HNCDI Explain: Grover Tutorial 3

This is tutorial 3 on Grover's Algorithm. This is a 5-qubit example, with varying Grover iterations. The notebook performs two Grover circuits: the first circuit with 1-iteration and the second with k'-iterations.

The code below will do the following. We will first select the maximum number of grover iterations determined by the parameter k, where $k-1 = k'$. We will then select a number from a list and then create the corresponding bit-string for the good item. We will import Qiskits existing algorithm that implements Grovers algorithm. We will then run Grover's algorithm for 1-iteration and k'-iterations and compare the probability that the marked item was found.

Task. In cell 2 below, modify the parameter k. How does this change the probability that the marked item is found?

In [1]:
```
# Default imports # Importing standard Qiskit libraries
import numpy as np
from qiskit import QuantumRegister, ClassicalRegister, QuantumCircuit, tr
from qiskit.compiler import transpile
from qiskit.tools.jupyter import *
from qiskit.visualization import *
from ibm_quantum_widgets import *

from qiskit import execute
from qiskit.providers.ibmq import least_busy

import random
from qiskit.quantum_info import Statevector
```

Define the parameter k that determines the maximum number of Grover iterations.

Task. In the cell below, modify the integer parameter k. For example, start with k is 4 and subsequently increase.

In [2]:
```
### Modify Parameter k here ###

k = 4

###

print({'The maximum number of Grover iterations is': k-1})
```

```
{'The maximum number of Grover iterations is': 3}
```

We will now step through Grover's algorithm, where we will be able to choose the marked item. First, we create a list of numbers from 0 to $2^n - 1$, where n is the number of qubits.

In [3]:
```
# number of qubits is 5
n = 5
```

```
myList = list(range(0, (2**n)))
print(myList)
```

```
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 2
0, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31]
```

From this list, choose a number that will correspond to the good marked item. We will convert this to a bit-string.

Note that this cell also allows you to randomly generate the good marked item. As default, it is set to 31, the last item on the list.

In [4]:
```
# Here we can enter the good item or randomly generate it
secret = 31
#secret = random.randint(0, 2**n -1)

secret_string = format(secret, "04b")  # format the owner in bit string

print({'The secret number is ': secret})
print({'And the corresponding secret string is ': secret_string})
```

```
{'The secret number is ': 31}
{'And the corresponding secret string is ': '11111'}
```

We will now create the state vector corresponding to the selected bit-string.

In [5]:
```
# Create state vector corresponding to the selected string
oracle = Statevector.from_label(secret_string)
print('This is the corresponding state for the marked item:')
oracle.draw(output='latex')
```

```
This is the corresponding state for the marked item:
```

Out[5]: $$ |11111\rangle$$

We will now import and use the existing Qiskit algorithms that perform Grover's circuit.

In [6]:
```
from qiskit.algorithms import AmplificationProblem
from qiskit.algorithms import Grover

problem = AmplificationProblem(oracle, is_good_state=secret_string)

#define several grover circuits for different no. of iterations
grover_circuits = []

print({'Thew maximum number of Grover iterations is': (k-1)})
#Construct Grover circuits for different k
for iteration in range(1, k):
    grover = Grover(iterations=iteration)
    circuit = grover.construct_circuit(problem)
    circuit.measure_all()
    grover_circuits.append(circuit)
```

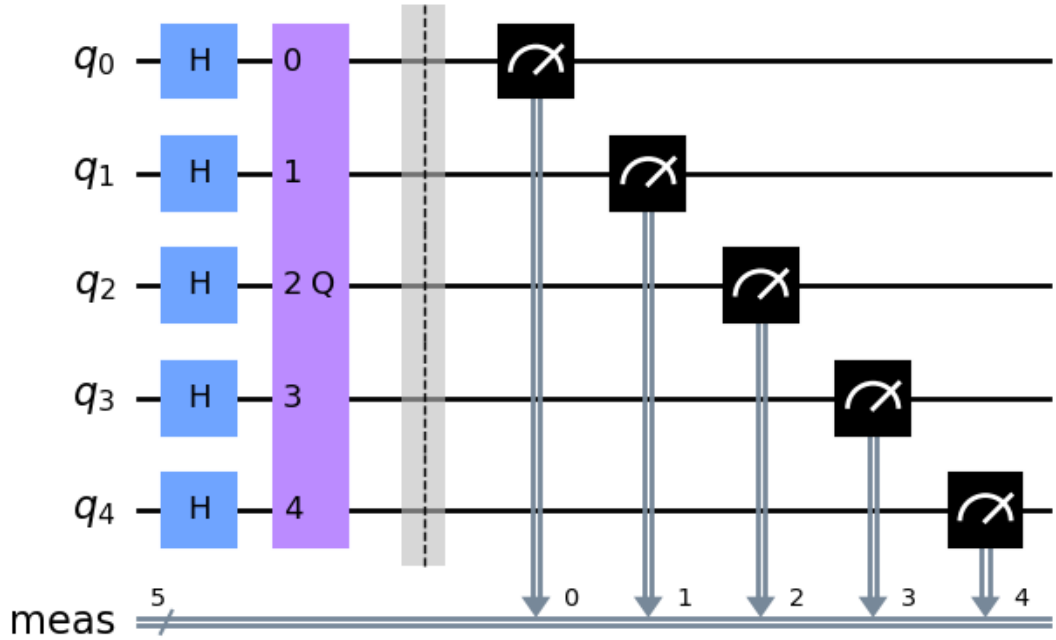
```
{'Thew maximum number of Grover iterations is': 3}
```

We will first submit the grover circuit with 1 iteration to a simulator.

In [7]:
```
# Grover's circuit with 1 iteration
print({'This is the Grover circuit with number of iterations =': (1)})
qc1 = grover_circuits[0]
qc1.draw()
```

```
{'This is the Grover circuit with number of iterations =': 1}
```

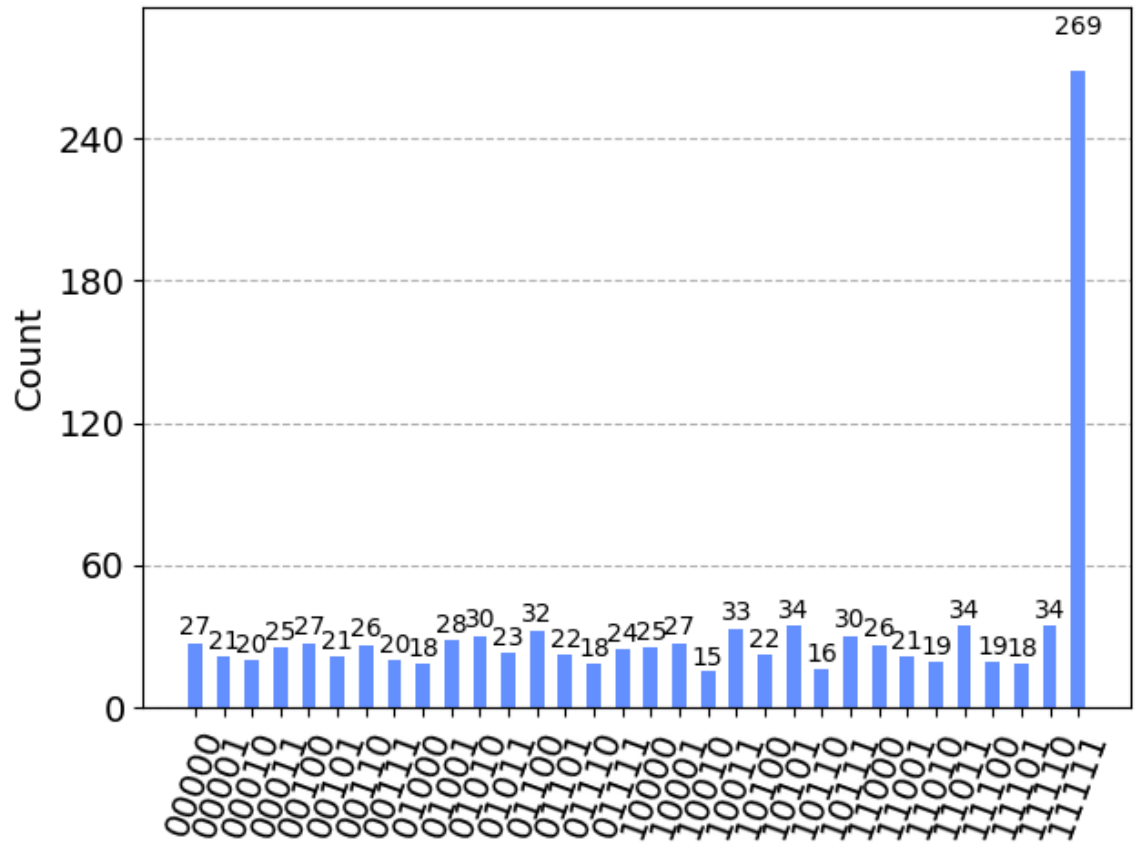
Out[7]:



In [8]:
```
print({'Recall the good marked item is': secret_string})
from qiskit import Aer, transpile
sim = Aer.get_backend('aer_simulator')
t_qc = transpile(qc1, sim)
counts = sim.run(t_qc).result().get_counts()
from qiskit.visualization import plot_histogram
plot_histogram(counts)
```

```
{'Recall the good marked item is': '11111'}
```

Out[8]:

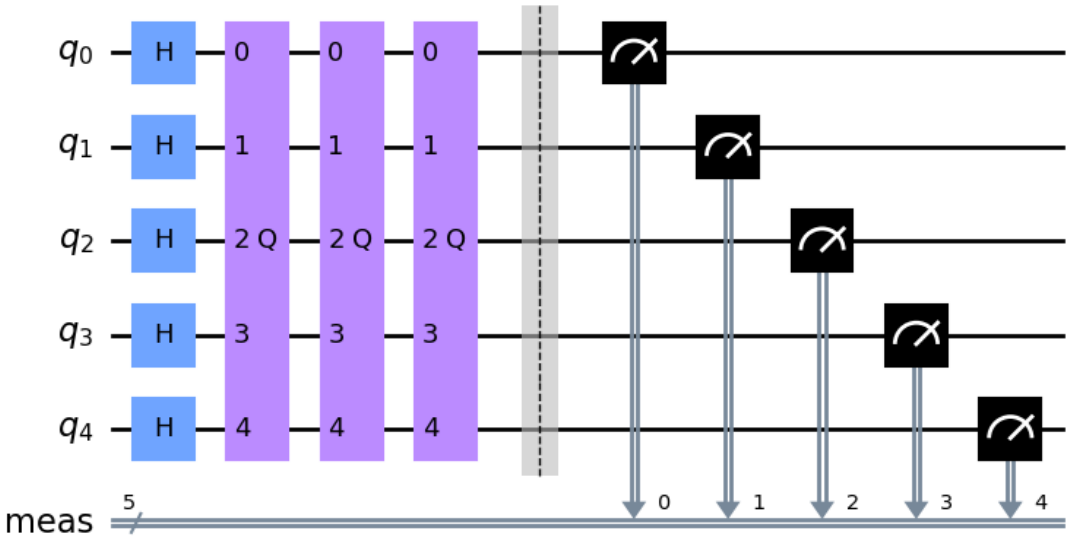


We will now submit the grover circuit with k iterations to a simulator.

In [9]:
```
# Grover's circuit with max number of iterations
print({'This is the Grover circuit with number of iterations =': (k-1)})
qcm = grover_circuits[k-2]
qcm.draw()
```

```
{'This is the Grover circuit with number of iterations =': 3}
```

Out[9]:

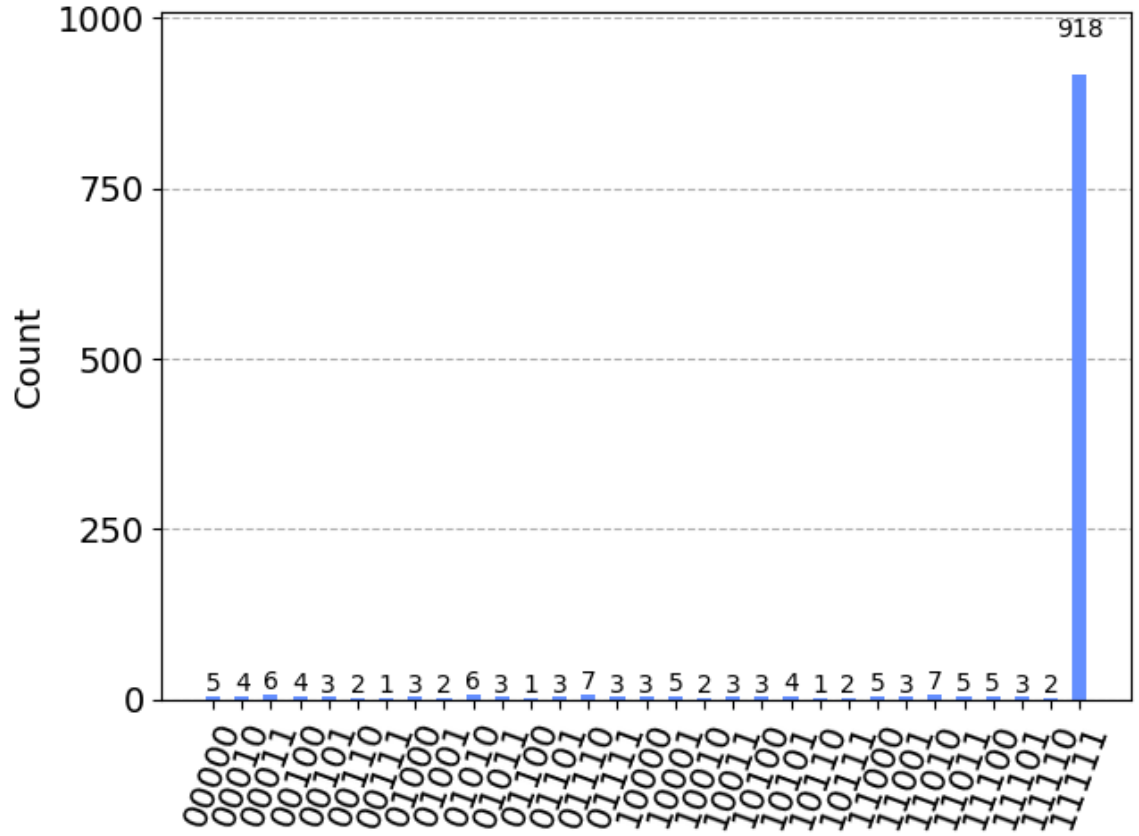


In [10]:
```
print({'Recall the good marked item is': secret_string})
from qiskit import Aer, transpile
sim = Aer.get_backend('aer_simulator')
t_qc = transpile(qcm, sim)
counts = sim.run(t_qc).result().get_counts()
```

```
from qiskit.visualization import plot_histogram
plot_histogram(counts)
```

```
{'Recall the good marked item is': '11111'}
```

Out[10]:



Compare this now to the Grover Circuit with 1-iteration. Has the marked item been found with high probability? How does the number of Grover circuits affect the probability that the marked good item was found?

In [ ]:

In [11]:
```
#Can compare to real quantum hardware
# circ = qc1

# from qiskit import execute
# from qiskit.providers.ibmq import least_busy
# provider = IBMQ.load_account()
# device = least_busy(provider.backends(filters=lambda x: x.configuration
# job = execute(circ, backend = device, shots =1024, optimization_level =
# from qiskit.tools.monitor import job_monitor
# job_monitor(job, interval = 2)
# results = job.result()
# answer = results.get_counts(circ)
# plot_histogram(answer)
```