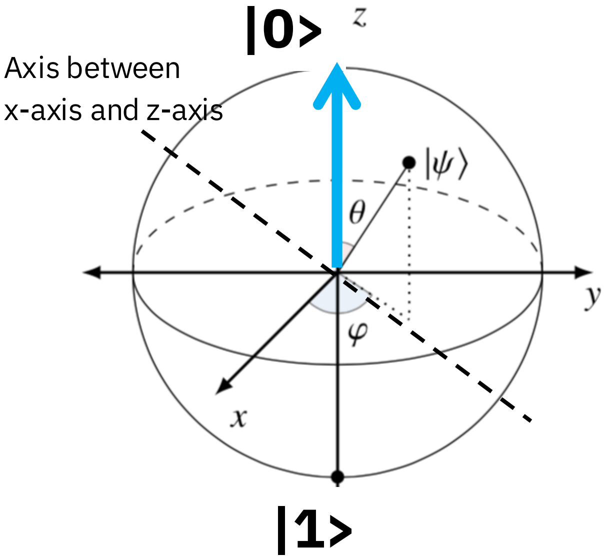
Bloch sphere



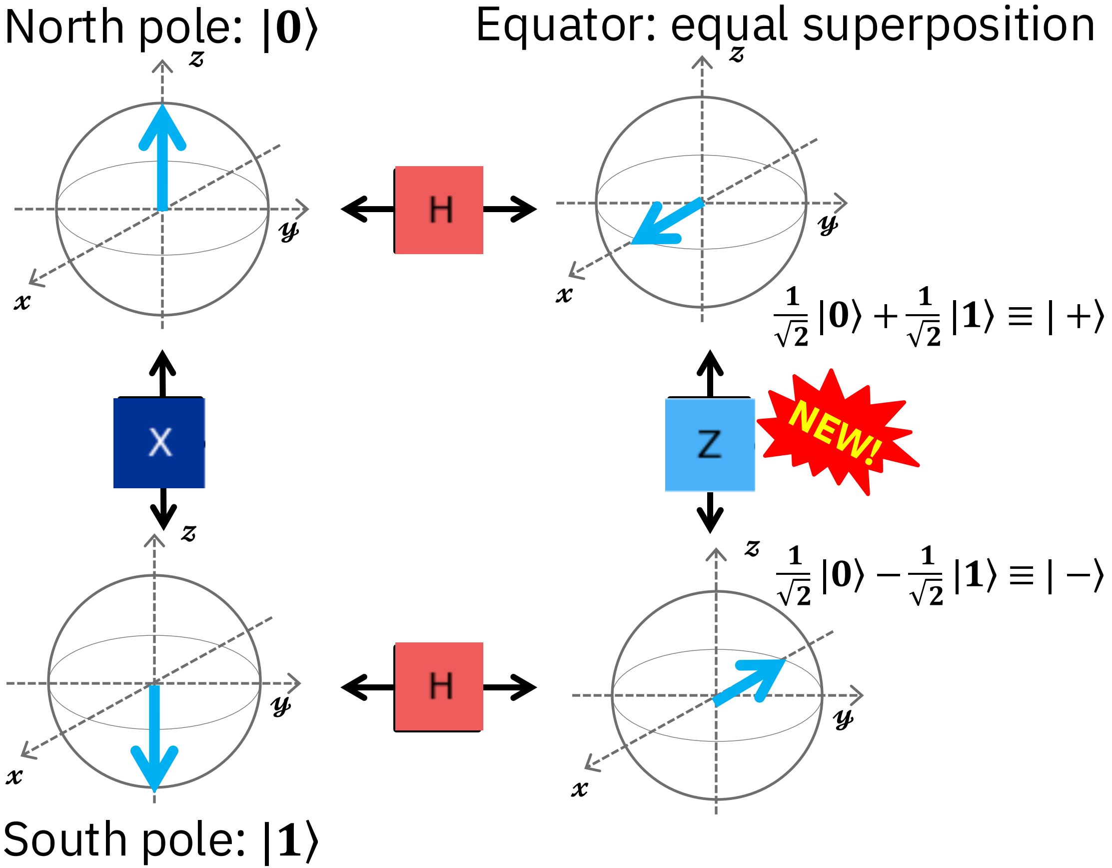
A pure quantum state is a vector pointing from the center to a point on the sphere of radius 1.



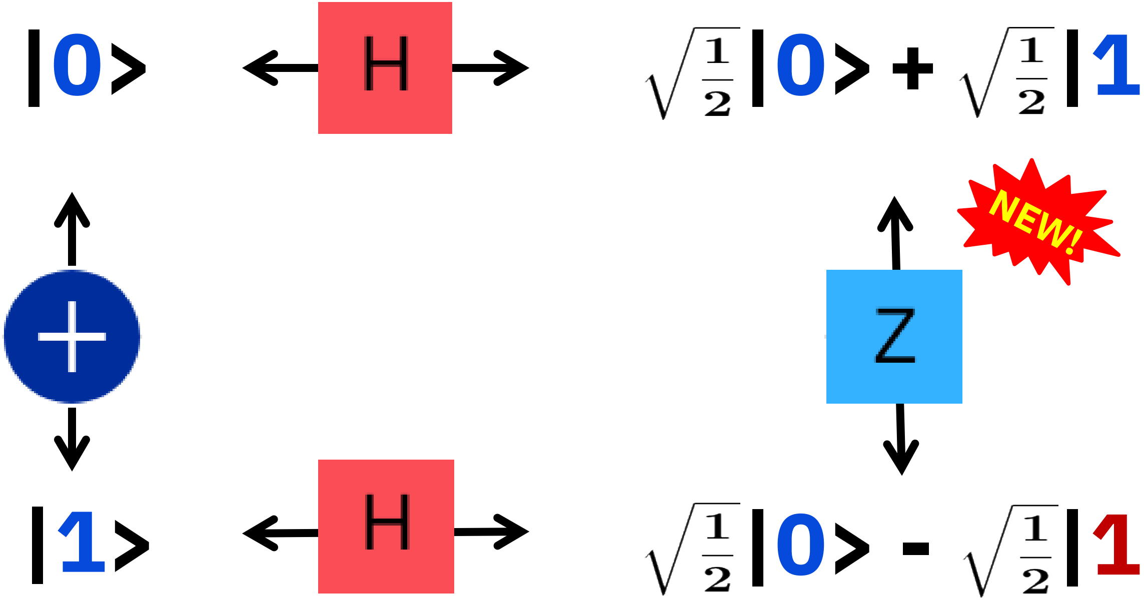
Bloch sphere



A pure quantum state is a vector pointing from the center to a point on the sphere of radius 1.



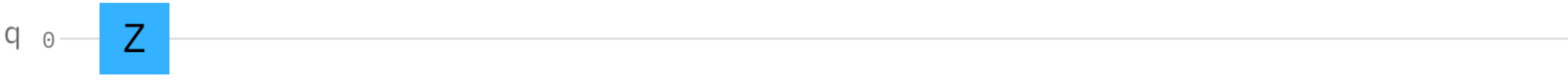
The typical calculations in quantum computing



3. Z gate

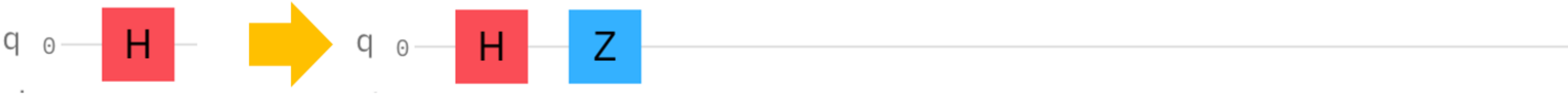
Try to build the circuits shown below. Let's check the changes in the bar graph.

3-1)

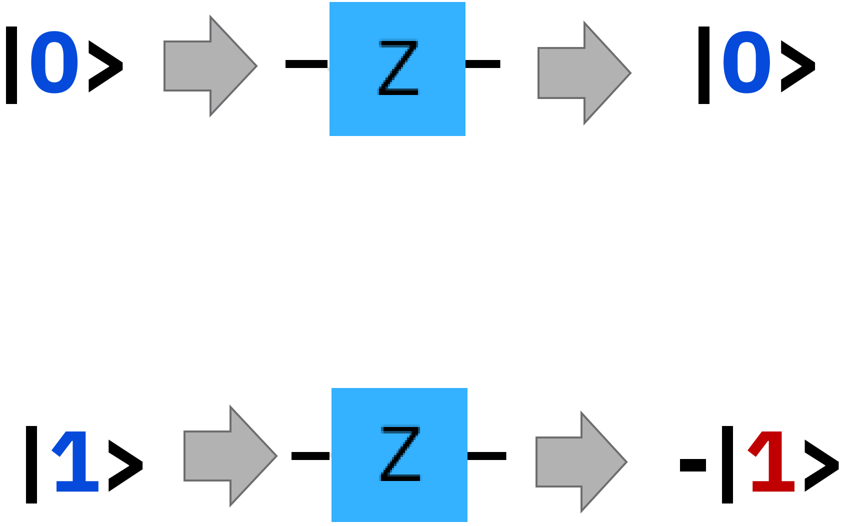


3-2)

3-3)



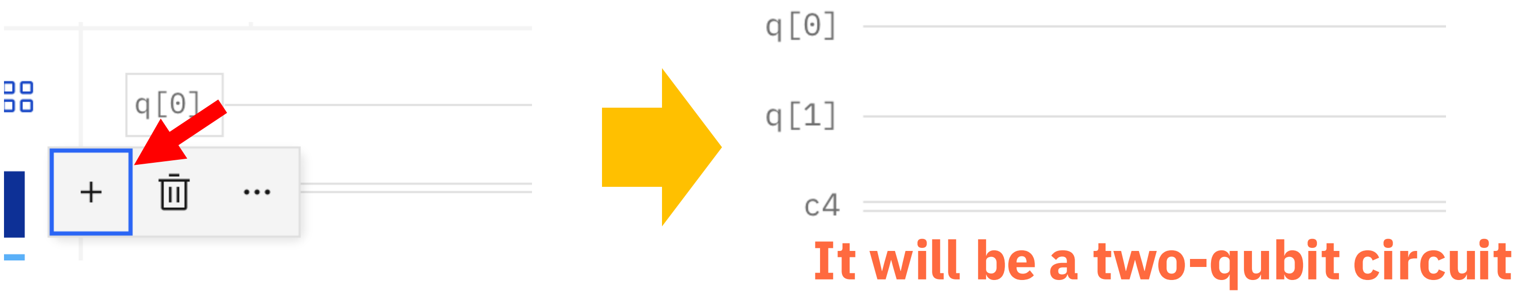
The typical calculations in quantum computing



Flips the sign of 1

4. Quantum superposition

Click q[0] and then click the "+" icon to prepare a two qubit circuit.



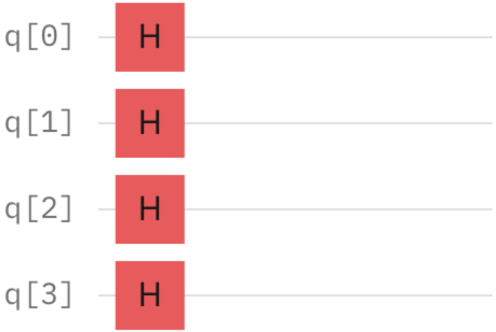
Try to build the circuits shown below. Let's check the changes in the bar graph.

4-1)

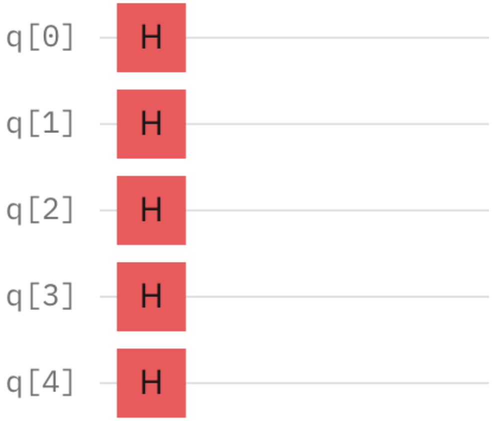
Click q[1] and then click the "+" icon to see the superposition state at 3-qubit, 4-qubit, and 5-qubit.

4-2)

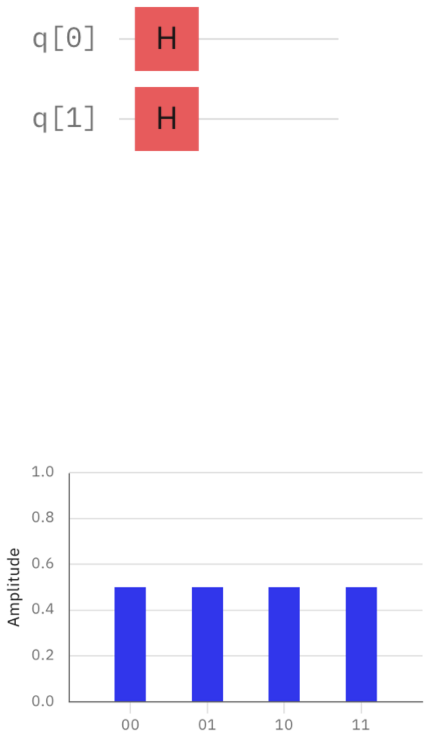
4-3)



4-4)

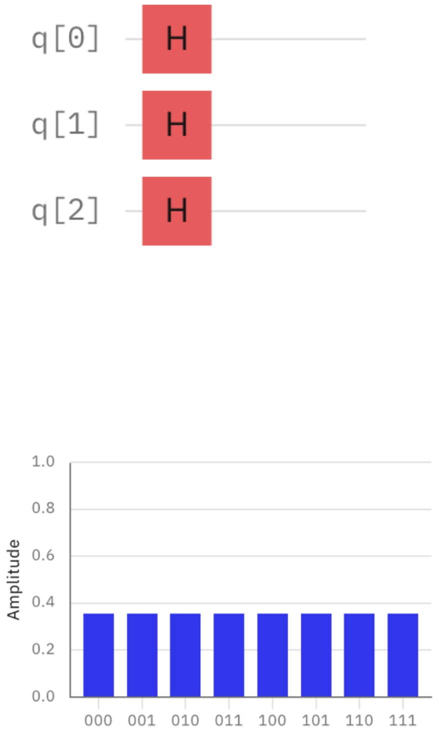


4-1)



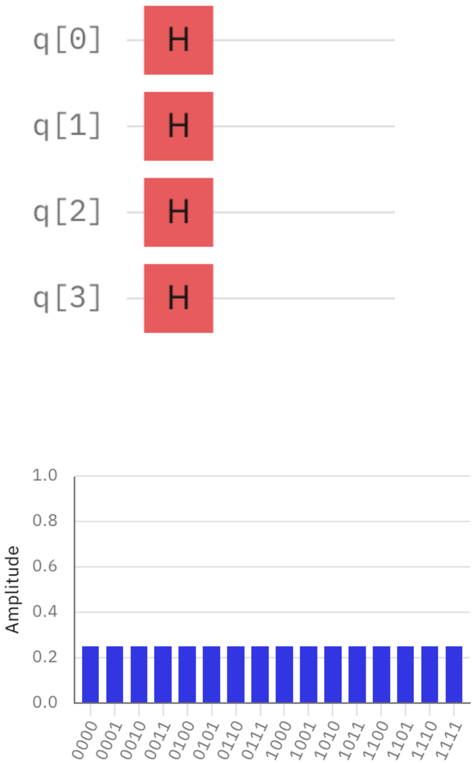
4 states

4-2)



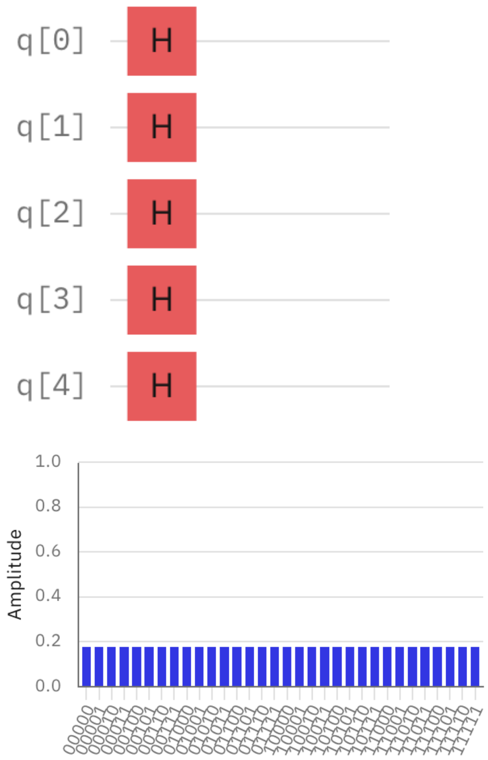
8 states

4-3)



16 states

4-4)

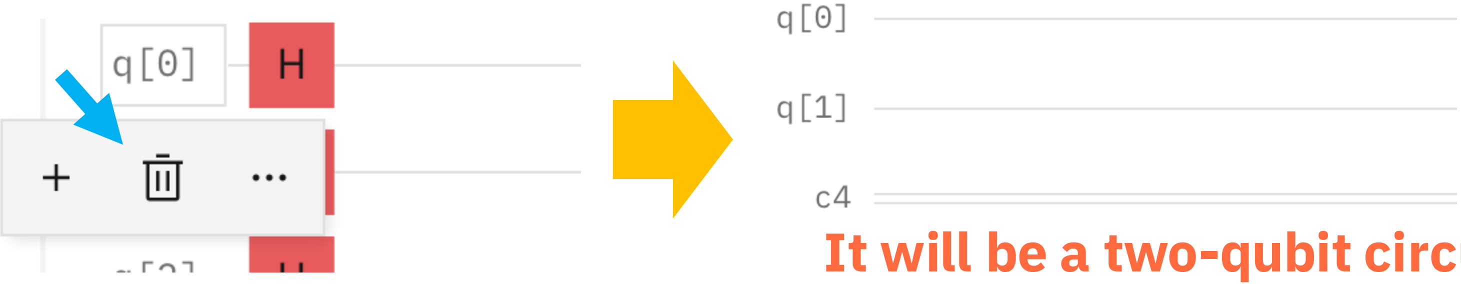


32 states

As the number of qubits (n) increases, we can see that the quantum state doubles to 2^n.

Go back to two qubit circuit again

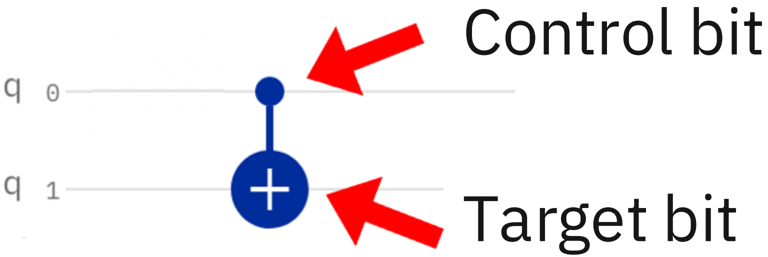
Click q[0], then click the trash icon, and repeat it to prepare the two qubit circuit.



It will be a two-qubit circuit

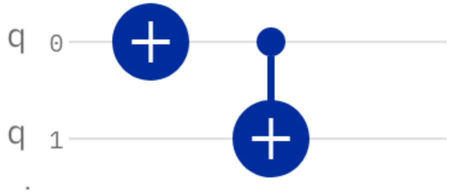
5. CNOT Gate (Control X-Gate)

CNOT gate flips the target bit only if the control bit is 1.

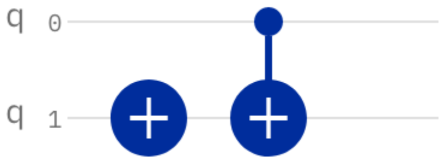


input		output	
Target bit	Control bit	Target bit	Control bit
0	0	0	0
1	0	1	0
0	1	**1**	**1**
1	1	**0**	**1**

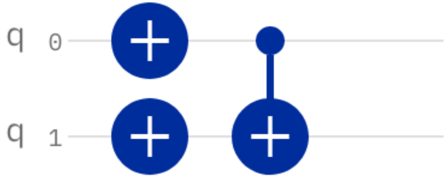
5-1)



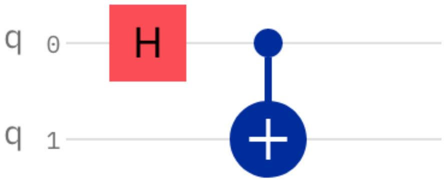
5-2)



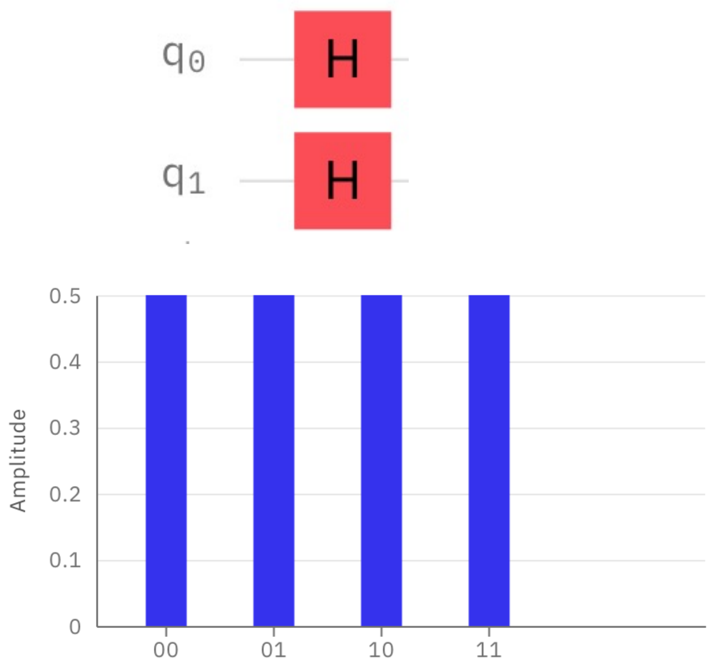
5-3)



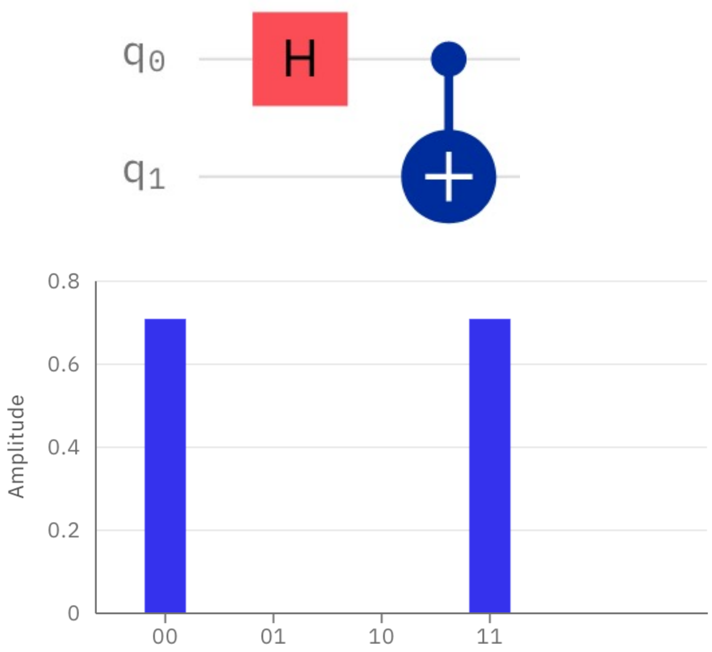
5-4)



Quantum superposition

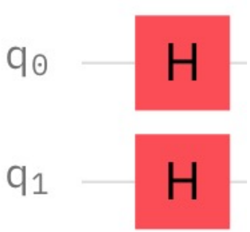


Quantum entanglement



CNOT gate makes entanglement.

Quantum superposition



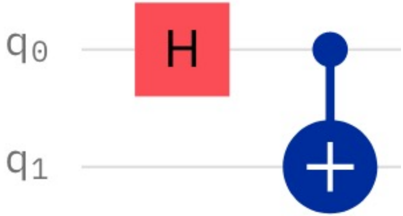
00 ••• 25%

01 ••• 25%

10 ••• 25%

11 ••• 25%

Quantum entanglement



00 ••• 50%

01 ••• 0%

10 ••• 0%

11 ••• 50%

If we know that one of the qubits is 0,
then the other is also 0.

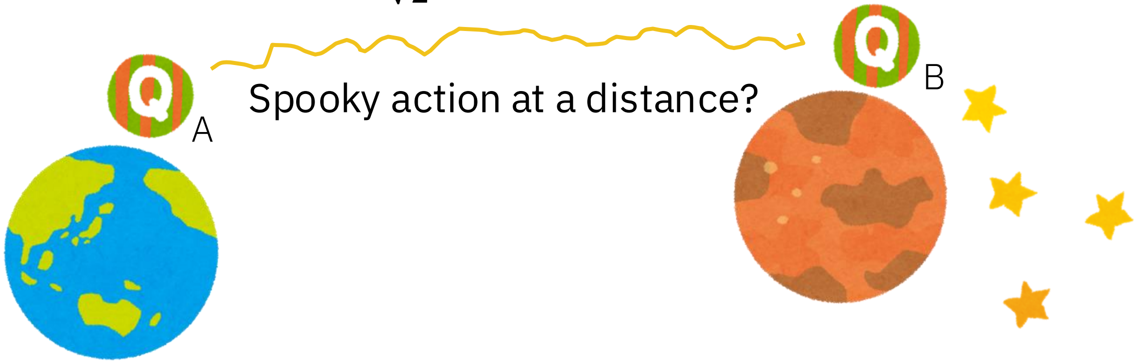
EPR Pair (Einstein-Podolsky-Rosen Pair)

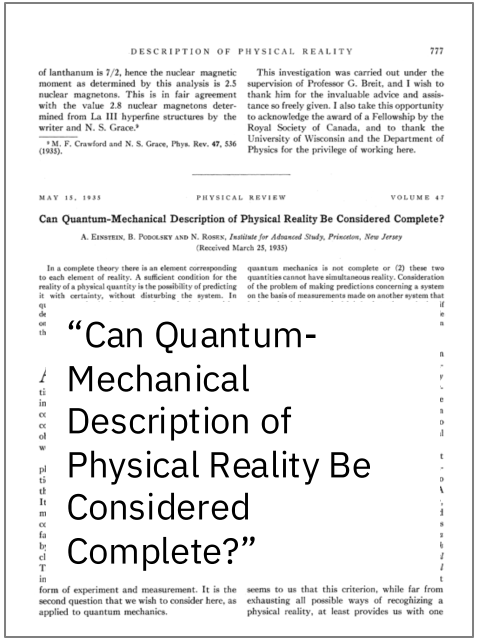
$$\text{EPR pair: } |\psi\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

More generally, two quantum states that are entangled are called EPR (Einstein-Podolsky-Rosen) pair after the EPR paradox.

EPR paradox: Suppose that quantum entangled pair are separated by a distance and one of them is observed. What happens?

$$|\psi_{AB}\rangle = \frac{1}{\sqrt{2}}(|0_A 0_B\rangle + |1_A 1_B\rangle)$$




DESCRIPTION OF PHYSICAL REALITY 777

of lanthanum is 7/2, hence the nuclear magnetic moment as determined by this analysis is 2.5 nuclear magnetons. This is in fair agreement with the value 2.8 nuclear magnetons determined from La III hyperfine structures by the writer and N. S. Grace.[9]

[9] M. F. Crawford and N. S. Grace, Phys. Rev. 47, 536 (1935).

This investigation was carried out under the supervision of Professor G. Breit, and I wish to thank him for the invaluable advice and assistance so freely given. I also take this opportunity to acknowledge the award of a Fellowship by the Royal Society of Canada, and to thank the University of Wisconsin and the Department of Physics for the privilege of working here.

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Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?

A. EINSTEIN, B. PODOLSKY AND N. ROSEN, *Institute for Advanced Study, Princeton, New Jersey*

(Received March 25, 1935)

In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty, without disturbing the system. In

quantum mechanics is not complete or (2) these two quantities cannot have simultaneous reality. Consideration of the problem of making predictions concerning a system on the basis of measurements made on another system that

form of experiment and measurement. It is the second question that we wish to consider here, as applied to quantum mechanics.

seems to us that this criterion, while far from exhausting all possible ways of recognizing a physical reality, at least provides us with one

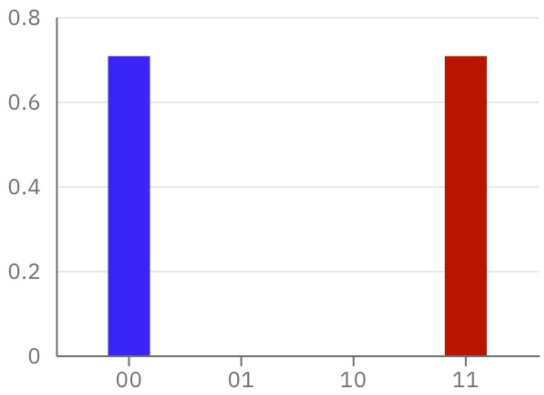
"Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?"

doi:10.1103/PhysRev.47.777 (1935)

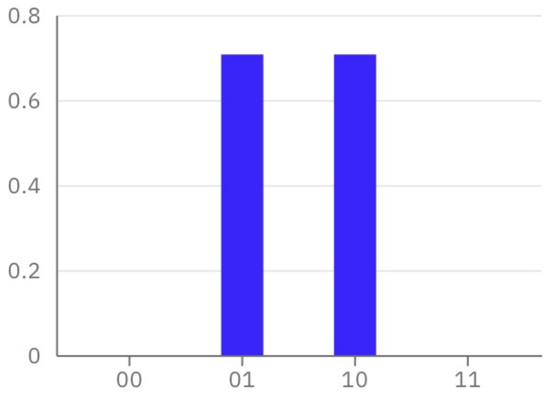
Advanced exercise

Let’s build the entangled states of two qubits. There are many ways to make it.

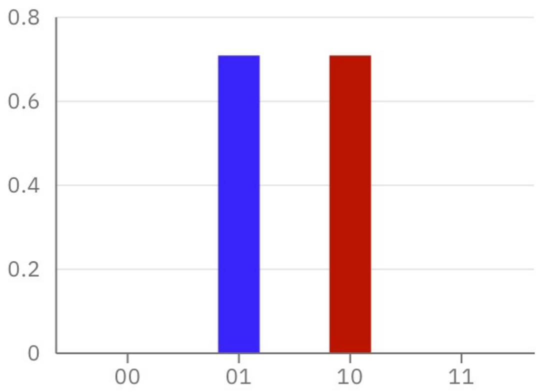
(1) $\frac{1}{\sqrt{2}}(|00\rangle - |11\rangle)$



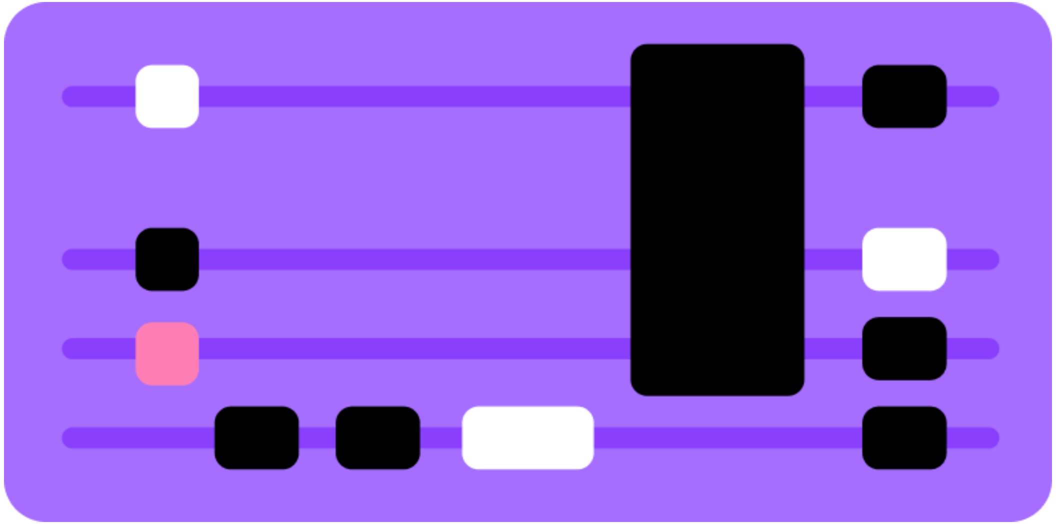
(2) $\frac{1}{\sqrt{2}}(|01\rangle + |10\rangle)$



(3) $\frac{1}{\sqrt{2}}(|01\rangle - |10\rangle)$



Before moving to Qiskit



Measurement

Measurement is forcing the qubit's state

$$\alpha|0\rangle + \beta|1\rangle \qquad s.t. |\alpha|^2 + |\beta|^2 = 1$$

to $|0\rangle$ or $|1\rangle$ by observing it, where

$|\alpha|^2$ is the probability we will get $|0\rangle$ when we measure.

$|\beta|^2$ is the probability we will get $|1\rangle$ when we measure. (Born rule)

So, α and β are called probability amplitudes.

For example,

- $\frac{\sqrt{2}}{2}|0\rangle + \frac{\sqrt{2}}{2}|1\rangle$ has an equal probability of becoming $|0\rangle$ or $|1\rangle$
- $\frac{\sqrt{3}}{2}|0\rangle - \frac{1}{2}i\,|1\rangle$ has a 75% chance of becoming $|0\rangle$.

Typical single-qubit gates

Pauli gates: $X = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix},\ Y = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix},\ Z = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

Other typical single-qubit gates:

$$H = \frac{1}{\sqrt{2}} \left[\begin{array}{cc} 1 & 1 \\ 1 & -1 \end{array} \right]; \quad S = \left[\begin{array}{cc} 1 & 0 \\ 0 & i \end{array} \right]; \quad T = \left[\begin{array}{cc} 1 & 0 \\ 0 & \exp(i\pi/4) \end{array} \right].$$

$$R_x(\theta) \equiv e^{-i\theta X/2} = \cos\frac{\theta}{2} I - i \sin\frac{\theta}{2} X = \left[\begin{array}{cc} \cos\frac{\theta}{2} & -i\sin\frac{\theta}{2} \\ -i\sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{array} \right]$$

$$R_y(\theta) \equiv e^{-i\theta Y/2} = \cos\frac{\theta}{2} I - i \sin\frac{\theta}{2} Y = \left[\begin{array}{cc} \cos\frac{\theta}{2} & -\sin\frac{\theta}{2} \\ \sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{array} \right]$$

$$R_z(\theta) \equiv e^{-i\theta Z/2} = \cos\frac{\theta}{2} I - i \sin\frac{\theta}{2} Z = \left[\begin{array}{cc} e^{-i\theta/2} & 0 \\ 0 & e^{i\theta/2} \end{array} \right].$$

Useful tool: https://javafxpert.github.io/grok-bloch/

Notation of multiple systems

- A one-qubit system can be in the superposition of two states:

$$|0\rangle\,, \quad |1\rangle$$

- A two-qubit system can be in the superposition of 2^2 states:

$$|0\rangle \otimes |0\rangle, \quad |1\rangle \otimes |0\rangle, \quad |0\rangle \otimes |1\rangle\,, \quad |1\rangle \otimes |1\rangle$$

- An n-qubit system can be in the superposition of 2^n states:

$$|0\rangle_{n-1} \otimes \cdots \otimes |0\rangle_0, \quad |0\rangle_{n-1} \otimes \cdots \otimes |0\rangle_1 \otimes |1\rangle_0, \quad \cdots, \ |1\rangle_{n-1} \otimes \cdots \otimes |1\rangle_0$$

Notation of multiple systems

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$$|0\rangle\,,\quad |1\rangle$$

- A two-qubit system can be in the superposition of 2^2 states:

$$|0\rangle\otimes|0\rangle,\quad |1\rangle\otimes|0\rangle,\quad |0\rangle\otimes|1\rangle\,,\quad |1\rangle\otimes|1\rangle$$
$$\equiv\quad |0\rangle|0\rangle,\qquad |1\rangle|0\rangle,\qquad |0\rangle|1\rangle\,,\qquad |1\rangle|1\rangle$$
$$\equiv\quad |00\rangle,\qquad |10\rangle,\qquad |01\rangle,\qquad |11\rangle$$

- An n-qubit system can be in the superposition of 2^n states:

$$|0\rangle_{n-1}\otimes\cdots\otimes|0\rangle_0,\quad |0\rangle_{n-1}\otimes\cdots\otimes|0\rangle_1\otimes|1\rangle_0,\quad \cdots,\ |1\rangle_{n-1}\otimes\cdots\otimes|1\rangle_0$$

Notation of multiple systems

- A one-qubit system can be in the superposition of two states:

$$|0\rangle\,,\quad |1\rangle$$

- A two-qubit system can be in the superposition of 2^2 states:

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$$\equiv \quad |0\rangle|0\rangle,\qquad |1\rangle|0\rangle,\qquad |0\rangle|1\rangle\,,\qquad |1\rangle|1\rangle$$

$$\equiv \quad |00\rangle,\qquad |10\rangle,\qquad |01\rangle,\qquad |11\rangle$$

- An n-qubit system can be in the superposition of 2^n states:

$$|0\rangle_{n-1}\otimes\cdots\otimes|0\rangle_0,\quad |0\rangle_{n-1}\otimes\cdots\otimes|0\rangle_1\otimes|1\rangle_0,\quad \cdots,\ |1\rangle_{n-1}\otimes\cdots\otimes|1\rangle_0$$

$$\equiv \quad |00\cdots0\rangle,\qquad |0\cdots01\rangle,\qquad \cdots,\ |1\cdots1\rangle$$

Tensor products

Tensor product of two vectors: multiply the right-hand vector by each component of the left-hand vector.

$$\begin{pmatrix} v_1 \\ \vdots \\ v_n \end{pmatrix} \otimes \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} v_1 \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix} \\ \vdots \\ v_n \begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix} \end{pmatrix}$$

Tensor product of two matrices: multiply the right-hand matrix by each element of the left-hand matrix.

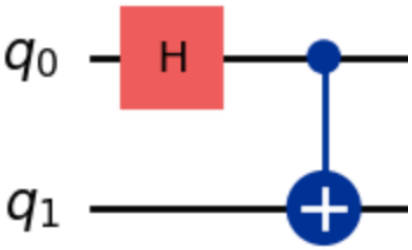
$$\mathrm{A} \otimes B = \begin{pmatrix} A_{11}B & A_{12}B \\ A_{21}B & A_{22}B \end{pmatrix} = \begin{pmatrix} \boxed{\begin{matrix} A_{11}B_{11} & A_{11}B_{12} \\ A_{11}B_{21} & A_{11}B_{22} \end{matrix}} & \boxed{\begin{matrix} A_{12}B_{11} & A_{12}B_{12} \\ A_{12}B_{21} & A_{12}B_{22} \end{matrix}} \\ \boxed{\begin{matrix} A_{21}B_{11} & A_{21}B_{12} \\ A_{21}B_{21} & A_{21}B_{22} \end{matrix}} & \boxed{\begin{matrix} A_{22}B_{11} & A_{22}B_{12} \\ A_{22}B_{21} & A_{22}B_{22} \end{matrix}} \end{pmatrix}$$

A two-qubit state can be represented as the tensor product of two single-qubit states.

$$|00\rangle = |0\rangle \otimes |0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \equiv |0\rangle, \qquad |01\rangle = |0\rangle \otimes |1\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \equiv |1\rangle,$$

$$|10\rangle = |1\rangle \otimes |0\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \equiv |2\rangle, \qquad |11\rangle = |1\rangle \otimes |1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \otimes \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \equiv |3\rangle$$

Entangled state



$$|0\rangle_1 \otimes |0\rangle_0 \underset{I\otimes H}{\rightarrow} |0\rangle \otimes \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

$$= \frac{1}{\sqrt{2}}(|00\rangle + |01\rangle)$$

$$\underset{CNOT}{\rightarrow} \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$$

An entangled state is a state $|\psi\rangle_{AB}$ consisting of quantum states $|\psi\rangle_A$ and $|\psi\rangle_{\mathrm{B}}$ that cannot be represented by a tensor product of individual quantum states.

$$\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle) \neq (a_0|0\rangle + a_1|1\rangle) \otimes (b_0|0\rangle + b_1|1\rangle)$$

$$= a_0 b_0|00\rangle + a_1 b_0|10\rangle + a_0 b_1|01\rangle + a_1 b_1|11\rangle$$

There is no coefficient which satisfies this equation. Therefore, this state is entangled state.

Qiskit hands-on

Please download the file, ”20251118_QLTP_IntroQC.ipynb”

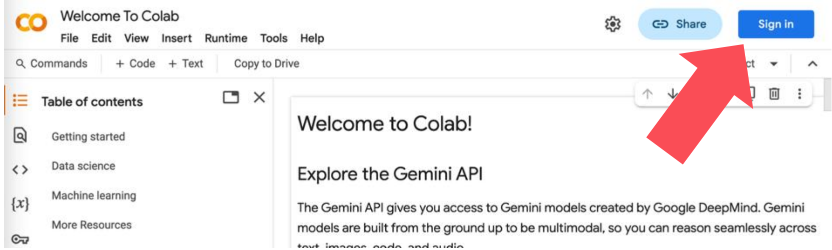
from URL: https://ibm.ent.box.com/folder/351459863769

Use Qiskit on Online lab environment

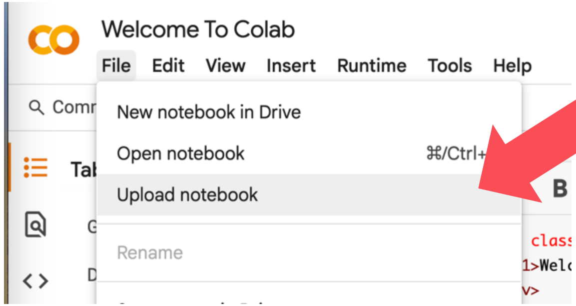
Reference: https://quantum.cloud.ibm.com/docs/en/guides/online-lab-environments

(1) Go to Google Colab and Sign in it.

https://colab.research.google.com/



(2) (next week) File → Upload notebook



You need to install Qiskit every time when you open new notebook.

Install and set up Qiskit 2.0 (macOS)

- Reference URL : https://quantum.cloud.ibm.com/docs/en/guides/install-qiskit (For non-macOS users, please refer this.)
- For those upgrading from version 0.x to 2.0: note that because Qiskit v2.0 uses a new packaging structure, you cannot use pip install -U qiskit to upgrade from any Qiskit 0.x version to 2.0.

1. Create a new virtual environment, using Python 3.8 or later.

```
python3 -m venv qiskit-venv
```

2. Activate the environment.

```
source qiskit-venv/bin/activate
```

3. Install Qiskit.

```
pip install qiskit
```

4. Install the necessary packages.

```
pip install qiskit-ibm-runtime
pip install qiskit[visualization]
pip install jupyter
pip install qiskit-aer
```

zsh users need to put 'qiskit[visualization]' in single quotes.

5. With the following command, you can launch Jupyter notebook and start using Qiskit.

```
jupyter notebook
```

6. Try the first cell of Hello world by copy and paste, and execute it by “Shift”+”Enter”.

6. If you are not planning to use the environment immediately, use the deactivate command to leave it.

```
deactivate
```

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