Goals

- Describe entangled states + product states ✓ ?
- Determine if a 2-qubit state is entangled
- Describe why entanglement helps us win CHSH ✓
- Practice 2-qubit measurements

Announcements

Exit Tickets

How did quantum help us win CHSH?

$$|\beta_{00}\rangle_{AB} = \frac{1}{\sqrt{2}}\left(|00\rangle_{AB} + |11\rangle_{AB}\right) = \frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|11\rangle$$

has a special property: entangled

def:

A state $|\psi\rangle_{AB}$ is a product state if $\exists\, |\psi_1\rangle, |\psi_2\rangle$ s.t. $|\psi\rangle_{AB} = |\psi_1\rangle|\psi_2\rangle$

A state $|\psi\rangle_{AB}$ is entangled if $\nexists\, |\psi_1\rangle, |\psi_2\rangle$ s.t. $|\psi\rangle_{AB} = |\psi_1\rangle|\psi_2\rangle$

There are valid 2-qubit states that can't be described as A system in a state + B system in a state.

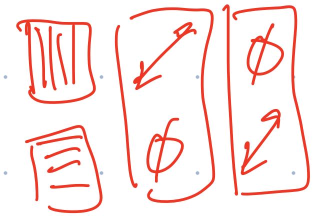
Similar to classical correlation $\Longrightarrow$ $Pr(00) = 1/2$

$Pr(11) = 1/2$

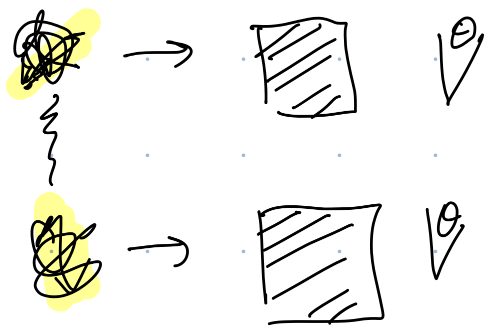
Value of bit 1?

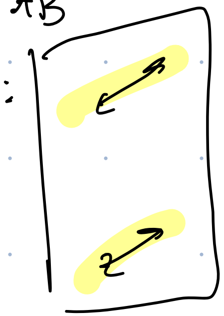
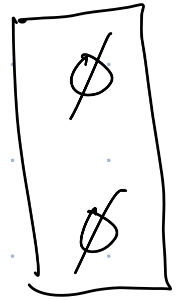
$$\frac{1}{\sqrt{2}}|\uparrow\downarrow\rangle - \frac{1}{\sqrt{2}}|\downarrow\uparrow\rangle$$

Property of $|\beta_{00}\rangle = \frac{1}{\sqrt{2}}|00\rangle_{AB} + \frac{1}{\sqrt{2}}|11\rangle_{AB}$



$|\beta_{00}\rangle$



Always:  or 

Amir

Bei

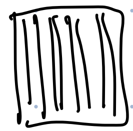
$x=0 \quad y=0$

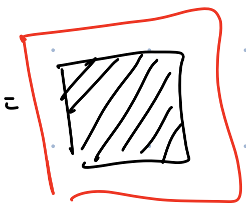
RR or QG

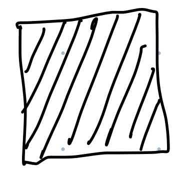
$x=0 \quad y=1$

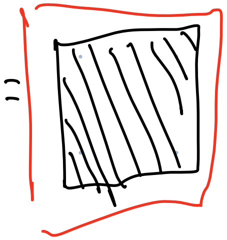
RR QG

$x=1 \quad y=0$

$x=0 \to M(0) =$ 

$x=1 \to M(\frac{\pi}{4}) =$ 

$y=0 \to M(\frac{\pi}{8}) =$ 

$y=1 \to M(\frac{-\pi}{8}) =$ 

$x \wedge y = 0 \Rightarrow$ want $a \oplus b = 0 \to a = b$ correlated

$x \wedge y = 1 \Rightarrow$ want $a \oplus b = 1 \to a \neq b$ anticorrelated