QISKIT

Quantum Information Science Kit
Open Source Code

ESFERA de BLOCH

$| \psi > = \alpha | 0 > + \beta | 1 >$ $\quad | \alpha |^2 + | \beta |^2 = 1$

$| \psi > = \cos(\Theta/2) | 0 > + e^{i\varphi} \text{sen}(\Theta/2) | 1 >$

$$\begin{cases} \alpha = \cos(\Theta/2) \\ \beta = e^{i\varphi} \text{sen}(\Theta/2) \end{cases}$$

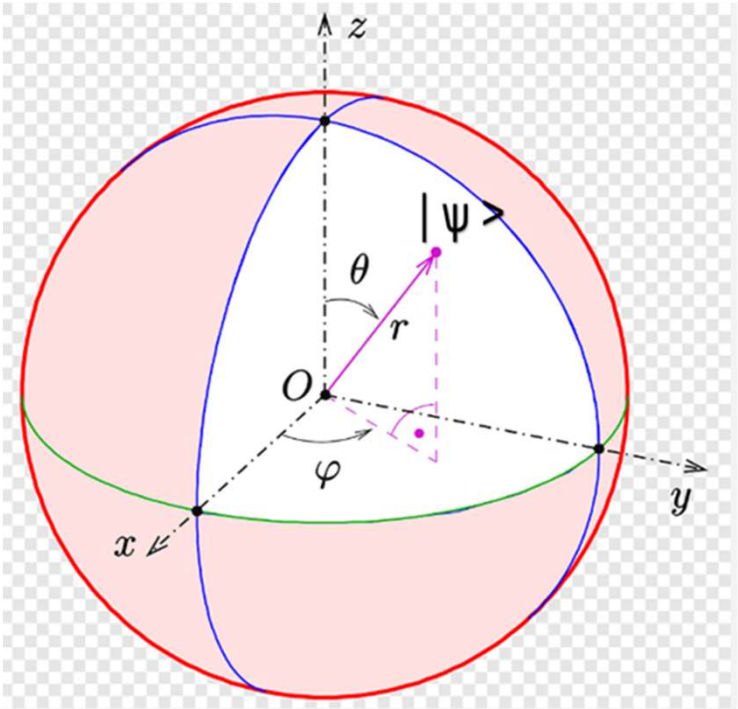
$|\alpha|^2 = \cos^2(\Theta/2)$

$|\beta|^2 = \text{sen}^2(\Theta/2)$

$| \alpha |^2 + | \beta |^2 = \cos^2(\Theta/2) + \text{sen}^2(\Theta/2)$

Espacio Hilbert
n = 2
Base
{|0>,|1>}

Qbits ∈ esp. Hilbert



ESFERA de BLOCH

Creación de un circuito simple y visualización de la esfera de Bloch

```
#########################################################
# CURSO QISKIT 2025
# Crear circuito simple y visualizar esfera de Bloch

from qiskit import QuantumCircuit
from qiskit.primitives import StatevectorSampler
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

qc = QuantumCircuit(1,1)
stateVectorResult = Statevector(qc)
plot_bloch_multivector(stateVectorResult)

#########################################################
```

ESFERA de BLOCH

Creación de un circuito simple y visualización de la esfera de Bloch

[1]:
```
from qiskit import QuantumCircuit
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qc = QuantumCircuit(1,1)
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```
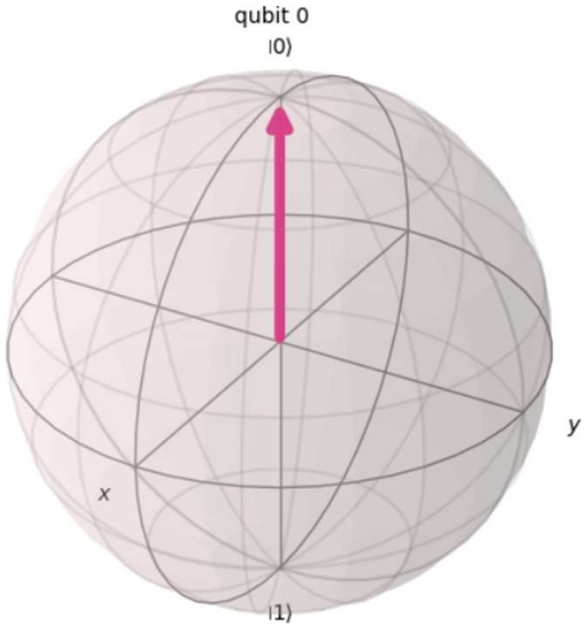
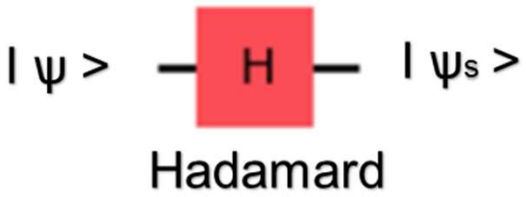

[1]:



Hadamard Gate

$$\frac{1}{\sqrt[2]{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$$



$$|\psi_s\rangle = H|0\rangle = \frac{1}{\sqrt[2]{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}\begin{pmatrix}1\\ 0\end{pmatrix} = \frac{1}{\sqrt[2]{2}}\begin{pmatrix}1\\ 1\end{pmatrix} = |+\rangle$$

$|0\rangle$

HADAMARD

Incorporación compuerta Hadamard y poner en superposición al qubit

```
##################################################
# CURSO QISKIT 2025
# Crear circuito simple con compuerta HADAMARD

from qiskit import QuantumCircuit
from qiskit.primitives import StatevectorSampler
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

qc = QuantumCircuit(1,1)

# agregamos compuerta Hadamard H

qc.h(0)
qc.draw(output='mpl')

##################################################
```

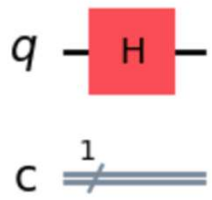
HADAMARD

Incorporación compuerta Hadamard y poner en superposición al qubit

[3]:

```
from qiskit import QuantumCircuit
from qiskit.primitives import StatevectorSampler
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

qc = QuantumCircuit(1,1)

# agregamos compuerta Hadamard H

qc.h(0)
qc.draw(output='mpl')
```

[3]:



HADAMARD

Incorporación compuerta Hadamard y poner en superposición al qubit

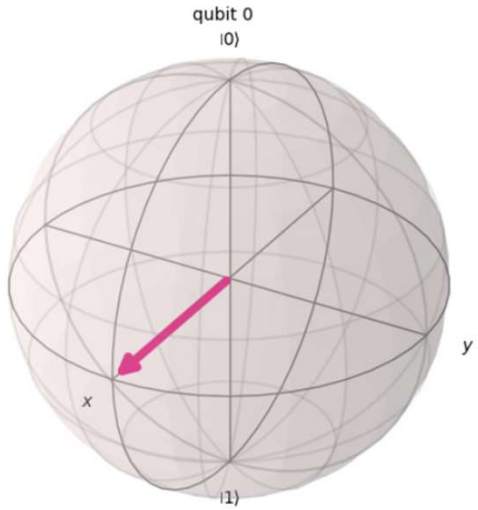
```
#########################################################
# CURSO QISKIT 2025
# Crear circuito simple y visualizar esfera de Bloch

from qiskit import QuantumCircuit
from qiskit.primitives import StatevectorSampler
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

qc = QuantumCircuit(1,1)

# agregamos compuerta Hadamard H

qc.h(0)
stateVectorResult = Statevector(qc)
plot_bloch_multivector(stateVectorResult)
#########################################################
```

HADAMARD

Incorporación compuerta Hadamard y poner en superposición al qubit

[4]:
```
################################################
# CURSO QISKIT 2025
# Crear circuito simple y visualizar esfera de Bloch

from qiskit import QuantumCircuit
from qiskit.primitives import StatevectorSampler
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

qc = QuantumCircuit(1,1)

# agregamos compuerta Hadamard H

qc.h(0)
stateVectorResult = Statevector(qc)
plot_bloch_multivector(stateVectorResult)
################################################
```

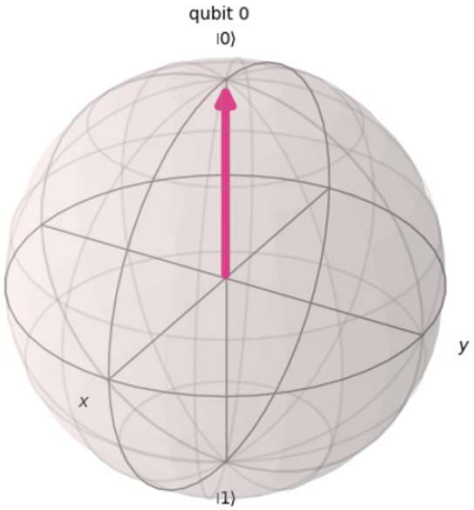
[4]:

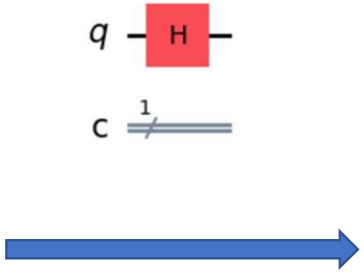


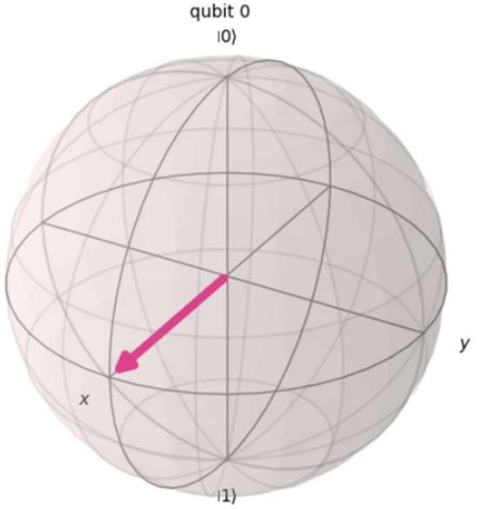
$|+\rangle = \frac{1}{\sqrt{2}} (|0\rangle + |1\rangle)$

HADAMARD

Incorporación compuerta Hadamard y poner en superposición al qubit







|0>

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

GATE X

Incorporación compuerta X

```
#######################################################
# CURSO QISKIT 2025
# Hadamard + X


qc = QuantumCircuit(1)

# agregamos compuerta X

qc.x(0)
qc.h(0)
qc.draw(output='mpl')
#######################################################
```

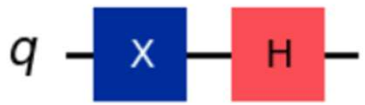
GATE X

Quantum Computing QISKIT

Incorporación compuerta X

[6]:
```
# CURSO QISKIT 2025
# Hadamard + X


qc = QuantumCircuit(1)

# agregamos compuerta X

qc.x(0)

qc.h(0)

qc.draw(output='mpl')
```

[6]:



GATE X

Incorporación compuerta X Esfera Bloch

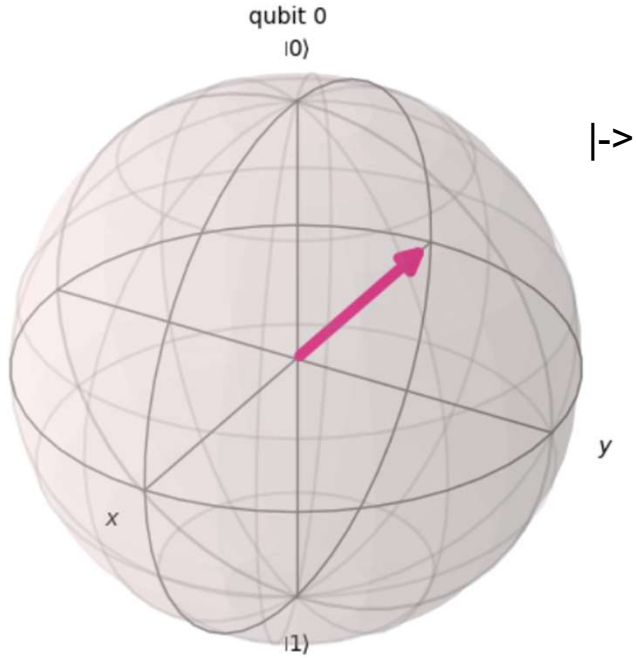
```
#######################################################
# CURSO QISKIT 2025
# Hadamard + X


qc = QuantumCircuit(1)

# agregamos compuerta X

qc.x(0)
qc.h(0)

stateVectorResult = Statevector(qc)
plot_bloch_multivector(stateVectorResult)
#######################################################
```

GATE X

Incorporación compuerta X Esfera Bloch

[7]:
```
qc = QuantumCircuit(1)

# agregamos compuerta X

qc.x(0)
qc.h(0)

stateVectorResult = Statevector(qc)
plot_bloch_multivector(stateVectorResult)
```

[7]:

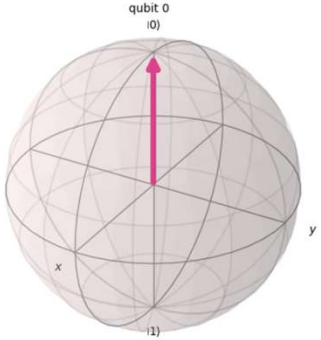


$|-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$

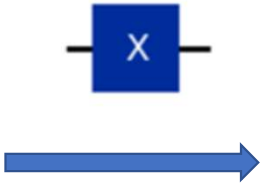
GATE X

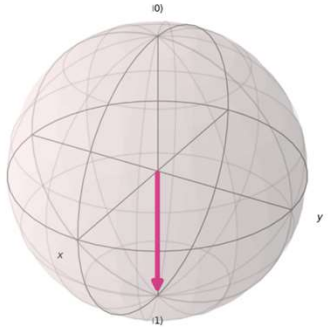
Quantum Computing QISKIT

Incorporación compuerta X+H Esfera Bloch

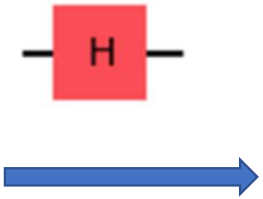


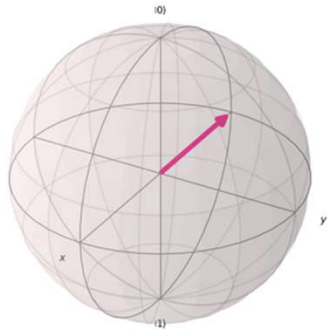
|0>





|1 >





|-> = $\frac{1}{\sqrt{2}}$ (|0> - |1>)

MEDICION

Incorporación Medidor (NO Reversible)

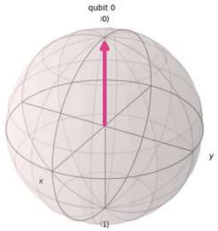
```
##########################################################
# CURSO QISKIT 2025
# Medidor


qc = QuantumCircuit(1,1)

# agregamos Medicion

qc.h(0)
qc.measure(0,0)
qc.draw(output='mpl')
##########################################################
```

MEDICION

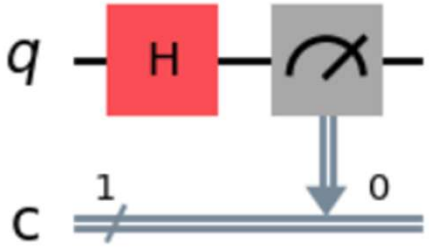
Incorporación Medidor

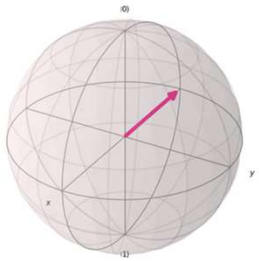
[17]:
```
qc = QuantumCircuit(1,1)

# agregamos Medicion

qc.h(0)
qc.measure(0,0)
qc.draw(output='mpl')
```

[17]:



|0>





|->

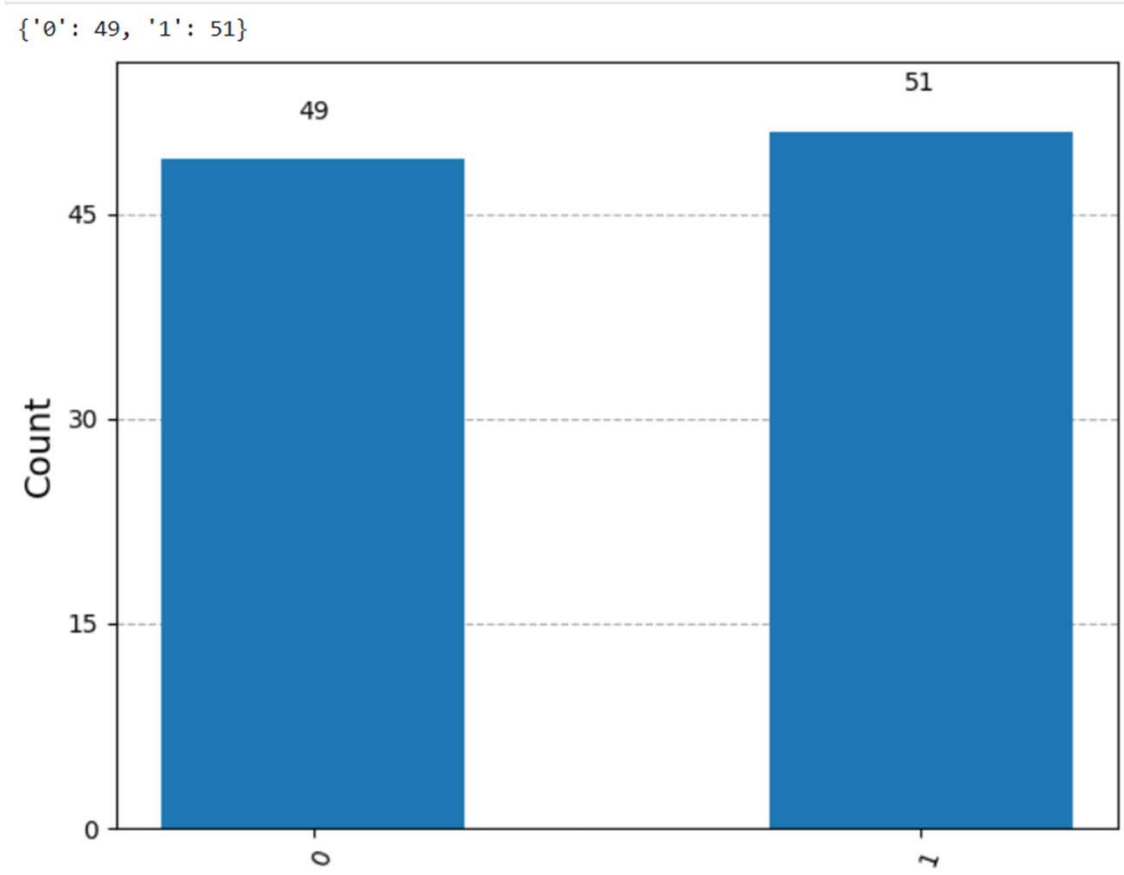
HISTOGRAMA

HISTOGRAMA

```
#######################################################
# CURSO QISKIT 2025
# HISTORGRAMA

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(1,1)

qc.h(0)
qc.measure(0,0)

simulator = AerSimulator()
compiled_circuit = transpile(qc, simulator)
sim_result = simulator.run(compiled_circuit, shots= 100, memory=True).result()
counts = sim_result.get_counts()
print(counts)
plot_histogram(counts)

#######################################################
```

HISTOGRAMA

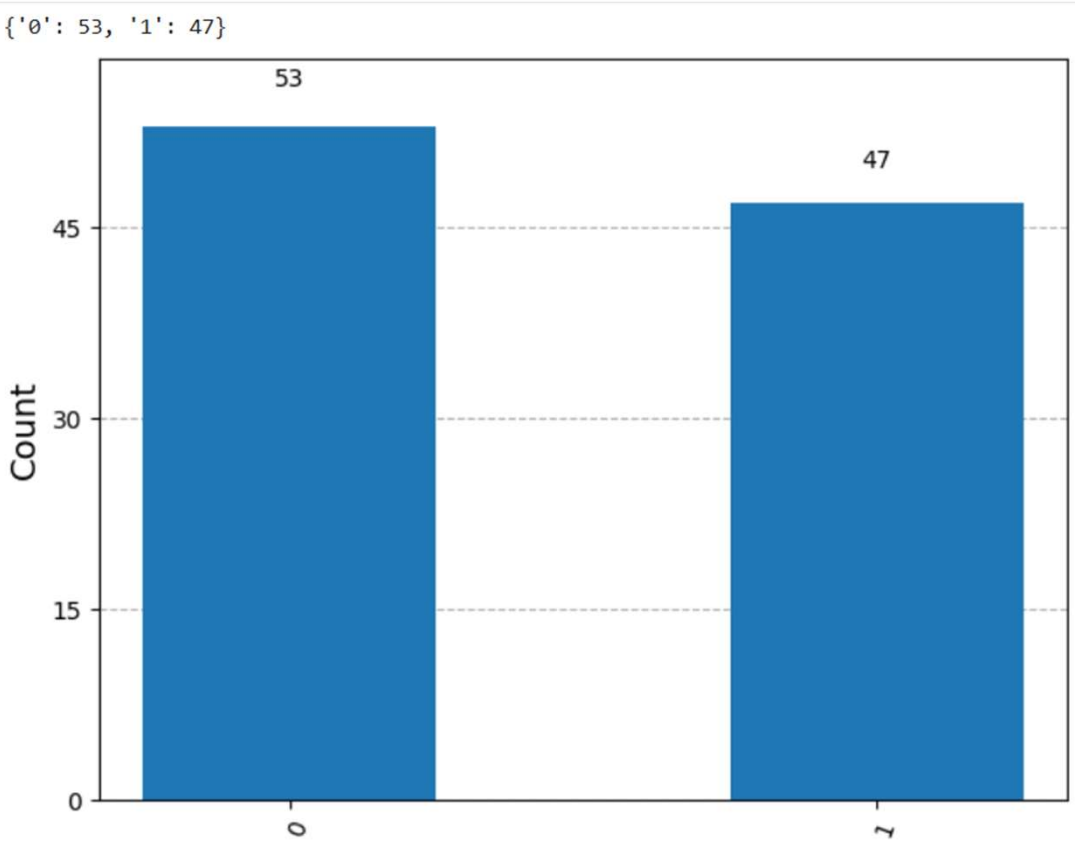
HISTOGRAMA



Simulación #1

HISTOGRAMA

HISTOGRAMA



Simulación #2

HISTOGRAMA

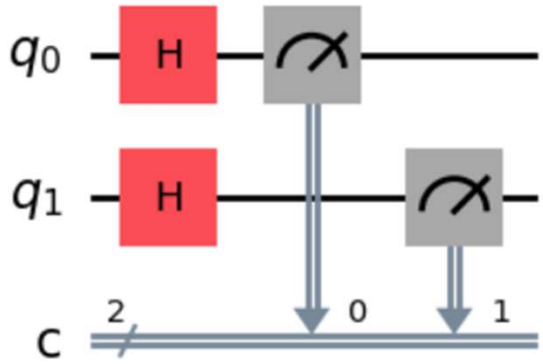
```
#########################################################
# CURSO QISKIT 2025
# HISTOGRAMA

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.h(0)
qc.h(1)
qc.measure([0,1],[0,1])
qc.draw(output='mpl')


#########################################################
```

HISTOGRAMA

HISTOGRAMA

[1]:
```
from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.h(0)
qc.h(1)
qc.measure([0,1],[0,1])
qc.draw(output='mpl')
```

[1]:



HISTOGRAMA

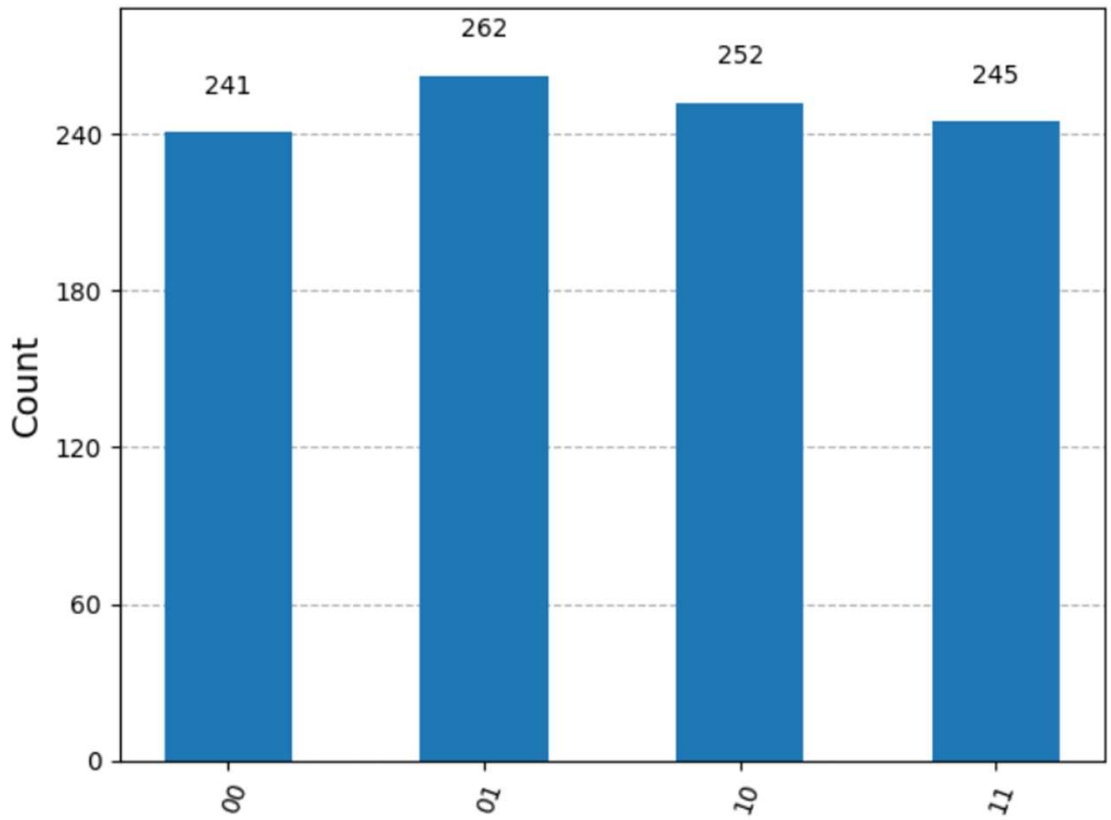
HISTOGRAMA

```
#########################################################
# CURSO QISKIT 2025
# HISTOGRAMA

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.h(0)
qc.h(1)
qc.measure([0,1],[0,1])
qc.draw(output='mpl')
simulator = AerSimulator()
compiled_circuit = transpile(qc, simulator)
sim_result = simulator.run(compiled_circuit, shots= 1000, memory=True).result()
counts = sim_result.get_counts()
print(counts)
plot_histogram(counts)

#########################################################
```

HISTOGRAMA

HISTOGRAMA

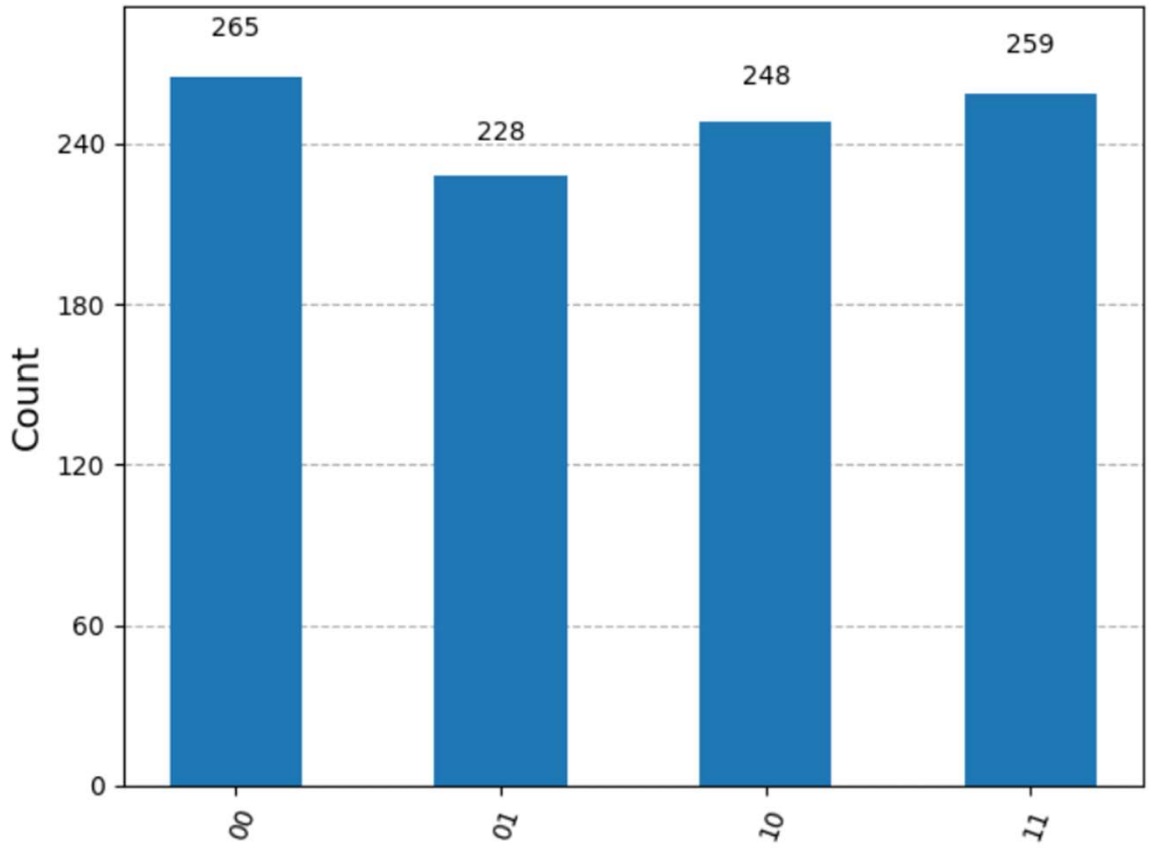
```
{'00': 241, '01': 262, '11': 245, '10': 252}
[3]:
```



Simulación #1
Shots = 1.000

HISTOGRAMA

```
{'00': 265, '11': 259, '10': 248, '01': 228}
[4]:
```



Simulación #2
Shots = 1.000

ENTAGLEMENT

Estados de Bell

$|q1q2\rangle \neq |q1\rangle \otimes |q2\rangle$

$|\psi_{in}\rangle$

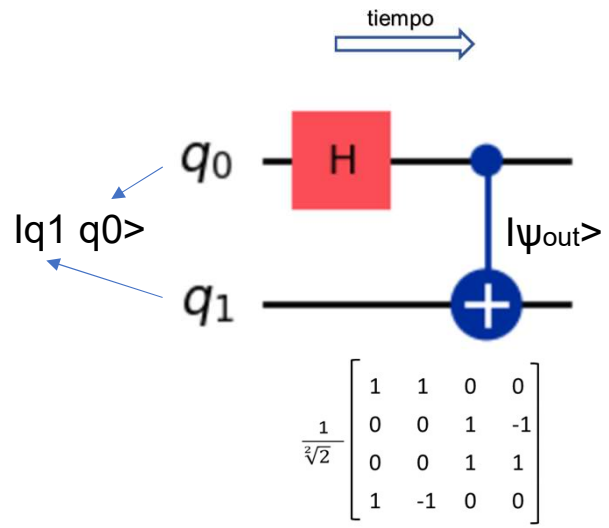
$|q1\ q0\rangle$

$|00\rangle$

$|01\rangle$

$|10\rangle$

$|11\rangle$



$|\psi_{out}\rangle$

Qbits - Entrelazados

$\frac{1}{\sqrt{2}}(|00\rangle + |11\rangle) = |\emptyset^{+}\rangle$

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

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

$\frac{1}{\sqrt{2}}(|01\rangle - |10\rangle) = |\Psi^{-}\rangle$

Estados Bell

$$\frac{1}{\sqrt{2}}\begin{bmatrix}1&1&0&0\\0&0&1&-1\\0&0&1&1\\1&-1&0&0\end{bmatrix} |10\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix}1&1&0&0\\0&0&1&-1\\0&0&1&1\\1&-1&0&0\end{bmatrix}\begin{pmatrix}0\\1\end{pmatrix}\otimes\begin{pmatrix}1\\0\end{pmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix}1&1&0&0\\0&0&1&-1\\0&0&1&1\\1&-1&0&0\end{bmatrix}\begin{pmatrix}0\\0\\1\\0\end{pmatrix} = \frac{1}{\sqrt{2}}\begin{pmatrix}0\\1\\1\\0\end{pmatrix} = |\Psi^{+}\rangle$$

Estado de Bell $|\emptyset^{+}>$

```
############################################################
# CURSO QISKIT 2025
# ENTAGLEMENT

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.h(0)
qc.cx(0,1)
qc.measure([0,1],[0,1])
qc.draw(output='mpl')


############################################################
```

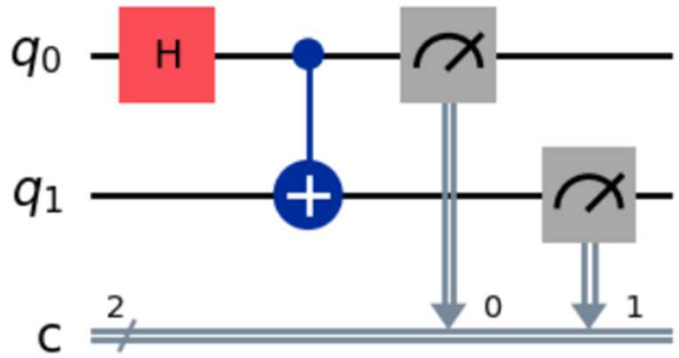
ENTAGLEMENT

Quantum Computing QISKIT

Estado de Bell $|Ø^+>$

[2]:
```
from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.h(0)
qc.cx(0,1)
qc.measure([0,1],[0,1])
qc.draw(output='mpl')
```

[2]:



$|Ø^+> = \frac{1}{\sqrt{2}} (|00> + |11>)$

ENTAGLEMENT

Estado de Bell $|\emptyset^{+}>$

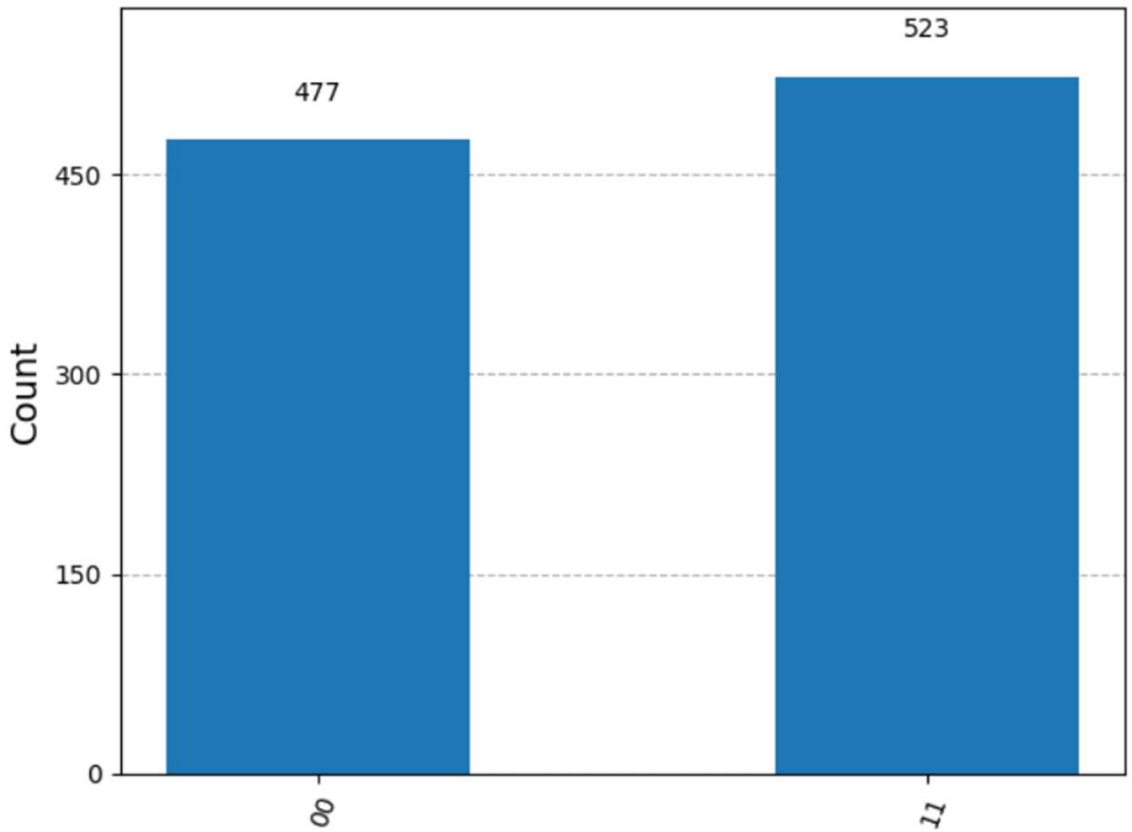
```
############################################################
# CURSO QISKIT 2025
# ENTAGLEMENT

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.h(0)
qc.cx(0,1)
qc.measure([0,1],[0,1])

simulator = AerSimulator()
compiled_circuit = transpile(qc, simulator)
sim_result = simulator.run(compiled_circuit, shots= 1000, memory=True).result()
counts = sim_result.get_counts()
print(counts)
plot_histogram(counts)
############################################################
```

ENTAGLEMENT

Quantum Computing QISKIT

Estado de Bell $|\emptyset^{+}>$

```
{'00': 477, '11': 523}
[4]:
```



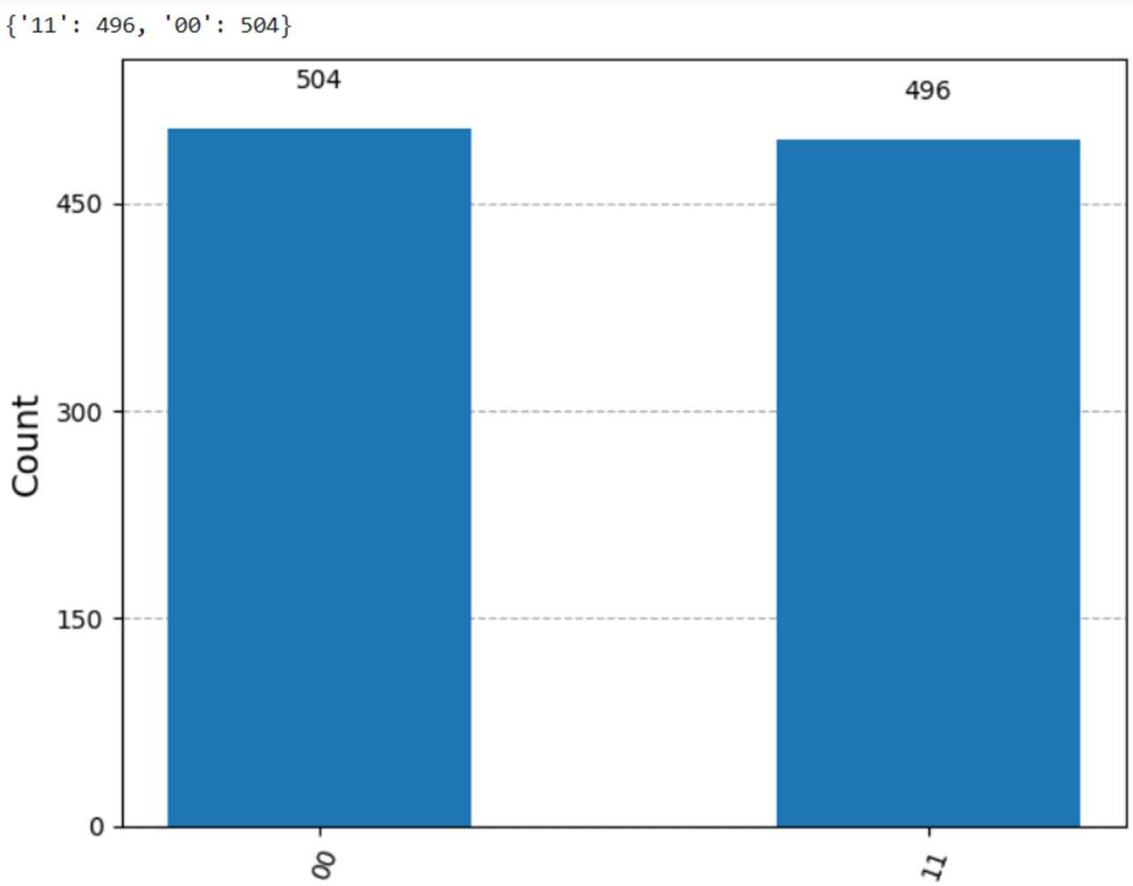
Simulación #1
Shots = 1.000

ENTAGLEMENT

Quantum Computing QISKIT

Estado de Bell $|\emptyset^{+}>$

[7]:



Simulación #2
Shots = 1.000

ENTAGLEMENT

Estado de Bell $|\Psi^+>$

```
#########################################################
# CURSO QISKIT 2025
# ENTAGLEMENT

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.x(1)
qc.barrier()
qc.h(0)
qc.cx(0,1)
qc.barrier()
qc.measure([0,1],[0,1])

qc.draw(output='mpl')
#########################################################
```

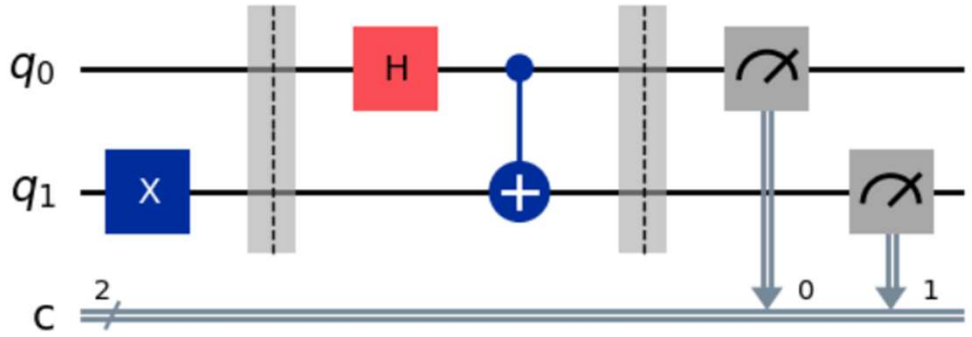
Quantum Computing QISKIT

ENTAGLEMENT

Estado de Bell $|\Psi^+>$

[2]:
```
from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.x(1)
qc.barrier()
qc.h(0)
qc.cx(0,1)
qc.barrier()
qc.measure([0,1],[0,1])

qc.draw(output='mpl')
```

[2]:



$$|\Psi^+> = \frac{1}{\sqrt{2}}(|01> + |10>)$$

ENTAGLEMENT

Estado de Bell $|\Psi^+>$

```
#########################################################
# CURSO QISKIT 2025
# ENTAGLEMENT

from qiskit import QuantumCircuit
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram

qc = QuantumCircuit(2,2)

qc.x(1)
qc.barrier()
qc.h(0)
qc.cx(0,1)
qc.barrier()
qc.measure([0,1],[0,1])

simulator = AerSimulator()
compiled_circuit = transpile(qc, simulator)
sim_result = simulator.run(compiled_circuit, shots= 1000, memory=True).result()
counts = sim_result.get_counts()
print(counts)
plot_histogram(counts)

#########################################################
```

Representación QUBIT con BLOCH

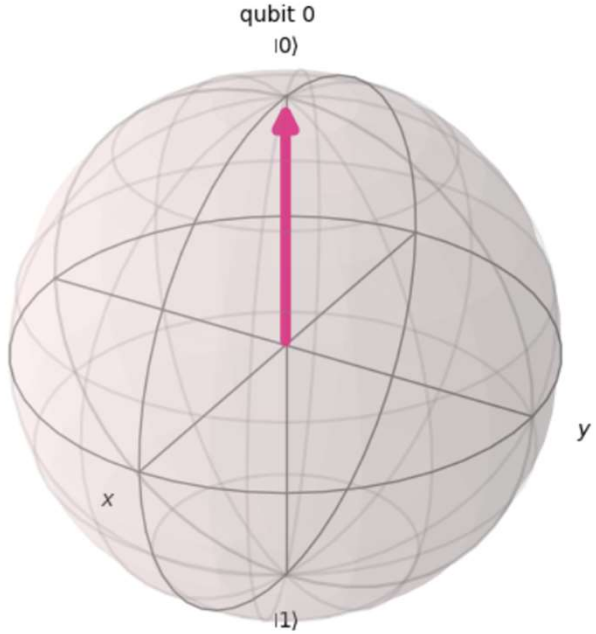
```
#########################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('bloch')
#########################################################
```

Representación QUBIT con BLOCH

```
•[4]: from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

qc = QuantumCircuit(1)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('bloch')
```

```
state vector results Statevector([1.+0.j, 0.+0.j],
            dims=(2,))
```

[4]:



QUBIT

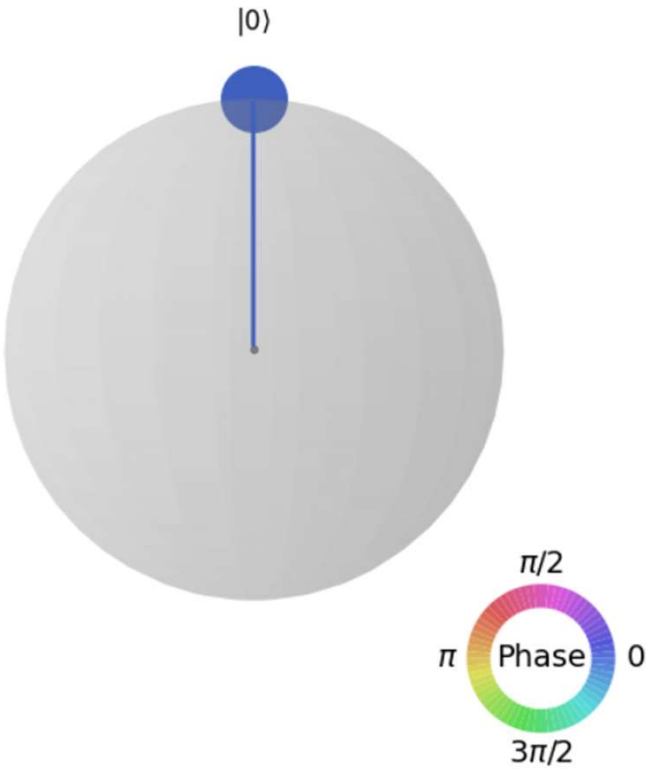
Representación QUBIT con QSPHERE

```
#####################################################
# CURSO QISKIT 2025
# Esfera de QSPHERE

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('qsphere')
#####################################################
```

Representación QUBIT con QSPHERE

```
state vector results Statevector([1.+0.j, 0.+0.j],
            dims=(2,))
```

[6]:

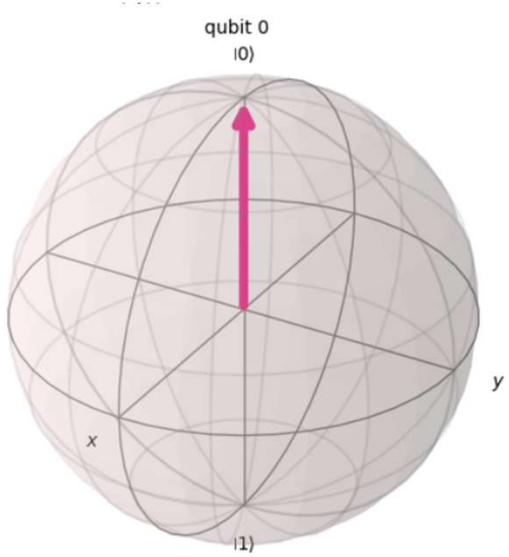


QUBIT

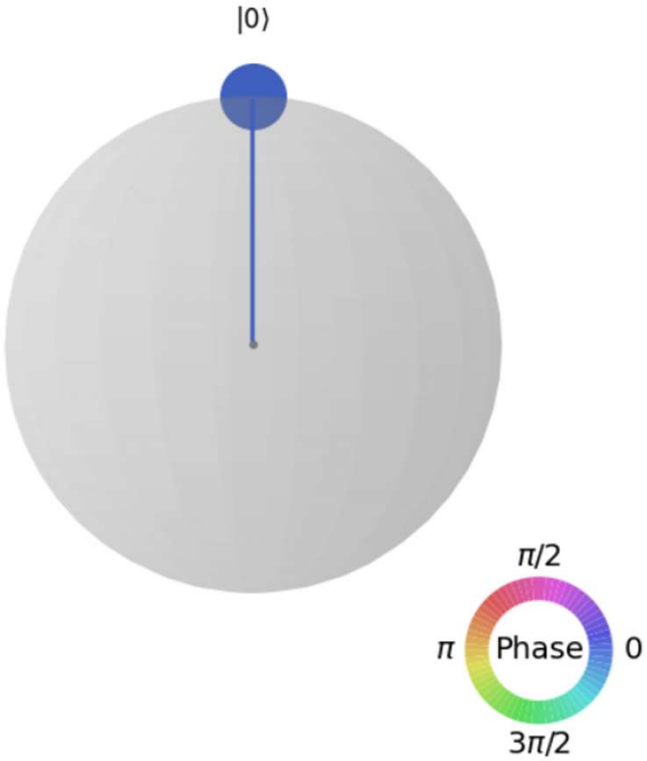
Quantum Computing QISKIT

Representación QUBIT |0>

[4]:



=



QUBIT

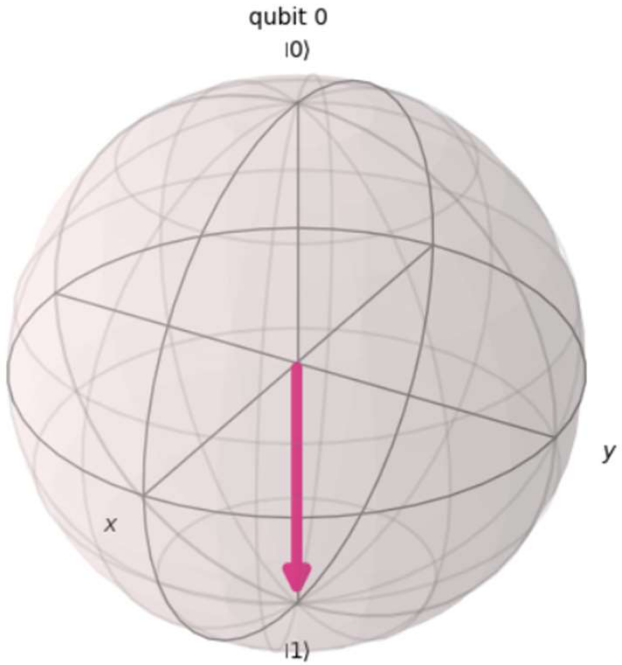
Representación QUBIT |1>

```
##################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
qc.x(0)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('bloch')
##################################################
```

Representación QUBIT |1>

```
state vector results Statevector([0.+0.j, 1.+0.j],
            dims=(2,))
```

[8]:



QUBIT

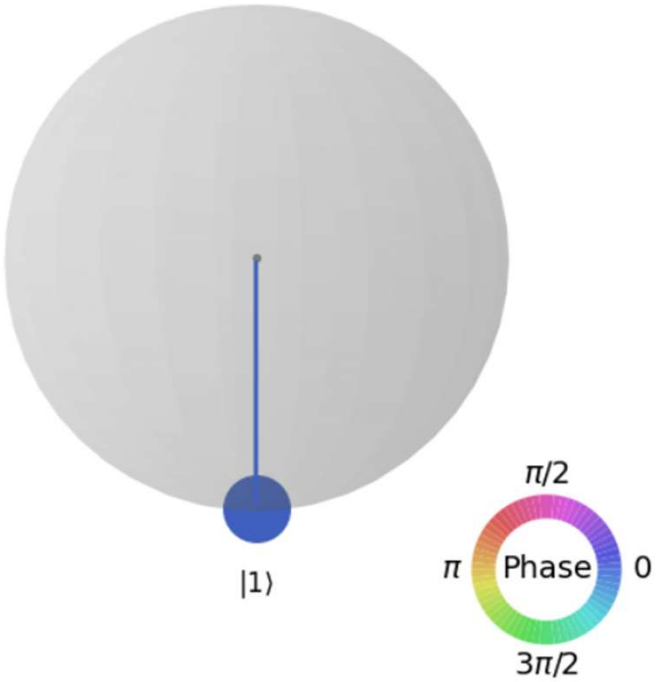
Representación QUBIT |1>

```
##########################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
qc.x(0)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('qsphere')
##########################################################
```

Representación QUBIT |1>

```
state vector results Statevector([0.+0.j, 1.+0.j],
            dims=(2,))
```

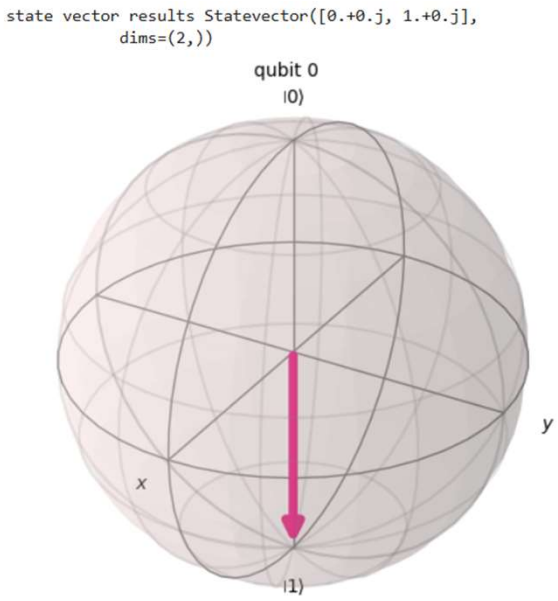
[9]:



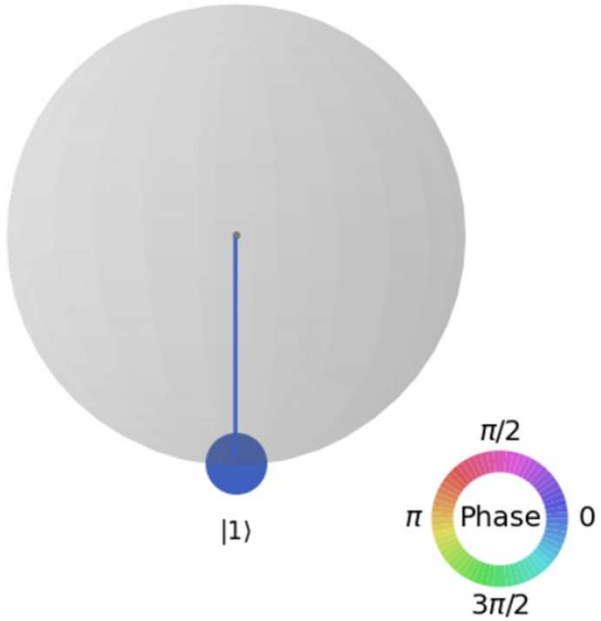
QUBIT

Quantum Computing QISKIT

Representación QUBIT |1>



=



Representación QUBIT |+>

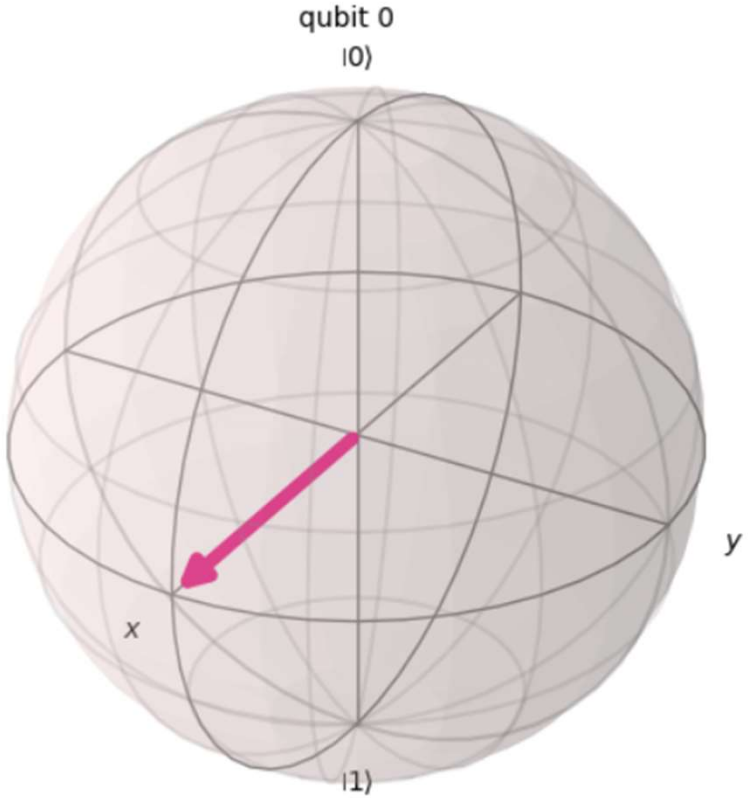
```
#########################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
qc.h(0)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('bloch')
#########################################################
```

QUBIT

Representación QUBIT |+>

```
state vector results Statevector([0.70710678+0.j, 0.70710678+0.j],
            dims=(2,))
```

[10]:



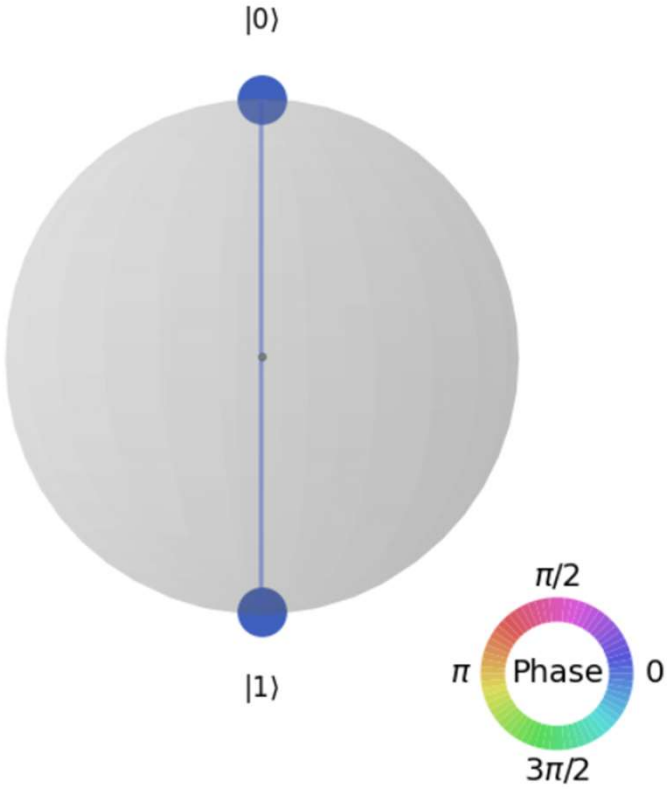
Representación QUBIT |+>

```
#############################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
qc.h(0)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('qsphere')
#############################################################
```

QUBIT

Representación QUBIT |+>

```
state vector results Statevector([0.70710678+0.j, 0.70710678+0.j],
            dims=(2,))
```



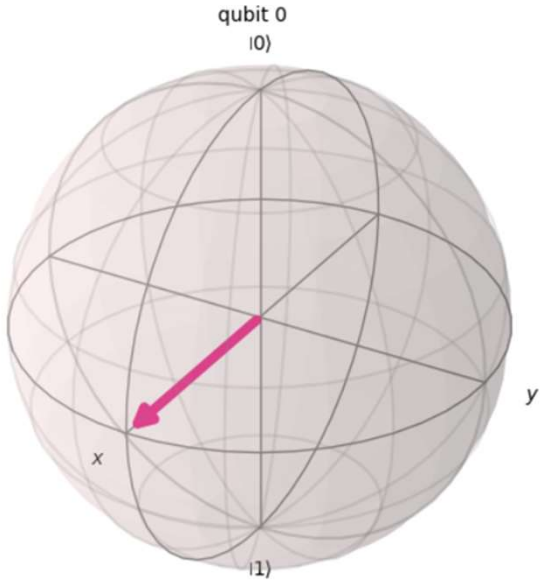
QUBIT

Quantum Computing QISKIT

Representación QUBIT |+>

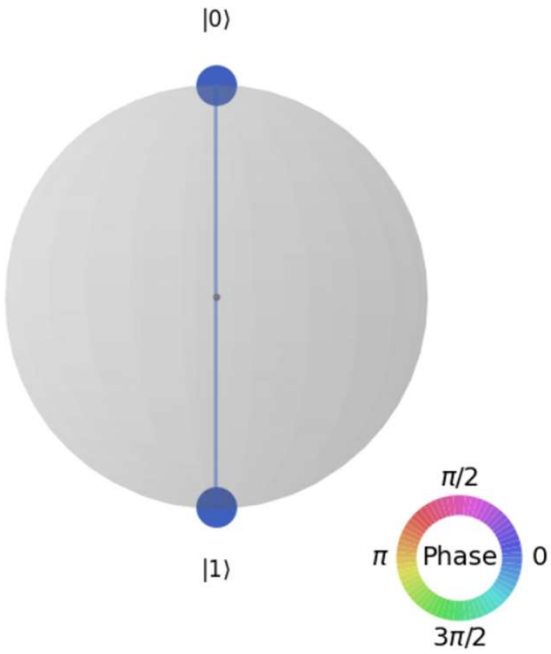
state vector results Statevector([0.70710678+0.j, 0.70710678+0.j],
dims=(2,))

[10]:



=

state vector results Statevector([0.70710678+0.j, 0.70710678+0.j],
dims=(2,))

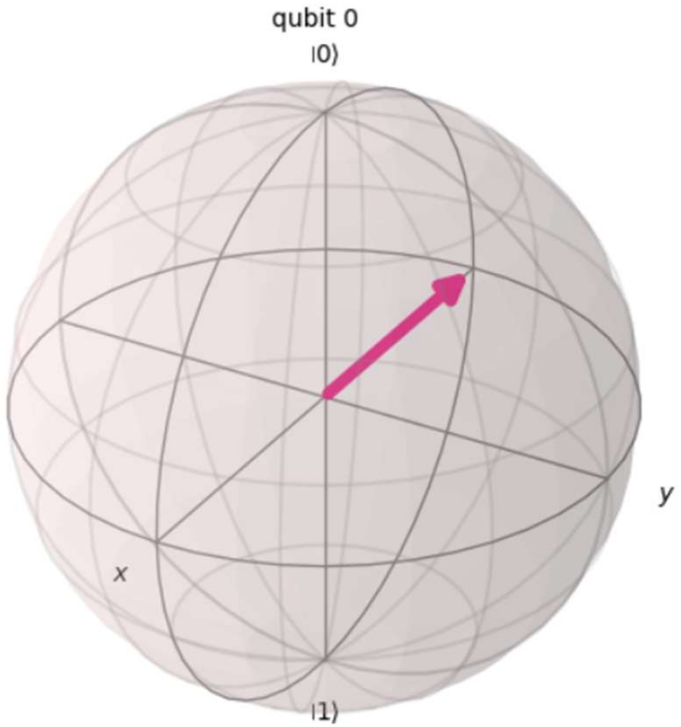


Representación QUBIT |->

```
#########################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
qc.x(0)
qc.h(0)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('bloch')
#########################################################
```

Representación QUBIT |->

```
state vector results Statevector([ 0.70710678+0.j, -0.70710678+0.j],
            dims=(2,))
```



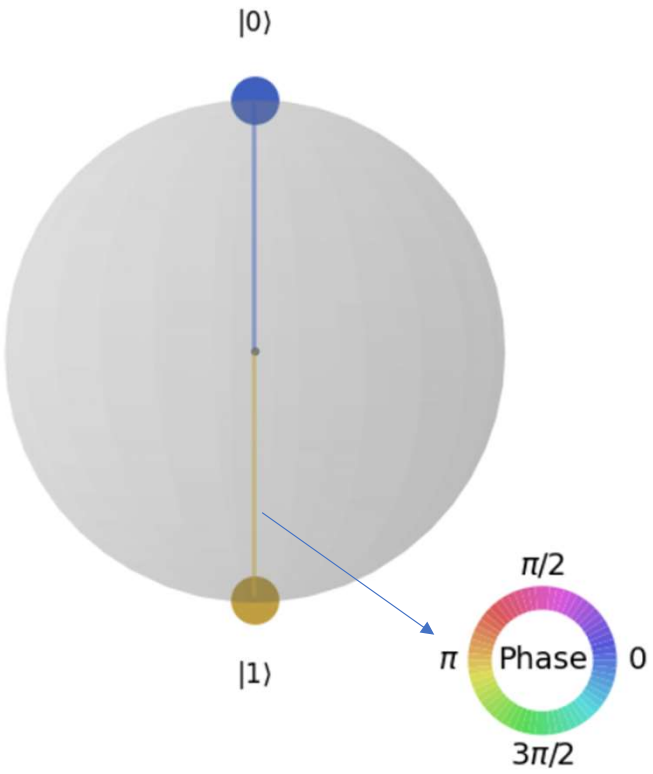
Representación QUBIT |->

```
#######################################################
# CURSO QISKIT 2025
# Esfera de BLOCH

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *


qc = QuantumCircuit(1)
qc.x(0)
qc.h(0)
stateVectorResult = Statevector(qc)
print('state vector results', stateVectorResult)
stateVectorResult.draw('qsphere')
#######################################################
```

QUBIT

Representación QUBIT |->

```
state vector results Statevector([ 0.70710678+0.j, -0.70710678+0.j],
            dims=(2,))
```

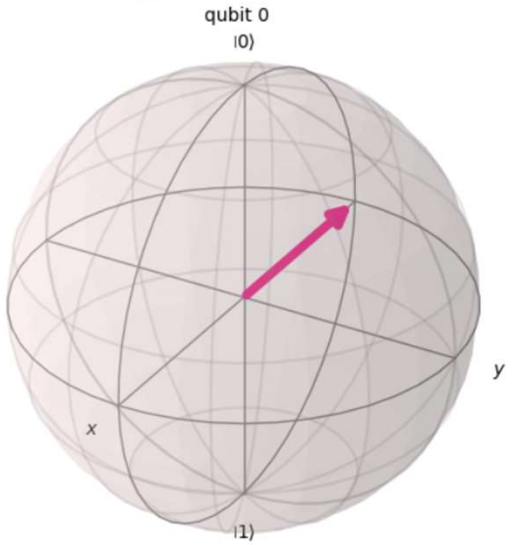


QUBIT

Quantum Computing QISKIT

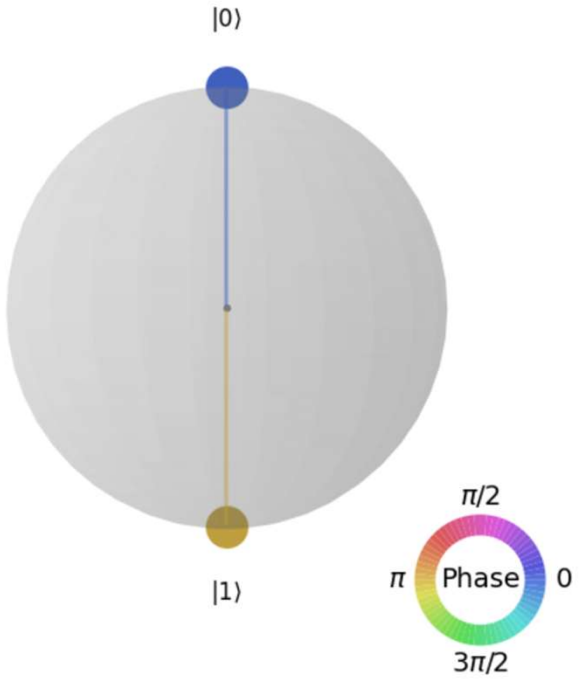
Representación QUBIT |->

state vector results Statevector([0.70710678+0.j, -0.70710678+0.j],
dims=(2,))



=

state vector results Statevector([0.70710678+0.j, -0.70710678+0.j],
dims=(2,))

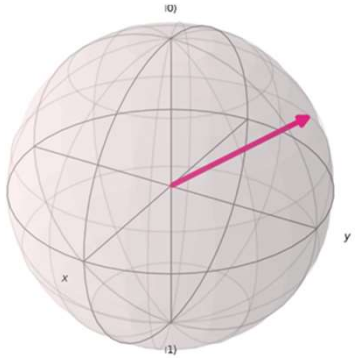


PAULI GATES

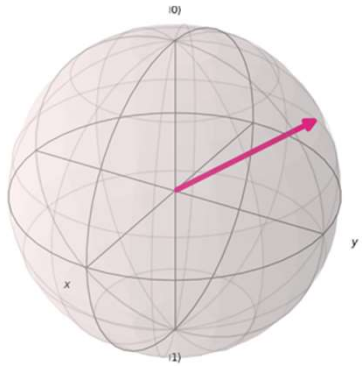
PAULI GATES GATE I identidad

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

$| \psi >$ — I — $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$



$I | \psi > = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$



tiempo

PAULI GATES

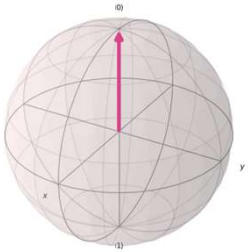
PAULI GATES GATE X

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

$$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$$

$| \psi > \quad X \quad | \psi_s >$

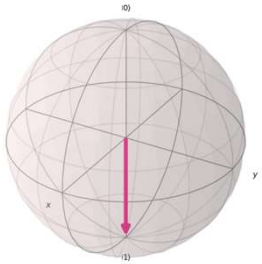
$| 0 >$



$\Theta s = \pi - \Theta e$

$\varphi s = \varphi e$

$$| \psi_s > = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \beta \\ \alpha \end{pmatrix}$$



$|1 >$

tiempo

PAULI GATES GATE X

```
#########################################################
# CURSO QISKIT 2025
# X GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.x(0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#########################################################
```

PAULI GATES GATE X

```
[16]: result
```

```
Statevector([0.+0.j, 1.+0.j],
            dims=(2,))
```

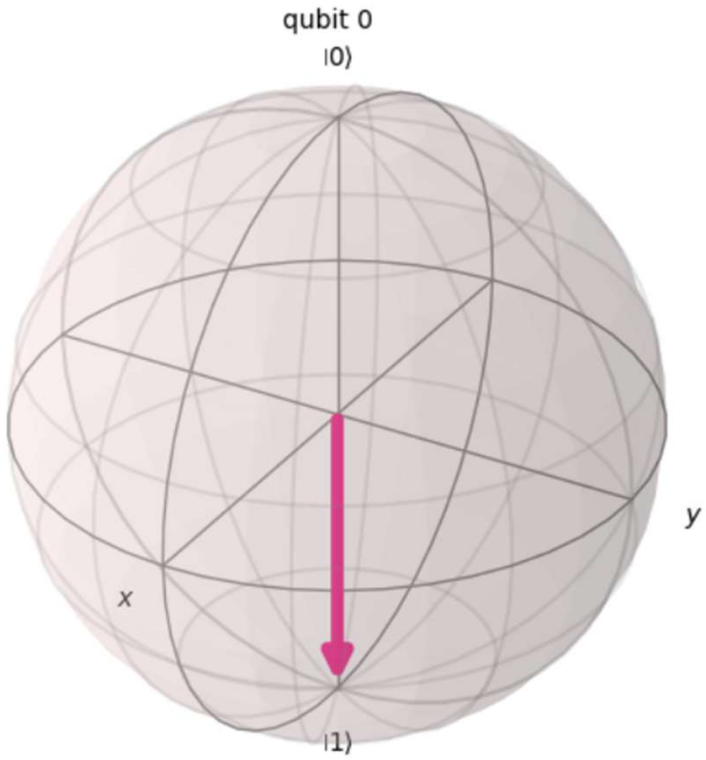
```
[17]: img
```

```
[17]:
```

PAULI GATES GATE X

```
[18]: bloch_sphere
```

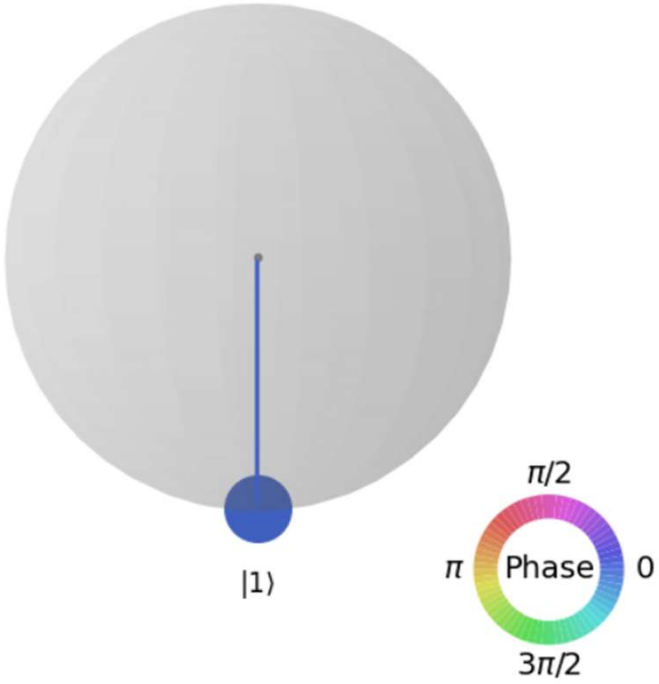
[18]:



PAULI GATES GATE X

```
[19]: qsphere
```

[19]:

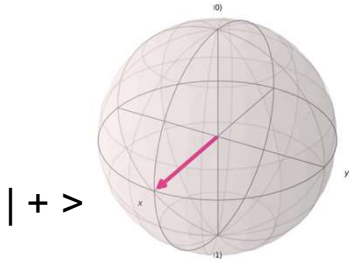


PAULI GATES

PAULI GATES GATE Y

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

$$\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$$



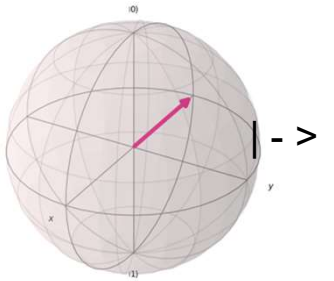
Θs = π - Θe

φs = π + φe

Fase absoluta no afecta

$$| \psi_s > = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} -i\beta \\ i\alpha \end{pmatrix} = -i \begin{pmatrix} \beta \\ -\alpha \end{pmatrix}$$

tiempo



PAULI GATES GATE Y

```
#######################################################
# CURSO QISKIT 2025
# Y GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.y(0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#######################################################
```

PAULI GATES GATE Y

```
[12]: result
```

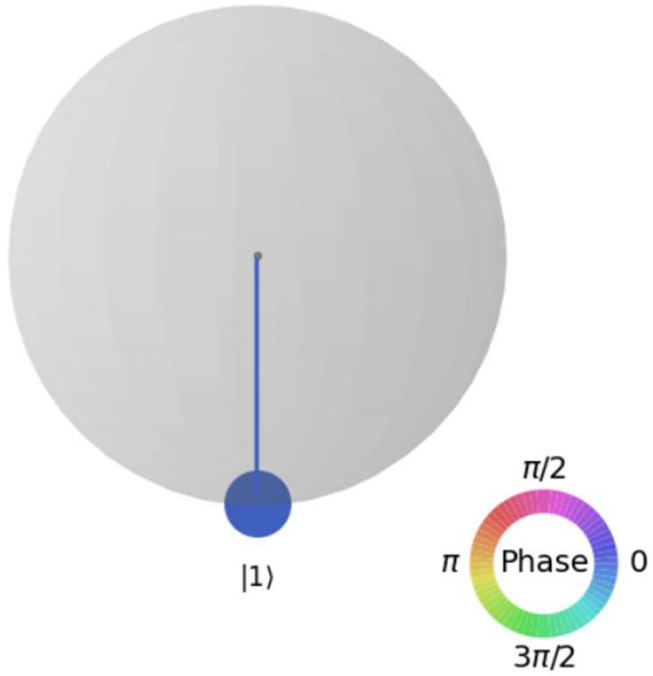
```
Statevector([0.+0.j, 0.+1.j],
            dims=(2,))
```

```
[13]: img
```

```
[13]:
```

PAULI GATES GATE Y

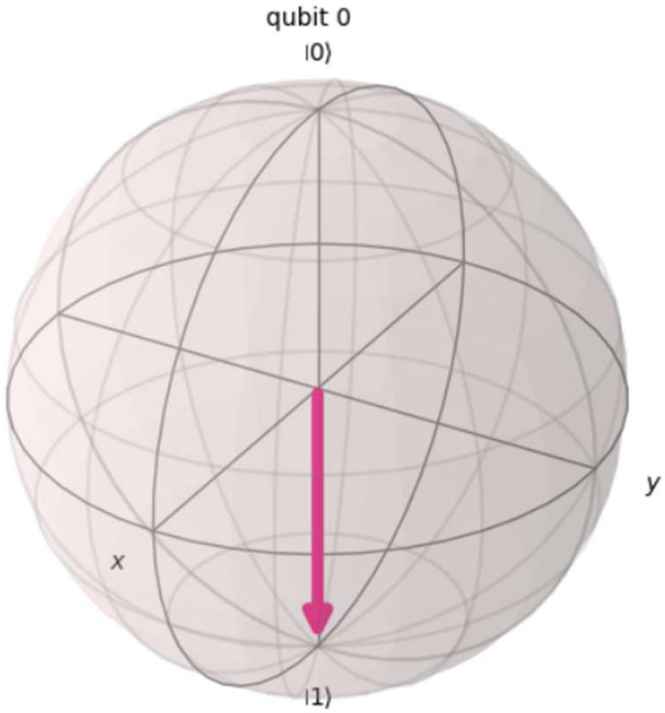
```
[14]: qsphere

[14]:
```



PAULI GATES GATE Y

```
[15]: bloch_sphere
```

[15]:



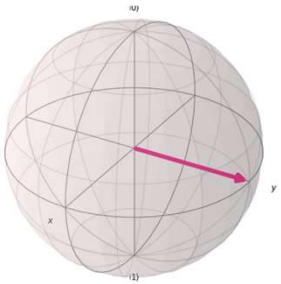
PAULI GATES

PAULI GATES GATE Z

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

$$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

$| \psi >$ — Z — $| \psi_s >$

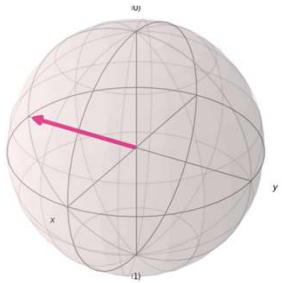


$| \psi >$

Rota $\varphi s = \pi + \varphi e$

$$| \psi_s > = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \alpha \\ -\beta \end{pmatrix}$$

tiempo



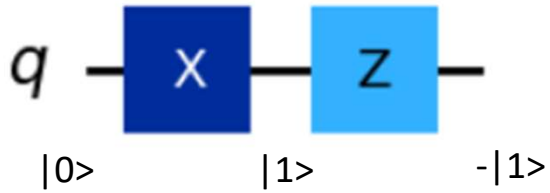
$| \psi_s >$

PAULI GATES GATE Z

```
#########################################################
# CURSO QISKIT 2025
# Z GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.x(0) # convierto |0> a |1> para que sea |1> la entrada de la Z Gate
qc.z(0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#########################################################
```

PAULI GATES GATE Z

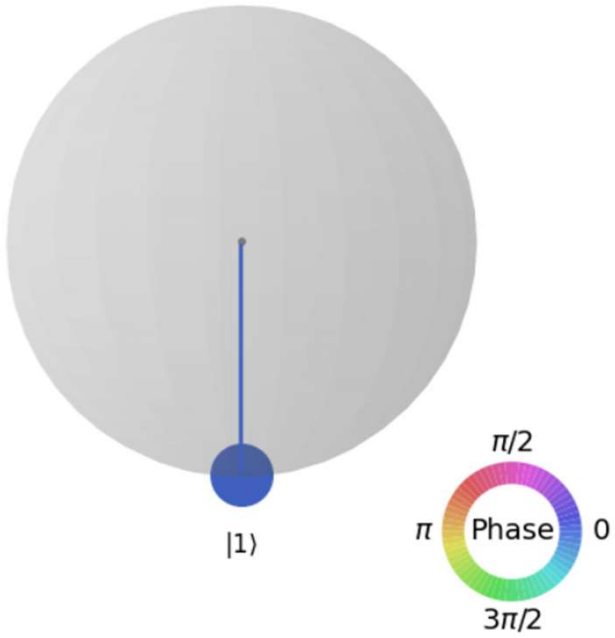
```
[17]: result

Statevector([ 0.+0.j, -1.+0.j],
            dims=(2,))

[18]: img

[18]:
```



PAULI GATES GATE Z

```
[19]: qsphere
```

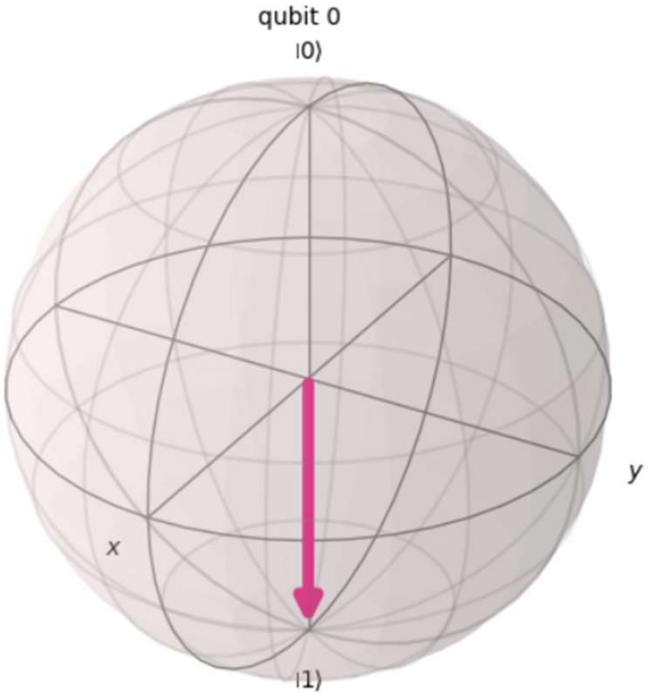
[19]:



PAULI GATES GATE Z

```
[20]: bloch_sphere
```

[20]:



PHASE GATES

S GATES

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi/2} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi/2} \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \alpha \\ e^{i\pi/2}\beta \end{pmatrix} = \begin{pmatrix} \alpha \\ i\beta \end{pmatrix}$$

$e^{i\pi/2} = i$

Q[0] = |+> $= \frac{1}{\sqrt{2}}$ (|0> + |1>)

tiempo

Salida = $\frac{1}{\sqrt{2}}$ (|0> + i |1>)

PHASE GATES

S GATES

```
#######################################################
# CURSO QISKIT 2025
# S GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

#------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.h(0)  # pasa |0> a |+> a la entrada de s
qc.s(0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#######################################################
```

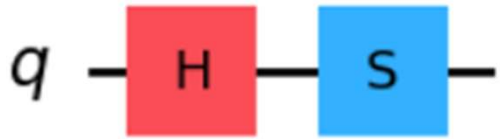
S GATES

```
[27]: result
```

```
Statevector([0.70710678+0.j        , 0.        +0.70710678j],
            dims=(2,))
```

```
[28]: img
```

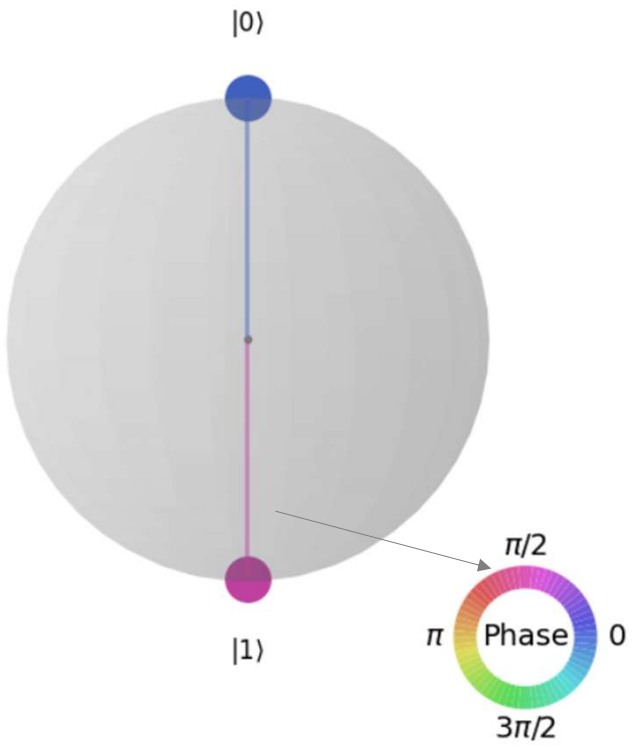
[28]:



S GATES

```
[29]: qsphere
```

[29]:

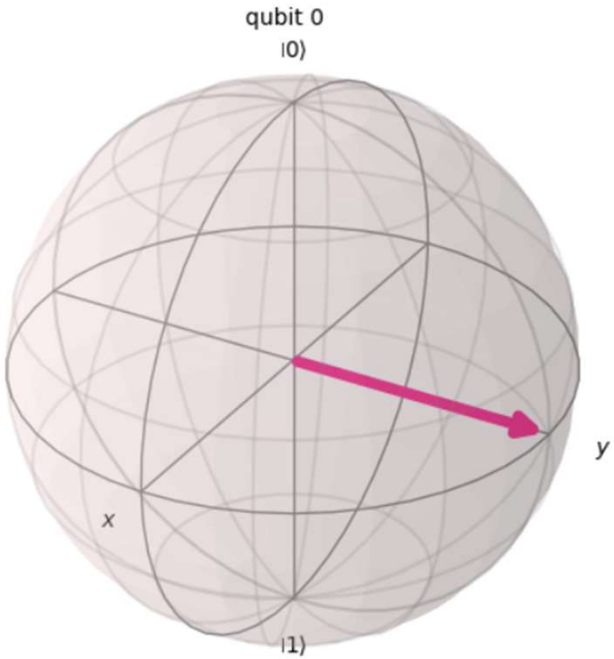


PHASE GATES

S GATES

```
[30]: bloch_sphere
```

[30]:



Salida = $\frac{1}{\sqrt{2}}$ (|0> + i |1>)

PHASE GATES

S† (dagger) GATES

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{-i\pi/2} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & -i \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{-i\pi/2} \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \alpha \\ e^{-i\pi/2}\beta \end{pmatrix} = \begin{pmatrix} \alpha \\ -i\beta \end{pmatrix}$$

$e^{-i\pi/2}$ = -i

Q[0] = |+> = $\frac{1}{\sqrt{2}}$ (|0> + |1>)

tiempo

Salida = $\frac{1}{\sqrt{2}}$ (|0> - i |1>)

PHASE GATES

S† (dagger) GATES

```
#########################################################
# CURSO QISKIT 2025
# S dagger GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.h(0)  # pasa |0> a |+> a la entrada de s
qc.sdg(0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#########################################################
```

PHASE GATES

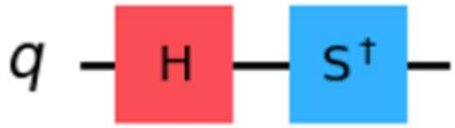
S† (dagger) GATES

[32]:
```
result
```

```
Statevector([0.70710678+0.j        , 0.        -0.70710678j],
            dims=(2,))
```

[33]:
```
img
```

[33]:

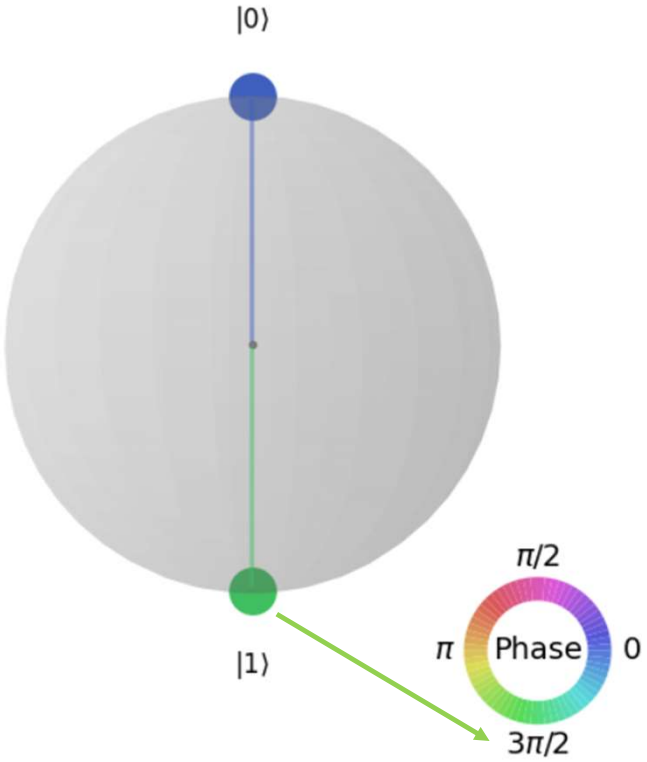


PHASE GATES

Quantum Computing QISKIT

S† (dagger) GATES

```
[34]: qsphere

[34]:
```



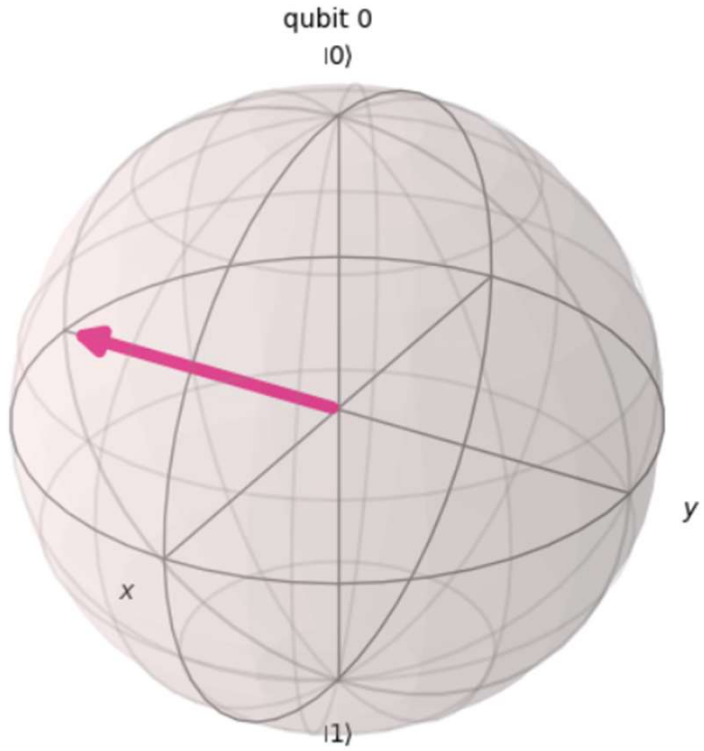
Salida = $\frac{1}{\sqrt{2}}$ (|0> - i |1>)

PHASE GATES

S† (dagger) GATES

```
[35]: bloch_sphere
```

[35]:



Salida = $\frac{1}{\sqrt{2}}$ (|0> - i |1>)

PHASE GATES

T GATES

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi/4} \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & e^{i\pi/4} \end{bmatrix} \begin{pmatrix} \alpha \\ \beta \end{pmatrix} = \begin{pmatrix} \alpha \\ e^{i\pi/4}\beta \end{pmatrix}$$

$e^{i\pi/2} = i$

Q[0] = |+> $= \frac{1}{\sqrt{2}}$ (|0> + |1>)

tiempo

Salida = $\frac{1}{\sqrt{2}}$ (|0> + $e^{i\pi/4}$|1>)

PHASE GATES

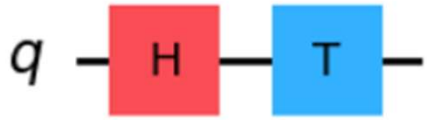
T GATES

```
#######################################################
# CURSO QISKIT 2025
# T GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

#------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.h(0)  # pasa |0> a |+> a la entrada de s
qc.t(0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#######################################################
```

PHASE GATES

T GATES

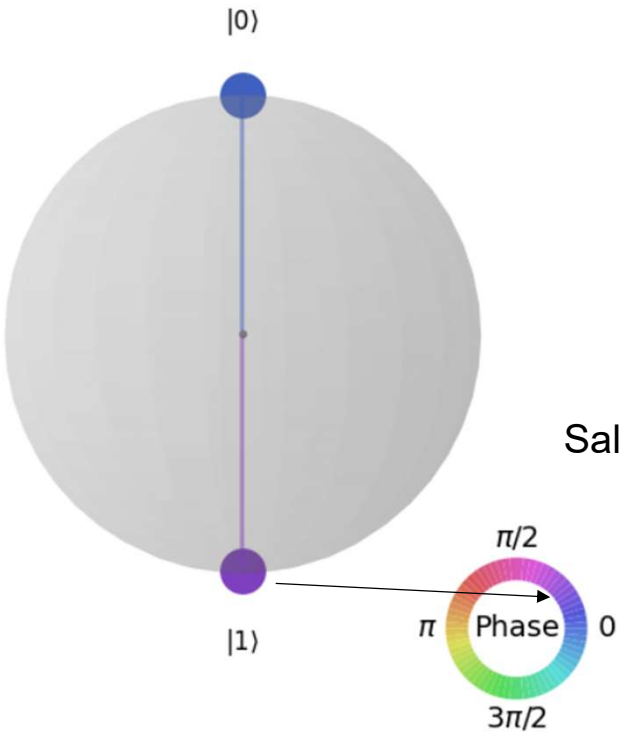
```
[37]: result

Statevector([0.70710678+0.j , 0.5       +0.5j],
            dims=(2,))

[38]: img

[38]:
```



PHASE GATES

T GATES

```
[39]: qsphere

[39]:
```



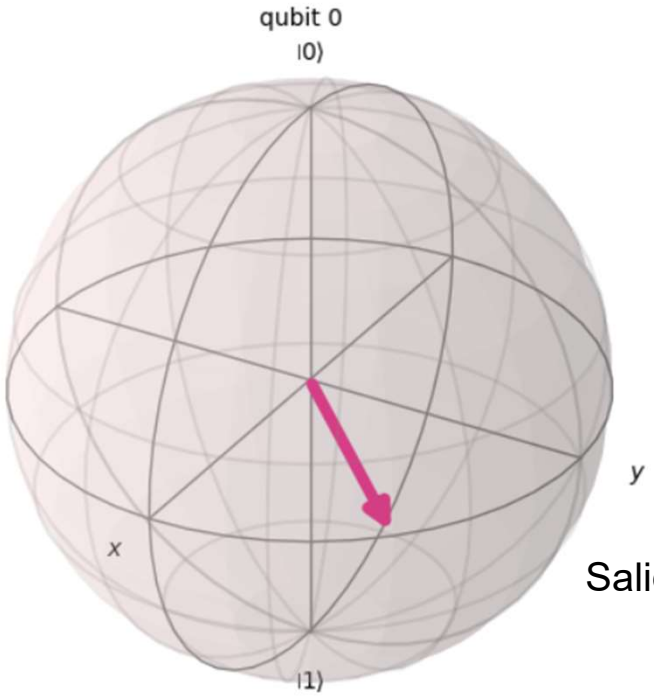
Salida = $\frac{1}{\sqrt{2}}$ (|0> + $e^{i\pi/4}$|1>)

PHASE GATES

T GATES

```
[40]: bloch_sphere
```

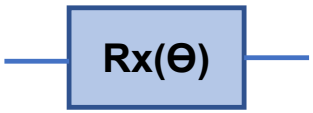
[40]:



Salida = $\frac{1}{\sqrt{2}}$ (|0> + $e^{i\pi/4}$|1>)

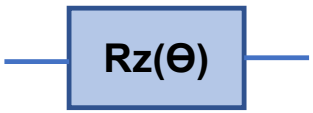
PHASE GATES

R GATES



$$\begin{bmatrix} \cos(\frac{\theta}{2}) & -i\sin(\frac{\theta}{2}) \\ -i\sin(\frac{\theta}{2}) & \cos(\frac{\theta}{2}) \end{bmatrix}$$

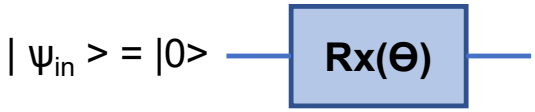
$$\begin{bmatrix} \cos(\frac{\theta}{2}) & -\sin(\frac{\theta}{2}) \\ \sin(\frac{\theta}{2}) & \cos(\frac{\theta}{2}) \end{bmatrix}$$



$$\begin{bmatrix} e^{-i\theta} & 0 \\ 0 & e^{i\theta} \end{bmatrix}$$

PHASE GATES

Rx GATES



$$|\psi_{out}\rangle = \begin{bmatrix} \cos(\frac{\theta}{2}) & -i\sin(\frac{\theta}{2}) \\ -i\sin(\frac{\theta}{2}) & \cos(\frac{\theta}{2}) \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \cos\left(\frac{\theta}{2}\right)|0> -i\sin\left(\frac{\theta}{2}\right)|1>$$

Tomando Θ = π/6 = 30

$$|\psi out> = \cos\left(\frac{\pi}{12}\right)|0> -i\sin\left(\frac{\pi}{12}\right)|1> = 0{,}9659|0> - i\ 0{,}2588|1>$$

PHASE GATES

Rx GATES

```
#########################################################
# CURSO QISKIT 2025
# Rx GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

from math import pi

#-----------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-----------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-----------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.rx(pi/6,0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#########################################################
```

Rx GATES

```
[2]: result
```

```
Statevector([0.96592583+0.j        , 0.        -0.25881905j],
            dims=(2,))
```

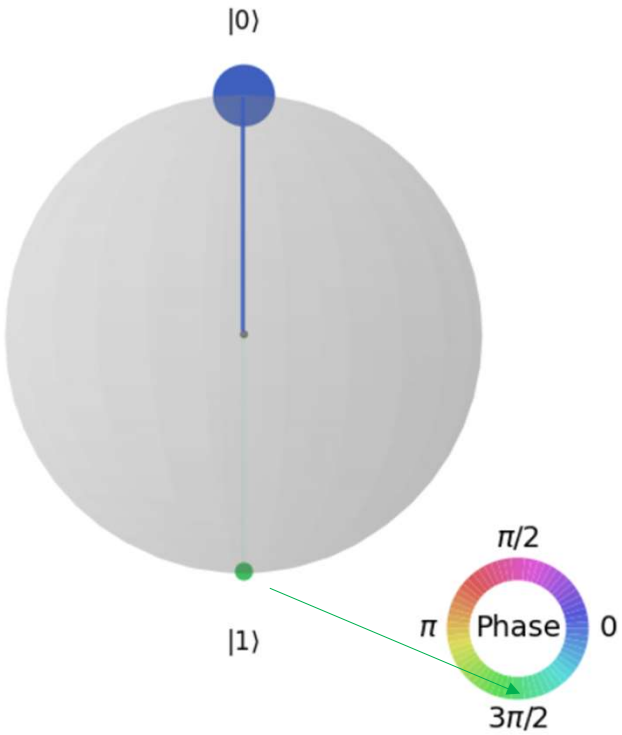
```
[3]: img
```

[3]:

Rx GATES

```
[4]: qsphere
```

[4]:

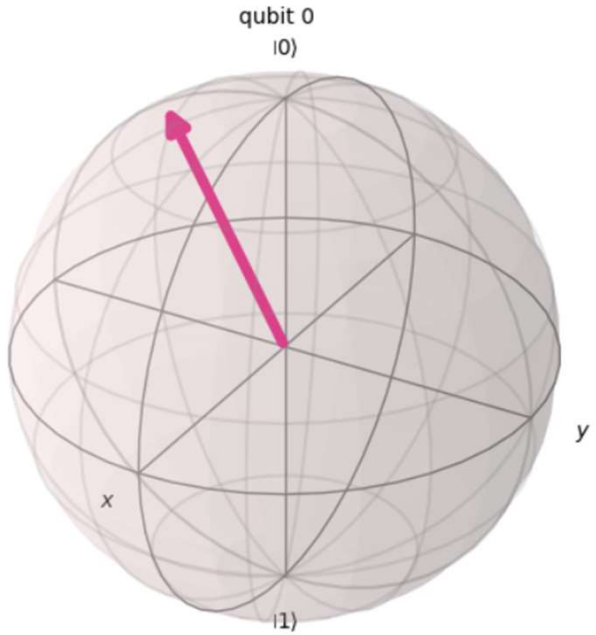


PHASE GATES

R GATES

```
[5]: bloch_sphere
```

[5]:



PHASE GATES

Ry GATES

$|\psi_{in}\rangle = |0\rangle$ — **Ry(Θ)** — $|\psi out\rangle = \begin{bmatrix} \cos(\frac{\Theta}{2}) & -\sin(\frac{\Theta}{2}) \\ \sin(\frac{\Theta}{2}) & \cos(\frac{\Theta}{2}) \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \cos\left(\frac{\Theta}{2}\right)|0> + \sin\left(\frac{\Theta}{2}\right)|1>$

Tomando Θ = π/6 = 30

$|\psi out\rangle = \cos\left(\frac{\pi}{12}\right)|0> + \sin(\frac{\pi}{12})|1\rangle = 0{,}9659\,|0\rangle + 0{,}2588\,|1\rangle$

Ry GATES

```
##########################################################################
# CURSO QISKIT 2025
# Ry GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *

from math import pi

#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.ry(pi/6,0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
##########################################################################
```

Ry GATES

[23]:
```
result
```

```
Statevector([0.96592583+0.j, 0.25881905+0.j],
            dims=(2,))
```

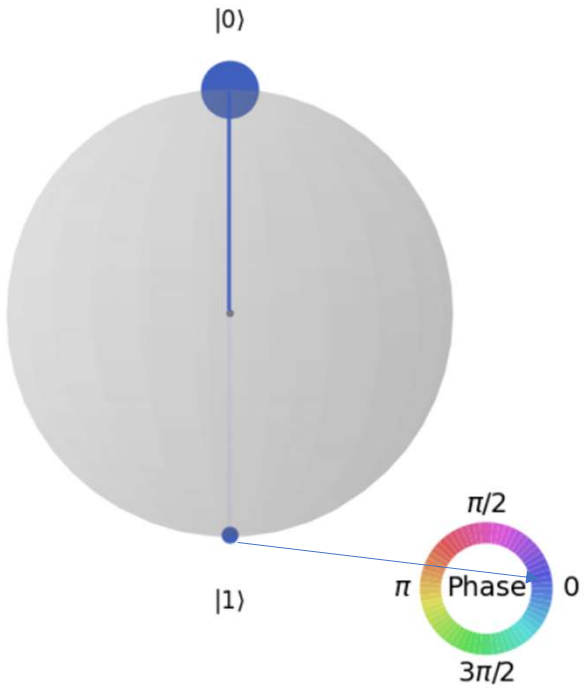
[24]:
```
img
```

[24]:

Ry GATES

```
[26]: qsphere
```

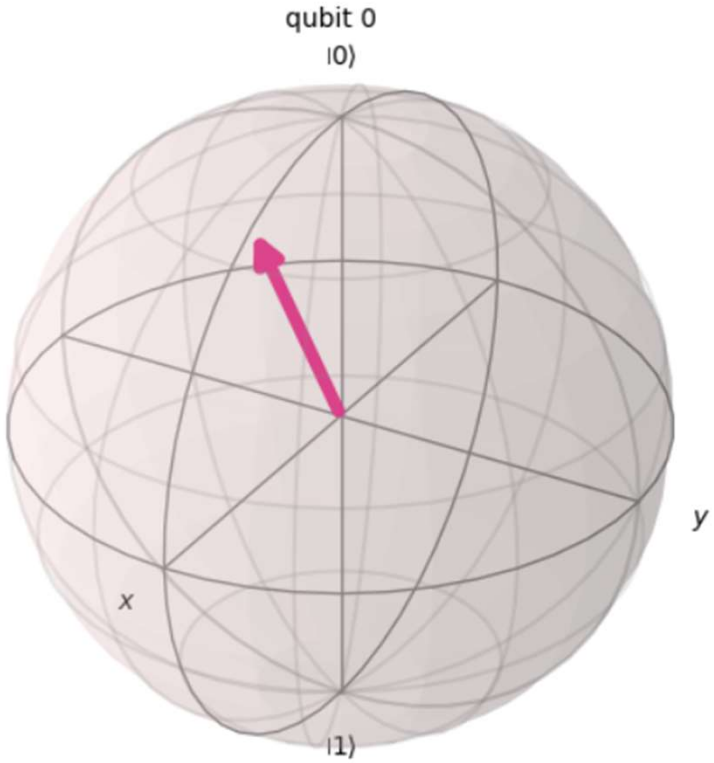
[26]:



Ry GATES

```
[25]: bloch_sphere
```

[25]:



PHASE GATES

Rz GATES

$|\psi_{in}\rangle = |0\rangle$ — **Rz(Θ)** — $|\psi out\rangle = \begin{bmatrix} e^{-i\theta/2} & 0 \\ 0 & e^{i\theta/2} \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = e^{-i\theta/2}|0\rangle =$

$= (\cos(\theta/2) - i\, sen(\theta/2))\,|0\rangle$

Tomando Θ = π/6 = 30

$\cos(\theta/2) = \cos(15) = 0{,}9659$

$sen(\theta/2) = sen(15) = 0{,}2588$

$|\psi out\rangle = (0.9659 - i0{,}2588)\,|0\rangle$

PHASE GATES

Rz GATES

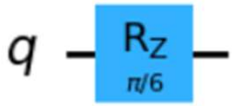
```
##########################################################################
# CURSO QISKIT 2025
# Rz GATES

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.rz(pi/6,0)

result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
##########################################################################
```

PHASE GATES

Quantum Computing QISKIT

Rz GATES

```
[28]: result

Statevector([0.96592583-0.25881905j, 0.        +0.j        ],
            dims=(2,))

[29]: img

[29]:
```

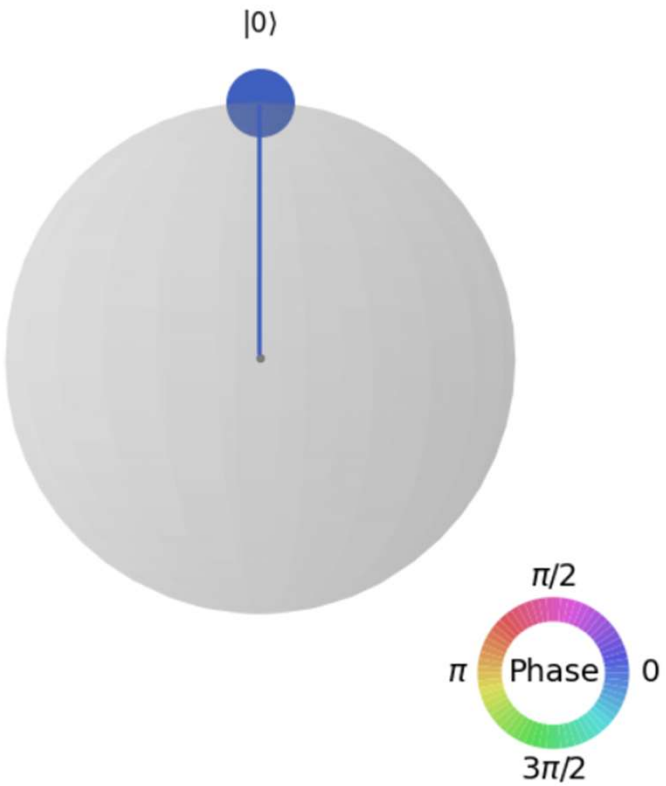


PHASE GATES

Rz GATES

```
[30]: qsphere
```

[30]:

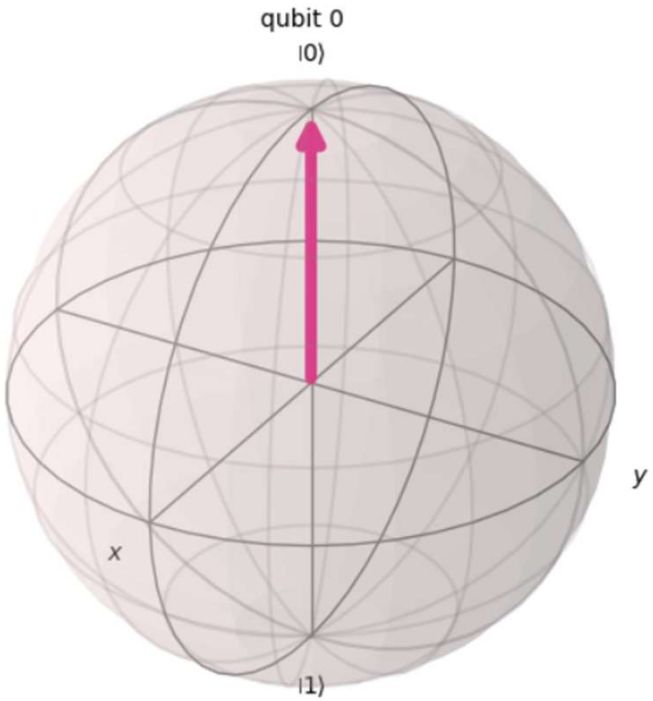


PHASE GATES

Rz GATES

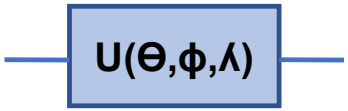
```
[31]: bloch_sphere
```

[31]:



UNIVERSAL U GATE

U GATE



$$\begin{bmatrix} \cos(\frac{\Theta}{2}) & -e^{-i\lambda}\sin(\frac{\Theta}{2}) \\ e^{i\phi}\sin(\frac{\Theta}{2}) & e^{i(\phi+\lambda)}\cos(\frac{\Theta}{2}) \end{bmatrix}$$

$|\psi_{in}\rangle = |0\rangle$ — U(Θ,ϕ,ʎ) — $|\psi out\rangle =$

$$\begin{bmatrix} \cos(\frac{\Theta}{2}) & -e^{-i\lambda}\sin(\frac{\Theta}{2}) \\ e^{i\phi}\sin(\frac{\Theta}{2}) & e^{i(\phi+\lambda)}\cos(\frac{\Theta}{2}) \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \cos\left(\frac{\Theta}{2}\right)|0> + e^{i\phi}\sin\left(\frac{\Theta}{2}\right)|1>$$

Tomando Θ = ϕ = ʎ = π/2 = 90

$$|\psi out\rangle = \cos\left(\frac{\pi/2}{2}\right)|0> + e^{i\pi/2}\sin(\frac{\pi/2}{2})|1> = 0{,}707\,|0> + i\,0{,}707\,|1> = \frac{1}{\sqrt{2}}\,(|0> + i|1>)$$

UNIVERSAL U GATE

U GATE

```
###############################################################################
# CURSO QISKIT 2025
# UNIVERSAL GATE

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#------------------------------------------------------------------------
qc = QuantumCircuit(1)
qc.u(pi/2, pi/2, pi/2, 0)
result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
###############################################################################
```

U GATE

```
[3]: result
```

```
Statevector([7.07106781e-01+0.j        , 4.32978028e-17+0.70710678j],
            dims=(2,))
```

```
[5]: img
```

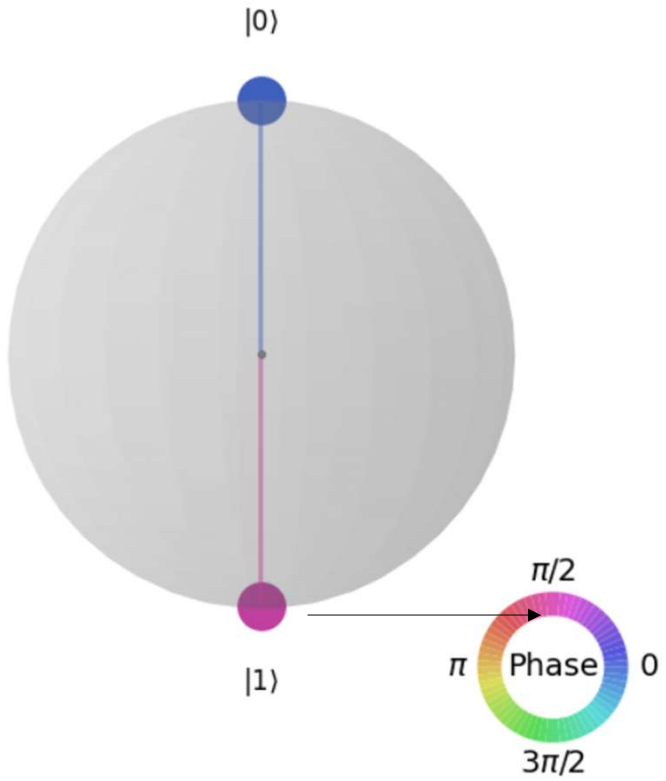
[5]:

UNIVERSAL U GATE

U GATE

```
[6]: qsphere
```

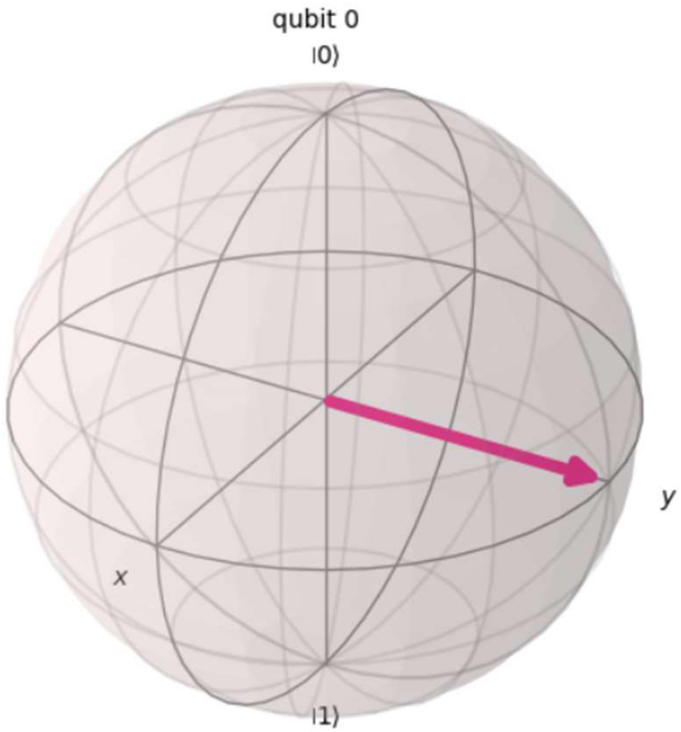
[6]:



U GATE

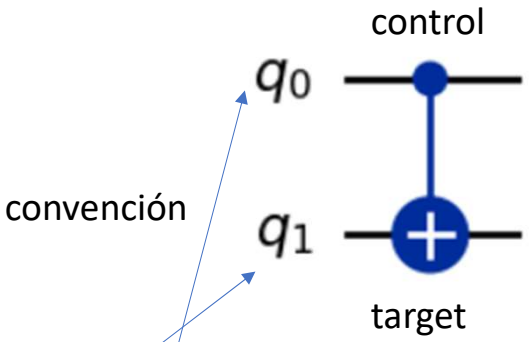
```
[7]: bloch_sphere
```

[7]:



Multi Qubit Gates

C - NOT



convención

$|q_1 q_0\rangle$

$\equiv$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

$|00\rangle \rightarrow |00\rangle$

$|01\rangle \rightarrow |11\rangle$

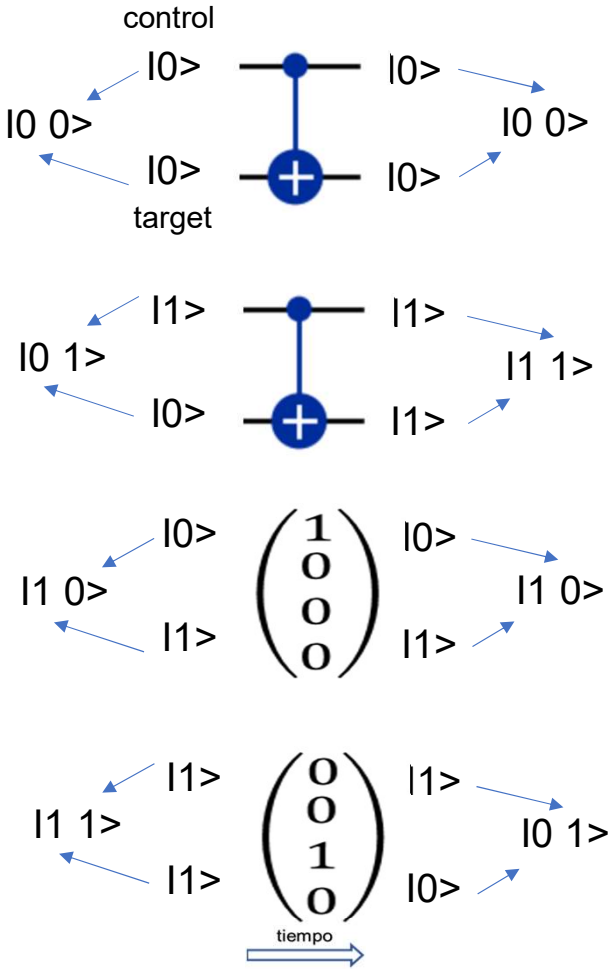
$|10\rangle \rightarrow |10\rangle$

$|11\rangle \rightarrow |01\rangle$

target control

Multi Qubit Gates

C - NOT



$$|\psi_{out}\rangle = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} = |0\ 0\rangle$$

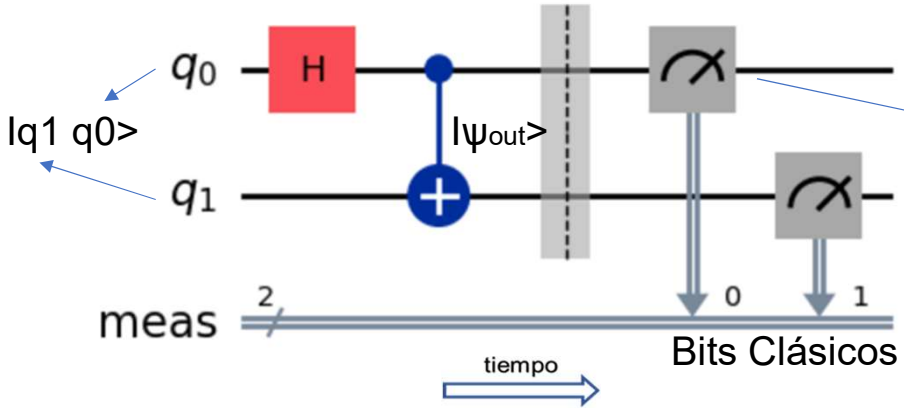
$$|\psi_{out}\rangle = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} = |1\ 1\rangle$$

$$|\psi_{out}\rangle = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} = |1\ 0\rangle$$

$$|\psi_{out}\rangle = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} = |0\ 1\rangle$$

Multi Qubit Gates

C - NOT



$|q1\ q0\rangle$

Puertas de Medición
Qbit a Bit
Destruye al Qbit

$$|\psi_{out}\rangle = (\text{C-NOT}) \times (I \otimes H)\ |q1\ q0\rangle$$

$$U = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \times \left[\frac{1}{\sqrt[2]{2}} \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & -1 \end{bmatrix} \right] = \frac{1}{\sqrt[2]{2}} \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 1 & 1 \\ 1 & -1 & 0 & 0 \end{bmatrix}$$

Multi Qubit Gates

C - NOT

Tomando $|\psi_{in}\rangle = |00\rangle$

$$|\psi_{out}\rangle = U\,|00\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 \\ 0 & 0 & 1 & 1 \\ 1 & -1 & 0 & 0 \end{bmatrix}\begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \frac{1}{\sqrt{2}}\left(|00\rangle + |11\rangle\right)$$

$$|\psi_{out}\rangle = \frac{1}{\sqrt{2}}\left(|00\rangle + |11\rangle\right)$$

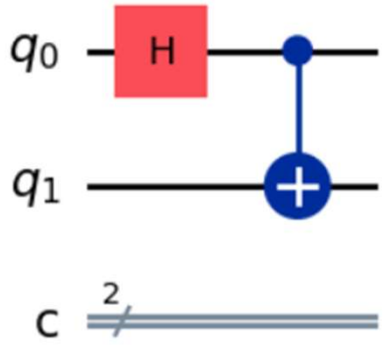
Multi Qubit Gates

C - NOT

```
###########################################################################
# CURSO QISKIT 2025
# Multi Qubit CNOT GATE

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#--------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#--------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)

    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#--------------------------------------------------------------------------
qc = QuantumCircuit(2,2)
qc.h(0)
qc.cx(0,1)
result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
###########################################################################
```

C - NOT

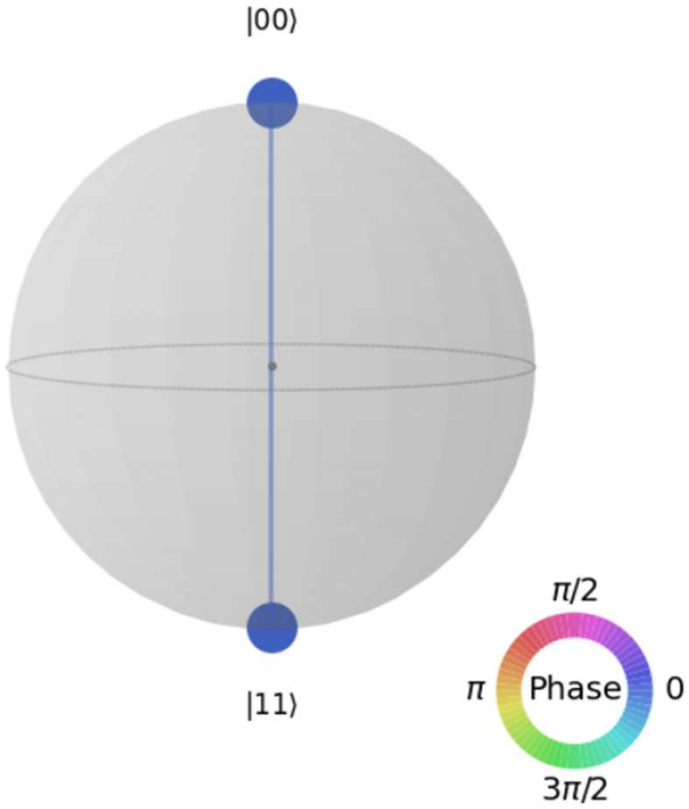
```
[13]: result

Statevector([0.70710678+0.j, 0.        +0.j, 0.        +0.j,
             0.70710678+0.j],
            dims=(2, 2))

[14]: img

[14]:
```



C - NOT

```
[15]: qsphere
```

```
[15]:
```



Multi Qubit Gates

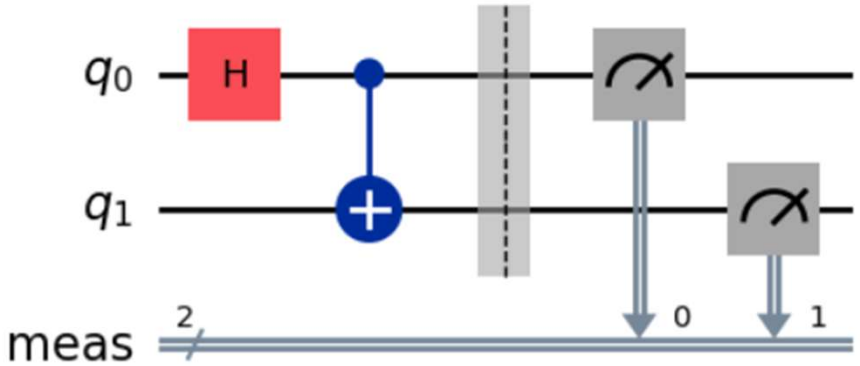
C – NOT histograma

```
#########################################################################
# CURSO QISKIT 2025
# Multi Qubit CNOT GATE con medidor

from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from qiskit import transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram
from math import pi
#------------------------------------------------------------------------
# Will run the circuit
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def exe_circuit(quantum_circuit):
    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Run
    simulator = AerSimulator()
    compiled_circuit = transpile(quantum_circuit, simulator)
    sim_result = simulator.run(compiled_circuit, shots= 1000, memory=True).result()
    counts = sim_result.get_counts()
    pl = plot_histogram(counts)
    #Return the results
    return circuit_diagram, counts, pl
#------------------------------------------------------------------------
qc = QuantumCircuit(2)
qc.h(0)
qc.cx(0,1)
qc.measure_all()
circ_diag, counts_, pl_ =  exe_circuit(qc)
print(counts_)
#########################################################################
```

C – NOT histograma

```
[2]: circ_diag
```

[2]:



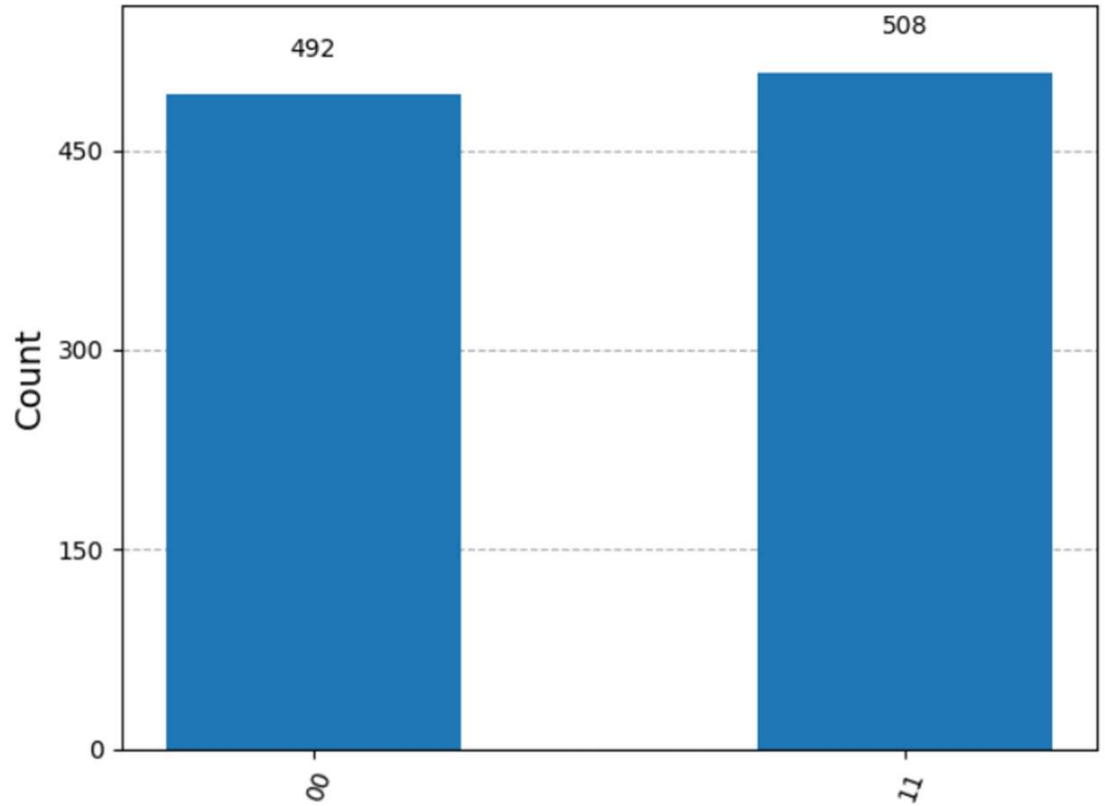

```
[5]: print(counts_)
{'00': 492, '11': 508}
```

Quantum Computing QISKIT

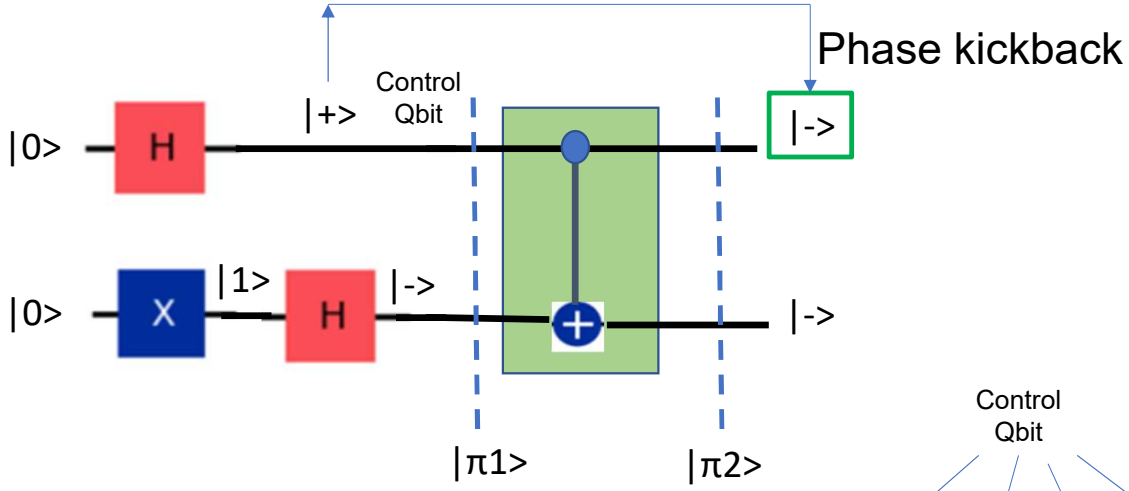
C – NOT histograma

```
[4]: pl_
```

[4]:



Phase Kickback (algoritmo Deuch lo utiliza)



$|\pi 1\rangle = |-\rangle \otimes |+\rangle = \frac{1}{2}(|0\rangle - |1\rangle) \otimes (|0\rangle + |1\rangle) = \frac{1}{2}(|00\rangle + |01\rangle - |10\rangle - |11\rangle)$

$|\pi 2\rangle = |-\rangle \otimes |+\rangle = \frac{1}{2}(|00\rangle + |11\rangle - |10\rangle - |01\rangle) = \frac{1}{2}(|0\rangle - |1\rangle) \otimes (|0\rangle - |1\rangle) = (|-\rangle \otimes |-\rangle)$

$|\pi 2\rangle = |OUT\rangle = (|-\rangle \otimes |-\rangle) = |--\rangle = \frac{1}{2}\,[\,|00\rangle + |11\rangle - |01\rangle - |10\rangle]$

Phase Kickback

```
################################################################################
# CURSO QISKIT 2025
# Multi Qubit PHASE KICK BACK
from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)
    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(2,2)
qc.h(0)
qc.x(1)
qc.h(1)
qc.barrier()
qc.cx(0,1)
qc.barrier()
result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
################################################################################
```

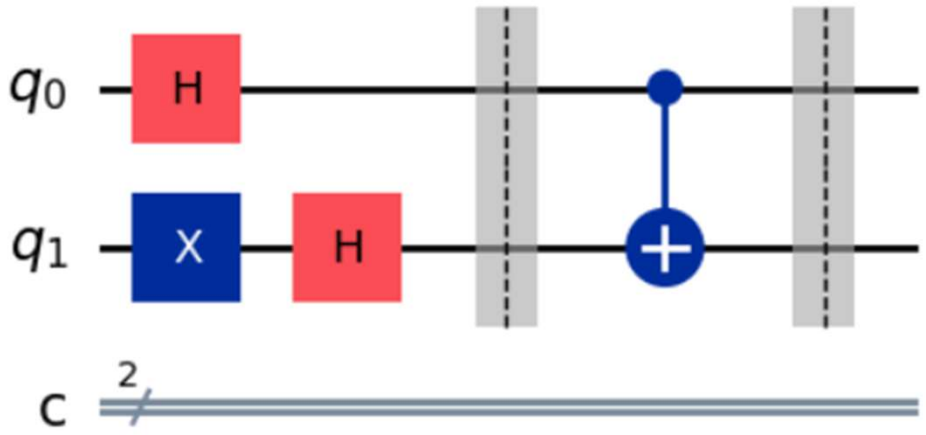
Phase Kickback

```
[2]: result
```

```
Statevector([ 0.5+0.j, -0.5+0.j, -0.5+0.j,  0.5+0.j],
            dims=(2, 2))
```

```
[3]: img
```

[3]:

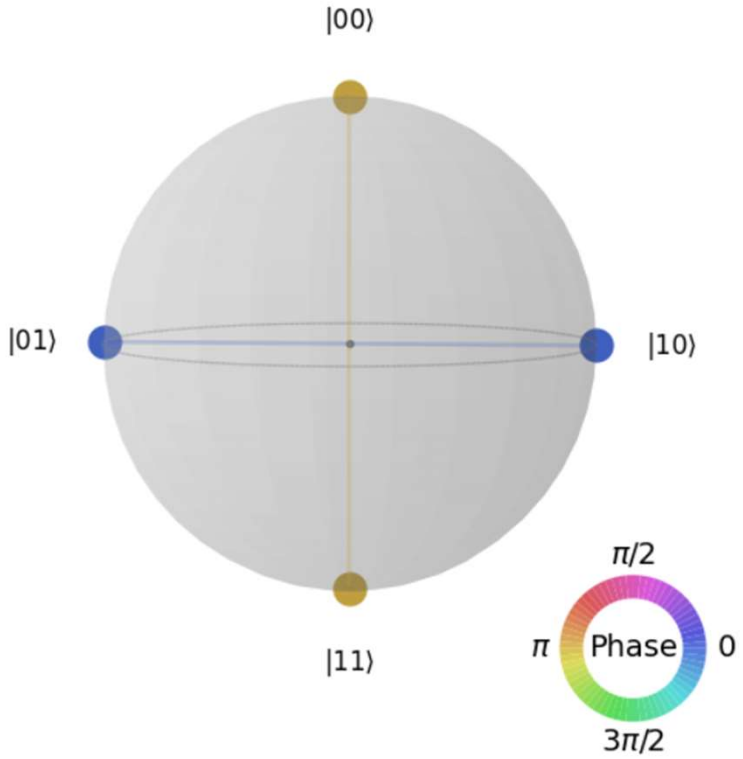


Quantum Computing QISKIT

Phase Kickback

```
[4]: qsphere
```

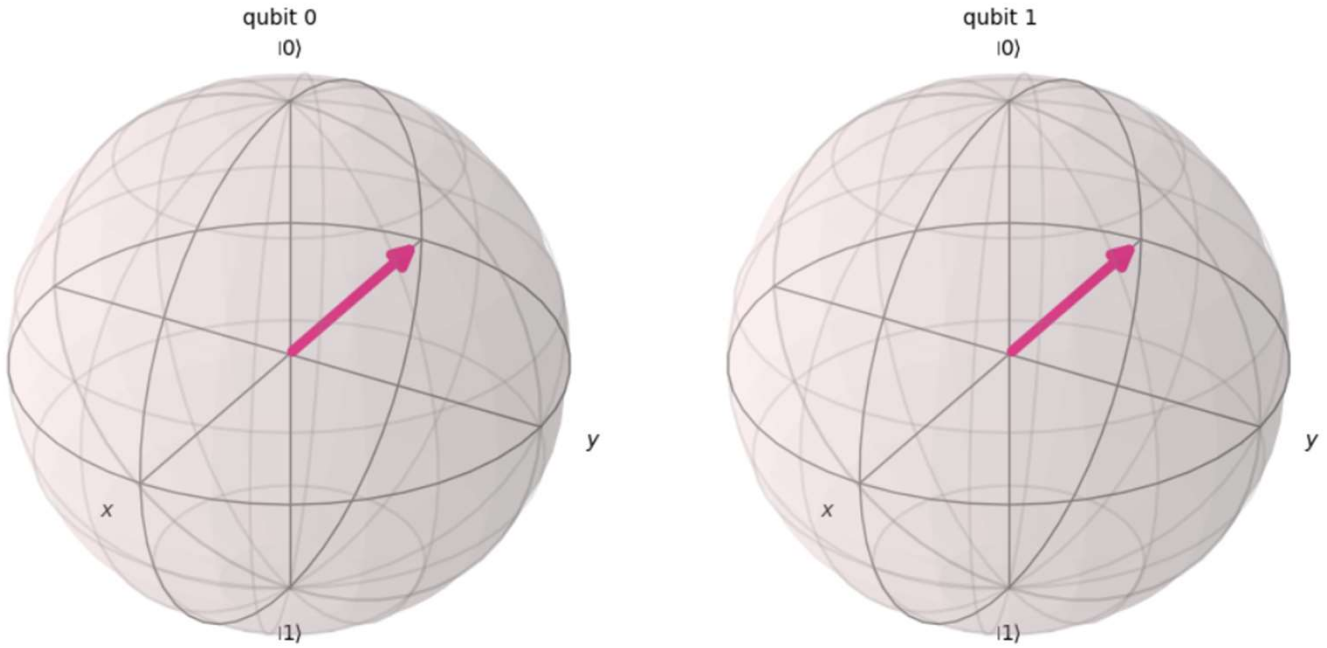
[4]:



Phase Kickback

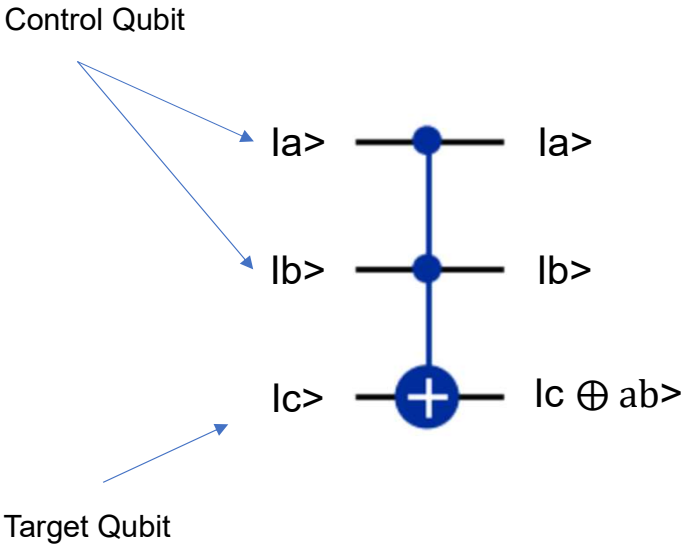
```
[5]: bloch_sphere
```

[5]:



Multi Qubit Gates

Toffoli Gate



$$\equiv \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Dimensión 8x8 – 3 qbits

Multi Qubit Gates

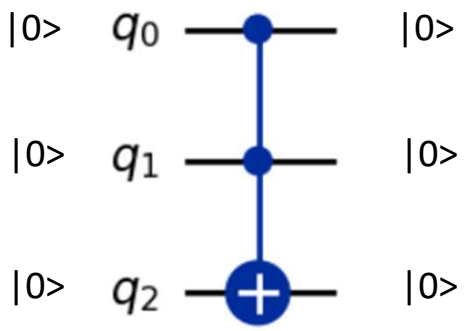
Toffoli Gate

```
##########################################################################
# CURSO QISKIT 2025
# Multi Qubit TOFFOLI
from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#-------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)
    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-------------------------------------------------------------------------
qc = QuantumCircuit(3)
qc.x(range(2))
qc.ccx(0,1,2)
result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
##########################################################################
```

Toffoli Gate

```
[12]: result

Statevector([1.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j,
             0.+0.j],
            dims=(2, 2, 2))

[13]: img

[13]:
```

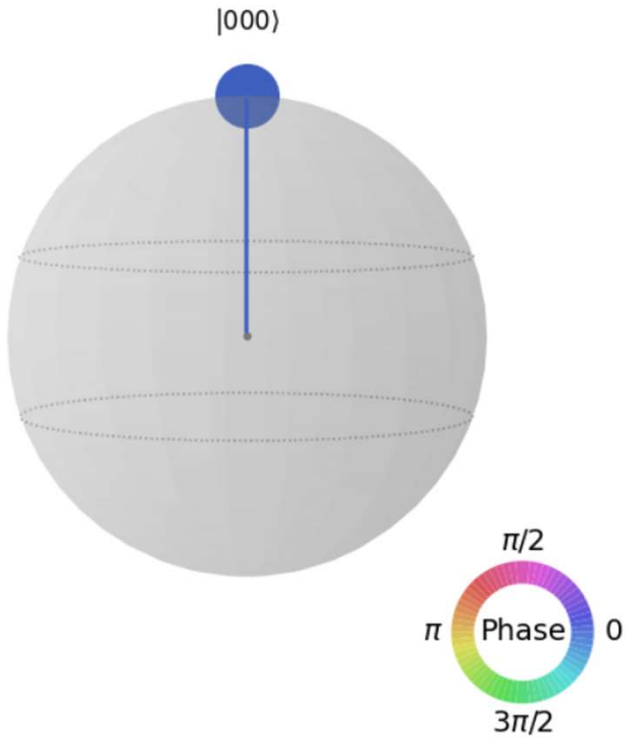
$$\begin{bmatrix}1\\0\\0\\0\end{bmatrix}$$



Toffoli Gate

```
[14]: qsphere
```

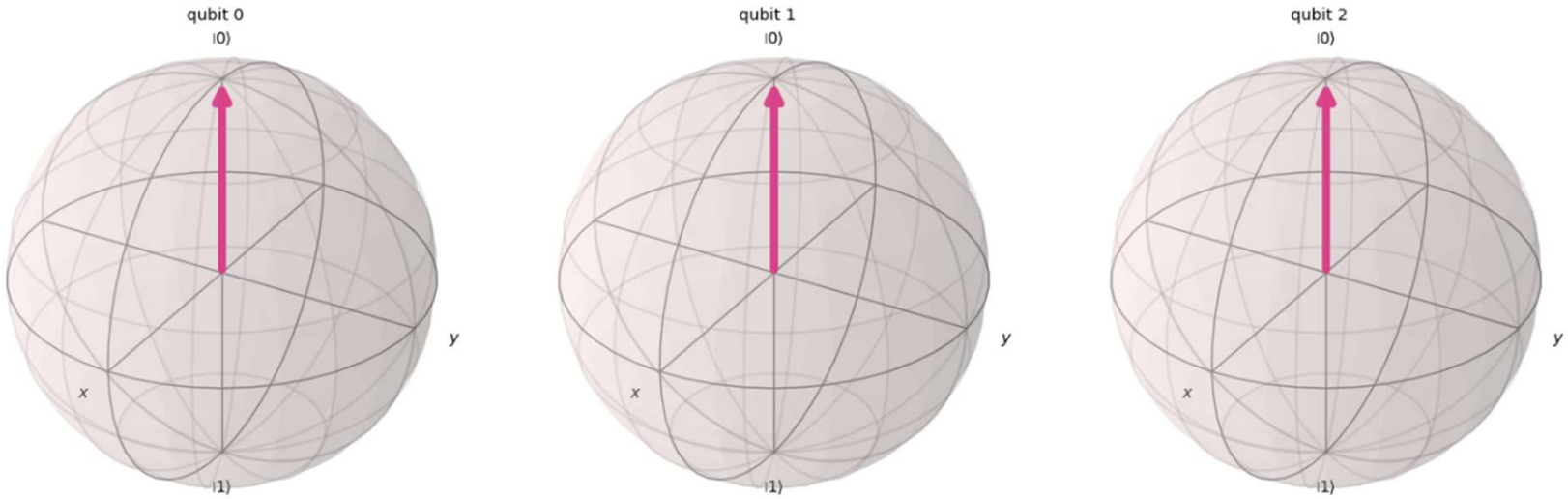
[14]:



Toffoli Gate

```
[15]: bloch_sphere
```

[15]:



Multi Qubit Gates

Toffoli Gate

```
#############################################################################
# CURSO QISKIT 2025
# Multi Qubit TOFFOLI
from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#-----------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#-----------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)
    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#-----------------------------------------------------------------------
qc = QuantumCircuit(3)
qc.x(range(2))
qc.ccx(0,1,2)
result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#############################################################################
```

Multi Qubit Gates

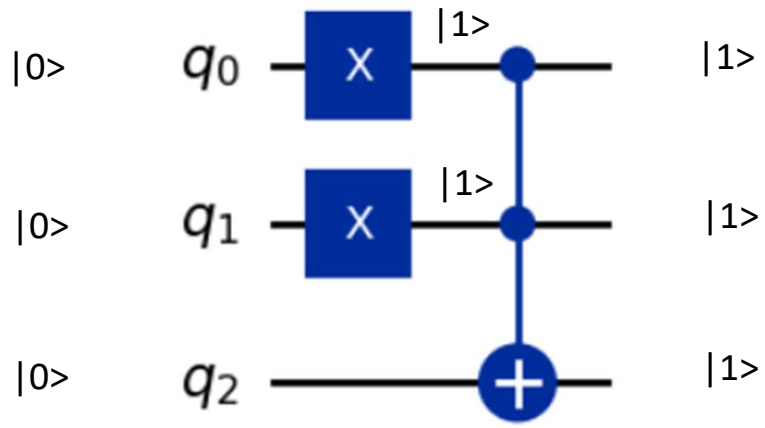
Toffoli Gate

```
[17]: result

Statevector([0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j, 0.+0.j,
             1.+0.j],
            dims=(2, 2, 2))
```

$$\begin{bmatrix}0\\0\\0\\1\end{bmatrix}$$

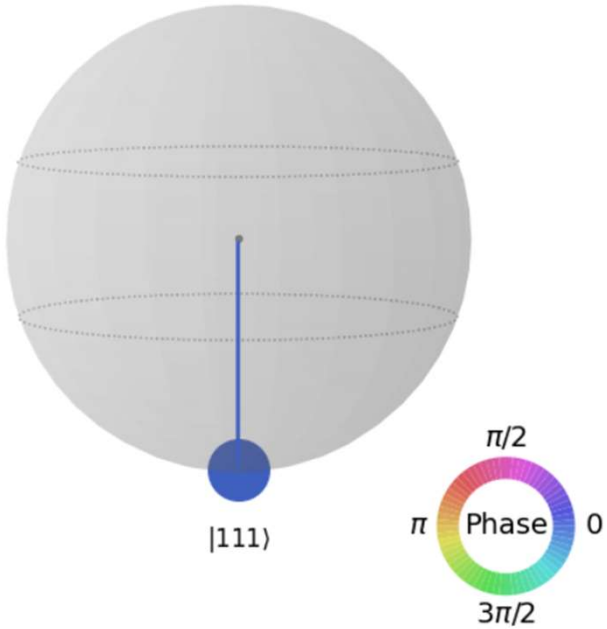
```
[18]: img
```

[18]:



Toffoli Gate

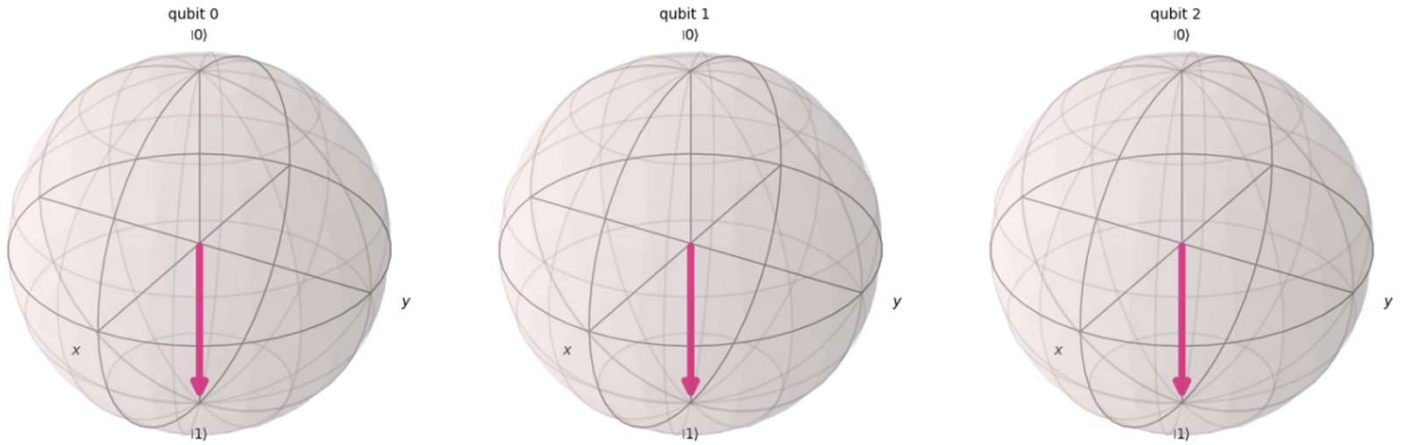
```
[19]: qsphere

[19]:
```



Toffoli Gate

```
[20]: bloch_sphere
```

[20]:



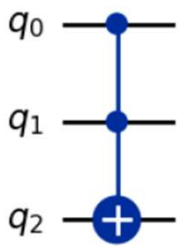
Toffoli Gate Decompose

```
#############################################################
# CURSO QISKIT 2025
# Multi Qubit TOFFOLI DECOMPOSED
from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#------------------------------------------------------------
def Diagramas(quantum_circuit):
    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    qc_decomposed = quantum_circuit.decompose()
    Decomp = qc_decomposed.draw(output='mpl')
    return circuit_diagram, Decomp
#------------------------------------------------------------
qc = QuantumCircuit(3)
qc.ccx(0,1,2)
Circuito, Circuito_decomp  = Diagramas(qc)
#############################################################
```

Toffoli Gate Decompose

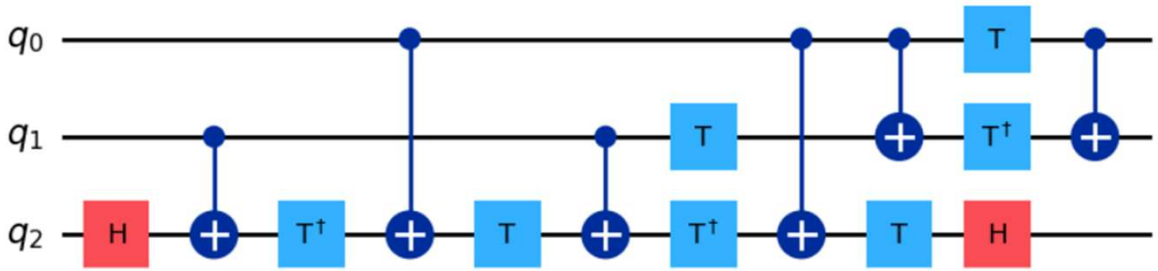
```
[22]: Circuito
```

[22]:

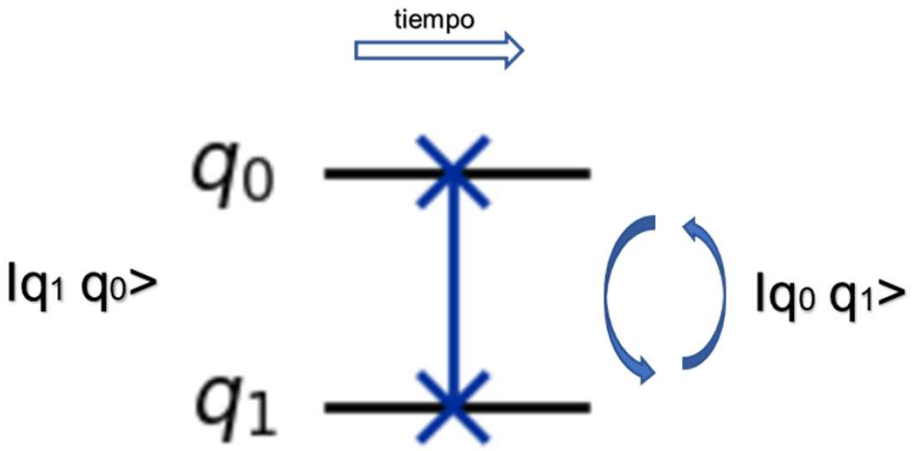



```
[23]: Circuito_decomp
```

[23]:



SWAP Gate



$$\equiv \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Multi Qubit Gates

SWAP Gate

```
#############################################################################
# CURSO QISKIT 2025
# Multi Qubit SWAP GATE
from qiskit import QuantumCircuit
from qiskit.quantum_info import Statevector
from qiskit.visualization import *
from math import pi
#----------------------------------------------------------------------------
# Execute circuit on the the State vector sampler
def run_sv_circuit(qc):
    # Run the circuit and return the state vector object result
    stateVectorResult = Statevector(qc)
    #qsphere = stateVectorResult.draw('qsphere')
    #bloch_sphere = stateVectorResult.draw('bloch')
    #circuit_image = qc.draw(output='mpl')
    return stateVectorResult
#----------------------------------------------------------------------------
# Will run the circuit on the state vector (sv) simulator
# Returns state vector results, circuit diagram, Sphere & Bloch sphere
def execute_circuit_sv(quantum_circuit):
    stateVectorResults = run_sv_circuit(quantum_circuit)
    #Draw the circuit diagram
    circuit_diagram = quantum_circuit.draw(output="mpl")
    #Draw the Qsphere
    q_sphere = stateVectorResults.draw('qsphere')
    #Draw the Bloch sphere
    bloch_sphere = stateVectorResults.draw('bloch')
    #Return the results, circuit diagram, and QSphere
    return stateVectorResults, circuit_diagram, q_sphere, bloch_sphere
#----------------------------------------------------------------------------
qc = QuantumCircuit(2)
qc.x(1)
qc.swap(0,1)
result, img, qsphere, bloch_sphere = execute_circuit_sv(qc)
#############################################################################
```

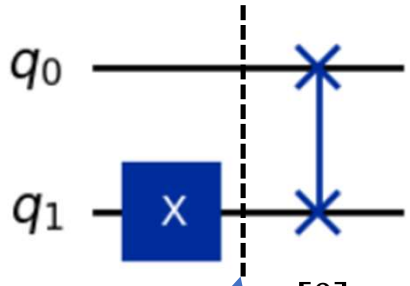
Multi Qubit Gates

SWAP Gate

```
[3]: img
```

[3]:

$$|00> = \begin{bmatrix}1\\0\\0\\0\end{bmatrix}$$



$$|01> = \begin{bmatrix}0\\1\\0\\0\end{bmatrix}$$

$$|10> = \begin{bmatrix}0\\1\\0\\0\end{bmatrix}$$

$\equiv$

$$|01> = \begin{bmatrix}0\\1\\0\\0\end{bmatrix}$$

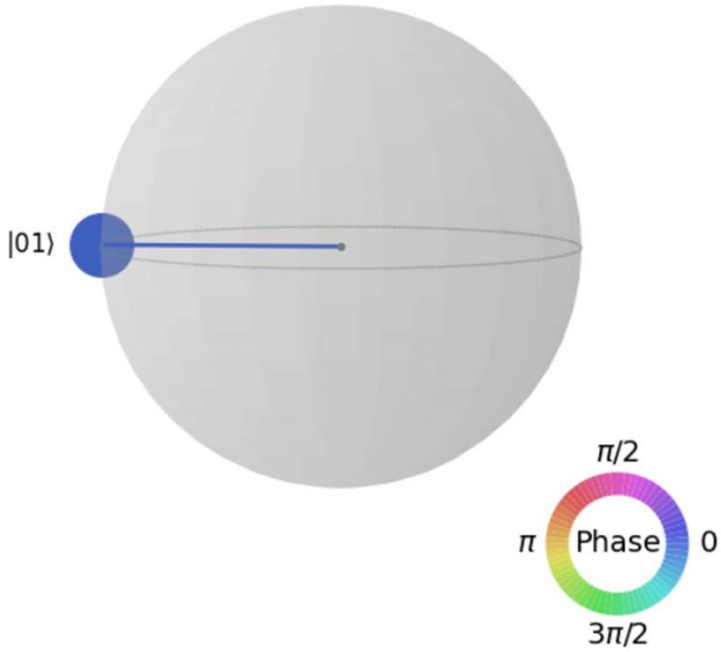
```
[2]: result
```

```
Statevector([0.+0.j, 1.+0.j, 0.+0.j, 0.+0.j],
            dims=(2, 2))
```

SWAP Gate

```
[4]: qsphere
```

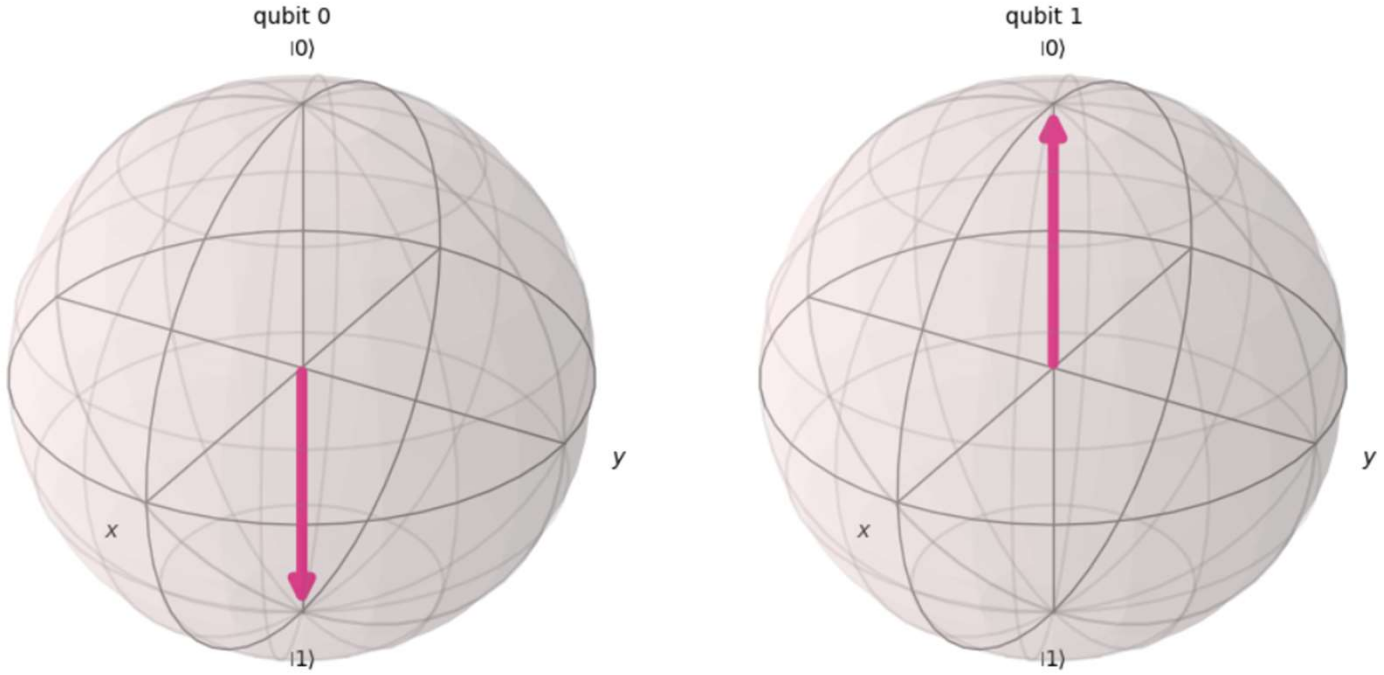
```
[4]:
```



SWAP Gate

```
[5]: bloch_sphere
```

[5]:



Constructores

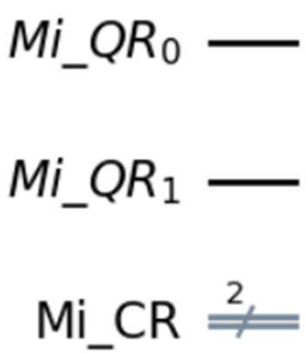
```
#######################################################################
# CURSO QISKIT 2025
# Constructors

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister

qc = QuantumCircuit(2,2)
qr = QuantumRegister(2,'Mi_QR')
cr = ClassicalRegister(2,'Mi_CR')
qc = QuantumCircuit(qr,cr)
qc.draw(output='mpl')
#######################################################################
```

Constructores

[1]:

```
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister

qc = QuantumCircuit(2,2)
qr = QuantumRegister(2,'Mi_QR')
cr = ClassicalRegister(2,'Mi_CR')
qc = QuantumCircuit(qr,cr)
qc.draw(output='mpl')
```

[1]:



Quantum Computing QISKIT

Constructores Alternativa Compacta

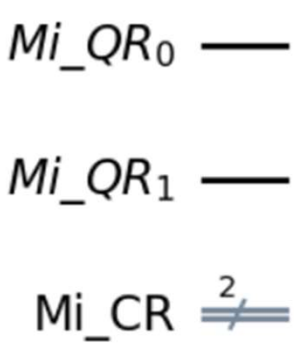
```
##########################################################################
# CURSO QISKIT 2025
# Constructors

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister

qc = QuantumCircuit(2,2)
qc = QuantumCircuit(QuantumRegister(2,'Mi_QR'),ClassicalRegister(2,'Mi_CR'))
qc.draw(output='mpl')
##########################################################################
```

Quantum Computing QISKIT

Constructores Alternativa Compacta

[2]:
```
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister

qc = QuantumCircuit(2,2)
qc = QuantumCircuit(QuantumRegister(2,'Mi_QR'),ClassicalRegister(2,'Mi_CR'))
qc.draw(output='mpl')
```

[2]:



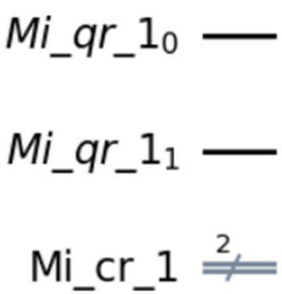
Circuitos Combinados

```
################################################################################
# CURSO QISKIT 2025
# COMBINAR CIRCUITOS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister

#-------------------------------------------------------------------------------
def Dibujar (qc_1, qc_2, qc_combined):
    #Draw circuit diagram #1
    circuito_1 = qc_1.draw(output='mpl')
    #Draw circuit diagram #2
    circuito_2 = qc_2.draw(output='mpl')
    #Draw circuit combinado
    combinado = qc_combined.draw(output='mpl')
    #Return the results
    return circuito_1, circuito_2, combinado
#-------------------------------------------------------------------------------
qr1 = QuantumRegister(2,'Mi_qr_1')
cr1 = ClassicalRegister(2,'Mi_cr_1')
qc1 = QuantumCircuit(qr1,cr1)

qr2 = QuantumRegister(2,'Mi_qr_2')
cr2 = ClassicalRegister(2,'Mi_cr_2')
qc2 = QuantumCircuit(qr2,cr2)
qc2.draw(output='mpl')

qc_combined = QuantumCircuit()
qc_combined.add_register(qr1,qr2,cr1,cr2)

circ_1, circ_2, circ_combined= Dibujar(qc1, qc2, qc_combined)
################################################################################
```

Circuitos Combinados

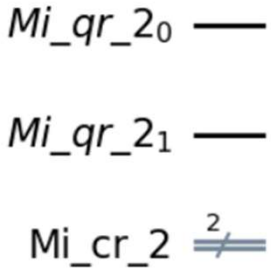
```
[7]: circ_1
```

[7]:



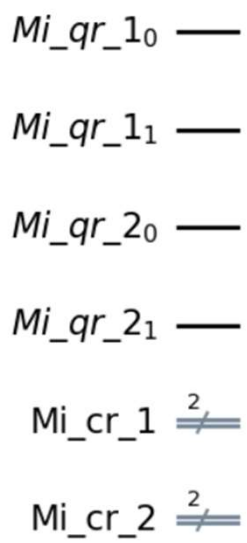

```
[8]: circ_2
```

[8]:




```
[9]: circ_combined
```

[9]:



RANDOM CIRCUITS GENERATORS

Width = 3 nro Qubits
Depth = 2 nro Std Gates

```
################################################################################
# CURSO QISKIT 2025
# RANDOM CIRCUITS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

qc = random_circuit(3,2,measure=True)
qc.draw(output='mpl')

################################################################################
```

Con Medidores

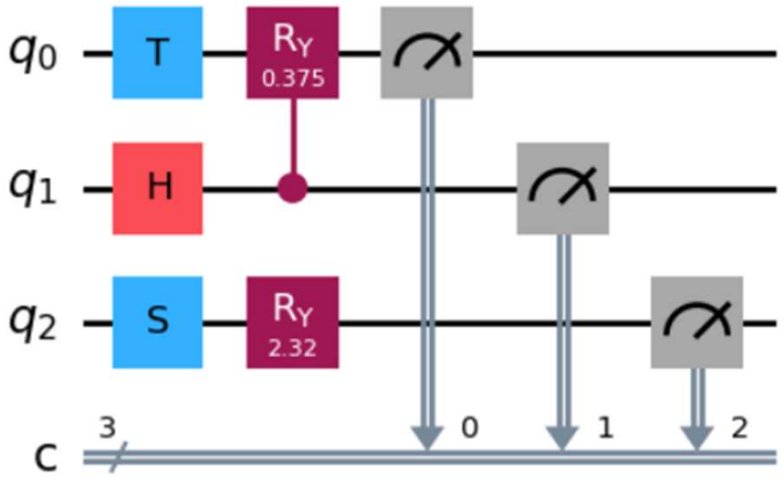
```
################################################################################
# CURSO QISKIT 2025
# RANDOM CIRCUITS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

qc = random_circuit(3,2,measure=False)
qc.draw(output='mpl')

################################################################################
```

Sin Medidores

RANDOM CIRCUITS GENERATORS

[12]:
```
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

qc = random_circuit(3,2,measure=True)
qc.draw(output='mpl')
```

[12]:

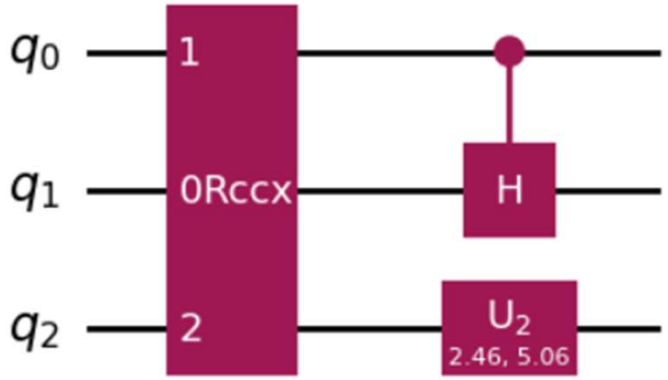


Ejecución #1
Con Medición
Width = 3
Depth = 2

RANDOM CIRCUITS GENERATORS

[14]:
```
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

qc = random_circuit(3,2,measure=False)
qc.draw(output='mpl')
```

[14]:



Ejecución #2
Sin Medición
Width = 3
Depth = 2

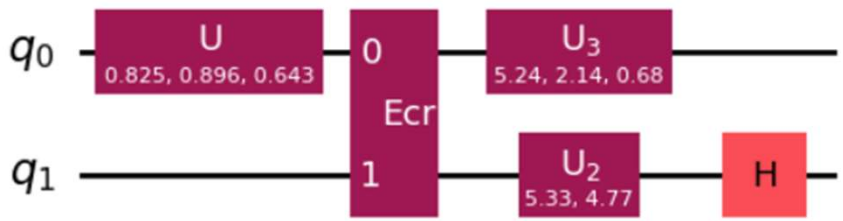
Obtención Propiedades del Circuito

WIDTH:	Cantidad de Qubits + Classical Bits
DEPTH:	Número de Standard Gates por Quibit (por línea)
CIRCUIT SIZE:	Número total de Gates
OPERATOR COUNT:	Listado de cada gate y su cantidad.

Obtención Propiedades del Circuito

```
#############################################################################
# CURSO QISKIT 2025
# WIDTH - DEPTH - CIRCUIT SIZE - NUMBER OPERATORS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

qc1 = random_circuit(2,2)
qc2 = random_circuit(2,2)
#concatenar
qc=qc1.compose(qc2,[0,1])
qc.draw(output='mpl')

#############################################################################
```

[3]:



Genero Circuito RANDOM

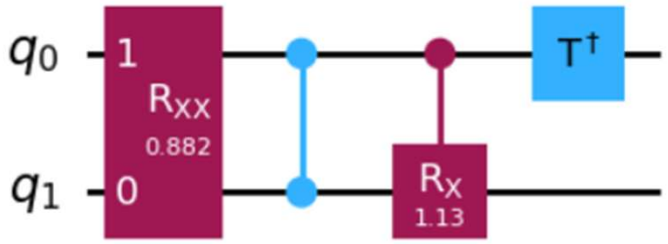
Obtención Propiedades del Circuito

```
################################################################################
# CURSO QISKIT 2025
# WIDTH - DEPTH - CIRCUIT SIZE - NUMBER OPERATORS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

#-------------------------------------------------------------------------------
#Defino Funcion print propiedades
def print_circuit_props(qc):
        width = qc.width()
        depth = qc.depth()
        num_operators = qc.count_ops()
        circuit_size = qc.size()
        print('WIDTH = ', width)
        print('DEPTH = ', depth)
        print('Circuit Size =', circuit_size)
        print('Numero Operadores = ', num_operators)
#-------------------------------------------------------------------------------
qc1 = random_circuit(2,2)
qc2 = random_circuit(2,2)
#concatenar
qc=qc1.compose(qc2,[0,1])
qc.draw(output='mpl')
################################################################################
```

```
################################################################################
# Luego ejecutar la impresion de propiedades

print_circuit_props(qc)

################################################################################
```

Obtención Propiedades del Circuito

[11]:



Ejecución # 1
Sin Medicion

[12]:

```
print_circuit_props(qc)
```

```
WIDTH =  2
DEPTH =  4
Circuit Size = 4
Numero Operadores =  OrderedDict({'rxx': 1, 'cz': 1, 'crx': 1, 'tdg': 1})
```

Obtención Propiedades del Circuito

[13]:

Ejecución # 2
Sin medicion

[14]:

```
print_circuit_props(qc)
```

```
WIDTH =  2
DEPTH =  4
Circuit Size = 4
Numero Operadores =  OrderedDict({'iswap': 1, 'ecr': 1, 'rx': 1, 'csdg': 1})
```

Quantum Computing QISKIT

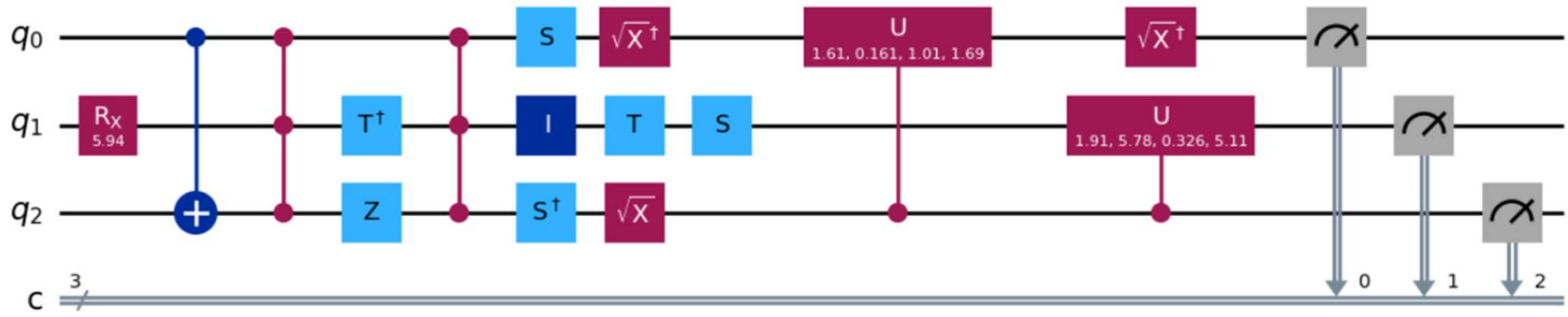
Obtención Propiedades del Circuito

```
###############################################################################
# CURSO QISKIT 2025
# WIDTH - DEPTH - CIRCUIT SIZE - NUMBER OPERATORS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

#------------------------------------------------------------------------
#Defino Funcion print propiedades
def print_circuit_props(qc):
        width = qc.width()
        depth = qc.depth()
        num_operators = qc.count_ops()
        circuit_size = qc.size()
        print('WIDTH = ', width)
        print('DEPTH = ', depth)
        print('Circuit Size =', circuit_size)
        print('Numero Operadores = ', num_operators)
#------------------------------------------------------------------------
qc1 = random_circuit(3,4)
qc2 = random_circuit(3,4,measure=True)
#concatenar
qc=qc1.compose(qc2,[0,1,2])
qc.draw(output='mpl')
###############################################################################

###############################################################################
# Luego ejecutar la impresion de propiedades

print_circuit_props(qc)

###############################################################################
```

Obtención Propiedades del Circuito

Ejecución # 1
Con medición

[20]:



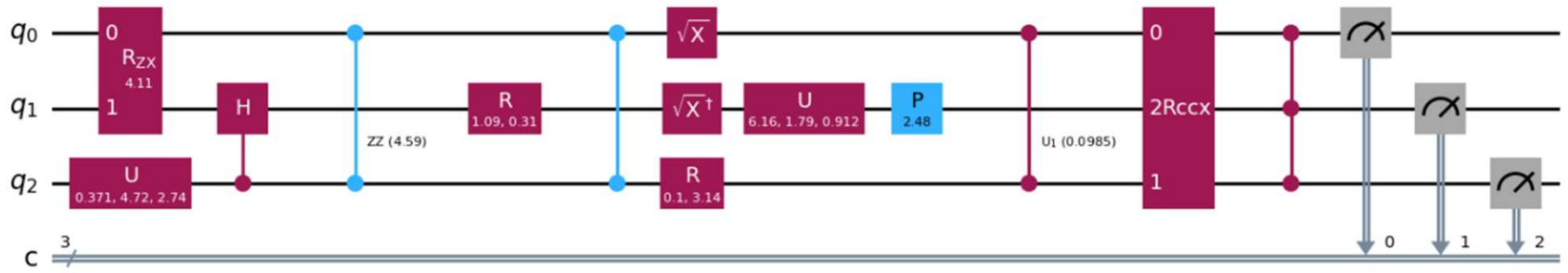
[21]:
```
print_circuit_props(qc)
```

```
WIDTH =  6
DEPTH =  9
Circuit Size = 19
Numero Operadores =  OrderedDict({'measure': 3, 'ccz': 2, 's': 2, 'sxdg': 2, 'cu': 2, 'rx': 1, 'cx': 1, 'tdg': 1, 'z': 1, 'id': 1, 'sdg': 1, 'sx': 1,
't': 1})
```

Obtención Propiedades del Circuito

Ejecución # 2
Con medición

[22]:



[23]:

```
print_circuit_props(qc)
```

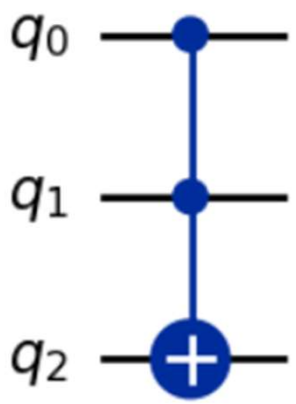
```
WIDTH =  6
DEPTH =  9
Circuit Size = 17
Numero Operadores =  OrderedDict({'measure': 3, 'u': 2, 'r': 2, 'rzx': 1, 'ch': 1, 'rzz': 1, 'cz': 1, 'sxdg': 1, 'sx': 1, 'p': 1, 'cu1': 1, 'rccx': 1,
'ccz': 1})
```

Obtención Propiedades TOFFOLI

```
###########################################################################
# CURSO QISKIT 2025
# WIDTH - DEPTH - CIRCUIT SIZE - NUMBER OPERATORS

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from qiskit.circuit.random import random_circuit

#--------------------------------------------------------------------------
#Defino Funcion print propiedades
def print_circuit_props(qc):
        width = qc.width()
        depth = qc.depth()
        num_operators = qc.count_ops()
        circuit_size = qc.size()
        print('WIDTH = ', width)
        print('DEPTH = ', depth)
        print('Circuit Size =', circuit_size)
        print('Numero Operadores = ', num_operators)
#--------------------------------------------------------------------------
qc = QuantumCircuit(3)
qc.ccx(0,1,2)
qc.draw(output='mpl')
###########################################################################

###########################################################################
# Luego ejecutar la impresion de propiedades

print_circuit_props(qc)

###########################################################################
```

Obtención Propiedades TOFFOLI

[24]:



[25]:

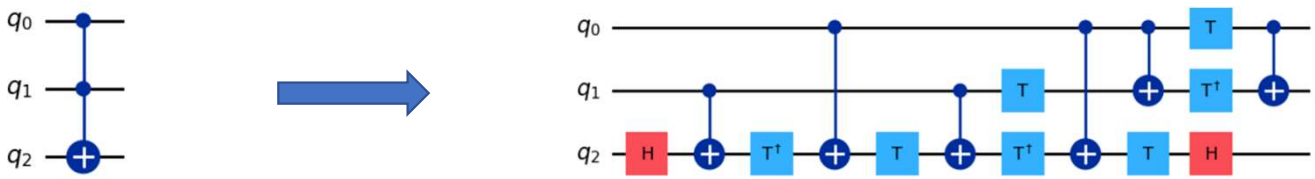
```
print_circuit_props(qc)
```

```
WIDTH =  3
DEPTH =  1
Circuit Size = 1
Numero Operadores =  OrderedDict({'ccx': 1})
```

Obtención Propiedades TOFFOLI Decompose

Toffoli se compone de varias Basis Gates

```
[27]: print_circuit_props(qc.decompose())

WIDTH =  3
DEPTH =  11
Circuit Size = 15
Numero Operadores =  OrderedDict({'cx': 6, 't': 4, 'tdg': 3, 'h': 2})
```



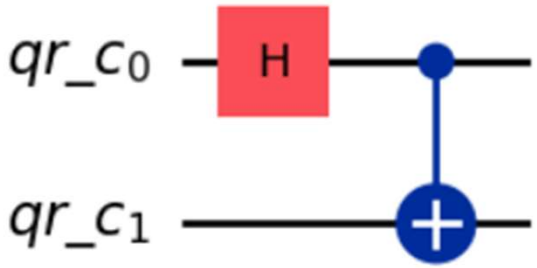
Lista Instrucciones - COMPOSITE

```
###############################################################################
# CURSO QISKIT 2025
# COMPOSITE LISTA INSTRUCCIONES
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
#------------------------------------------------------------------------------
#Creacion Lista Instrucciones COMPOSITE
qr = QuantumRegister(2, name= 'qr_c')
comp_qc = QuantumCircuit(qr, name='Mi Composite')
comp_qc.h(0)
comp_qc.cx(0,1)
#creo lista de instrucciones del quantumCircuit
composite_inst = comp_qc.to_instruction()
comp_qc.draw(output='mpl')
###############################################################################

###############################################################################
#Creacion nuevo circuito
qr2 = QuantumRegister(3,'qr')
qc = QuantumCircuit(qr2)
qc.h(0)
qc.cx(0,1)
qc.cx(0,2)
qc.draw(output='mpl')
###############################################################################

###############################################################################
#Append el compuesto tomado del listado de instrucciones
qc.append(composite_inst, [qr2[0], qr2[1]])
qc.draw(output='mpl')
###############################################################################
```

Lista Instrucciones - COMPOSITE

[2]:
```
from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
#-------------------------------------------------------------------------
#Creacion Lista Instrucciones COMPOSITE
qr = QuantumRegister(2, name= 'qr_c')
comp_qc = QuantumCircuit(qr, name='Mi Composite')
comp_qc.h(0)
comp_qc.cx(0,1)
#creo lista de instrucciones del quantumCircuit
composite_inst = comp_qc.to_instruction()
comp_qc.draw(output='mpl')
```

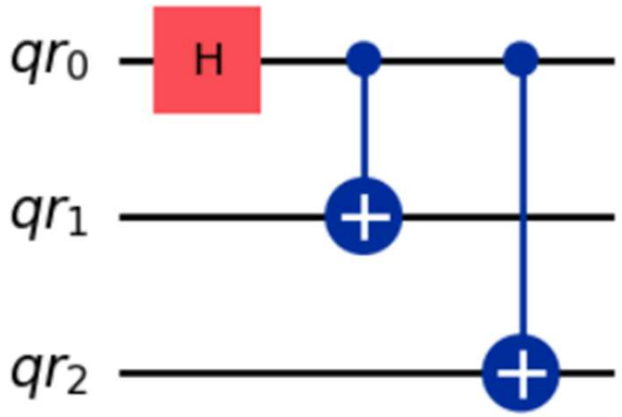
[2]:



Lista Instrucciones - COMPOSITE

[3]:
```
#Creacion nuevo circuito
qr2 = QuantumRegister(3,'qr')
qc = QuantumCircuit(qr2)
qc.h(0)
qc.cx(0,1)
qc.cx(0,2)
qc.draw(output='mpl')
```

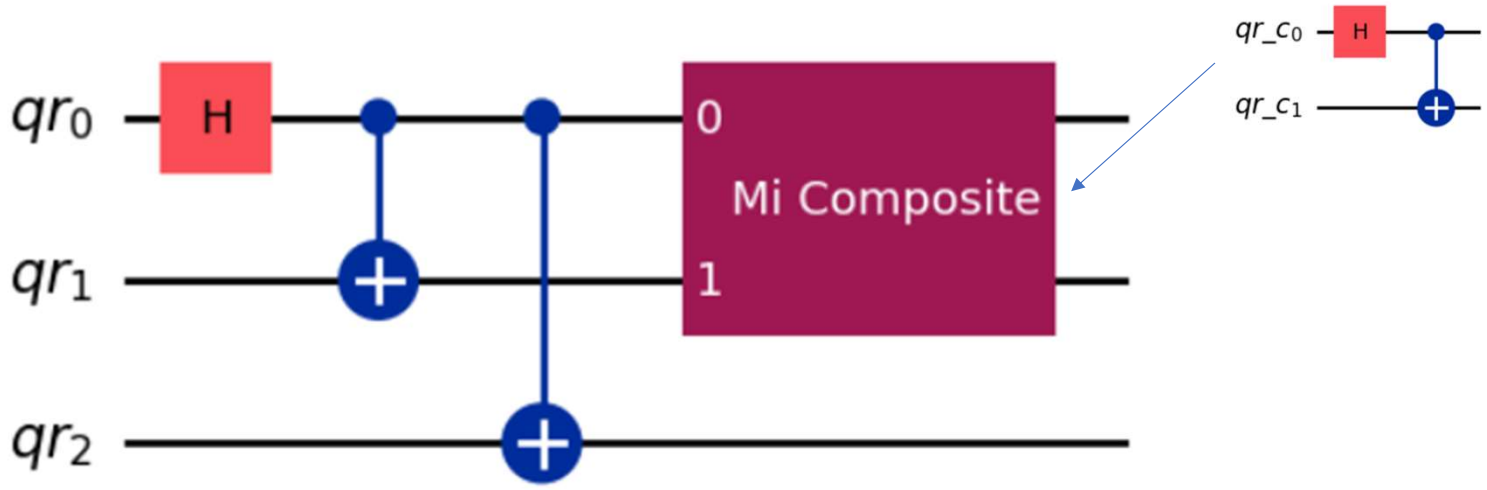
[3]:



Lista Instrucciones - COMPOSITE

[4]:
```
#Append el compuesto tomado del listado de instrucciones
qc.append(composite_inst, [qr2[0], qr2[1]])
qc.draw(output='mpl')
```

[4]:

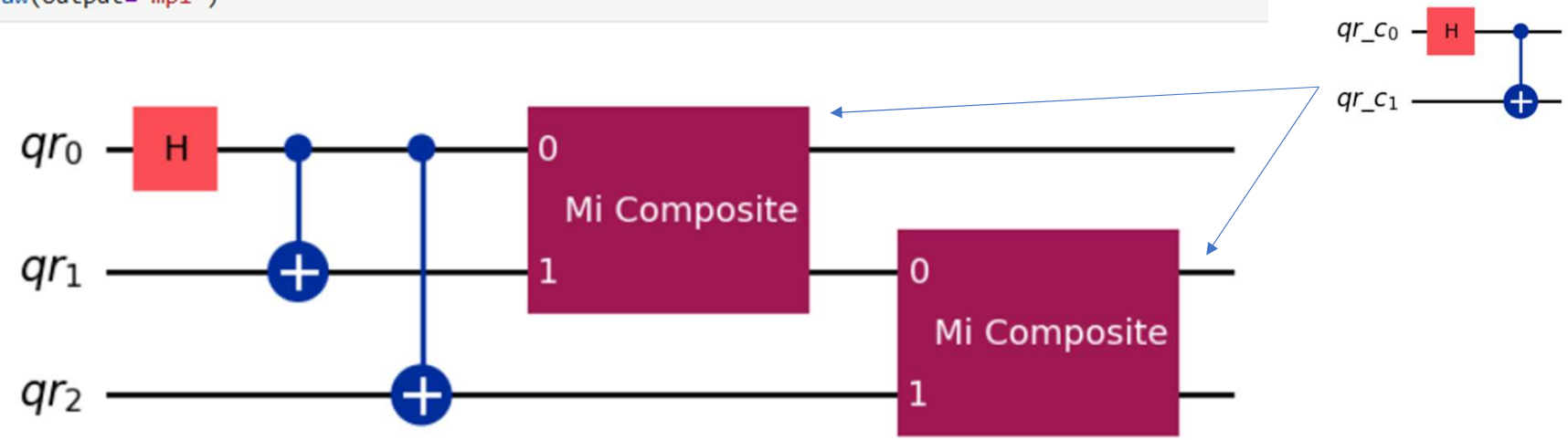


Lista Instrucciones - COMPOSITE

Ejecuto nuevamente el append del composite para los qubits 1 y 2

```
[5]: #Append el compuesto tomado del listado de instrucciones
     qc.append(composite_inst, [qr2[1], qr2[2]])
     qc.draw(output='mpl')
```

[5]:



INTRODUCCIÓN

Aparenta desperdicio recursos y tiempo

- El problema que resuelve es muy simple
- Problema inventado. Jamás lo encontramos en el mundo real
- La técnica utilizada por este algoritmo no tiene semejanza a los procedimientos paso a paso aplicados en computación clásica

Como prueba de concepto, el algoritmo de Deutsch es un gran salto hacia adelante.

DESCRIPCIÓN

Resuelve un problema relacionado a funciones:

- BALANCEADAS
- CONSTANTES

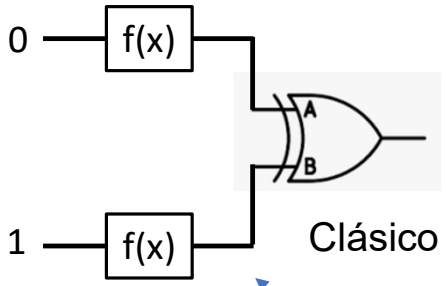
DESCRIPCIÓN Funciones Constantes y Balanceadas

El problema que resuelve ilustra la forma como mediante un circuito cuántico se pueden resolver varios (en este caso dos) pasos, o evaluaciones, en uno aplicando superposición.

Función:
- Constante
- o
- Balanceada

Constante:
- f(0) = f(1) = 0 (*ZERO*)
- o
- f(0) = f(1) = 1 (*ONE*)

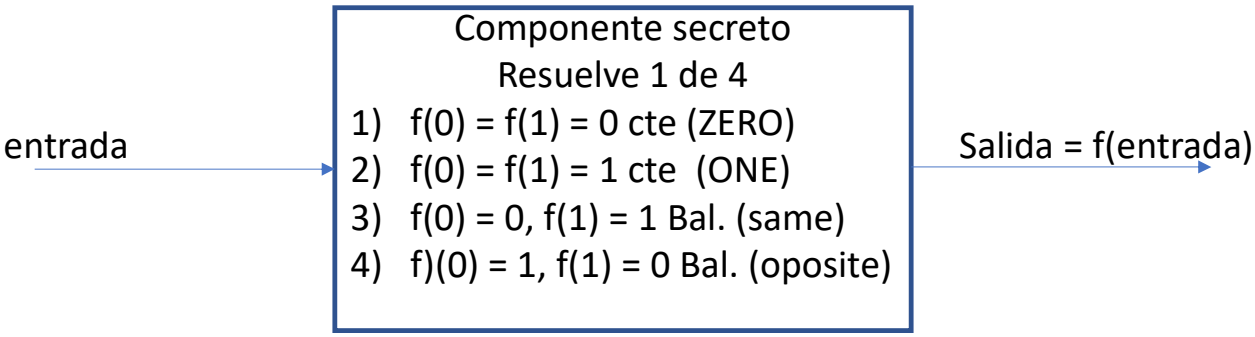
Balanceada:
- f(0) = 0 y f(1) = 1 (*Same_As)*
- o
- f(0) = 1 y f(0) = 0 (*Opposite_Of*)



- = 0 f(x) es Constante
- = 1 f(x) es Balanceada

Clásico: requiere evaluar la función **2 veces**.

Resolución forma clásica

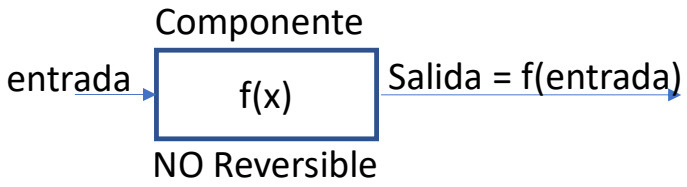


Input es 0 y almaceno la salida en variable a
Input es 1 y almaceno la salida en variable b
Si a = b
Función Constante
Si no
Función Balanceada

Evaluación en 2 pasos

Componente Secreto F(x) debe ser reversible

Debido a la propiedad de REVERSIBILIDAD de las compuertas cuánticas, el componente secreto que resuelve la función y que deseamos conocer si es una función Balanceada o Constante, debe ser **REVERSIBLE**



Entrada	Salida
0	0
1	0

Ejemplo
Si f(x) es CTE (ZERO)

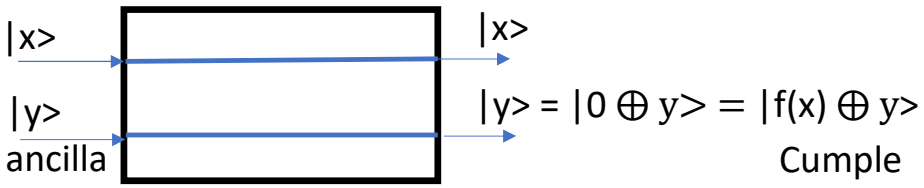
SI Reversible

Seteando y = 0 (ancilla), la salida inferior es
$|f(x) \oplus y\rangle = |f(x) \oplus 0\rangle = |f(x)\rangle$

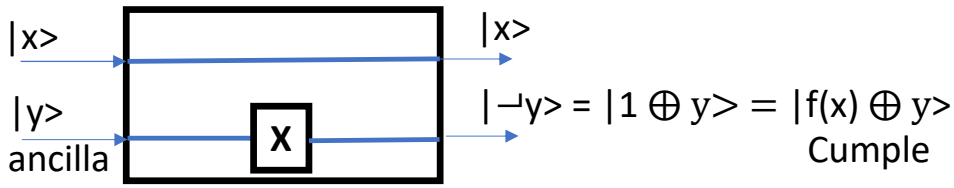
DEUTSCH'S ALGORITHM

Componente Secreto F(x) debe ser reversible

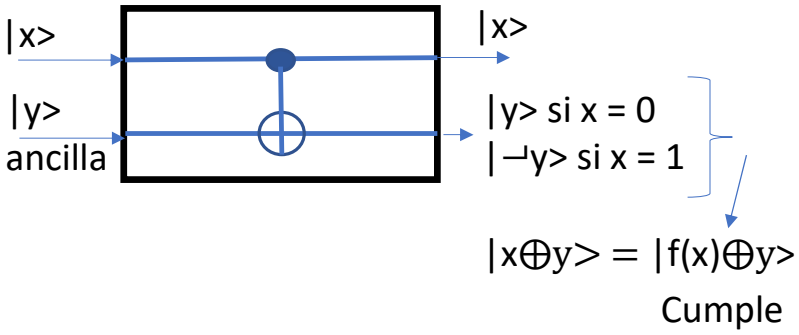
Función ZERO f(x) = 0 siempre.



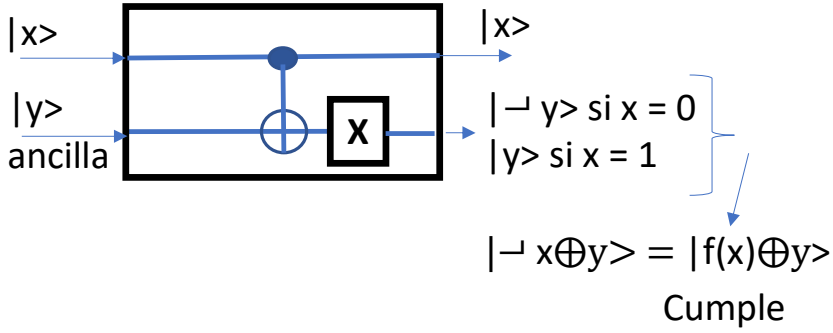
Función ONE f(x) = 1 siempre.



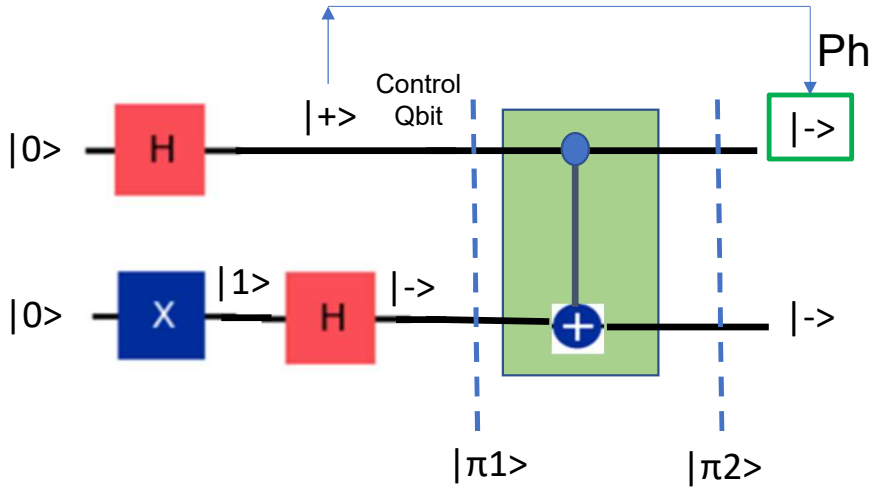
Función Same as f(x) = x.



Función Opposite of as f(x) = ¬ x.



Phase Kickback



Contrariamente a lo esperado
El control Qbit cambia pero el
Target Qubit No Cambia

Control Qbit

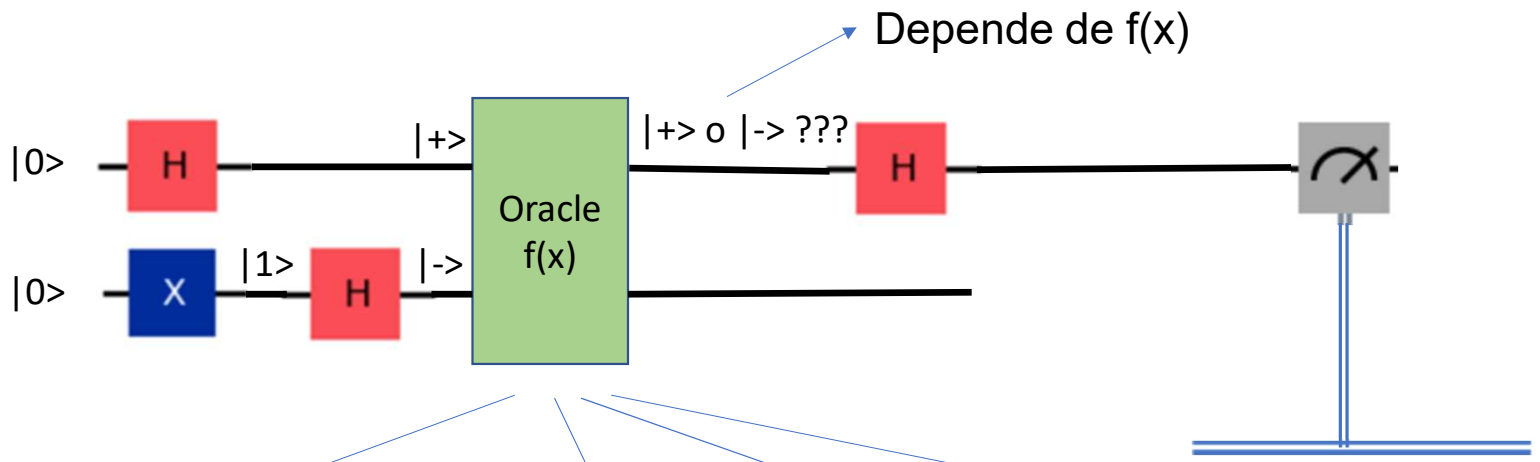
$|\pi 1\rangle = |-\rangle \otimes |+\rangle = \frac{1}{2}(|0\rangle-|1\rangle) \otimes (|0\rangle+|1\rangle) = \frac{1}{2}(|00\rangle+|01\rangle-|10\rangle-|11\rangle)$

$|\pi 2\rangle = |-\rangle \otimes |+\rangle = \frac{1}{2}(|00\rangle+|11\rangle-|10\rangle-|01\rangle) = \frac{1}{2}(|0\rangle-|1\rangle) \otimes (|0\rangle-|1\rangle) = (|-\rangle \otimes |-\rangle)$

$|Salida\rangle = |-\rangle \otimes |-\rangle = |-\rangle\,|-\rangle$

DEUTSCH'S ALGORITHM

ORÁCULO



DEUTSCH'S ALGORITHM

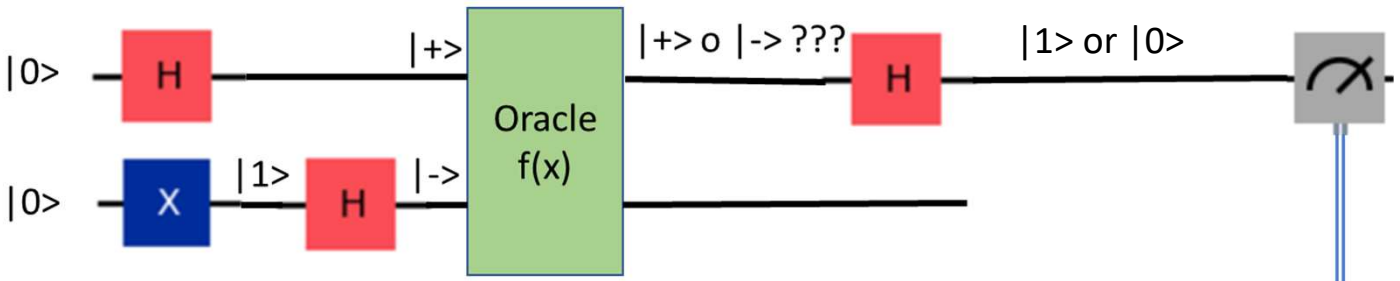
ORÁCULO

|+> No hay C-Not en el Oráculo

|-> Si hay C-Not en el Oráculo

|0> No hay C-Not en el Oráculo

|1> Si hay C-Not en el Oráculo



RESUELTO EN UN SOLO INTENTO O EVALUACIÓN

Programa QuisKit

```
#########################################################################
# CURSO QISKIT 2025
# DEUTSCH Algorithm

from qiskit import QuantumCircuit, QuantumRegister, ClassicalRegister
from enum import Enum
from qiskit.quantum_info import Statevector
from qiskit.visualization import plot_bloch_multivector

qc = QuantumCircuit(2,2)
qr = QuantumRegister(2,'Mi_QR')
cr = ClassicalRegister(2,'Mi_CR')
qc = QuantumCircuit(qr,cr)
qc.draw(output='mpl')
#------------------------------------------------------------------------
class SimpleBinary(Enum):
    ZERO        = 0
    ONE         = 1
    SAME_AS     = 2
    OPPOSITE_OF = 3
#------------------------------------------------------------------------
def get_oracle(circ, function):
    # if function == SimpleBinary.ZERO:
        # Do nothing
    if function == SimpleBinary.ONE:
        circ.x(1)
    elif function == SimpleBinary.SAME_AS:
        circ.cx(0, 1)
    elif function == SimpleBinary.OPPOSITE_OF:
        circ.cx(0, 1)
        circ.x(1)
    return circ
#------------------------------------------------------------------------
```

Programa QuisKit

```
#-------------------------------------------------------------
def get_function():
    print('Which function? (0/1/2/3)')
    print(' 0: ZERO')
    print(' 1: ONE')
    print(' 2: SAME_AS')
    print(' 3: OPPOSITE_OF')
    value = input('> ')
    return SimpleBinary(int(value))
#-------------------------------------------------------------
circ = QuantumCircuit(2, 1)
function = get_function()
circ.x(1)
circ.h(0)
circ.h(1)
circ.barrier()
circ = get_oracle(circ, function)
circ.barrier()
circ.h(0)
circ.measure(0, 0)
display(circ.draw('mpl'))
```

Programa QuisKit

```
from qiskit import transpile
from qiskit_aer import Aer
from qiskit_aer import AerSimulator

shots = 1
simulator = AerSimulator()
compiled_circuit = transpile(circ, simulator)
sim_result = simulator.run(compiled_circuit, shots=1).result()
counts = sim_result.get_counts()
print(counts)
print(function)
print(counts)
number_of_0s = counts.get('0')
number_of_1s = counts.get('1')

if number_of_0s is not None and number_of_0s == shots:
    print('Constant')
elif number_of_1s is not None and number_of_1s == shots:
    print('Balanced')
else:
    print("Results aren't conclusive")
#############################################################################
```

Ejecución Programa QuisKit

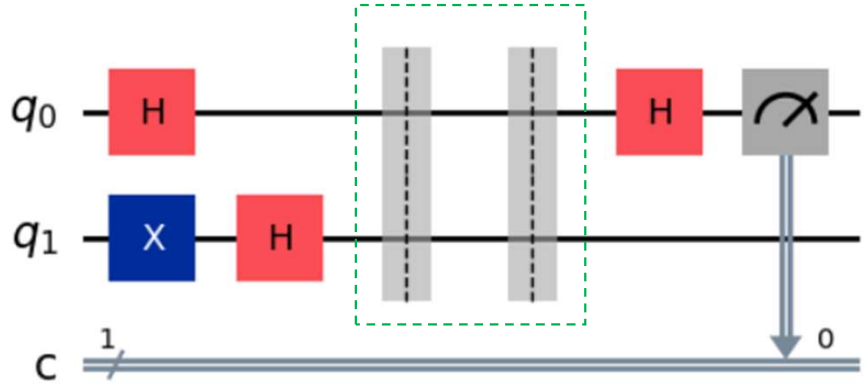
```
Which function? (0/1/2/3)
 0: ZERO
 1: ONE
 2: SAME_AS
 3: OPPOSITE_OF
> ↑↓ for history. Search history with c-↑/c-↓
```

Ingresar 0, 1, 2 o 3

Ejecución Programa QuisKit

```
Which function? (0/1/2/3)
 0: ZERO
 1: ONE
 2: SAME_AS
 3: OPPOSITE_OF
> 0
```

Ingreso 0



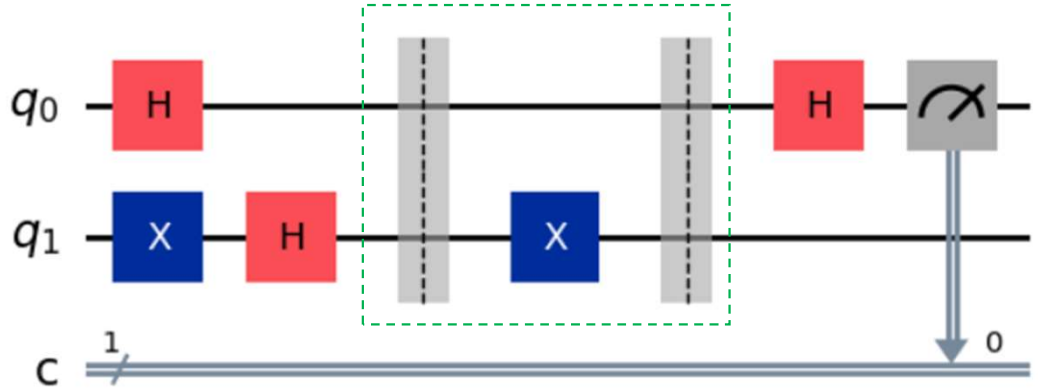
Mide '0'

```
{'0': 1}
SimpleBinary.ZERO
{'0': 1}
Constant
```

Ejecución Programa QuisKit

```
Which function? (0/1/2/3)
 0: ZERO
 1: ONE
 2: SAME_AS
 3: OPPOSITE_OF
> 1
```

Ingreso 1



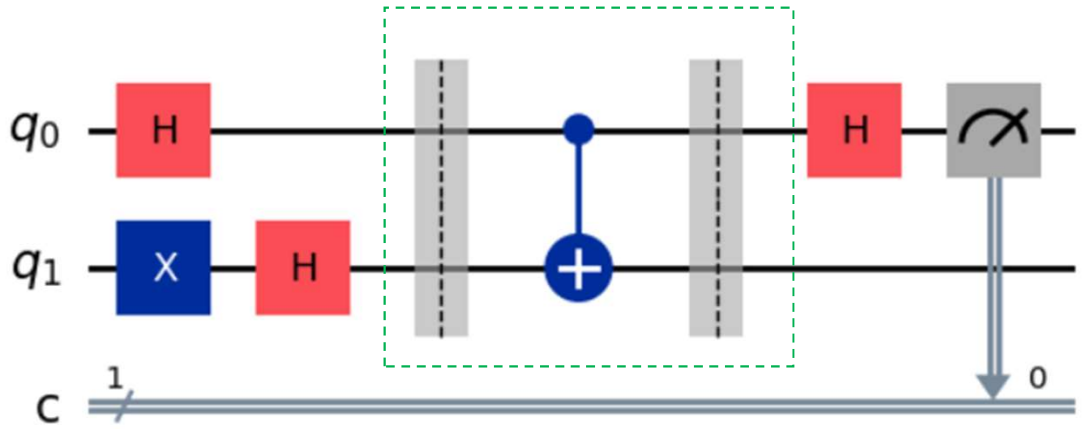
Mide '0'

```
{'0': 1}
SimpleBinary.ONE
{'0': 1}
Constant
```

Ejecución Programa QuisKit

Ingreso 2

```
Which function? (0/1/2/3)
 0: ZERO
 1: ONE
 2: SAME_AS
 3: OPPOSITE_OF
>  2
```



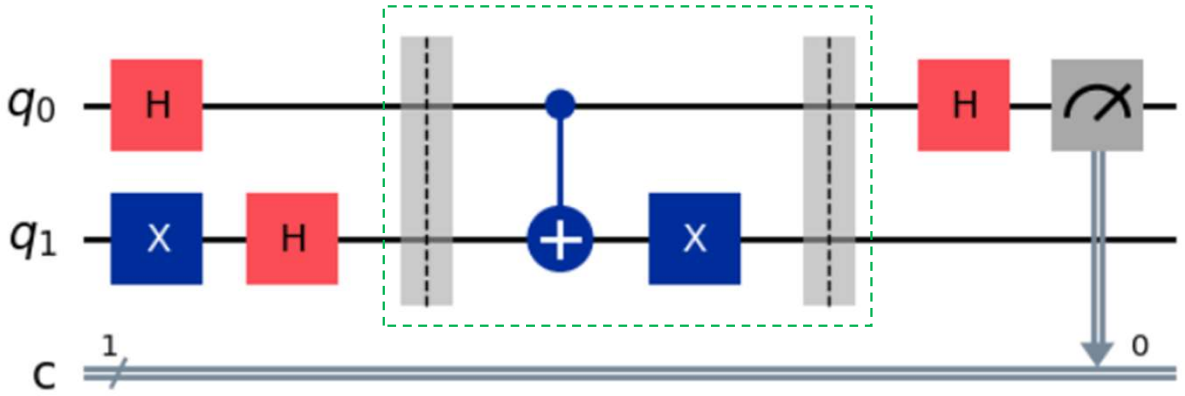
Mide '1'

```
{'1': 1}
SimpleBinary.SAME_AS
{'1': 1}
Balanced
```

Ejecución Programa QuisKit

Ingreso 3

```
Which function? (0/1/2/3)
 0: ZERO
 1: ONE
 2: SAME_AS
 3: OPPOSITE_OF
>  3
```



Mide '1'

```
{'1': 1}
SimpleBinary.OPPOSITE_OF
{'1': 1}
Balanced
```