Simon's Algorithm

1. Installation

In [2]:

```
from qiskit import IBMQ, Aer
from qiskit.providers.ibmq import least_busy
from qiskit import QuantumCircuit, transpile, assemble
from qiskit.visualization import plot_histogram
from qiskit_textbook.tools import simon_oracle

# The function simon_oracle (imported above) creates a Simon oracle for the bitstring b
```

We now implement Simon's algorithm for an example with 3 quibits and b = '110'

2. Circuit

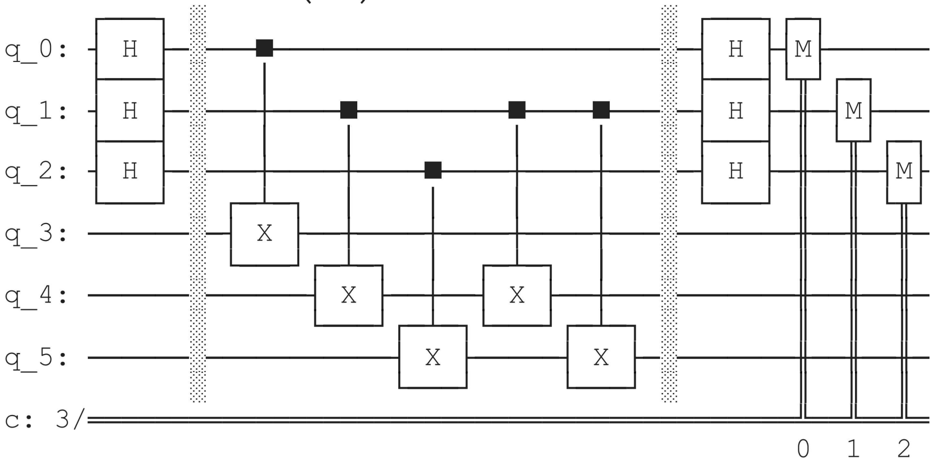
In [3]:

```
b = '110'

n = len(b)
simon_circuit = QuantumCircuit(n*2, n)

# Apply Hadamard gates before querying the oracle
simon_circuit.h(range(n))

# Apply barrier for visual separation
simon_circuit.barrier()1
simon_circuit += simon_oracle(b)

# Apply barrier for visual separation
simon_circuit.barrier()

# Apply Hadamard gates to the input register
simon_circuit.h(range(n))

# Measure qubits
```

```
simon_circuit.measure(range(n), range(n))
simon_circuit.draw()
```

```
<ipython-input-3-43e26ab50455>:12: DeprecationWarning: The QuantumCircuit.__iadd__() method is being deprecated. Use the compose()
(potentially with the inplace=True argument) and tensor() methods which are more flexible w.r.t circuit register compatibility.
  simon_circuit += simon_oracle(b)
C:\Users\hrith\anaconda3\lib\site-packages\qiskit\circuit\quantumcircuit.py:942: DeprecationWarning: The QuantumCircuit.extend() m
ethod is being deprecated. Use the compose() (potentially with the inplace=True argument) and tensor() methods which are more flex
ible w.r.t circuit register compatibility.
  return self.extend(rhs)
```

Out[3]:

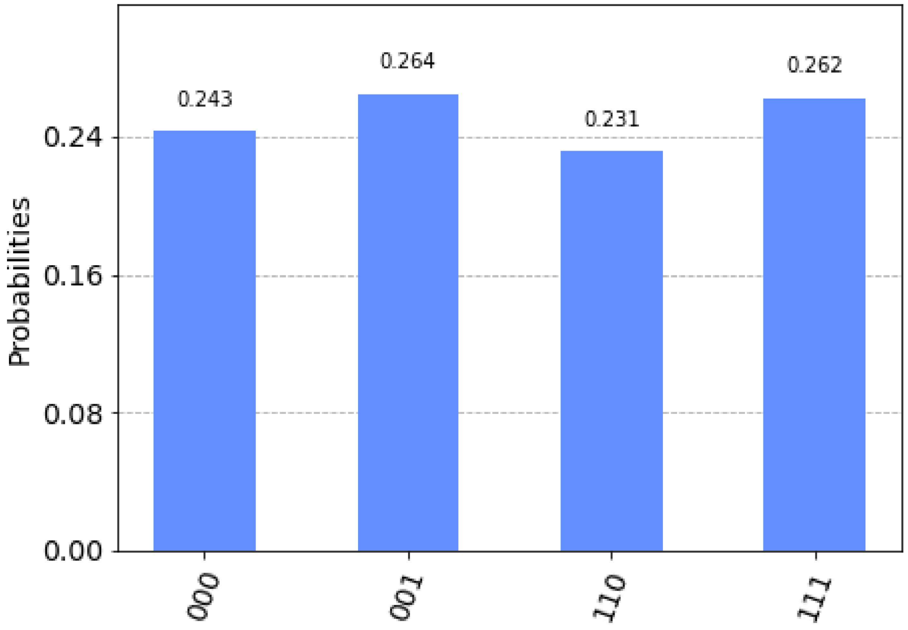


3. Simulator Output

In [4]:

```
# use local simulator
aer_sim = Aer.get_backend('aer_simulator')
shots = 1024
qobj = assemble(simon_circuit, shots=shots)
results = aer_sim.run(qobj).result()
counts = results.get_counts()
plot_histogram(counts)
```

Out[4]:



4. Verify result(Simulator)

In [5]:

```
# Calculate the dot product of the results
def bdotz(b, z):
    accum = 0
    for i in range(len(b)):
        accum += int(b[i]) * int(z[i])
    return (accum % 2)

for z in counts:
    print( '{}.{} = {} (mod 2)'.format(b, z, bdotz(b,z)) )
```

```
110.110 = 0 (mod 2)
110.000 = 0 (mod 2)
110.001 = 0 (mod 2)
110.111 = 0 (mod 2)
```

Using these results, we can recover the value of $b = 110$ by solving this set of simultaneous equations. For example, say we first measured `001`, this tells us:

$$\begin{aligned} b \cdot 001 &= 0 \\ (b_2 \cdot 0) + (b_1 \cdot 0) + (b_0 \cdot 1) &= 0 \\ (\cancel{b_2 \cdot 0}) + (\cancel{b_1 \cdot 0}) + (b_0 \cdot 1) &= 0 \\ b_0 &= 0 \end{aligned}$$

If we next measured `111`, we have:

$$\begin{aligned} b \cdot 111 &= 0 \\ (b_2 \cdot 1) + (b_1 \cdot 1) + (\cancel{0 \cdot 1}) &= 0 \\ (b_2 \cdot 1) + (b_1 \cdot 1) &= 0 \end{aligned}$$

Which tells us either:

$$b_2 = b_1 = 0, \quad b = 000$$

or

$$b_2 = b_1 = 1, \quad b = 110$$

Of which $b = 110$ is the non-trivial solution to our simultaneous equations. We can solve these problems in general using Gaussian elimination, which has a run time of $O(n^3)$.

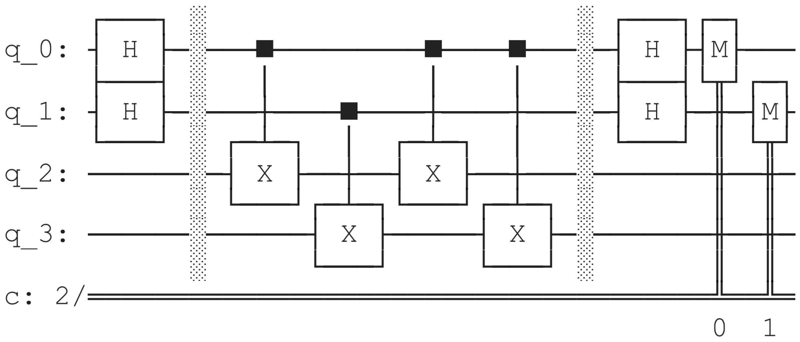
5. Real Device

We are using 4 qubits because most of the IBM Quantum devices have 5 qubits only

In [8]:

```python
b = '11'
n = len(b)
simon_circuit_2 = QuantumCircuit(n*2, n)

# Apply Hadamard gates before querying the oracle
simon_circuit_2.h(range(n))
simon_circuit_2.barrier()

# Query oracle
simon_circuit_2 += simon_oracle(b)
simon_circuit_2.barrier()

# Apply Hadamard gates to the input register
simon_circuit_2.h(range(n))

# Measure qubits
simon_circuit_2.measure(range(n), range(n))
simon_circuit_2.draw()
```

Out[8]:



The outputs are different, but the input collisions are the same, i.e. both have the property that $f(x) = f(x \oplus 11)$

In [9]:

```python
# Load our saved IBMQ accounts and get the least busy backend device with less than or equal to 5 qubits
IBMQ.load_account()
provider = IBMQ.get_provider(hub='ibm-q')
backend = least_busy(provider.backends(filters=lambda x: x.configuration().n_qubits >= n and
                                      not x.configuration().simulator and x.status().operational==True))
print("least busy backend: ", backend)

# Execute and monitor the job
from qiskit.tools.monitor import job_monitor
```

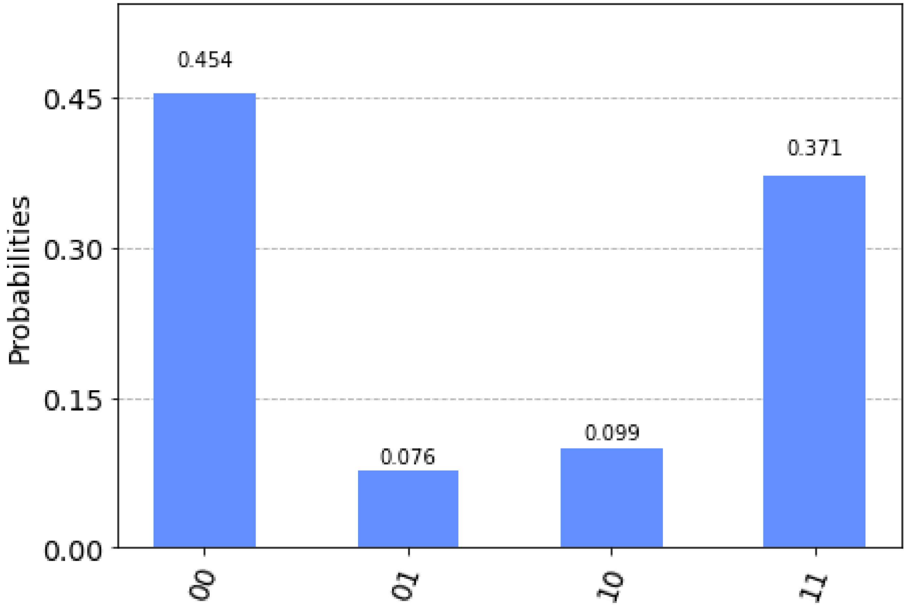
```
shots = 1024
transpiled_simon_circuit = transpile(simon_circuit_2, backend, optimization_level=3)
qobj = assemble(transpiled_simon_circuit, shots=shots)
job = backend.run(qobj)
job_monitor(job, interval=2)
```

```
least busy backend:  ibmq_lima
<ipython-input-9-8416f06a3ca6>:13: DeprecationWarning: Passing a Qobj to Backend.run is deprecated and will be removed in a future release. Please pass in circuits or pulse schedules instead.
  job = backend.run(qobj)
Job Status: job has successfully run
```

In [10]:

```
# Get results and plot counts
device_counts = job.result().get_counts()
plot_histogram(device_counts)
```

Out[10]:



6. Verify Result(Real Device)

In [11]:

```
# Calculate the dot product of the results
def bdotz(b, z):
```

```
    accum = 0
    for i in range(len(b)):
        accum += int(b[i]) * int(z[i])
    return (accum % 2)

print('b = ' + b)
for z in device_counts:
    print( '{}.{} = {} (mod 2) ({:.1f}%)'.format(b, z, bdotz(b,z), device_counts[z]*100/shots))
```

```
b = 11
11.00 = 0 (mod 2) (45.4%)
11.01 = 1 (mod 2) (7.6%)
11.10 = 1 (mod 2) (9.9%)
11.11 = 0 (mod 2) (37.1%)
```

As we can see, the most significant results are those for which **b·z=0(mod 2)**. The other results are erroneous, but have a lower probability of occurring. Assuming we are unlikely to measure the erroneous results, we can then use a classical computer to recover the value of **b** by solving the linear system of equations. For this **n=2** case, **b=11**.

In [ ]:

```

```