Lab-01 :Quantum Bit(Qubit) as State Vector, Quantum Operators, Quantum Circuits and Visulaization

Classical Computer uses classical variables like complex variables, objects, class and data structures for writing modern software.

Quantum Computer uses basic quantum variable qubit(quantum analogy of the bit) for describing the quantum states of the quantum system. It uses the quantum gates(quantum analogy of digital gates) used to manipulate the quantum information(qubits). Using these quantum gates we can find new ways to design quantum algorithms.

Quantum algorithms/quantum systems states can be manipulated with the some collection of quantum gates which form the quantum circuit. Thus we are going to build at the end some quantum circuit for manipulation of the qubits.

```
# Importing all the tools from python libraries
from qiskit import QuantumCircuit, assembler, Aer
from qiskit.quantum_info import Statevector, Operator
from qiskit.visualization import plot_histogram, plot_bloch_vector,
plot_bloch_multivector

from math import sqrt, pi
from numpy import array
from numpy import matmul

# Qubit as state vector
ket_0 = array([1,0])
ket_1 = array([0,1])

# average of the |0> and |1>
display(ket_0/2 + ket_1/2)
```

```
array([0.5, 0.5])
```

```
# Let's create matrices that used as operators
M_1 = array([[1, 1], [0, 0]])
M_2 = array([[1, 1], [1, 0]])

# avearage of operator
display(M_1/2 + M_2/2)
```

```
array([[1. , 1. ],
       [0.5, 0. ]])
```

```
# matrix - vector multiplication i.e apply operator on qubit
display(matmul(M_1, ket_0)) # M_1 * |0>
```

```
display(matmul(M_1, ket_1)) # M_1 * |1>
display(matmul(M_2, ket_0)) # M_2 * |0>
display(matmul(M_2, ket_1)) # M_2 * |1>

# matrix - matrix multiplication
display(matmul(M_1, M_2))
display(matmul(M_2, M_1))
```

```
array([1, 0])
```

```
array([1, 0])
```

```
array([1, 1])
```

```
array([1, 0])
```

```
array([[2, 1],
       [0, 0]])
```

```
array([[1, 1],
       [1, 1]])
```

```
# Creating qubit as statevector
u = Statevector([1/sqrt(2), 1/sqrt(2)])
v = Statevector([(1 + 2.j)/3, -2/3])
w = Statevector([1/3, 2/3])
display(u, v, w)
```

```
Statevector([0.70710678+0.j, 0.70710678+0.j],
            dims=(2,))
Statevector([ 0.33333333+0.66666667j, -0.66666667+0.j        ],
            dims=(2,))
Statevector([0.33333333+0.j, 0.66666667+0.j],
            dims=(2,))
```

```
# visualize the state vector as vector and latex symbol
display(u.draw('latex'))
display(v.draw('latex'))
display(w.draw('latex'))
```

```
<IPython.core.display.Latex object>
```

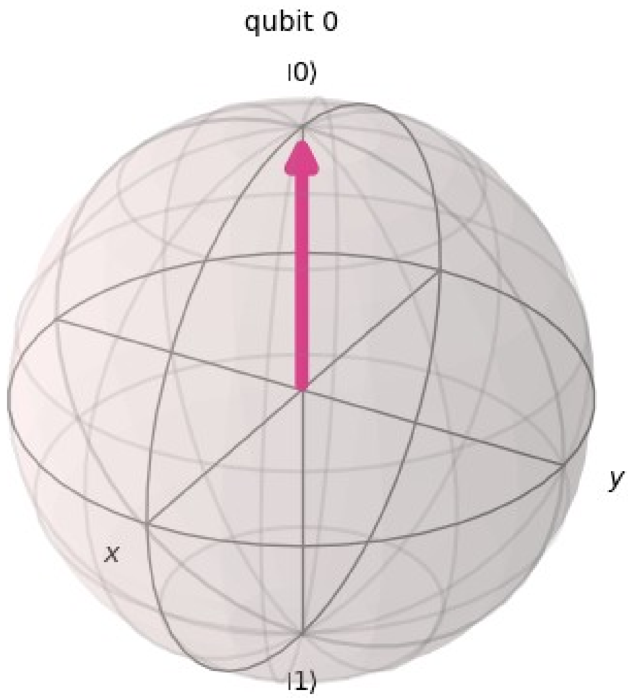
```
<IPython.core.display.Latex object>
```

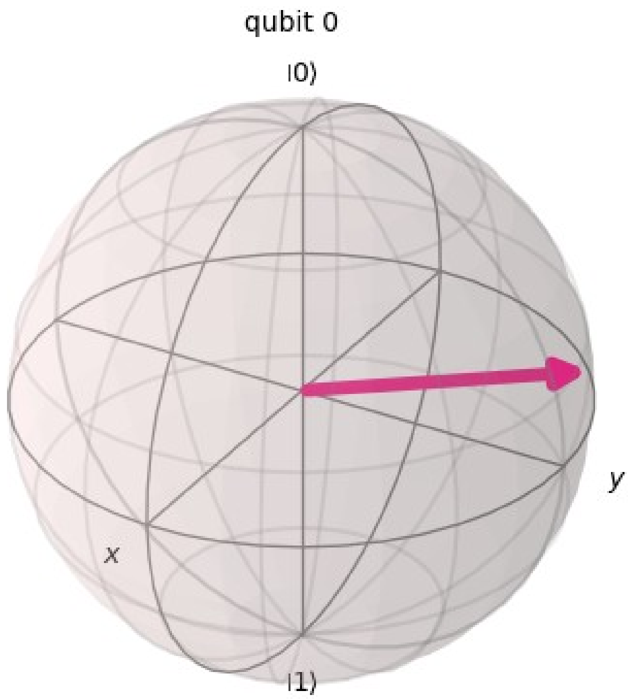
```
<IPython.core.display.Latex object>
```

```
# Let's check is these state vector valid quantum state vector
display(u.is_valid())
display(v.is_valid())
display(w.is_valid()) # because it's not normalized
```

```
True
```

```
True

False

display(plot_bloch_multivector(u), plot_bloch_multivector(v))
```





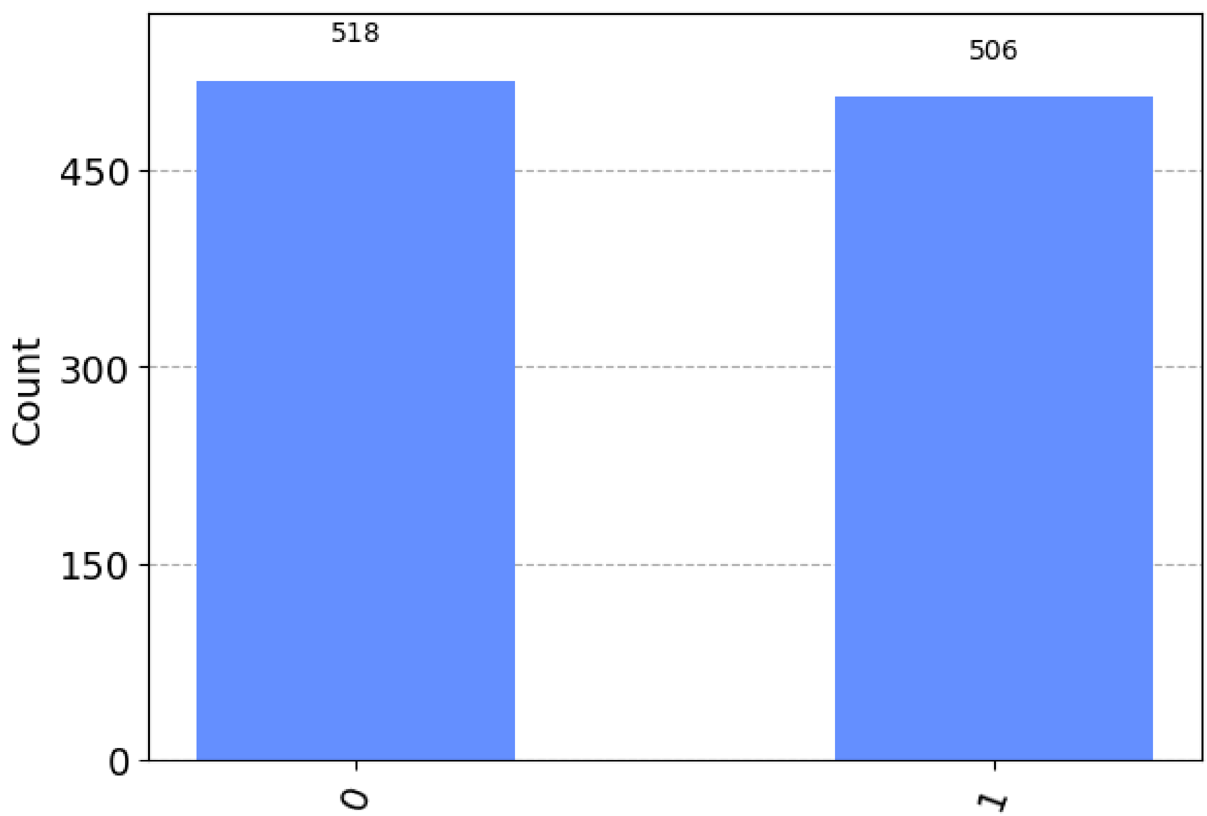

```
# Let's measure the quantum states from state vector class and
simulated
display(u.measure())
display(v.measure())
display(w.measure()) # You can see why it is not a valid qubit
```

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

('0',
 Statevector([0.4472136+0.89442719j, 0.        +0.j        ],
             dims=(2,)))

----------------------------------------------------------------------
-----
ValueError                                Traceback (most recent call
last)
Cell In[14], line 4
      2 display(u.measure())
      3 display(v.measure())
----> 4 display(w.measure())

File c:\Users\irpra\miniconda3\envs\Quanta\Lib\site-packages\qiskit\
quantum_info\states\quantum_state.py:327, in
QuantumState.measure(self, qargs)
```

```
    325 dims = self.dims(qargs)
    326 probs = self.probabilities(qargs)
--> 327 sample = self._rng.choice(len(probs), p=probs, size=1)
    329 # Format outcome
    330 outcome = self._index_to_ket_array(sample, self.dims(qargs),
string_labels=True)[0]

File _generator.pyx:828, in numpy.random._generator.Generator.choice()

ValueError: probabilities do not sum to 1
```

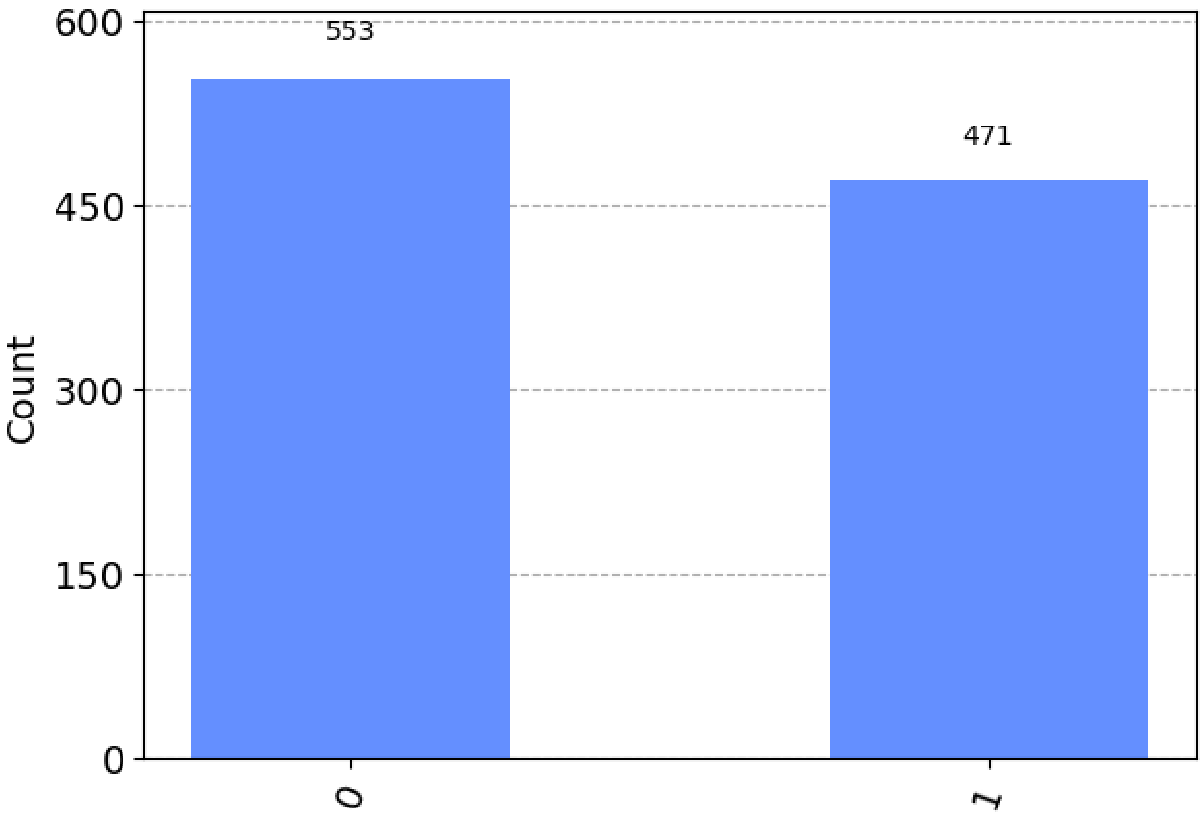
The outcome of measuring the vector `v` 1024 times, which (with high probability) results in the outcome 0 approximately 5 out of every 9 times (or about 518 of the 1024 trials) and the the outcome 1 approximately 4 out of every 9 times (or about 506 out of the 1024 trials).

```
stats = u.sample_counts(1024)
display(stats)
plot_histogram(stats)

{'0': 518, '1': 506}
```



```
stats = v.sample_counts(1024)
display(stats)
plot_histogram(stats)
```

```
{'0': 553, '1': 471}
```



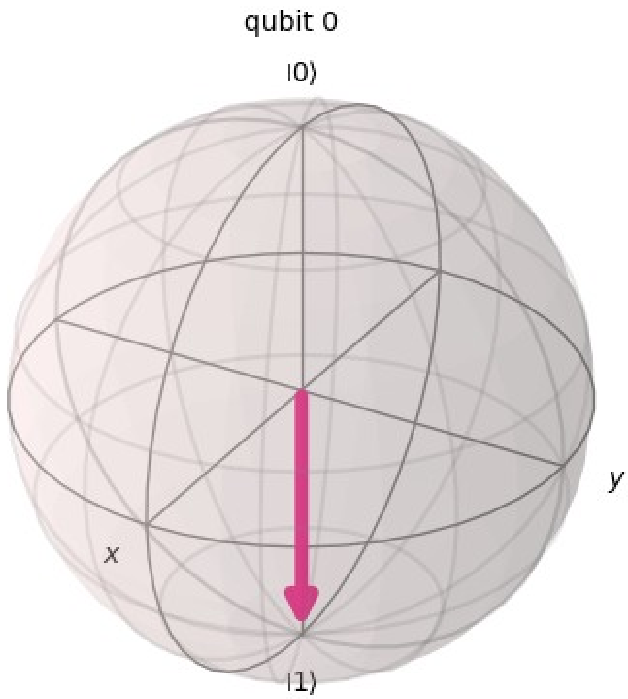

```
# Applying Unitary Operation on state vectors
X = Operator([[0,1],[1,0]])
Y = Operator([[0,-1.j],[1.j,0]])
Z = Operator([[1,0],[0,-1]])
H = Operator([[1/sqrt(2),1/sqrt(2)],[1/sqrt(2),-1/sqrt(2)]])
S = Operator([[1,0],[0,1.j]])
T = Operator([[1,0],[0,(1+1.j)/sqrt(2)]])
display(X, Y, Z, H, S, T)
```

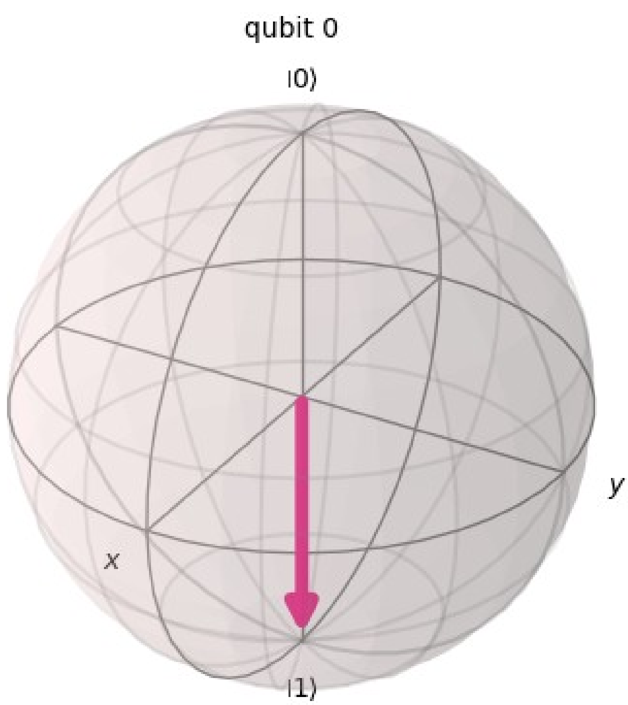
```
Operator([[0.+0.j, 1.+0.j],
          [1.+0.j, 0.+0.j]],
         input_dims=(2,), output_dims=(2,))

Operator([[ 0.+0.j, -0.-1.j],
          [ 0.+1.j,  0.+0.j]],
         input_dims=(2,), output_dims=(2,))
```

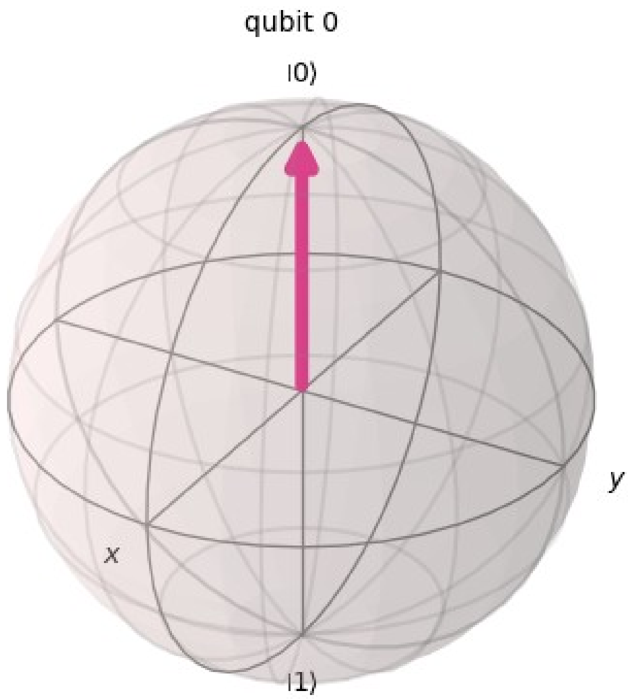
```
Operator([[ 1.+0.j,  0.+0.j],
          [ 0.+0.j, -1.+0.j]],
         input_dims=(2,), output_dims=(2,))

Operator([[ 0.70710678+0.j,  0.70710678+0.j],
          [ 0.70710678+0.j, -0.70710678+0.j]],
         input_dims=(2,), output_dims=(2,))

Operator([[1.+0.j, 0.+0.j],
          [0.+0.j, 0.+1.j]],
         input_dims=(2,), output_dims=(2,))

Operator([[1.        +0.j        , 0.        +0.j        ],
          [0.        +0.j        , 0.70710678+0.70710678j]],
         input_dims=(2,), output_dims=(2,))

# applying Operator X on state vector u
u_1 = u.evolve(X)
u_2 = u.evolve(Y)
u_3 = u.evolve(Z)
u_4 = u.evolve(H)
u_5 = u.evolve(S)
u_6 = u.evolve(T)
display(u_1.draw('latex'), u_2.draw('latex'), u_3.draw('latex'),
u_4.draw('latex'), u_5.draw('latex'))

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>
```

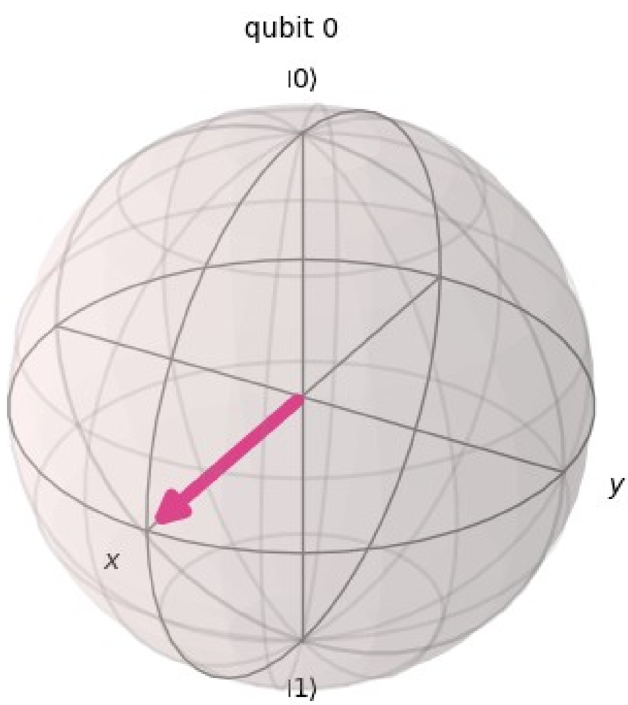
You can seen after applying Operators on $u=1/2* \mid 0\rangle + 1/2* \mid 1\rangle$

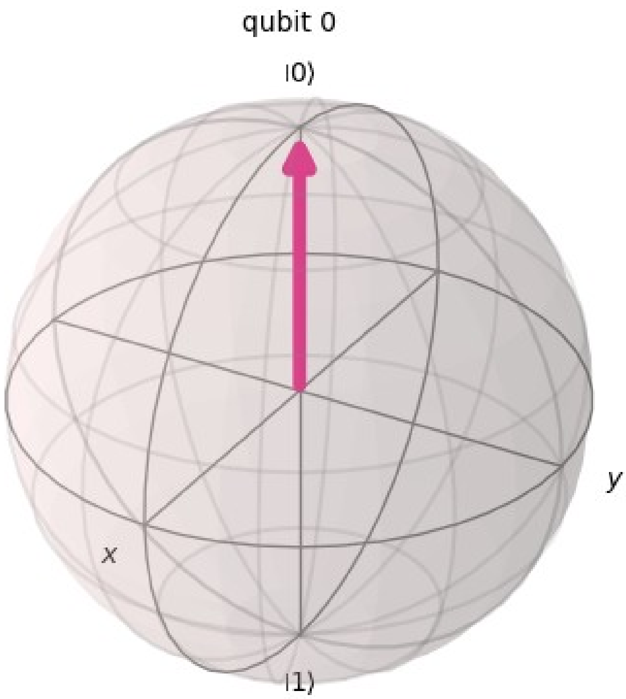
```
display(plot_bloch_multivector(u_1),
        plot_bloch_multivector(u_2),
        plot_bloch_multivector(u_3),
        plot_bloch_multivector(u_4),
        plot_bloch_multivector(u_5))
```


qubit 0
|0⟩
y
x
|1⟩


qubit 0
|0⟩
y
x
|1⟩

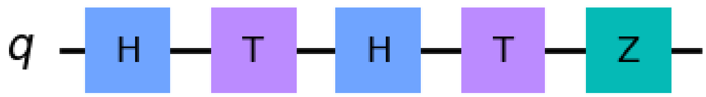

qubit 0
|0⟩
y
x
|1⟩


qubit 0
|0⟩
y
x
|1⟩




```
v_1 = v.evolve(H)
v_2 = v.evolve(T)
v_3 = v.evolve(H)
v_4 = v.evolve(T)
v_5 = v.evolve(Z)

display(v_1.draw('latex'), v_2.draw('latex'), v_3.draw('latex'),
v_4.draw('latex'), v_5.draw('latex'))

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

<IPython.core.display.Latex object>

# Let's create a quantum circuits
# Thus, a sequence of unitary operation performed on a single qubit
qc = QuantumCircuit(1)

qc.h(0)
qc.t(0)
qc.h(0)
qc.t(0)
```

```
qc.z(0)
qc.draw(output="mpl")
```

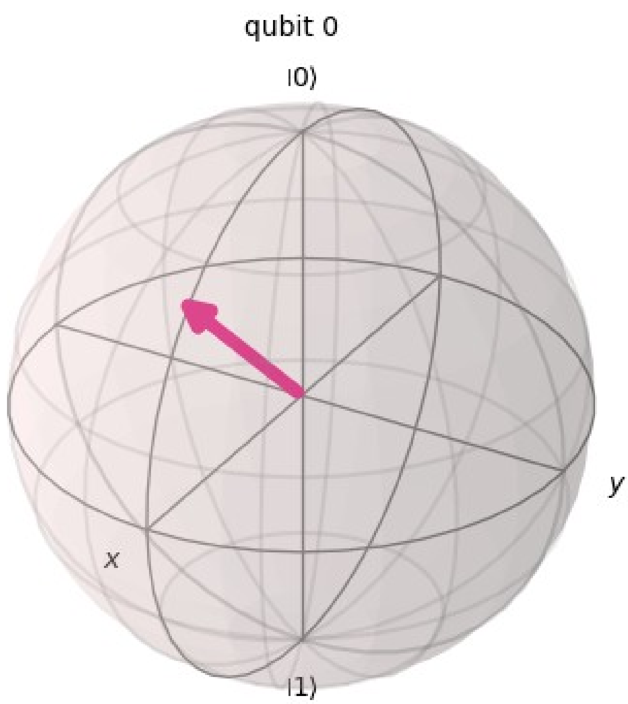



```
display(qc.draw('latex'))
```

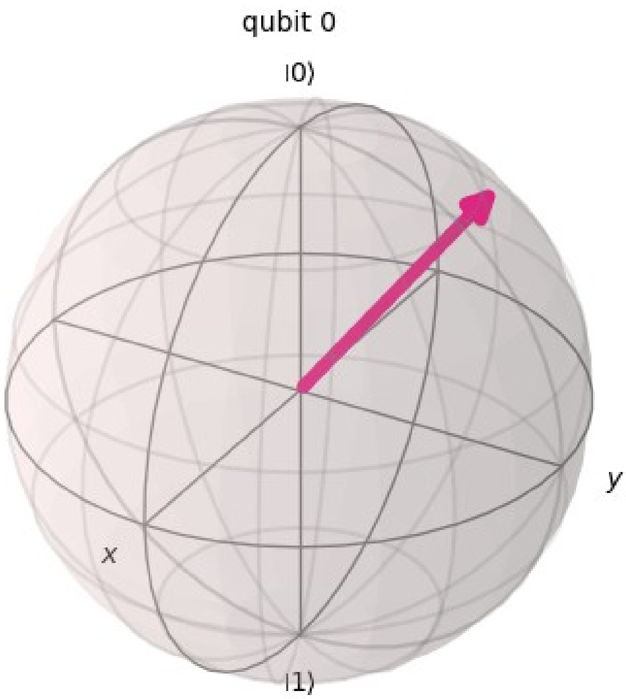
```
---------------------------------------------------------------------------
MissingOptionalLibraryError               Traceback (most recent call last)
Cell In[26], line 1
----> 1 display(qc.draw('latex'))

File c:\Users\irpra\miniconda3\envs\Quanta\Lib\site-packages\qiskit\circuit\quantumcircuit.py:1913, in QuantumCircuit.draw(self, output, scale, filename, style, interactive, plot_barriers, reverse_bits, justify, vertical_compression, idle_wires, with_layout, fold, ax, initial_state, cregbundle, wire_order)
   1910 # pylint: disable=cyclic-import
   1911 from qiskit.visualization import circuit_drawer
-> 1913 return circuit_drawer(
   1914     self,
   1915     scale=scale,
   1916     filename=filename,
   1917     style=style,
   1918     output=output,
   1919     interactive=interactive,
   1920     plot_barriers=plot_barriers,
   1921     reverse_bits=reverse_bits,
   1922     justify=justify,
   1923     vertical_compression=vertical_compression,
   1924     idle_wires=idle_wires,
   1925     with_layout=with_layout,
   1926     fold=fold,
   1927     ax=ax,
   1928     initial_state=initial_state,
   1929     cregbundle=cregbundle,
   1930     wire_order=wire_order,
   1931 )

File c:\Users\irpra\miniconda3\envs\Quanta\Lib\site-packages\qiskit\visualization\circuit\circuit_visualization.py:262, in
```

```
circuit_drawer(circuit, scale, filename, style, output, interactive,
plot_barriers, reverse_bits, justify, vertical_compression,
idle_wires, with_layout, fold, ax, initial_state, cregbundle,
wire_order)
    247     return _text_circuit_drawer(
    248         circuit,
    249         filename=filename,
   (...)
    259         wire_order=complete_wire_order,
    260     )
    261 elif output == "latex":
--> 262     image = _latex_circuit_drawer(
    263         circuit,
    264         filename=filename,
    265         scale=scale,
    266         style=style,
    267         plot_barriers=plot_barriers,
    268         reverse_bits=reverse_bits,
    269         justify=justify,
    270         idle_wires=idle_wires,
    271         with_layout=with_layout,
    272         initial_state=initial_state,
    273         cregbundle=cregbundle,
    274         wire_order=complete_wire_order,
    275     )
    276 elif output == "latex_source":
    277     return _generate_latex_source(
    278         circuit,
    279         filename=filename,
   (...)
    289         wire_order=complete_wire_order,
    290     )

File c:\Users\irpra\miniconda3\envs\Quanta\Lib\site-packages\qiskit\
utils\lazy_tester.py:148, in
LazyDependencyManager.require_in_call.<locals>.decorator.<locals>.out(
*args, **kwargs)
    146 @functools.wraps(function)
    147 def out(*args, **kwargs):
--> 148     self.require_now(feature)
    149     return function(*args, **kwargs)

File c:\Users\irpra\miniconda3\envs\Quanta\Lib\site-packages\qiskit\
utils\lazy_tester.py:223, in LazyDependencyManager.require_now(self,
feature)
    221 if self:
    222     return
--> 223 raise MissingOptionalLibraryError(
    224     libname=self._name, name=feature,
```

```
pip_install=self._install, msg=self._msg
    225 )

MissingOptionalLibraryError: "The 'pdflatex' library is required to
use 'LaTeX circuit drawing'.  You will likely need to install a full
LaTeX distribution for your system."

# Till now , we created out quantum circuit
# Now, we are going to apply operations sequencially on qubit
v_new = v.evolve(qc)
display(v_new.draw('latex'))

<IPython.core.display.Latex object>

display(plot_bloch_multivector(v_new))
```

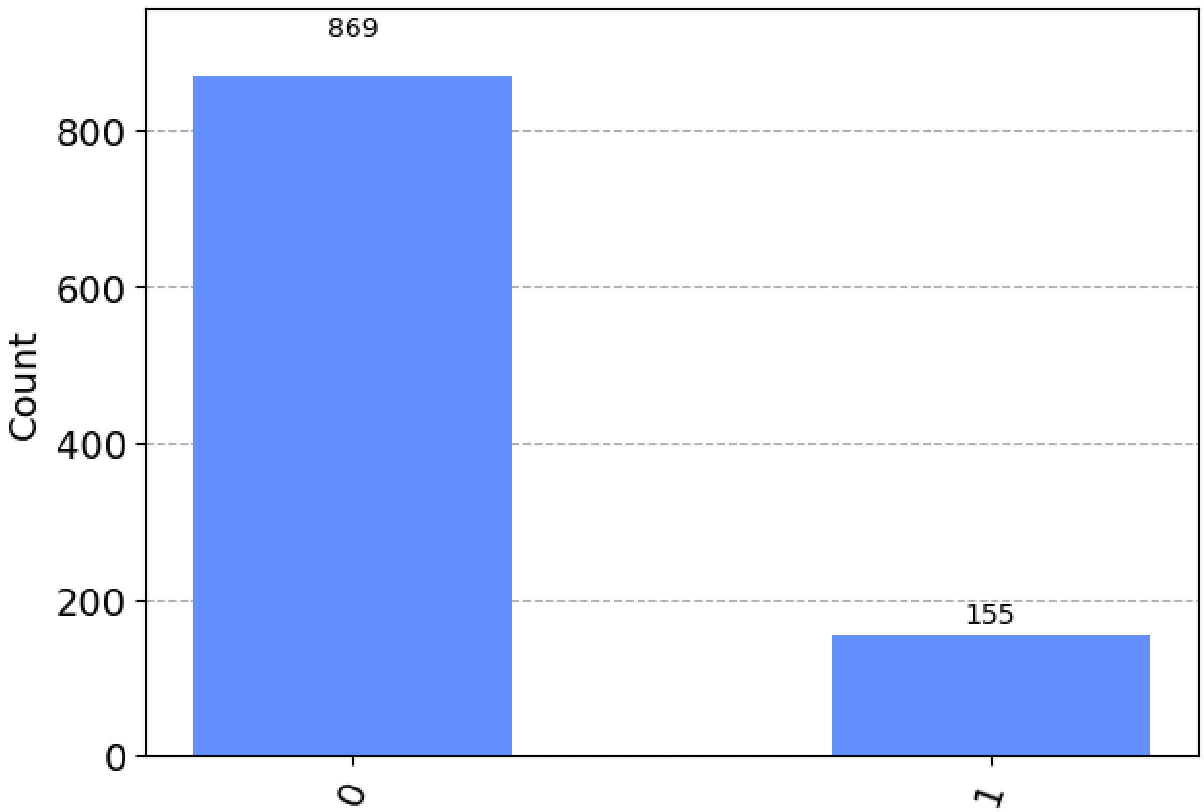



```
u_new = u.evolve(qc)
display(u_new.draw('latex'))

<IPython.core.display.Latex object>

display(plot_bloch_multivector(u_new))
```

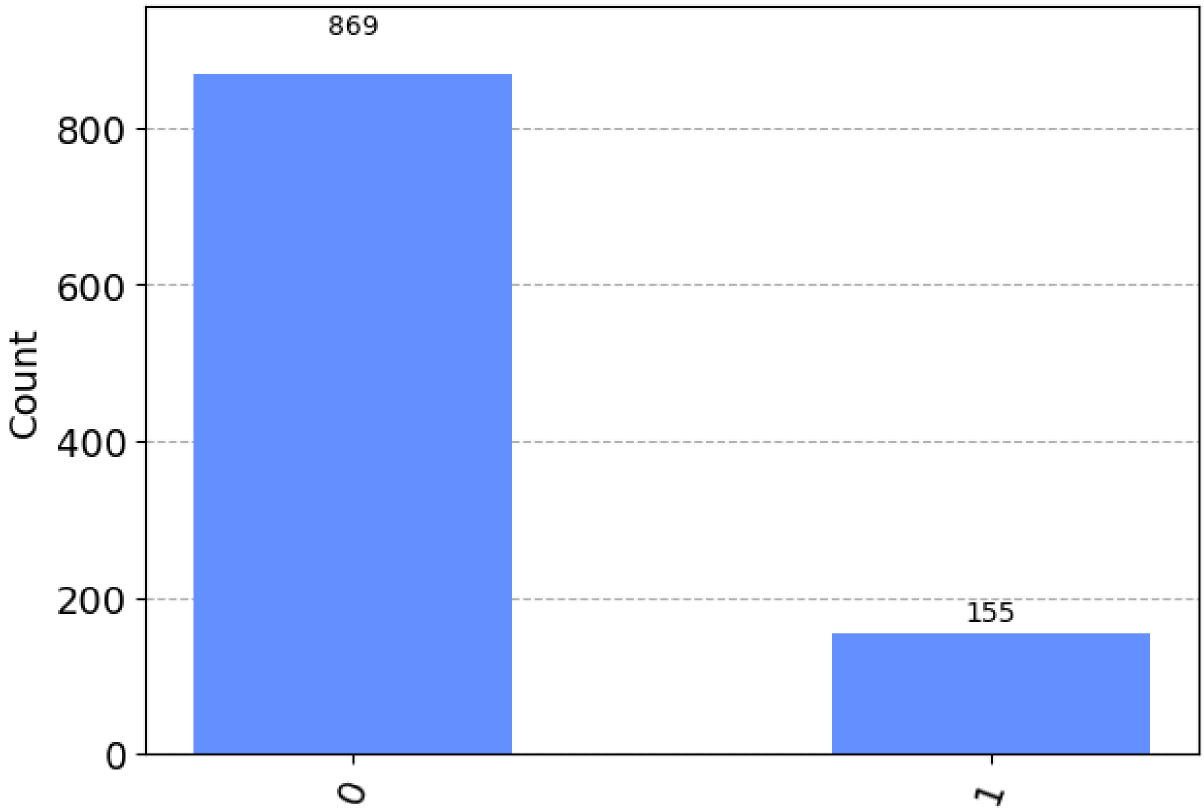


Let's simulate the our result of running the experiment like preparing the state ¿0⟩, applying the sequence of operations represented by the circuit and measuring 1024 times

```
stats = u_new.sample_counts(1024)
plot_histogram(stats)
```




```
stats = v_new.sample_counts(1024)
plot_histogram(stats)
```



Conclusion

Reference

1. Qiskit Textbook


```
import qiskit.tools.jupyter
%qiskit_version_table
%qiskit_copyright
```

```
<IPython.core.display.HTML object>
```

```
<IPython.core.display.HTML object>
```