Quantum Entanglement

You've gotta be pulling my leg!

Quantum Entanglement

Quantum Gates are no longer a math game.

Physicists can really build them!

https://www.epiqc.cs.uchicago.edu/resources/

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ENTANGLEMENT in the QUANTUM world

Qubits become entangled in a special way.

Consider... \( y = |0\rangle \) and \( z = |0\rangle \)

in this quantum circuit:

\[
\begin{array}{c|c}
|y\rangle & \text{Hadamard} \\
\hline
0 & 0 \\
1 & 1
\end{array}
\]

There's a 50/50 probability of measuring them in the same state, but never in opposite states!

\[
\frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|01\rangle + \frac{1}{\sqrt{2}}|10\rangle + \frac{1}{\sqrt{2}}|11\rangle
\]

For this circuit, when one of the entangled qubits is measured, the other is forced to take the same value.

Now the math Einstein didn't trust...

1. The Hadamard Gate acts on \( y \), producing \( y' \):

\[
\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 \sqrt{2} \\ -1 \end{bmatrix}
\]

2. To apply a 2-qubit gate, first combine the probabilities for \( y' \) and \( z \):

\[
y' = \frac{1}{\sqrt{2}}|0\rangle + \frac{1}{\sqrt{2}}|1\rangle \quad \text{and} \quad z = |0\rangle + |1\rangle
\]

\[
\begin{bmatrix} \frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|01\rangle + \frac{1}{\sqrt{2}}|10\rangle + \frac{1}{\sqrt{2}}|11\rangle \\
0 & 1 & 1 & 0 \\
0 & 0 & 1 & 0 \\
0 & 0 & 1 & 0
\end{bmatrix}
\]

Convert to matrix notation

3. The C-NOT Gate acts on \( z \) and \( y' \):

\[
\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0
\end{bmatrix} \begin{bmatrix} 1 \sqrt{2} \\ 1 \sqrt{2} \\ 1 \sqrt{2} \\ 1 \sqrt{2}
\end{bmatrix} = \begin{bmatrix} 1 \sqrt{2} \\ 1 \sqrt{2} \\ 1 \sqrt{2} \\ 1 \sqrt{2}\end{bmatrix}
\]

Quantum Entanglement

Your brain ENTANGLES visual data

Look at the top row of boxes. They all face the same way, either up or to the right or down. They all face the same way.

Your brain can see them both ways. Without a reference your brain can't tell which way!

What if coin flips were entangled?!?

Inconceivable!

I don't believe it. The math must be wrong!

We could create the following scenario:

Two coins:

One coin:

0%

0%

25%

25%

25%

25%

Entangled with math

Sometimes TWO things are dependent

For example:

I have 10 marbles.
I close the boxes & give Box B to a friend.
She opens it & finds 4 marbles. Then, she says... There are 6 marbles in Box A.

How did she know how many were in Box A WITHOUT opening it???

Because...

In Box A without opening it are 6 marbles in Box A.

The open is + finds 4 marbles.
I close the Boxes if.
She gives Box B to a friend. I have to marbles.
I close the Boxes if.
She says... There are 6 marbles in Box A.

The open is + finds 4 marbles.
I close the Boxes if.
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