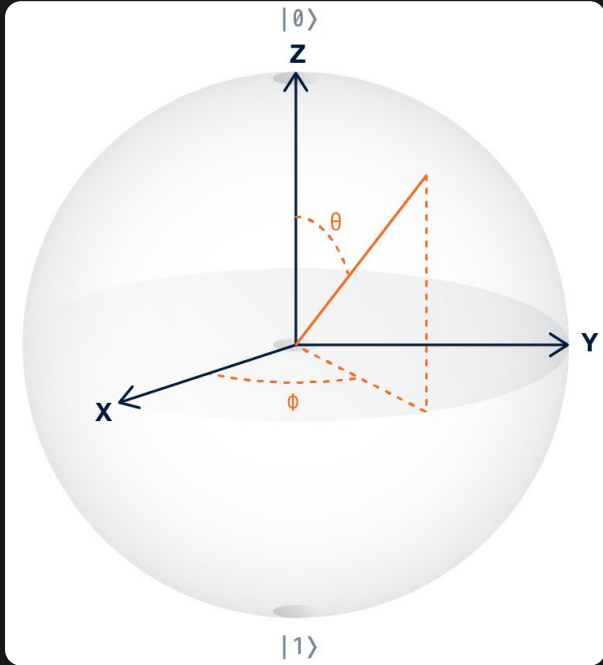# $T/T^\dagger$ ($\sqrt[4]{Z}/\sqrt[4]{Z}^\dagger$) Gates



$$T = \begin{bmatrix} 1 & 0 \\ 0 & e^{\frac{i\pi}{4}} \end{bmatrix}$$

$$T^\dagger = \begin{bmatrix} 1 & 0 \\ 0 & e^{-\frac{i\pi}{4}} \end{bmatrix}$$

# Exercise: Qiskit Superposition and Phase

# Entanglement

# Review: Entangled Statevectors

$$\begin{pmatrix} 1 \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

How might we entangle two qubits?

Bell State: H + CNOT (Show in Qiskit, show histogram and bloch sphere)

# Qiskit: Intro to Phase Kickback

Put a $|0\rangle$ into superposition with H, it has positive phase.

Put a $|1\rangle$ into superposition with H, it has negative phase.

Show matrix multiplication with CNOT (from $|+\rangle$ to $|-\rangle$) to see what will happen

# Phase Kickback: Using a controlled gate to modify the control qubit

Wrap a CNOT in H gates -- shows kickback

# References

- Qiskit Textbook. Single Qubit Gates
- Qiskit Textbook. Phase Kickback
- Qiskit Textbook. Multiple Qubits and Entangled States