Installation

In [1]:
```
import numpy as np
from numpy import pi

from qiskit import QuantumCircuit, transpile, assemble, Aer, IBMQ
from qiskit.providers.ibmq import least_busy
from qiskit.tools.monitor import job_monitor
from qiskit.visualization import plot_histogram, plot_bloch_multivector
```

General QFT

In [2]:
```
def qft(circuit, n):
    """QFT on the first n qubits in circuit"""
    qft_rotations(circuit, n)
    swap_registers(circuit, n)
    return circuit

def qft_rotations(circuit, n):
    if n == 0: # Exit function if circuit is empty
        return circuit
    n -= 1 # Indexes start from 0
    circuit.h(n) # Apply the H-gate to the most significant qubit
    for qubit in range(n):
        # For each less significant qubit, we need to do a
        # smaller-angled controlled rotation:
        circuit.cp(pi/2**(n-qubit), qubit, n)

    # At the end of our function, we call the same function again on
    # the next qubits (we reduced n by one earlier in the function)
    qft_rotations(circuit, n)

def swap_registers(circuit, n):
    for qubit in range(n//2):
        circuit.swap(qubit, n-qubit-1)
    return circuit
```

Inverese QFT operation

In [3]:
```
def inverse_qft(circuit, n):
```

```python
    """Does the inverse QFT on the first n qubits in circuit"""
    # First we create a QFT circuit of the correct size:
    qft_circ = qft(QuantumCircuit(n), n)
    # Then we take the inverse of this circuit
    invqft_circ = qft_circ.inverse()
    # And add it to the first n qubits in our existing circuit
    circuit.append(invqft_circ, circuit.qubits[:n])
    return circuit.decompose() # .decompose() allows us to see the individual gates
```

1. The above implementation of QFT was tested by preparing the Fourier state |5⟩ for which QFT†|5⟩=|101⟩. Try to find the state |a⟩ such that QFT†|a⟩=|100⟩

It is clear that here a will be 4. We will verify that for a = 4, we get QFT output as 100.

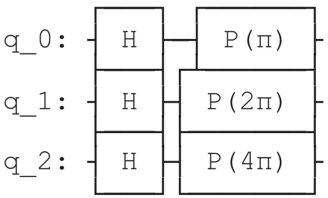
In [44]:

```python
# Putting the qubit in the state |4>

nqubits = 3
number = 4
qc = QuantumCircuit(nqubits)
for qubit in range(nqubits):
    qc.h(qubit)
qc.p(number*pi/4,0)
qc.p(number*pi/2,1)
qc.p(number*pi,2)

qc.draw()
```

Out[44]:

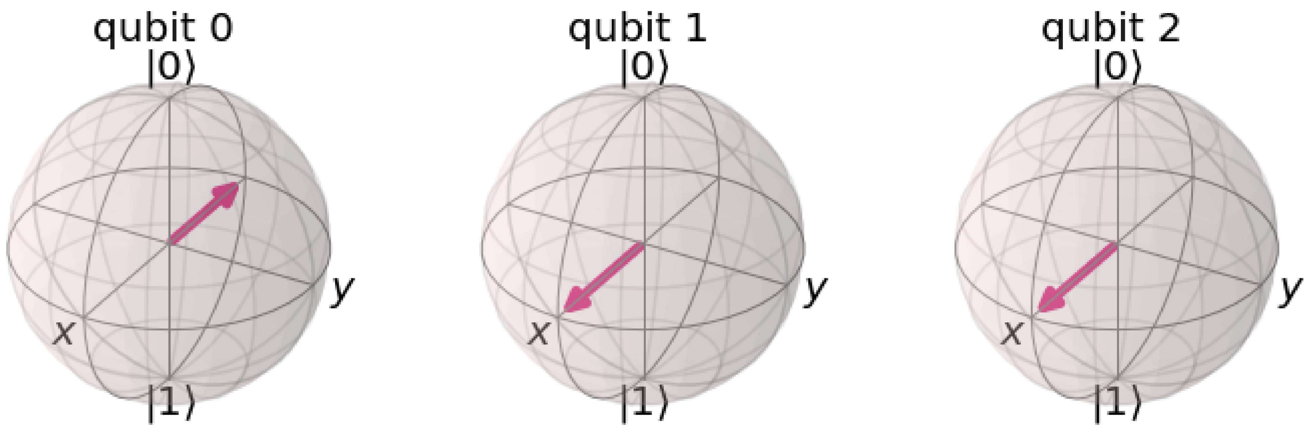


In [45]:

```python
qc_init = qc.copy()
qc_init.save_statevector()
sim = Aer.get_backend("aer_simulator")
```

```python
statevector = sim.run(qc_init).result().get_statevector()
plot_bloch_multivector(statevector)
```

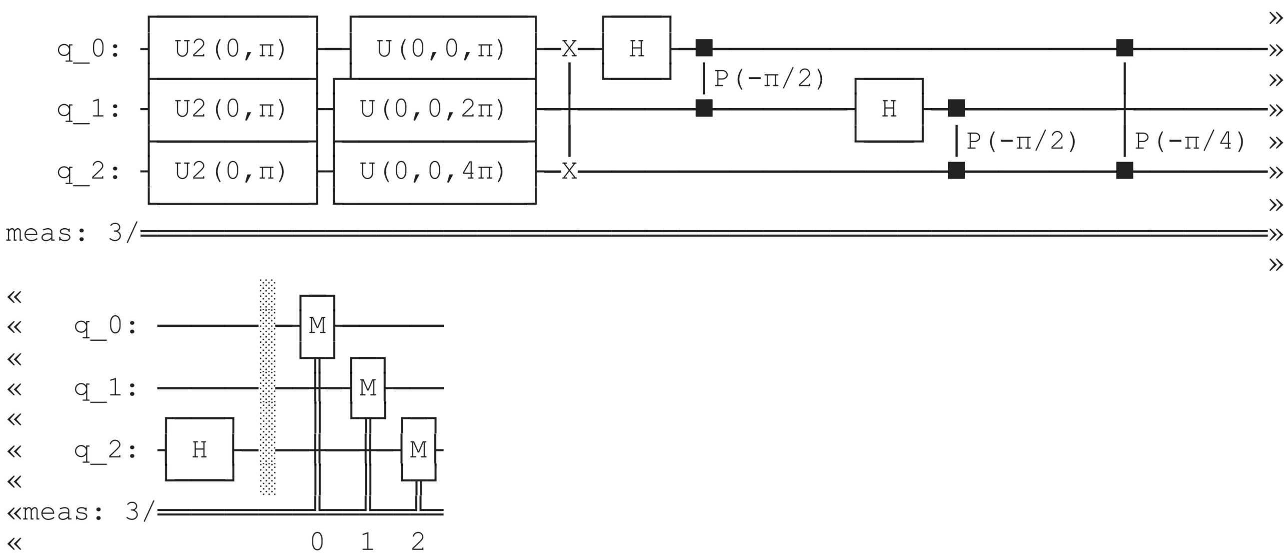
Out[45]:



In [46]:

```python
qc = inverse_qft(qc, nqubits)
qc.measure_all()
qc.draw()
```

Out[46]:



In [47]:

```python
# Load our saved IBMQ accounts and get the least busy backend device with less than or equal to nqubits
```

```
IBMQ.load_account()
provider = IBMQ.get_provider(hub='ibm-q')
backend = least_busy(provider.backends(filters=lambda x: x.configuration().n_qubits >= nqubits
                                       and not x.configuration().simulator
                                       and x.status().operational==True))
print("least busy backend: ", backend)
```

```
ibmqfactory.load_account:WARNING:2022-01-26 21:46:01,961: Credentials are already in use. The existing account in the session will be replaced.
least busy backend:  ibmq_bogota
```

In [48]:

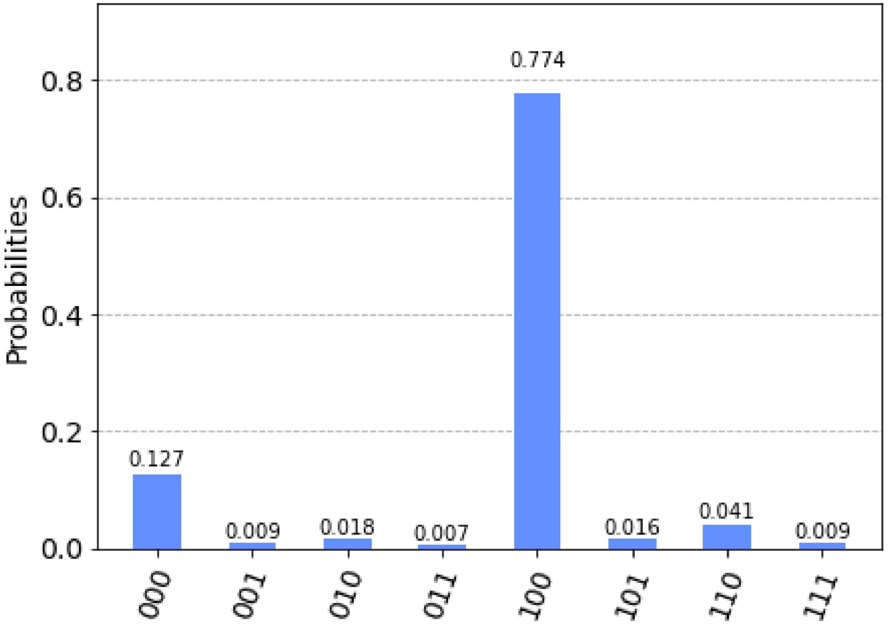
```
shots = 1024
transpiled_qc = transpile(qc, backend, optimization_level=3)
job = backend.run(transpiled_qc, shots=shots)
job_monitor(job)
```

```
Job Status: job has successfully run
```

In [49]:

```
counts = job.result().get_counts()
plot_histogram(counts)
```

Out[49]:



We see that the highest probability outcome is 100, when we take a = 4

2. Find the state |b⟩ such that QFT†|b⟩=|011⟩

It is clear that here a will be 3. We will verify that for a = 3, we get QFT output as 011.

In [50]:

```
# Putting the qubit in the state |4>

nqubits = 3
number = 3
qc = QuantumCircuit(nqubits)
for qubit in range(nqubits):
    qc.h(qubit)
qc.p(number*pi/4,0)
qc.p(number*pi/2,1)
qc.p(number*pi,2)

qc.draw()
```

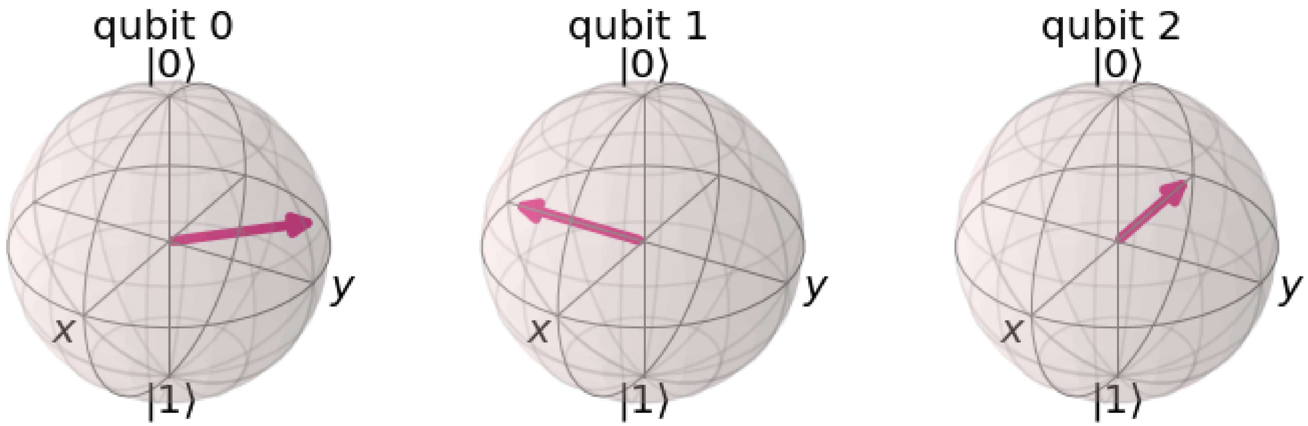
Out[50]:

```
     ┌───┐┌──────────┐
q_0: ┤ H ├┤ P(3π/4)  ├
     ├───┤├──────────┤
q_1: ┤ H ├┤ P(3π/2)  ├
     ├───┤└┬───────┬─┘
q_2: ┤ H ├─┤ P(3π) ├──
     └───┘ └───────┘
```

In [51]:

```
qc_init = qc.copy()
qc_init.save_statevector()
sim = Aer.get_backend("aer_simulator")
statevector = sim.run(qc_init).result().get_statevector()
plot_bloch_multivector(statevector)
```

Out[51]:



In [52]:

```
qc = inverse_qft(qc, nqubits)
qc.measure_all()
qc.draw()
```

Out[52]:

```
          ┌──────────┐┌─────────────┐   ┌───┐                               »
     q_0: ┤ U2(0,π)  ├┤ U(0,0,3π/4) ├─X─┤ H ├─■───────────────────────■──────»
          ├──────────┤├─────────────┤ │ └───┘ │P(-π/2) ┌───┐          │      »
     q_1: ┤ U2(0,π)  ├┤ U(0,0,3π/2) ├─┼───────■────────┤ H ├─■────────┼──────»
          ├──────────┤└┬───────────┬┘ │                └───┘ │P(-π/2) │P(-π/4) »
     q_2: ┤ U2(0,π)  ├─┤ U(0,0,3π) ├──X──────────────────────■────────■──────»
          └──────────┘ └───────────┘                                        »
  meas: 3/══════════════════════════════════════════════════════════════════»
                                                                            »
«                   ░ ┌─┐
«     q_0: ─────────░─┤M├──────
«                   ░ └╥┘┌─┐
«     q_1: ─────────░──╫─┤M├───
«          ┌───┐    ░  ║ └╥┘┌─┐
«     q_2: ┤ H ├────░──╫──╫─┤M├
«          └───┘    ░  ║  ║ └╥┘
«  meas: 3/════════════╩══╩══╩═
«                      0  1  2
```

In [53]:

```
# Load our saved IBMQ accounts and get the least busy backend device with less than or equal to nqubits
IBMQ.load_account()
provider = IBMQ.get_provider(hub='ibm-q')
backend = least_busy(provider.backends(filters=lambda x: x.configuration().n_qubits >= nqubits
```

```
                                                  and not x.configuration().simulator
                                                  and x.status().operational==True))
print("least busy backend: ", backend)
```

```
ibmqfactory.load_account:WARNING:2022-01-26 22:28:26,938: Credentials are already in use. The existing account in the session will be replaced.
least busy backend:  ibmq_bogota
```

In [54]:

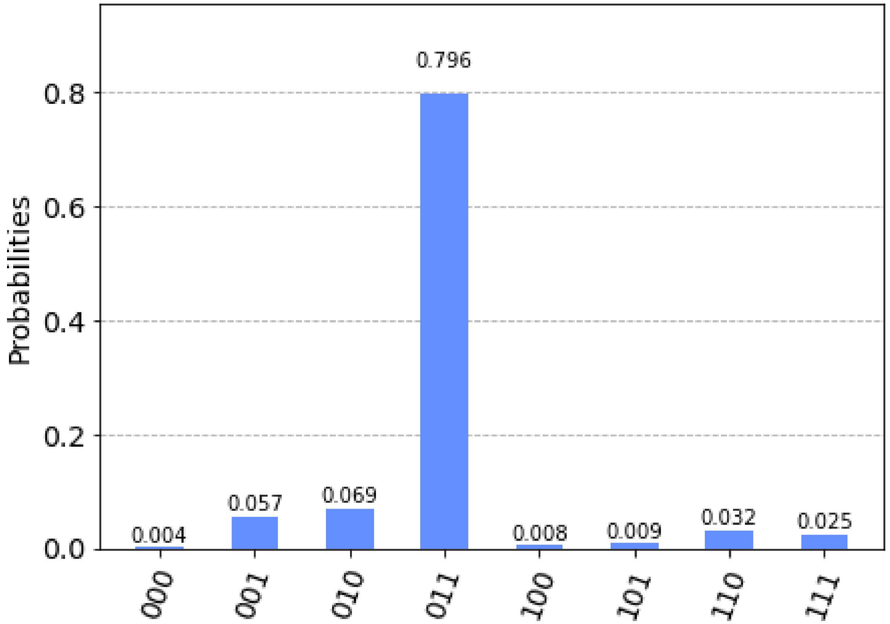
```
shots = 1024
transpiled_qc = transpile(qc, backend, optimization_level=3)
job = backend.run(transpiled_qc, shots=shots)
job_monitor(job)
```

```
Job Status: job has successfully run
```

In [55]:

```
counts = job.result().get_counts()
plot_histogram(counts)
```

Out[55]:



We see that the highest probability outcome is 011, when we take a = 3

In [ ]: