



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\local\programs\python\python312\lib\site-packages (from qiskit) (0.16.0)

Requirement already satisfied: numpy<3,>=1.17 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit) (2.3.2)

Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit) (1.16.1)

Requirement already satisfied: dill>=0.3 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit) (0.4.0)

Requirement already satisfied: stevedore>=3.0.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit) (5.4.1)

Requirement already satisfied: typing-extensions in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit) (4.14.1)

Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from stevedore>=3.0.0->qiskit) (6.1.1)

Requirement already satisfied: setuptools in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pbr>=2.0.0->stevedore>=3.0.0->qiskit) (80.9.0)

Requirement already satisfied: qiskit-ibm-runtime in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (0.41.0)

Requirement already satisfied: requests>=2.19 in c:\users\vinay\appdata\local\programs\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\local\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\programs\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\appdata\roaming\python\python312\site-packages (from qiskit-ibm-runtime) (2.9.0.post0)

Requirement already satisfied: ibm-platform-services>=0.22.6 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit-ibm-runtime) (0.68.1)

Requirement already satisfied: pydantic>=2.5.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.11.7)

Requirement already satisfied: qiskit>=1.4.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit-ibm-runtime) (2.1.1)

Requirement already satisfied: packaging in c:\users\vinay\appdata\local\programs\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\vinay\appdata\local\programs\python\python312\lib\site-packages (from ibm-platform-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\local\programs\python\python312\lib\site-packages (from ibm_cloud_sdk_core<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\python\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\appdata\local\programs\python\python312\lib\site-packages (from requests>=2.19->qiskit-ibm-runtime) (3.4.2)

Requirement already satisfied: idna<4,>=2.5 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from requests>=2.19->qiskit-ibm-runtime) (3.10)

Requirement already satisfied: certifi>=2017.4.17 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from requests>=2.19->qiskit-ibm-runtime) (2025.8.3)

Requirement already satisfied: annotated-types>=0.6.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qiskit-ibm-runtime) (0.7.0)

Requirement already satisfied: pydantic-core==2.33.2 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qiskit-ibm-runtime) (2.33.2)

Requirement already satisfied: typing-extensions>=4.12.2 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qiskit-ibm-runtime) (4.14.1)

Requirement already satisfied: typing-inspection>=0.4.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pydantic>=2.5.0->qiskit-ibm-runtime) (0.4.1)

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Requirement already satisfied: scipy>=1.5 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit>=1.4.1->qiskit-ibm-runtime) (1.16.1)

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Requirement already satisfied: stevedore>=3.0.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit>=1.4.1->qiskit-ibm-runtime) (5.4.1)

Requirement already satisfied: cryptography>=1.3 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from requests-ntlm>=1.1.0->qiskit-ibm-runtime) (45.0.6)

Requirement already satisfied: pypng>=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\programs\python\python312\lib\site-packages (from cryptography>=1.3->requests-ntlm>=1.1.0->qiskit-ibm-runtime) (1.17.1)

Requirement already satisfied: pycparser in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from cffi>=1.14->cryptography>=1.3->requests-ntlm>=1.1.0->qiskit-ibm-runtime) (2.22)

Requirement already satisfied: sspilib>=0.1.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pypng>=0.4.0->requests-ntlm>=1.1.0->qiskit-ibm-runtime) (0.3.1)

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Requirement already satisfied: qiskit[visualization] in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (2.1.1)

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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)

Requirement already satisfied: cycler>=0.10 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (0.12.1)

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)

Requirement already satisfied: pyparsing>=2.3.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib>=3.3->qiskit[visualization]) (3.2.3)

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Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\python\python312\site-packages (from python-dateutil>=2.7->matplotlib>=3.3->qiskit[visualization]) (1.17.0)

Requirement already satisfied: pandas>=1.2 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from seaborn>=0.9.0->qiskit[visualization])

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Requirement already satisfied: pytz>=2020.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pandas>=1.2->seaborn>=0.9.0->qiskit[visualization]) (2025.2)

Requirement already satisfied: tzdata>=2022.7 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pandas>=1.2->seaborn>=0.9.0->qiskit[visualization]) (2025.2)

Requirement already satisfied: pbr>=2.0.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from stevedore>=3.0.0->qiskit[visualization]) (6.1.1)

Requirement already satisfied: setuptools in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from pbr>=2.0.0->stevedore>=3.0.0->qiskit[visualization]) (80.9.0)

Requirement already satisfied: mpmath<1.4,>=1.1.0 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from sympy>=1.3->qiskit[visualization]) (1.3.0)

Requirement already satisfied: qiskit-aer in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (0.17.2)

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Requirement already satisfied: numpy>=1.16.3 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from qiskit-aer) (2.3.2)

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Requirement already satisfied: psutil>=5 in c:\users\vinay\appdata\roaming\python\python312\site-packages (from qiskit-aer) (6.1.1)

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Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\python\python312\site-packages (from python-dateutil>=2.8.0->qiskit-aer) (1.17.0)

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Requirement already satisfied: matplotlib in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (3.10.5)

Requirement already satisfied: contourpy>=1.0.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib) (1.3.3)

Requirement already satisfied: cycler>=0.10 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib) (0.12.1)

Requirement already satisfied: fonttools>=4.22.0 in c:\users\vinay\appdata\local

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Requirement already satisfied: kiwisolver>=1.3.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib) (1.4.8)
Requirement already satisfied: numpy>=1.23 in c:\users\vinay\appdata\local\programs\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\programs\python\python312\lib\site-packages (from matplotlib) (11.3.0)
Requirement already satisfied: pyparsing>=2.3.1 in c:\users\vinay\appdata\local\programs\python\python312\lib\site-packages (from matplotlib) (3.2.3)
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Requirement already satisfied: six>=1.5 in c:\users\vinay\appdata\roaming\python\python312\site-packages (from python-dateutil>=2.7->matplotlib) (1.17.0)

Import the necessary modules

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

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

Create a Quantum Circuit with two qubits

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

Apply Hadamard gate on the qubit-0

```
In [19]: 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]: qc.cx(0,1)
```

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

Use the Aer backend simulator

```
In [21]: 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

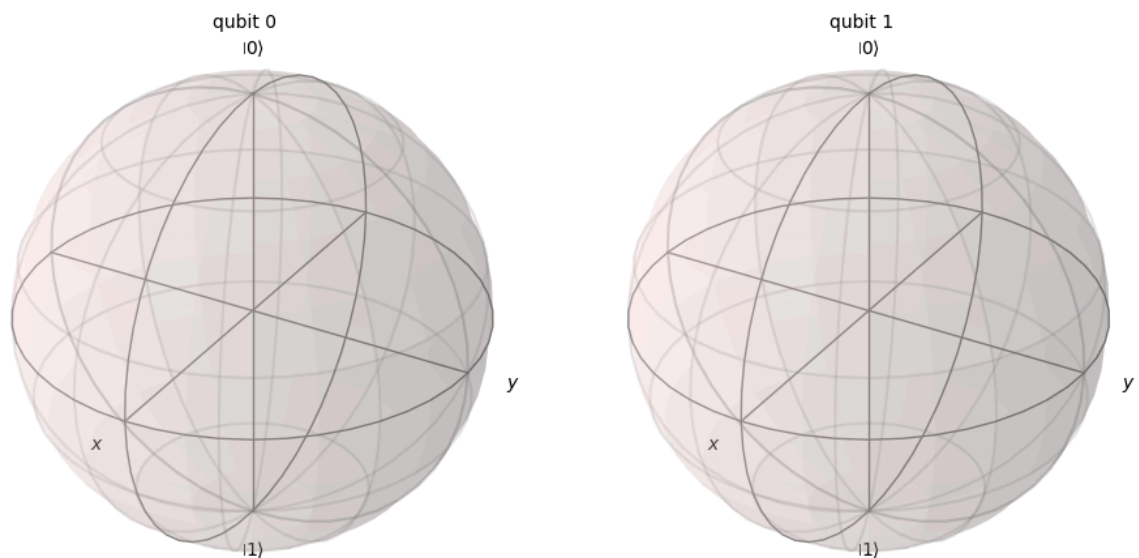
```
In [23]: result = sim.run(qc).result()
```

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