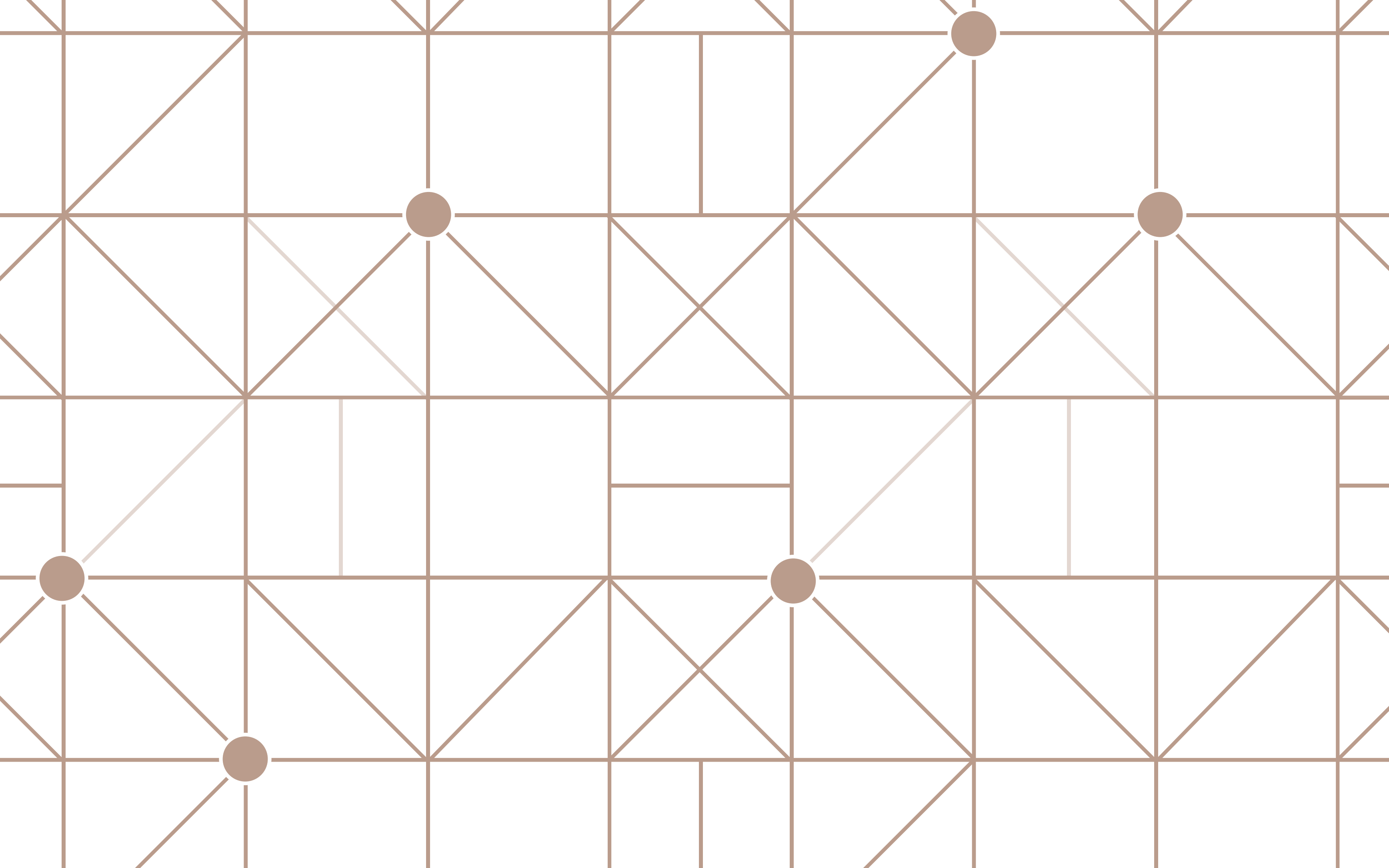

SC Quantum Bootcamp

Week 3:

- You should be comfortable:
  - logging in to qBraid
  - launching a Lab instance
  - choosing + fixing the right env for your job
  - requesting more credits when you need them!!

- We've covered:
  - linear algebra
  - basics of quantum programming
  - intro to quantum computing!

PLEASE DON'T HESITATE TO ASK QUESTIONS ABOUT ANY OF THIS!! AND MORE!!

Today!

Quantum Teleportation

- used to perform remote operations on quantum systems
  specially when qubit can't be moved from one location to another
- important in QEC

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entangle!!

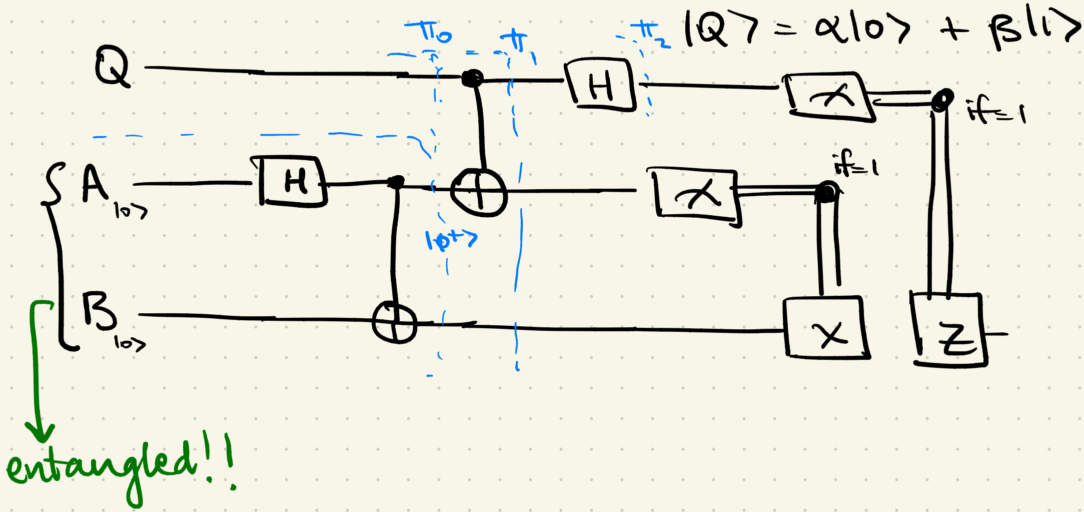
Alice Bob

send message qubit to Bob!

she doesn't know state!!

not sending matter!

just information



Bell state:

$$\frac{1}{\sqrt{2}}(|\overset{0}{0}\rangle + |\overset{1}{1}\rangle)$$

$|0\rangle$

$\downarrow H$

$H|0\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$ superposition

$\downarrow$ tensor w/ $|0\rangle$

entangled! $\leftarrow$ $\boxed{|\phi^+\rangle}$

$H|0\rangle \otimes |0\rangle$

CNOT

$\text{CNOT}(H|0\rangle \otimes |0\rangle) = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$

$|\phi^+\rangle$, $|\phi^-\rangle$, $|\psi^+\rangle$, $|\psi^-\rangle$

$\downarrow$ $\downarrow$ $\downarrow$ $\downarrow$

$\frac{|00\rangle + |11\rangle}{\sqrt{2}}$ 00 − 11   01 + 10   01 − 10

Alice is sending Bob a string

00   01   10   11

(B, A, Q) state :

$$|\pi_0\rangle = |\Phi^+\rangle \otimes (\alpha|0\rangle + \beta|1\rangle)$$

$$= \frac{\alpha|000\rangle + \alpha|110\rangle + \beta|001\rangle + \beta|111\rangle}{\sqrt{2}}$$

$\downarrow$ CNOT

$$|\pi_1\rangle = \frac{\alpha|000\rangle + \alpha|110\rangle + \beta|011\rangle + \beta|101\rangle}{\sqrt{2}}$$

$\downarrow$ Hadamard

$$|\pi_2\rangle = \frac{1}{2}(\alpha|0\rangle + \beta|1\rangle)|00\rangle$$

$$+ \frac{1}{2}(\alpha|0\rangle - \beta|1\rangle)|01\rangle$$

$$+ \frac{1}{2}(\alpha|1\rangle + \beta|0\rangle)|10\rangle$$

$$+ \frac{1}{2}(\alpha|1\rangle - \beta|0\rangle)|11\rangle$$

$$H|\pi_1\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \alpha|000\rangle$$

$$= \frac{1}{\sqrt{2}}\left(\frac{\alpha|0\rangle + \beta|1\rangle}{\sqrt{2}}\right)|00\rangle$$

$$= \frac{1}{2}(\alpha|0\rangle + \beta|1\rangle)|00\rangle$$

$$\text{state} = \frac{M_i|\psi\rangle}{\sqrt{p_i}} \qquad M_i = I_0 \otimes |00\rangle\langle 00|$$

$$H|0\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}} \rightarrow |+\rangle \qquad H|1\rangle = \frac{|0\rangle - |1\rangle}{\sqrt{2}} \rightarrow |-\rangle$$

BAQ

$$|\pi_1\rangle = \alpha|000\rangle + \frac{\alpha|110\rangle + \beta|011\rangle + \beta|101\rangle}{\sqrt{2}}$$

$\downarrow H$

$$H|\pi_1\rangle = \frac{1}{\sqrt{2}}\left(\underbrace{\alpha|00\rangle|+\rangle}_{} + \alpha|11\rangle|+\rangle + \beta|01\rangle|-\rangle + \beta|10\rangle|-\rangle\right)$$

$$= \frac{1}{2}\overbrace{\alpha|000\rangle + \alpha|001\rangle} + \alpha|110\rangle + \alpha|111\rangle$$

$$+ \beta|010\rangle - \beta|011\rangle + \beta|100\rangle - \beta|101\rangle$$

$$\text{state} = \frac{1}{\sqrt{p_i}}\, I_0 \otimes |00\rangle\langle 00|\pi_2\rangle$$

$$= \frac{(\alpha|0\rangle + \beta|1\rangle)\langle 00|00\rangle \cdot 2}{\sqrt{1/4}}$$

$$\text{State} = \alpha|0\rangle + \beta|1\rangle$$

$$a, q = 0, 0 \qquad p(00) = 1/4$$

$$(B, A, Q) = \boxed{(\alpha|0\rangle + \beta|1\rangle)}\,|00\rangle$$

Bob does nothing

$a, q = 0, 1$ $\qquad p(01) = 1/4$

$(B, A, Q) = (\alpha|0\rangle - \beta|1\rangle)\,|01\rangle$

Bob applies Z

$a, q = 1, 0$ $\qquad p(10) = 1/4$

$BAQ = (\alpha|1\rangle + \beta|0\rangle)\,|10\rangle$

Bob applies X

$p(11) = 1/4$

$a, q = 1, 1$

$BAQ = (\alpha|1\rangle - \beta|0\rangle)\,|10\rangle$

Bob applies XZ

$Z(\alpha|0\rangle - \beta|1\rangle) = \alpha|0\rangle + \beta|1\rangle$

$X(\alpha|1\rangle + \beta|0\rangle) = \alpha|0\rangle + \beta|1\rangle$

$ZX(\alpha|1\rangle - \beta|0\rangle) = \alpha|0\rangle + \beta|1\rangle$

$I(\alpha|0\rangle + \beta|1\rangle = \alpha|0\rangle + \beta|1\rangle$

In every case!!

Bob ends up w/ $\alpha|0\rangle + \beta|1\rangle$

which is the message qubit Q!!

preserve no-cloning theorem!!