

## 2.2 Multiple Qubits and Entangled States

1) Write the tensor product of

$$\begin{aligned}
 \bullet |0\rangle|1\rangle &= \begin{bmatrix} 1 \\ 0 \end{bmatrix} \otimes \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \begin{bmatrix} 0 \\ 1 \end{bmatrix} \\ 0 \begin{bmatrix} 0 \\ 1 \end{bmatrix} \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \\
 \bullet |0\rangle|+\rangle &= \begin{bmatrix} 1 \\ 0 \end{bmatrix} \otimes \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \begin{bmatrix} 1 \\ 1 \end{bmatrix} \\ 0 \begin{bmatrix} 1 \\ 1 \end{bmatrix} \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \end{bmatrix} \\
 \bullet |+\rangle|1\rangle &= \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix} \otimes \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \begin{bmatrix} 0 \\ 1 \end{bmatrix} \\ 1 \begin{bmatrix} 0 \\ 1 \end{bmatrix} \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \end{bmatrix} \\
 \bullet |-\rangle|+\rangle &= \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix} \otimes \frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = \frac{1}{2} \begin{bmatrix} 1 \begin{bmatrix} 1 \\ 1 \end{bmatrix} \\ -1 \begin{bmatrix} 1 \\ 1 \end{bmatrix} \end{bmatrix} = \frac{1}{2} \begin{bmatrix} 1 \\ 1 \\ -1 \\ -1 \end{bmatrix}
 \end{aligned}$$

2) Write the state:  $|\psi\rangle = 1/\sqrt{2} (|00\rangle + i|01\rangle)$  as two separate qubits.

Ans.  $1/\sqrt{2} (|00\rangle + i|01\rangle) = |0\rangle \otimes 1/\sqrt{2} (|0\rangle + i|1\rangle)$

3) Calculate the single qubit unitary (U) created by the sequence of gates:  $U = XZH$ . Use Qiskit's unitary simulator to check your results.

(Refer pdf1 file attached)

4) Create a quantum circuit that produces  $1/\sqrt{2} (|01\rangle + |10\rangle)$ . Use the statevector simulator to verify your result.

(Refer pdf1 file attached)

5) The circuit created above transform the state  $|00\rangle$  to  $1/\sqrt{2} (|01\rangle + |10\rangle)$ , calculate the unitary of this circuit using Qiskit's simulator.

(Refer pdf1 file attached)

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