Practical 1 - Setting up Qiskit and Basic Quantum circuit

Install the required packages

In [1]:
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!pip3 install qiskit
!pip3 install qiskit-ibm-runtime
!pip3 install qiskit[visualization]
!pip3 install qiskit-aer
!pip3 install matplotlib
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------------------------------- ------ 8.1/9.6 MB 281.8 kB/s eta 0:00:06
-------------------------------- ---- 8.4/9.6 MB 290.6 kB/s eta 0:00:05
------------------------------------ 9.4/9.6 MB 324.1 kB/s eta 0:00:01
------------------------------------ 9.4/9.6 MB 324.1 kB/s eta 0:00:01
------------------------------------ 9.4/9.6 MB 324.1 kB/s eta 0:00:01
------------------------------------ 9.6/9.6 MB 321.6 kB/s  0:00:29
Installing collected packages: qiskit-aer
Successfully installed qiskit-aer-0.17.2
Requirement already satisfied: matplotlib in c:\users\vinay\appdata\local\progr
ams\python\python312\lib\site-packages (3.10.5)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\vinay\appdata\loca
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Requirement already satisfied: cycler>=0.10 in c:\users\vinay\appdata\local\pro
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Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\loca
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Requirement already satisfied: pillow>=8 in c:\users\vinay\appdata\local\progra
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Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
n\python312\site-packages (from python-dateutil>=2.7->matplotlib) (1.17.0)
```

Import the packages

In [2]:
```python
from qiskit import QuantumCircuit
from qiskit_aer import Aer
```

```python
from qiskit.visualization import plot_bloch_multivector

import matplotlib.pyplot as plt
%matplotlib inline
```

In [3]:
```python
qc = QuantumCircuit(1)
```

In [4]:
```python
qc.h(0)
```

Out[4]: <qiskit.circuit.instructionset.InstructionSet at 0x20194641510>

Use the Aer backend simulator

In [5]:
```python
sim = Aer.get_backend('aer_simulator')
```

Save the statevector

In [6]:
```python
qc.save_statevector()
```

Out[6]: <qiskit.circuit.instructionset.InstructionSet at 0x20194642d40>

Execute the quantum circuit

In [7]:
```python
result = sim.run(qc).result()
```

Retrieve the current statevector

In [8]:
```python
state = result.get_statevector()
```

Visualize the statevector on a Bloch Sphere. The qubit |0> has been put in superposition |+>

In [11]:
```python
fig = plot_bloch_multivector(state)
# fig
```

qubit 0
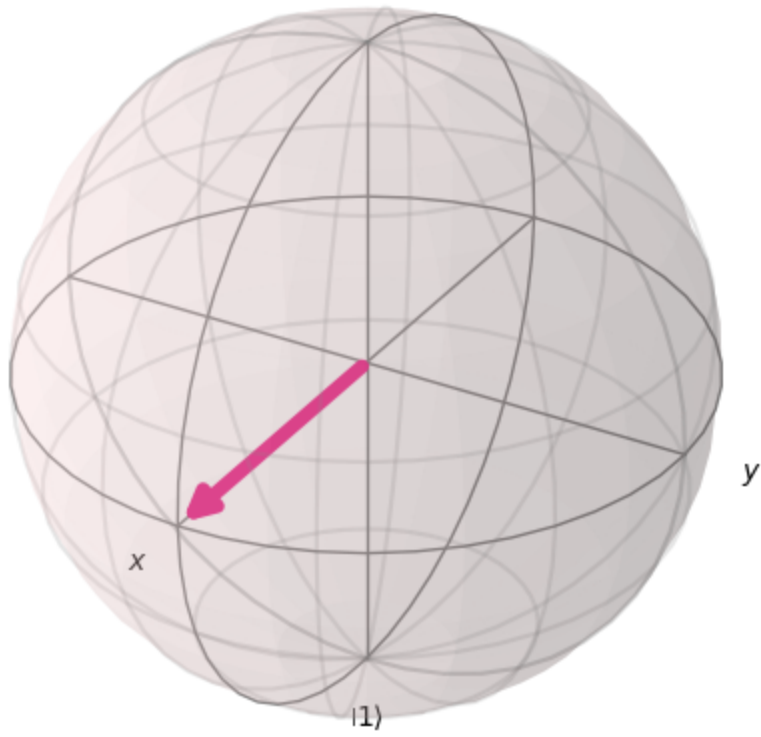
Practical 2 - Single Qubit Gates and Bloch Sphere Visulatization

In [1]:
```
!pip3 install qiskit
!pip3 install qiskit-ibm-runtime
!pip3 install qiskit[visualization]
!pip3 install qiskit-aer
!pip3 install matplotlib
```

```
Requirement already satisfied: qiskit in c:\users\vinay\appdata\local\programs\
python\python312\lib\site-packages (2.1.1)
Requirement already satisfied: rustworkx>=0.15.0 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from qiskit) (0.16.0)
Requirement already satisfied: numpy<3,>=1.17 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from qiskit) (2.3.2)
Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: dill>=0.3 in c:\users\vinay\appdata\local\progra
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Requirement already satisfied: stevedore>=3.0.0 in c:\users\vinay\appdata\loca
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Requirement already satisfied: typing-extensions in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from qiskit) (4.14.1)
Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\progr
ams\python\python312\lib\site-packages (from stevedore>=3.0.0->qiskit) (6.1.1)
Requirement already satisfied: setuptools in c:\users\vinay\appdata\local\progr
ams\python\python312\lib\site-packages (from pbr>=2.0.0->stevedore>=3.0.0->qisk
it) (80.9.0)
Requirement already satisfied: qiskit-ibm-runtime in c:\users\vinay\appdata\loc
al\programs\python\python312\lib\site-packages (0.41.0)
Requirement already satisfied: requests>=2.19 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.32.4)
Requirement already satisfied: requests-ntlm>=1.1.0 in c:\users\vinay\appdata\l
ocal\programs\python\python312\lib\site-packages (from qiskit-ibm-runtime)
(1.3.0)
Requirement already satisfied: numpy>=1.13 in c:\users\vinay\appdata\local\prog
rams\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.3.2)
Requirement already satisfied: urllib3>=1.21.1 in c:\users\vinay\appdata\local\
programs\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.5.0)
Requirement already satisfied: python-dateutil>=2.8.0 in c:\users\vinay\appdat
a\roaming\python\python312\site-packages (from qiskit-ibm-runtime) (2.9.0.post
0)
Requirement already satisfied: ibm-platform-services>=0.22.6 in c:\users\vinay\
appdata\local\programs\python\python312\lib\site-packages (from qiskit-ibm-runt
ime) (0.68.1)
Requirement already satisfied: pydantic>=2.5.0 in c:\users\vinay\appdata\local\
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Requirement already satisfied: qiskit>=1.4.1 in c:\users\vinay\appdata\local\pr
ograms\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.1.1)
Requirement already satisfied: packaging in c:\users\vinay\appdata\local\progra
ms\python\python312\lib\site-packages (from qiskit-ibm-runtime) (23.2)
Requirement already satisfied: ibm_cloud_sdk_core<4.0.0,>=3.24.2 in c:\users\vi
nay\appdata\local\programs\python\python312\lib\site-packages (from ibm-platfor
m-services>=0.22.6->qiskit-ibm-runtime) (3.24.2)
Requirement already satisfied: PyJWT<3.0.0,>=2.10.1 in c:\users\vinay\appdata\l
ocal\programs\python\python312\lib\site-packages (from ibm_cloud_sdk_cor
e<4.0.0,>=3.24.2->ibm-platform-services>=0.22.6->qiskit-ibm-runtime) (2.10.1)
Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
n\python312\site-packages (from python-dateutil>=2.8.0->qiskit-ibm-runtime)
(1.17.0)
Requirement already satisfied: charset_normalizer<4,>=2 in c:\users\vinay\appda
ta\local\programs\python\python312\lib\site-packages (from requests>=2.19->qisk
it-ibm-runtime) (3.4.2)
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Requirement already satisfied: idna<4,>=2.5 in c:\users\vinay\appdata\local\pro
grams\python\python312\lib\site-packages (from requests>=2.19->qiskit-ibm-runti
me) (3.10)
Requirement already satisfied: certifi>=2017.4.17 in c:\users\vinay\appdata\loc
al\programs\python\python312\lib\site-packages (from requests>=2.19->qiskit-ib
m-runtime) (2025.8.3)
Requirement already satisfied: annotated-types>=0.6.0 in c:\users\vinay\appdat
a\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qisk
it-ibm-runtime) (0.7.0)
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t-ibm-runtime) (2.33.2)
Requirement already satisfied: typing-extensions>=4.12.2 in c:\users\vinay\appd
ata\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qi
skit-ibm-runtime) (4.14.1)
Requirement already satisfied: typing-inspection>=0.4.0 in c:\users\vinay\appda
ta\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qis
kit-ibm-runtime) (0.4.1)
Requirement already satisfied: rustworkx>=0.15.0 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from qiskit>=1.4.1->qiskit-ibm-r
untime) (0.16.0)
Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\progr
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ms\python\python312\lib\site-packages (from qiskit>=1.4.1->qiskit-ibm-runtime)
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Requirement already satisfied: stevedore>=3.0.0 in c:\users\vinay\appdata\loca
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untime) (5.4.1)
Requirement already satisfied: cryptography>=1.3 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from requests-ntlm>=1.1.0->qiski
t-ibm-runtime) (45.0.6)
Requirement already satisfied: pyspnego>=0.4.0 in c:\users\vinay\appdata\local\
programs\python\python312\lib\site-packages (from requests-ntlm>=1.1.0->qiskit-
ibm-runtime) (0.11.2)
Requirement already satisfied: cffi>=1.14 in c:\users\vinay\appdata\local\progr
ams\python\python312\lib\site-packages (from cryptography>=1.3->requests-ntl
m>=1.1.0->qiskit-ibm-runtime) (1.17.1)
Requirement already satisfied: pycparser in c:\users\vinay\appdata\local\progra
ms\python\python312\lib\site-packages (from cffi>=1.14->cryptography>=1.3->requ
ests-ntlm>=1.1.0->qiskit-ibm-runtime) (2.22)
Requirement already satisfied: sspilib>=0.1.0 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from pyspnego>=0.4.0->requests-ntl
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Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: numpy<3,>=1.17 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (2.3.2)
Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (1.16.1)
Requirement already satisfied: dill>=0.3 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (0.4.0)
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Requirement already satisfied: matplotlib>=3.3 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (3.10.5)
Requirement already satisfied: pydot in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (4.0.1)
Requirement already satisfied: Pillow>=4.2.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (11.3.0)
Requirement already satisfied: pylatexenc>=1.4 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (2.10)
Requirement already satisfied: seaborn>=0.9.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (0.13.2)
Requirement already satisfied: sympy>=1.3 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit[visualization]) (1.14.0)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (1.3.3)
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Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (4.59.0)
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (1.4.8)
Requirement already satisfied: packaging>=20.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (23.2)
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Requirement already satisfied: pandas>=1.2 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from seaborn>=0.9.0->qiskit[visualizat

ion]) (2.3.1)
Requirement already satisfied: pytz>=2020.1 in c:\users\vinay\appdata\local\pro
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kit[visualization]) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from pandas>=1.2->seaborn>=0.9.0->q
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Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: mpmath<1.4,>=1.1.0 in c:\users\vinay\appdata\loc
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Requirement already satisfied: scipy>=1.0 in c:\users\vinay\appdata\local\progr
ams\python\python312\lib\site-packages (from qiskit-aer) (1.16.1)
Requirement already satisfied: psutil>=5 in c:\users\vinay\appdata\roaming\pyth
on\python312\site-packages (from qiskit-aer) (6.1.1)
Requirement already satisfied: python-dateutil>=2.8.0 in c:\users\vinay\appdat
a\roaming\python\python312\site-packages (from qiskit-aer) (2.9.0.post0)
Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
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Requirement already satisfied: rustworkx>=0.15.0 in c:\users\vinay\appdata\loca
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Requirement already satisfied: typing-extensions in c:\users\vinay\appdata\loca
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iskit-aer) (6.1.1)
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ams\python\python312\lib\site-packages (from pbr>=2.0.0->stevedore>=3.0.0->qisk
it>=1.1.0->qiskit-aer) (80.9.0)
Requirement already satisfied: matplotlib in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: cycler>=0.10 in c:\users\vinay\appdata\local\pro
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Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\loca

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Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\vinay\appdata\loca
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Requirement already satisfied: numpy>=1.23 in c:\users\vinay\appdata\local\prog
rams\python\python312\lib\site-packages (from matplotlib) (2.3.2)
Requirement already satisfied: packaging>=20.0 in c:\users\vinay\appdata\local\
programs\python\python312\lib\site-packages (from matplotlib) (23.2)
Requirement already satisfied: pillow>=8 in c:\users\vinay\appdata\local\progra
ms\python\python312\lib\site-packages (from matplotlib) (11.3.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from matplotlib) (3.2.3)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\vinay\appdata\r
oaming\python\python312\site-packages (from matplotlib) (2.9.0.post0)
Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
n\python312\site-packages (from python-dateutil>=2.7->matplotlib) (1.17.0)
```

In [2]:
```python
from qiskit import QuantumCircuit
from qiskit_aer import Aer
from qiskit.visualization import plot_bloch_multivector

import matplotlib.pyplot as plt
%matplotlib inline
```

1. Use the Aer backend simulator - Simulate Quantum circuit on local machine
2. Save the current state-vector
3. Execute the quantum circuit
4. Retrieve the current state vector
5. Visualize the statevector on a Bloch Sphere.

In [7]:
```python
qc = QuantumCircuit(4)
```

In [8]:
```python
sim = Aer.get_backend("aer_simulator")
qc.save_statevector()
result = sim.run(qc).result()
state = result.get_statevector()

fig = plot_bloch_multivector(state)
# fig
```
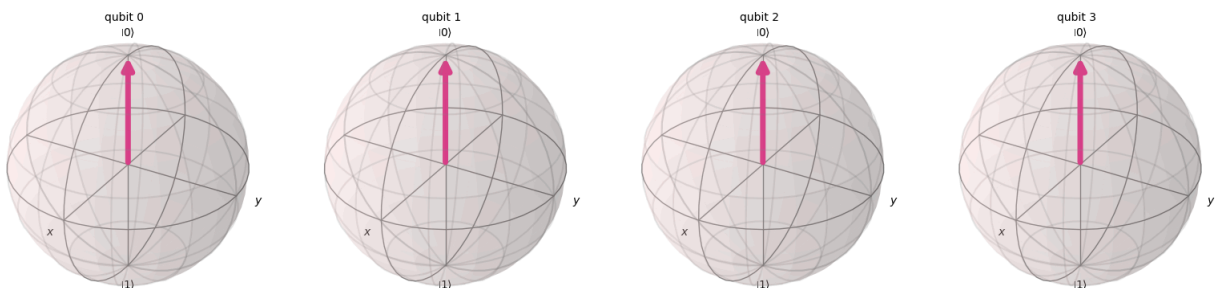
```
In [9]:   qc_gates = QuantumCircuit(4)
```

```
In [10]:  qc_gates.h(0)
          qc_gates.x(1)
          qc_gates.y(2)
          qc_gates.z(3)
```

Out[10]: <qiskit.circuit.instructionset.InstructionSet at 0x2022913e7d0>

```
In [11]:  sim = Aer.get_backend("aer_simulator")
          qc_gates.save_statevector()
          result = sim.run(qc_gates).result()
          state_gates = result.get_statevector()

          fig = plot_bloch_multivector(state_gates)
          # fig
```
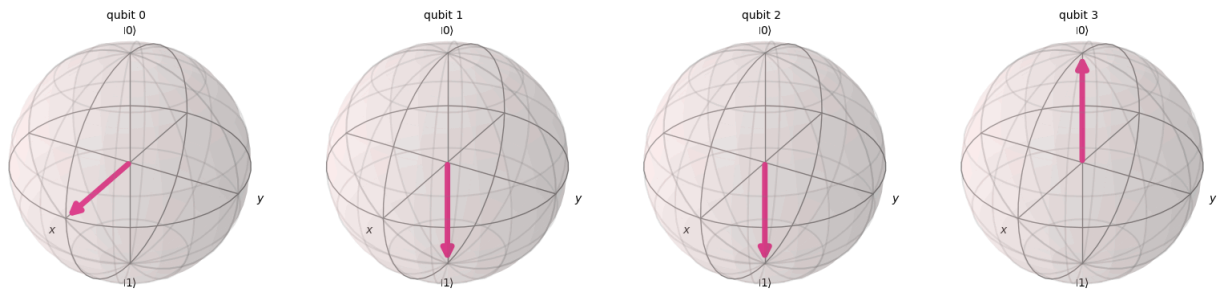
Practical 3 - Multiple Qubits system and Entanglement

Install the necessary packages

```
In [13]:  !pip3 install qiskit
          !pip3 install qiskit-ibm-runtime
          !pip3 install qiskit[visualization]
          !pip3 install qiskit-aer
          !pip3 install matplotlib
```

```
Requirement already satisfied: qiskit in c:\users\vinay\appdata\local\programs\
python\python312\lib\site-packages (2.1.1)
Requirement already satisfied: rustworkx>=0.15.0 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from qiskit) (0.16.0)
Requirement already satisfied: numpy<3,>=1.17 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from qiskit) (2.3.2)
Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: dill>=0.3 in c:\users\vinay\appdata\local\progra
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Requirement already satisfied: stevedore>=3.0.0 in c:\users\vinay\appdata\loca
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Requirement already satisfied: typing-extensions in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from qiskit) (4.14.1)
Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: setuptools in c:\users\vinay\appdata\local\progr
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it) (80.9.0)
Requirement already satisfied: qiskit-ibm-runtime in c:\users\vinay\appdata\loc
al\programs\python\python312\lib\site-packages (0.41.0)
Requirement already satisfied: requests>=2.19 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.32.4)
Requirement already satisfied: requests-ntlm>=1.1.0 in c:\users\vinay\appdata\l
ocal\programs\python\python312\lib\site-packages (from qiskit-ibm-runtime)
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Requirement already satisfied: urllib3>=1.21.1 in c:\users\vinay\appdata\local\
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ime) (0.68.1)
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nay\appdata\local\programs\python\python312\lib\site-packages (from ibm-platfor
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Requirement already satisfied: PyJWT<3.0.0,>=2.10.1 in c:\users\vinay\appdata\l
ocal\programs\python\python312\lib\site-packages (from ibm_cloud_sdk_cor
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Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
n\python312\site-packages (from python-dateutil>=2.8.0->qiskit-ibm-runtime)
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ta\local\programs\python\python312\lib\site-packages (from requests>=2.19->qisk
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Requirement already satisfied: typing-extensions>=4.12.2 in c:\users\vinay\appd
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Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (4.59.0)
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Requirement already satisfied: packaging>=20.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (23.2)
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Requirement already satisfied: pandas>=1.2 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from seaborn>=0.9.0->qiskit[visualizat

ion]) (2.3.1)
Requirement already satisfied: pytz>=2020.1 in c:\users\vinay\appdata\local\pro
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Requirement already satisfied: tzdata>=2022.7 in c:\users\vinay\appdata\local\p
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Requirement already satisfied: mpmath<1.4,>=1.1.0 in c:\users\vinay\appdata\loc
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grams\python\python312\lib\site-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\loca

Import the necessary modules

In [14]:
```python
from qiskit import QuantumCircuit
from qiskit_aer import Aer
from qiskit.visualization import plot_bloch_multivector
import matplotlib.pyplot as plt
%matplotlib inline

# from from google.colab google.colab import import drive drive
from IPython.display import display, Image
```

Create a Quatum Circuit with two qubits

In [18]:
```python
qc = QuantumCircuit(2)
```

Apply Hadamard gate on the qubit-0

In [19]:
```python
qc.h(0)
```

Out[19]: <qiskit.circuit.instructionset.InstructionSet at 0x1dba2693b50>

Apply CNOT(CX) gate with qubit-0 as control qubit and qubit-1 as target qubit to create the Bell States

In [20]:
```python
qc.cx(0,1)
```

Out[20]: <qiskit.circuit.instructionset.InstructionSet at 0x1dba37007f0>

Use the Aer backend simulator

In [21]:
```python
sim = Aer.get_backend("aer_simulator")
```

Save the current statevector

```
In [22]:  qc.save_statevector()
```

```
Out[22]:  <qiskit.circuit.instructionset.InstructionSet at 0x1dba268d0f0>
```

Execute the quantum circuit

```
In [23]:  result = sim.run(qc).result()
```

Retrieve the current statevector

```
In [24]:  state = result.get_statevector()
```

Visualize the statevector on a Bloch Sphere. This shows that the individual qubits are in mixed state, when measured the qubits collapse to the base state in entangled mode i.e., based on state of one qubit we can deduce the state of the other qubit.

```
In [28]:  # drive.mount( "/content/drive" )
          fig = plot_bloch_multivector(state)

          filename = "./Images/Practical-3_Entanglement_Bell_State_Bloch_Sphere.png"
          fig.savefig(filename)
          plt.close(fig)
          display(Image(filename))
```
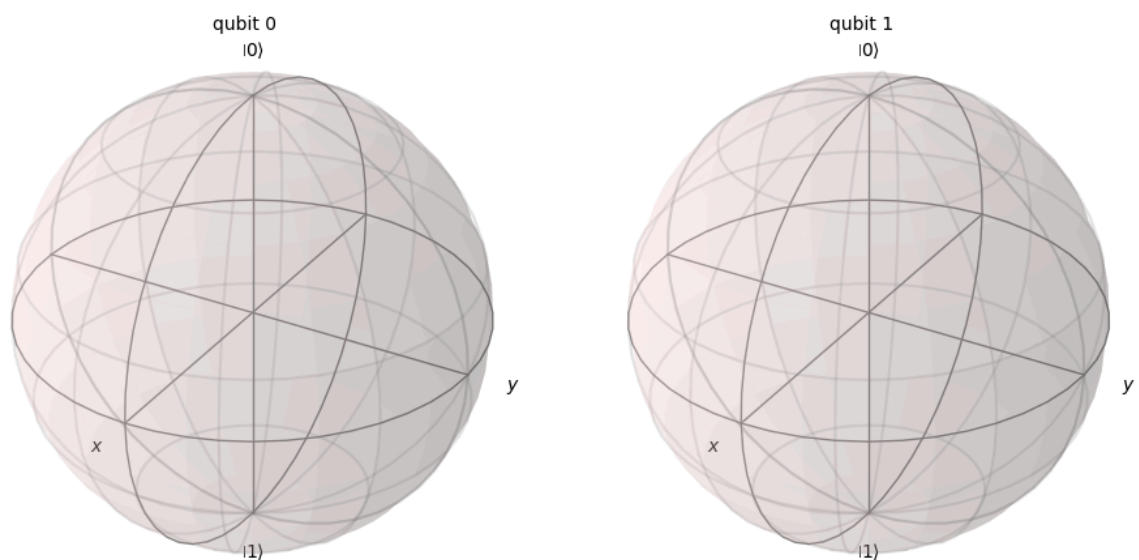

This is how the qubits are visible

Img_P3

Practical 4 - Quantum Teleportation

In [1]:
```
!pip3 install qiskit
!pip3 install qiskit_aer
!pip3 install qiskit[quantum_info]
!pip3 install qiskit[visualization]
```

```
Requirement already satisfied: qiskit in c:\users\vinay\appdata\local\programs\
python\python312\lib\site-packages (2.1.1)
Requirement already satisfied: rustworkx>=0.15.0 in c:\users\vinay\appdata\loca
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WARNING: qiskit 2.1.1 does not provide the extra 'quantum-info'
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al\programs\python\python312\lib\site-packages (from sympy>=1.3->qiskit[visuali
zation]) (1.3.0)
```

In [2]:
```python
from qiskit import QuantumCircuit, transpile
from qiskit_aer import AerSimulator
from qiskit.quantum_info import state_fidelity, partial_trace, Statevector
from qiskit.visualization import plot_histogram
```

In [3]:
```python
# Step 1: Prepare the initial state to teleport on qubit 0
initial_qc = QuantumCircuit(1)
initial_qc.h(0)
initial_qc.t(0)
initial_state = Statevector.from_instruction(initial_qc)
```

In [4]:
```python
# Step 2: Create quantum circuit with 3 qubits and 3 classical bits
qc = QuantumCircuit(3, 3)
```

In [5]:
```python
# Step 3: Prepare qubit 0 to be teleported (T gate)
qc.h(0)
qc.t(0)
```

Out[5]: <qiskit.circuit.instructionset.InstructionSet at 0x1df0c9331c0>

In [6]:
```python
# Step 4: Create entangled Bell pair (qubits 1 & 2)
qc.h(1)
qc.cx(1, 2)
```

Out[6]: <qiskit.circuit.instructionset.InstructionSet at 0x1df0c931b70>

In [7]:
```python
# Step 5: Teleportation protocol
qc.cx(0, 1)
qc.h(0)
```

Out[7]: <qiskit.circuit.instructionset.InstructionSet at 0x1dfa6b8c640>

```
In [8]:   # Step 6: Measure qubits 0 & 1 and store results
          qc.measure([0, 1], [0, 1])
```

Out[8]:   <qiskit.circuit.instructionset.InstructionSet at 0x1dfa6a52110>

```
In [9]:   # Step 7: Conditional corrections based on measurement outcomes
          qc.cx(1, 2)
          qc.cz(0, 2)
```

Out[9]:   <qiskit.circuit.instructionset.InstructionSet at 0x1dfa6b8e5f0>

```
In [10]:  # Step 8: Save the statevector before measuring qubit 2
          qc.save_statevector()
```

Out[10]: <qiskit.circuit.instructionset.InstructionSet at 0x1df0c9323e0>

```
In [11]:  # Step 9: Measure the destination qubit (qubit 2)
          qc.measure(2, 2)
```

Out[11]: <qiskit.circuit.instructionset.InstructionSet at 0x1dfa6b1e9e0>

```
In [12]:  # Step 10: Remove final measurements for statevector output
          qc_no_meas = qc.remove_final_measurements(inplace=False)
```

```
In [13]:  # Step 11: Create AerSimulator with statevector method
          sim = AerSimulator(method='statevector')
          qc_compiled = transpile(qc_no_meas, sim)
```

```
In [14]:  # Step 12: Run simulation and get statevector
          result = sim.run(qc_compiled).result()
          final_state = result.get_statevector()
```

```
In [15]:  # Step 13: Partial trace to get qubit 2 state
          rho_out = partial_trace(final_state, [0, 1])
```

```
In [16]:  # Step 14: Calculate fidelity
          fidelity = state_fidelity(initial_state, rho_out)
          print(f"Fidelity between input and teleported qubit: {fidelity:.1f}")
```

          Fidelity between input and teleported qubit: 1.0

Pratical 5 - Desutsch Algorithm

In [1]:
```
!pip3 install qiskit
!pip3 install qiskit_aer
!pip3 install qiskit[visualization]
```

```
Requirement already satisfied: qiskit in c:\users\vinay\appdata\local\programs\
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rams\python\python312\lib\site-packages (from seaborn>=0.9.0->qiskit[visualizat
ion]) (2.3.1)

In [2]:
```python
import matplotlib.pyplot as plt
%matplotlib inline
from qiskit import QuantumCircuit
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram
```

In [3]:
```python
def constant_oracle_0():
    """Oracle for f(x) = 0 (constant) - identity"""
    oracle = QuantumCircuit(2)
    return oracle
```

In [4]:
```python
def constant_oracle_1():
    """Oracle for f(x) = 1 (constant) - flips the output qubit"""
    oracle = QuantumCircuit(2)
    oracle.x(1)
    return oracle
```

In [5]:
```python
def balanced_oracle_x():
    """Oracle for f(x) = x (balanced) - CNOT gate"""
    oracle = QuantumCircuit(2)
    oracle.cx(0, 1)
    return oracle
```

In [6]:
```python
def deutsch_algorithm(oracle):
    # Create a 2-qubit, 1-classical-bit circuit
    qc = QuantumCircuit(2, 1)
    # Initialize second qubit to |1>
    qc.x(1)
    # Apply Hadamard on both qubits
    qc.h([0, 1])
    qc.barrier() # add a barrier for readability
    # Apply the oracle
    qc.compose(oracle, inplace=True) # append the oracle circuit to qc
    qc.barrier()
    # Apply Hadamard on the first qubit
    qc.h(0)
```

```
        # Measure the first qubit
        qc.measure(0, 0)
        return qc
```

In [7]:
```
# Select oracle to test; change to test different oracles
oracle = balanced_oracle_x()
```

In [8]:
```
# Create the Deutsch algorithm circuit with the chosen oracle
circuit = deutsch_algorithm(oracle)
print(circuit.draw())
```

```
q_0: ┤ H ├──────────────■──────┤ H ├┤M├
     └───┘┌───┐     ┌───┴───┐   └───┘└╥┘
q_1: ┤ X ├┤ H ├─────┤   X   ├──────────╫─
     └───┘└───┘     └───────┘          ║
c: 1/══════════════════════════════════╩═
                                       0
```
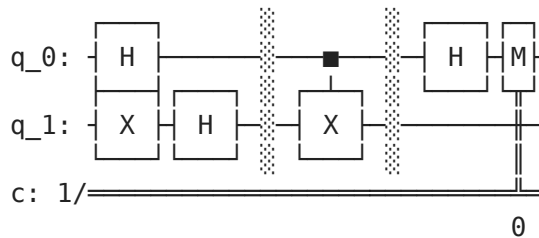
In [9]:
```
# Use Qiskit Aer simulator
simulator = AerSimulator()
```

In [10]:
```
# Execute the circuit on the simulator with 100 shots
result = simulator.run(circuit, shots=100).result()
counts = result.get_counts()

print("Measurement results:", counts)
```

```
Measurement results: {'1': 100}
```

In [11]:
```
# Plot the results
hist_fig = plot_histogram(counts)
hist_fig
```
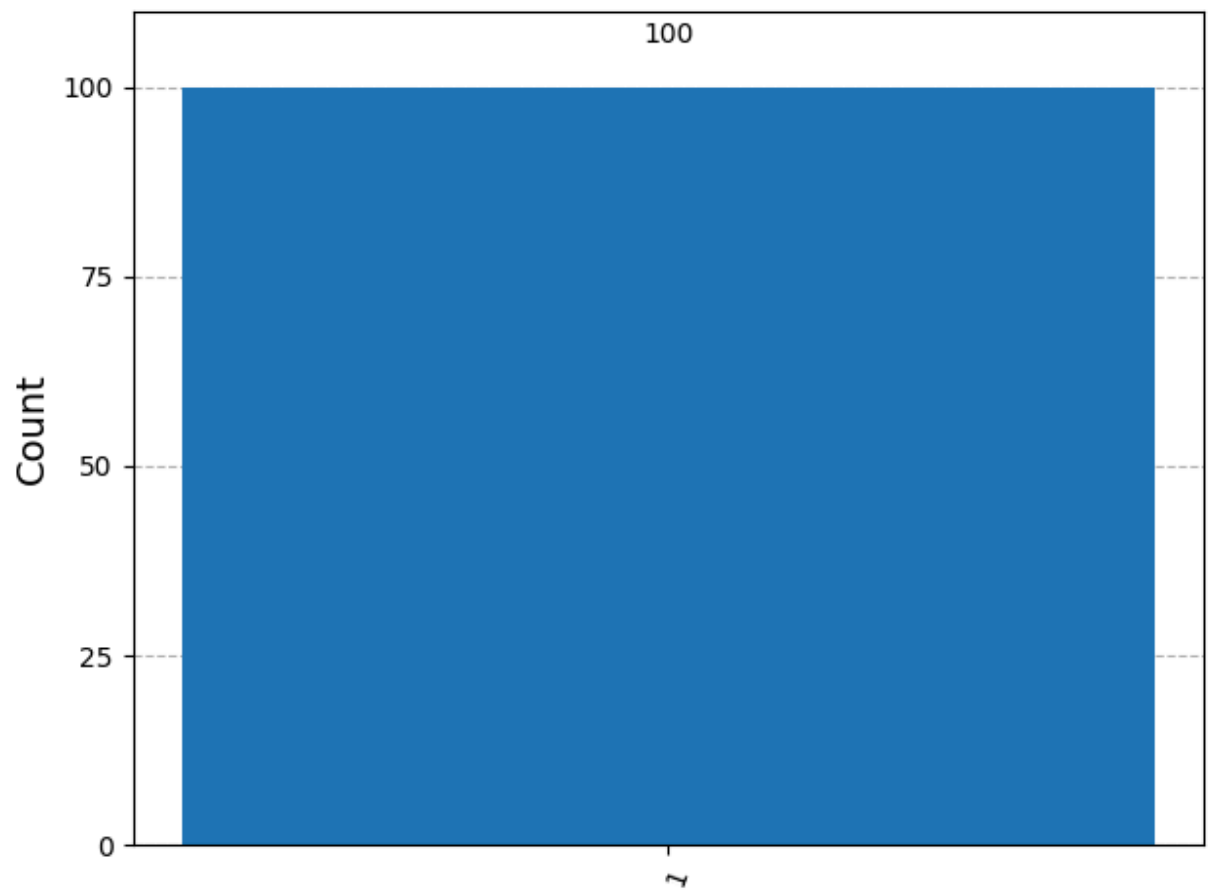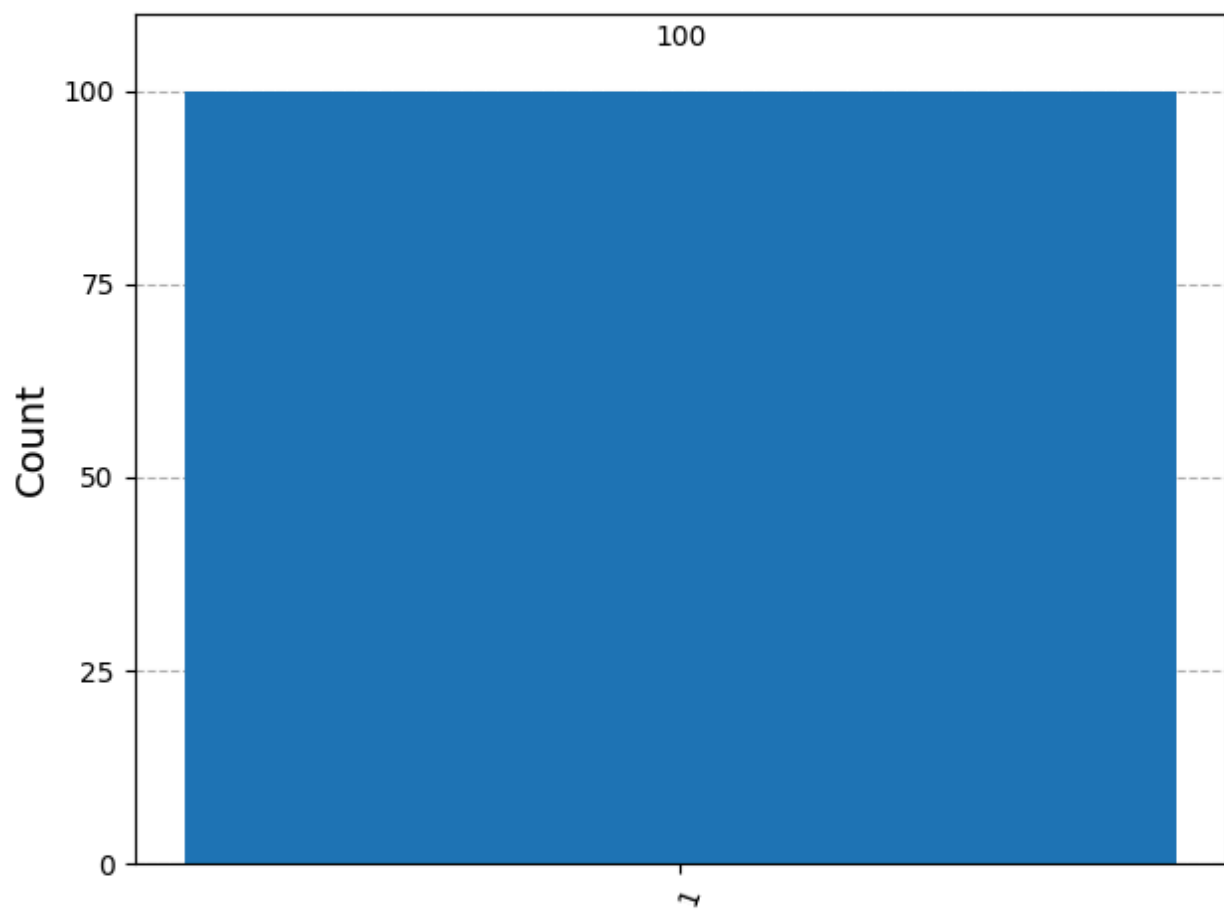
Practical 6 - Deutsch Jozsa Alogrithm

In [1]:
```
!pip install qiskit
!pip install qiskit_aer
!pip install qiskit[visualization]
```

```
Requirement already satisfied: qiskit in c:\users\vinay\appdata\local\programs\
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Requirement already satisfied: rustworkx>=0.15.0 in c:\users\vinay\appdata\loca
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Requirement already satisfied: numpy<3,>=1.17 in c:\users\vinay\appdata\local\p
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Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: typing-extensions in c:\users\vinay\appdata\loca
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Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: setuptools in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: qiskit_aer in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: qiskit>=1.1.0 in c:\users\vinay\appdata\local\pr
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```

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

In [3]:
```python
def dj_oracle( n, balanced = True ):
    oracle = QuantumCircuit ( n + 1 )
    if balanced:
        for qubit in range( n ):
            oracle.cx( qubit, n )
    else:
        pass
    return oracle
```

In [4]:
```python
def deutsch_joza( n, oracle ):
    circuit = QuantumCircuit( n+1, n )
    circuit.x( n )
    circuit.h( n )
    circuit.h( range( n ) )
    circuit.compose( oracle, inplace = True )
    circuit.h( range( n ) )
    circuit.measure( range( n ), range( n ) )
    return circuit
```

In [5]:
```python
n = 3
oracle = dj_oracle( n, balanced = True )
dj_circuit = deutsch_joza( n, oracle )

# Use AerSimulator from qiskit_aer
simulator = AerSimulator()

job = simulator.run( dj_circuit, shots = 1024 )
result = job.result()
counts = result.get_counts()

print( "Measurement results:", counts )

if '0'*n in counts:
```

```
        print( "Function is constant." )
    else:
        print( "Function is balanced." )

    dj_circuit.draw( "mpl")
    result = job.result()

    dj_circuit.draw( "mpl")
    plot_histogram( counts )
```

Measurement results: {'111': 1024}
Function is balanced.
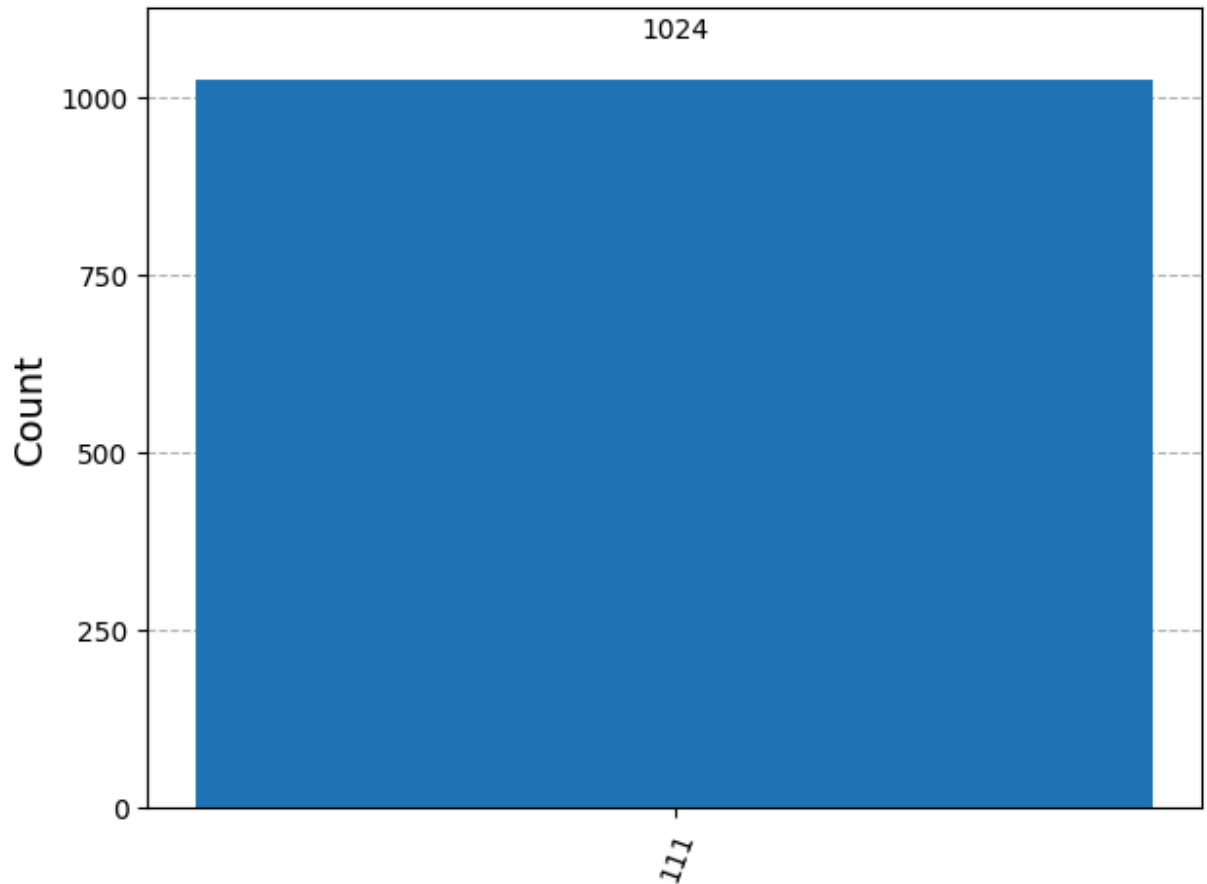
Practical 7 - Grover Algorithm

Grover's Algo

```
In [19]:  !pip install qiskit
          !pip install qiskit_aer
          !pip install qiskit[visualization]
```

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In [20]:
```python
from qiskit import QuantumCircuit, transpile
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram
import math
import matplotlib.pyplot as plt
```

In [21]:
```python
from qiskit import QuantumCircuit

def oracle_for_value(n_qubits, values, search_value):
    """
    Constructs an oracle which flips the phase of all indices
    where the element in 'values' equals 'search_value'.
    """
    oracle = QuantumCircuit(n_qubits, name='oracle')

    # Mark all indices i where values[i] == search_value
    for i, val in enumerate(values):
        if val == search_value:
            # --- This entire block must be indented ---

            # Apply X gates on qubits where the bit of i is '0'
            bits = format(i, f'0{n_qubits}b')
            for qubit, bit in enumerate(reversed(bits)):
                if bit == '0':
                    oracle.x(qubit)

            # Apply multi-controlled Z-gate (implemented with h, mcx, h)
            oracle.h(n_qubits - 1)
            oracle.mcx(list(range(n_qubits - 1)), n_qubits - 1)
            oracle.h(n_qubits - 1)

            # Uncompute the X gates to return to the original state
            for qubit, bit in enumerate(reversed(bits)):
                if bit == '0':
                    oracle.x(qubit)

            # Optional: Add a barrier for better visualization between marked
```

```
        oracle.barrier()

    return oracle
```

```
In [22]: def diffuser( n_qubits ):
           diff = QuantumCircuit( n_qubits)
           diff.h( range(n_qubits))
           diff.x( range(n_qubits))
           diff.h( n_qubits - 1 )
           diff.mcx( list (range( n_qubits - 1 ) ), n_qubits - 1 )
           diff.h( n_qubits - 1 )
           diff.x( range( n_qubits ) )
           diff.h( range( n_qubits ) )
           return diff
```

```
In [23]: def run_grover( n_qubits, oracle, search_value_occurrences ):
           iterations = math.floor( ( math.pi / 4 ) * math.sqrt( 2**n_qubits / search_v
           qc = QuantumCircuit( n_qubits, n_qubits )
           qc.h( range( n_qubits ) )
           diff = diffuser( n_qubits )
           for _ in range(iterations):
             qc.compose( oracle, inplace = True )
             qc.compose( diff, inplace = True )

           qc.measure( range( n_qubits ), range( n_qubits ) )
           simulator = AerSimulator()
           compiled_circuit = transpile( qc, simulator )
           result = simulator.run( compiled_circuit, shots=1024 ).result()
           counts = result.get_counts()
           return counts
```

```
In [24]: values = [4, 2, 5, 8, 7]
         search_value = 5
```

```
In [25]: # Number of qubits to cover index range
         n_qubits = 3
         # Build oracle without target index knowledge
         oracle = oracle_for_value( n_qubits, values, search_value )
         oracle.draw(output='mpl')
```

Out[25]:
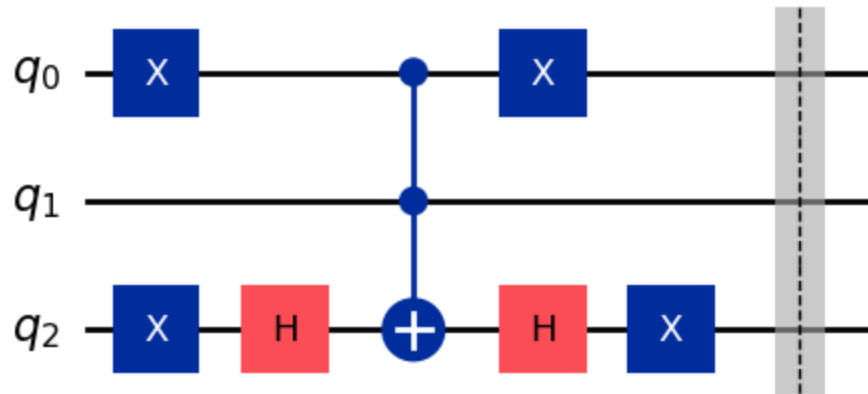
In [26]:
```python
# How many indices have search_value? In this example just one
search_value_occurrences = 0
for i in range( len( values ) ):
  if values[ i ] == search_value:
    search_value_occurrences += 1
    counts = run_grover( n_qubits, oracle, search_value_occurrences )
print( f"Measurement counts (index of '{search_value}' showing high probabilit
fig, ax = plt.subplots( figsize = ( 8, 6 ) ) # Create figure and axis
plot_histogram( counts, ax = ax )
plt.show()
```

Measurement counts (index of '5' showing high probability):
 {'010': 968, '000': 10, '011': 14, '110': 4, '111': 9, '100': 6, '101': 7, '00
1': 6}

```
In [1]: !pip install qiskit
        !pip install qiskit-aer
        !pip install qiskit[visualization]
```

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Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
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```
6.0)
Requirement already satisfied: numpy<3,>=1.17 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from qiskit[visualization]) (2.3.2)
Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\progr
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Requirement already satisfied: matplotlib>=3.3 in c:\users\vinay\appdata\local\
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Requirement already satisfied: pydot in c:\users\vinay\appdata\local\programs\p
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Requirement already satisfied: Pillow>=4.2.1 in c:\users\vinay\appdata\local\pr
ograms\python\python312\lib\site-packages (from qiskit[visualization]) (11.3.0)
Requirement already satisfied: pylatexenc>=1.4 in c:\users\vinay\appdata\local\
programs\python\python312\lib\site-packages (from qiskit[visualization]) (2.10)
Requirement already satisfied: seaborn>=0.9.0 in c:\users\vinay\appdata\local\p
rograms\python\python312\lib\site-packages (from qiskit[visualization]) (0.1
3.2)
Requirement already satisfied: sympy>=1.3 in c:\users\vinay\appdata\local\progr
ams\python\python312\lib\site-packages (from qiskit[visualization]) (1.14.0)
Requirement already satisfied: contourpy>=1.0.1 in c:\users\vinay\appdata\loca
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ualization]) (1.3.3)
Requirement already satisfied: cycler>=0.10 in c:\users\vinay\appdata\local\pro
grams\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualiz
ation]) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[vis
ualization]) (4.59.0)
Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\vinay\appdata\loca
l\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[vis
ualization]) (1.4.8)
Requirement already satisfied: packaging>=20.0 in c:\users\vinay\appdata\local\
programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visua
lization]) (23.2)
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l\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[vis
ualization]) (3.2.3)
Requirement already satisfied: python-dateutil>=2.7 in c:\users\vinay\appdata\r
oaming\python\python312\site-packages (from matplotlib>=3.3->qiskit[visualizati
on]) (2.9.0.post0)
Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\pytho
n\python312\site-packages (from python-dateutil>=2.7->matplotlib>=3.3->qiskit[v
isualization]) (1.17.0)
Requirement already satisfied: pandas>=1.2 in c:\users\vinay\appdata\local\prog
rams\python\python312\lib\site-packages (from seaborn>=0.9.0->qiskit[visualizat
ion]) (2.3.1)
```

In [2]:
```python
from qiskit import QuantumCircuit
from qiskit_aer import AerSimulator
from qiskit.visualization import plot_histogram
import math
from fractions import Fraction
```

In [3]:
```python
def continued_fraction( x, max_denominator ):
    frac = Fraction( x ).limit_denominator( max_denominator )
    return frac.denominator
```

In [4]:
```python
def quantum_order_finding( a, N ):
    n = int( math.ceil( math.log2( N ) ) )

    qc = QuantumCircuit( 2*n + n, 2*n )
    qc.x( 2*n + n - 1 )
    qc.h( range( 2*n ) )

    # Inverse QFT on upper register (simplified)
    for qubit in range( 2*n // 2 ):
        qc.swap( qubit, 2*n - qubit - 1 )
    for j in range( 2*n ):
        for m in range( j ):
            qc.cp( -math.pi / float( 2 ** ( j - m ) ), m, j )
        qc.h( j )

    qc.measure( range( 2*n ), range( 2*n ) )

    simulator = AerSimulator()
    job = simulator.run( qc, shots = 1024 )
    result = job.result()
    counts = result.get_counts()

    measured = max( counts, key = counts.get )
    decimal = int( measured, 2 )

    phase = decimal / ( 2 ** ( 2 * n ) )
    r = continued_fraction( phase, N )
```

```
        return r
```

```python
def find_factors( N ):
    for a in range( 2, N ):
        if math.gcd( a, N ) != 1:
            factor = math.gcd(a, N)
            print( f"Found non-trivial factor {factor} by gcd with a={a}" )
            return factor

        print( f"Trying a = {a}" )
        r = quantum_order_finding (a, N )
        print( f"Estimated order r = {r}" )

        if r is None or r % 2 != 0:
            print( f"r = {r} is odd or None; trying next a" )
            continue

        x = pow( a, r // 2, N )

        if x == N - 1:
            print( "x ≡ -1 mod N; trying next a" )
            continue

        factor1 = math.gcd( x - 1, N )
        factor2 = math.gcd( x + 1, N )

        print( f"Possible factors: {factor1}, {factor2}" )
        if factor1 != 1 and factor1 != N:
            print( f"Non-trivial factor found: {factor1}" )
            return factor1

        if factor2 != 1 and factor2 != N:
            print (f"Non-trivial factor found: {factor2}" )
            return factor2

    print("Failed to find factors with all candidates")
    return None
```

```python
N = 11235
factor = find_factors(N)
print(f"Result: factor of {N} is {factor}")
```

```
Trying a = 2
Estimated order r = 1
r = 1 is odd or None; trying next a
Found non-trivial factor 3 by gcd with a=3
Result: factor of 11235 is 3
```