THIS IS CS4084!

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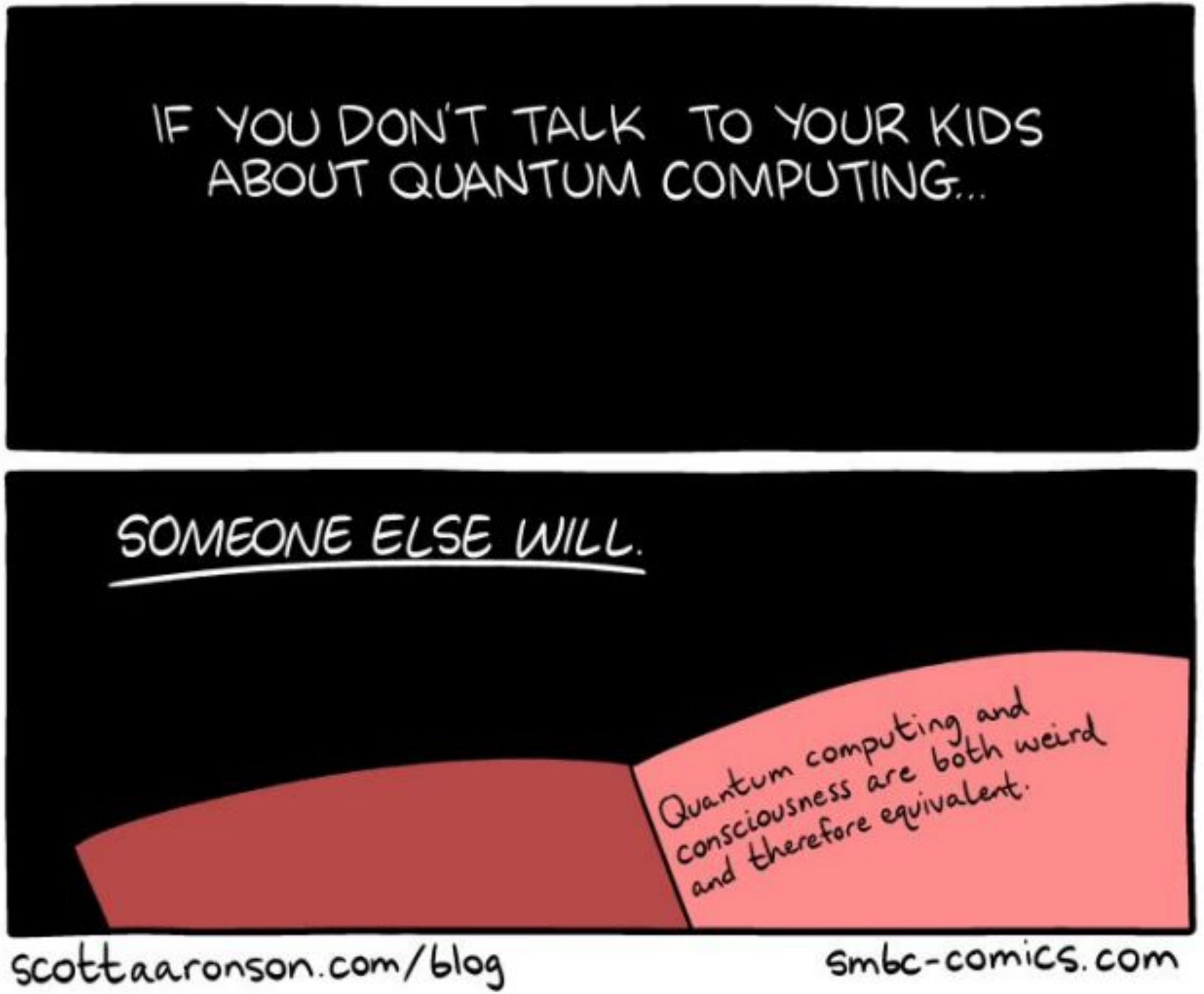
IF YOU DON'T TALK TO YOUR KIDS ABOUT QUANTUM COMPUTING...
SOMEONE ELSE WILL.
Quantum computing and consciousness are both weird and therefore equivalent.
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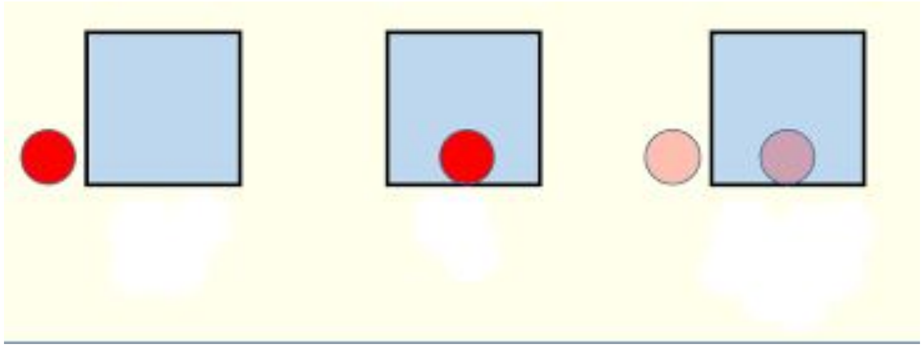
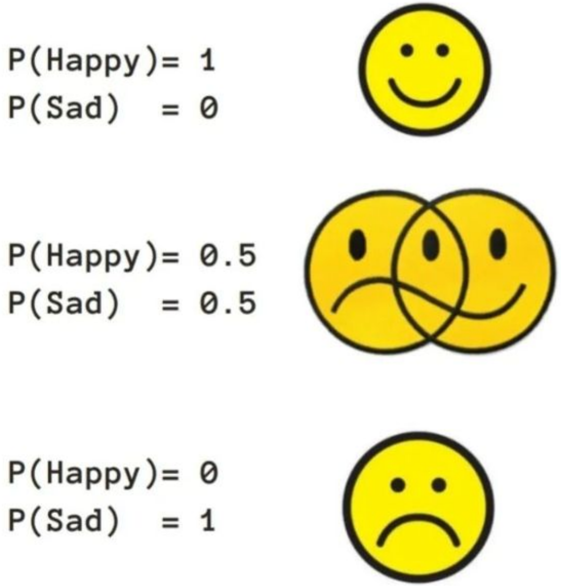
Single Qubit System

Superposition

Superposition is the ability of a quantum system to be in multiple states at the same time until it is measured.





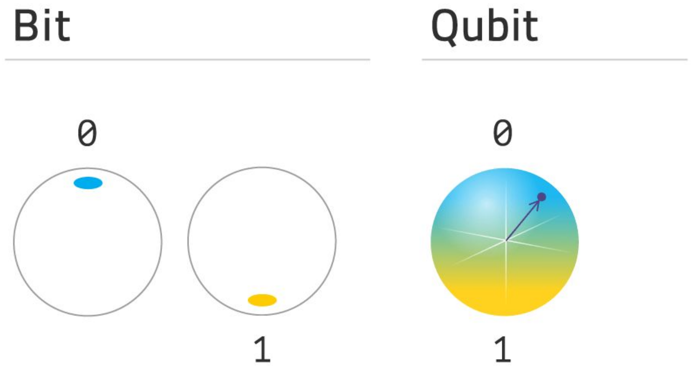
Quantum System

Any system that obeys the laws of quantum mechanics.

- Superposition
- Entanglement (We will study later)
- Quantization

Bit Vs Qubit

Quantum bits or qubits are similar to bits in that there are two measurable states called the 0 & 1.



However, qubits can also be in a superposition state of these 0 and 1 states.

Bit Vs Qubit

A classical bit can take two different values (0 or 1). It is discrete.

A qubit can “take” infinitely many different values.

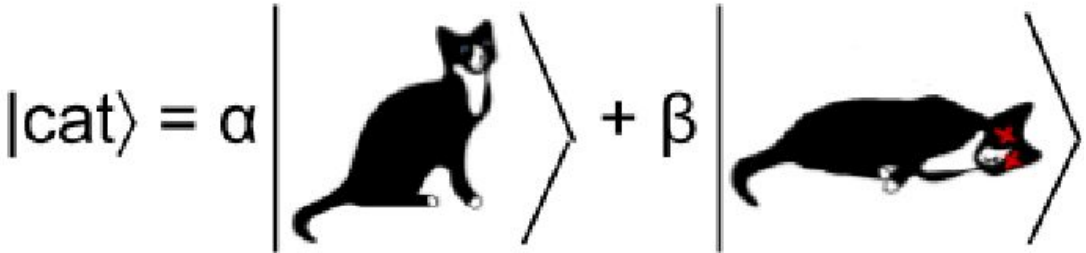
Dirac Bra-Ket Notation

Bra-ket notation is named after the symbols it uses:

"bra" $\langle$ and "ket" $\rangle$

A quantum state is represented by a ket vector = $|\psi\rangle$

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$



Dirac Bra-Ket Notation

The symbol “|>” denotes a column vector, and is known as a “ket”.

The “bra” (<|) form of a vector is just the conjugate transpose of the original.

$$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$$

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$$

$$\langle 0| = \begin{pmatrix} 1 & 0 \end{pmatrix}$$

$$\langle 1| = \begin{pmatrix} 0 & 1 \end{pmatrix}$$

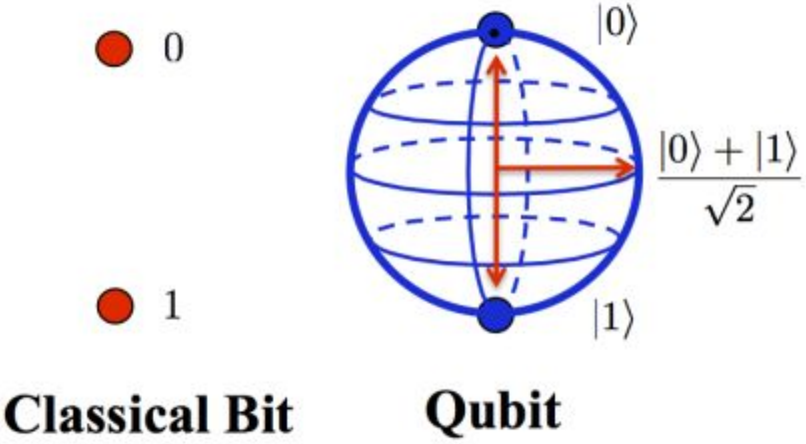
$$|1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

A generic qubit is in a **superposition**

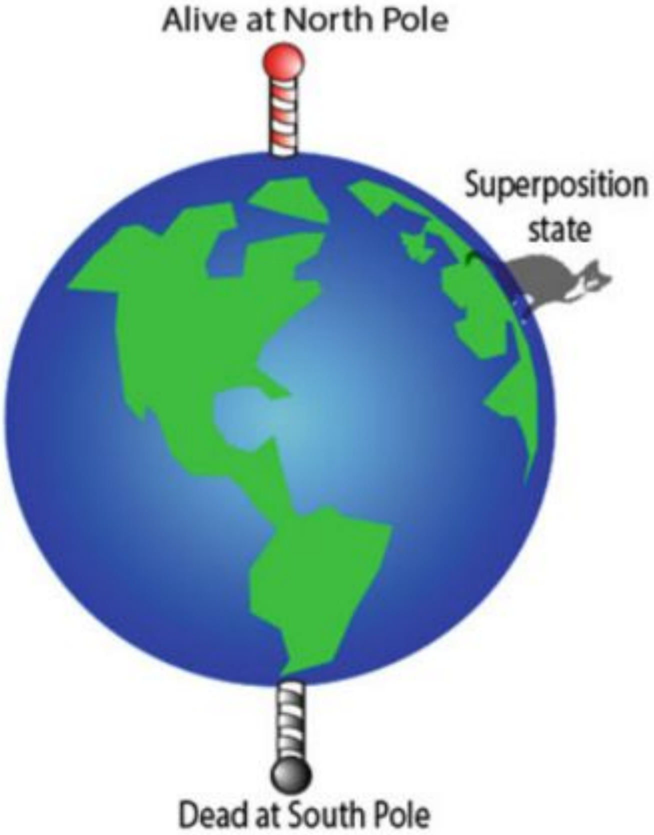
$$|\psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle$$

where α and β are **complex numbers** such that

$$|\alpha|^2 + |\beta|^2 = 1$$



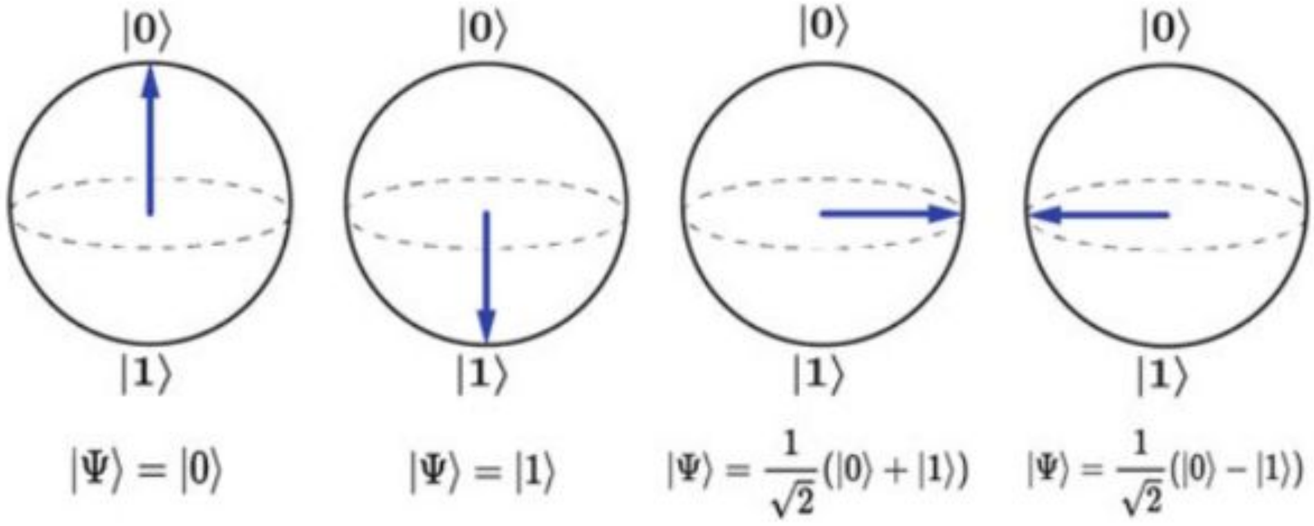
Bloch Sphere



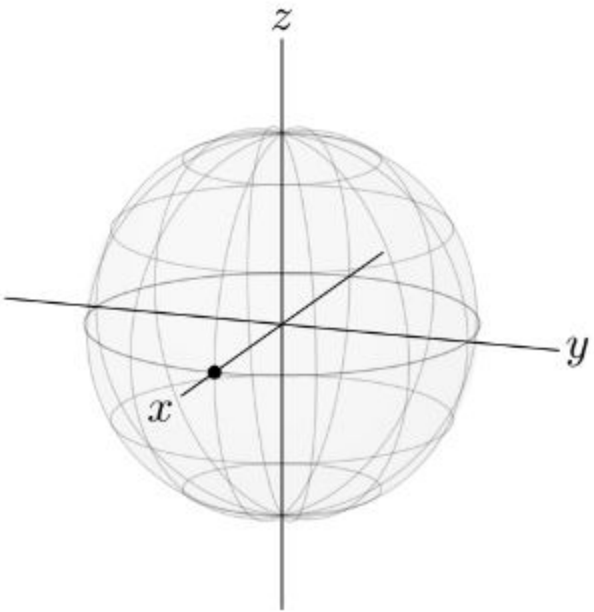
Bloch Sphere

A single qubit can be visualized using the Bloch sphere.

It is a unit sphere which means radius=1



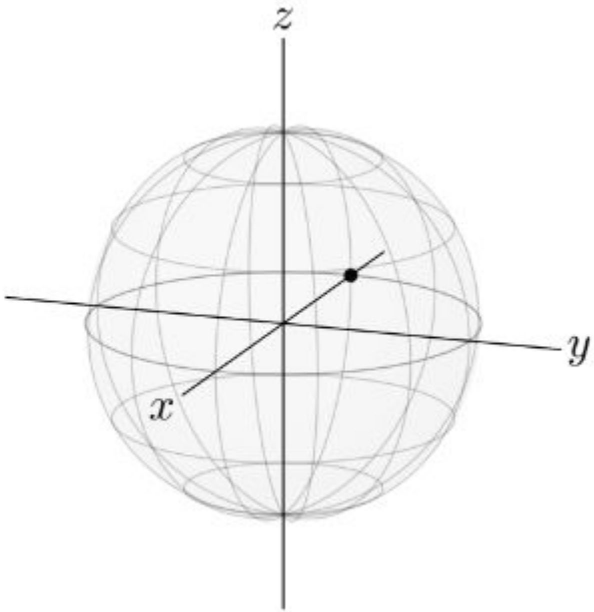
Bloch Sphere



$$\frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right).$$

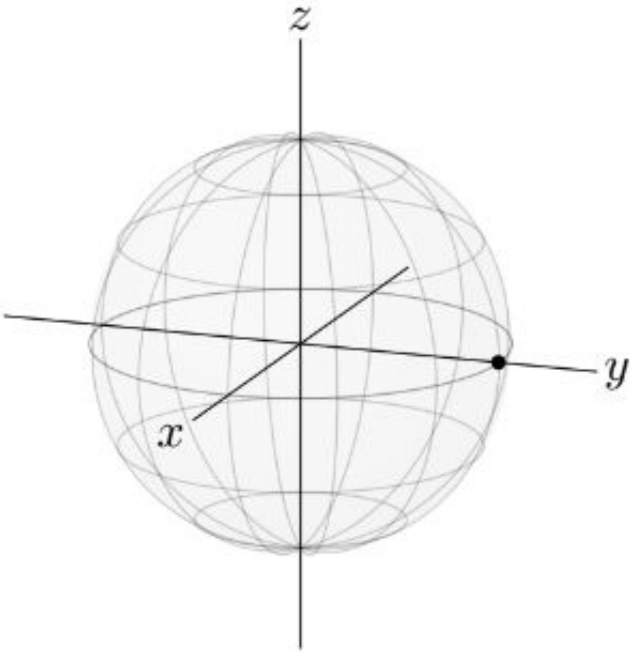
Bloch Sphere

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

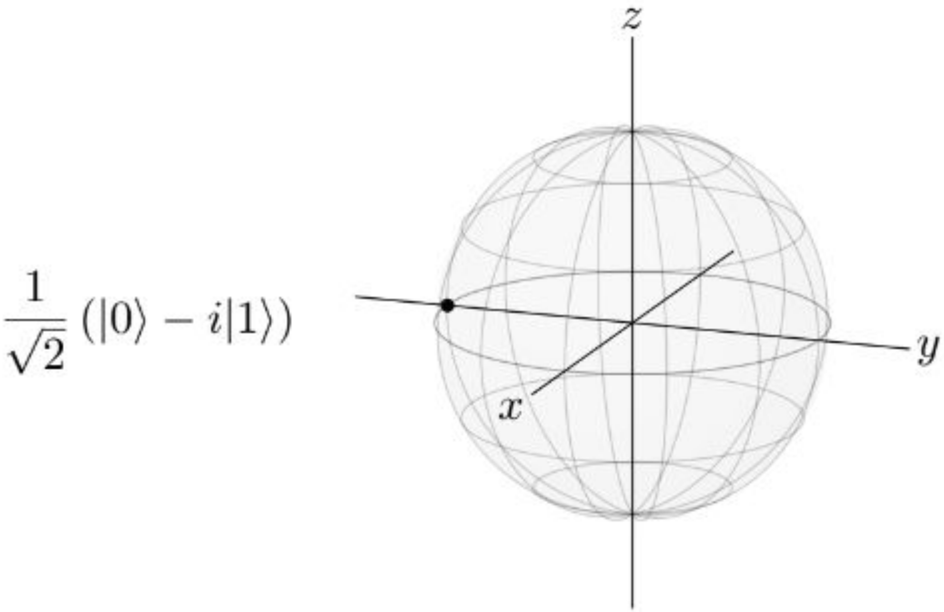


Bloch Sphere

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

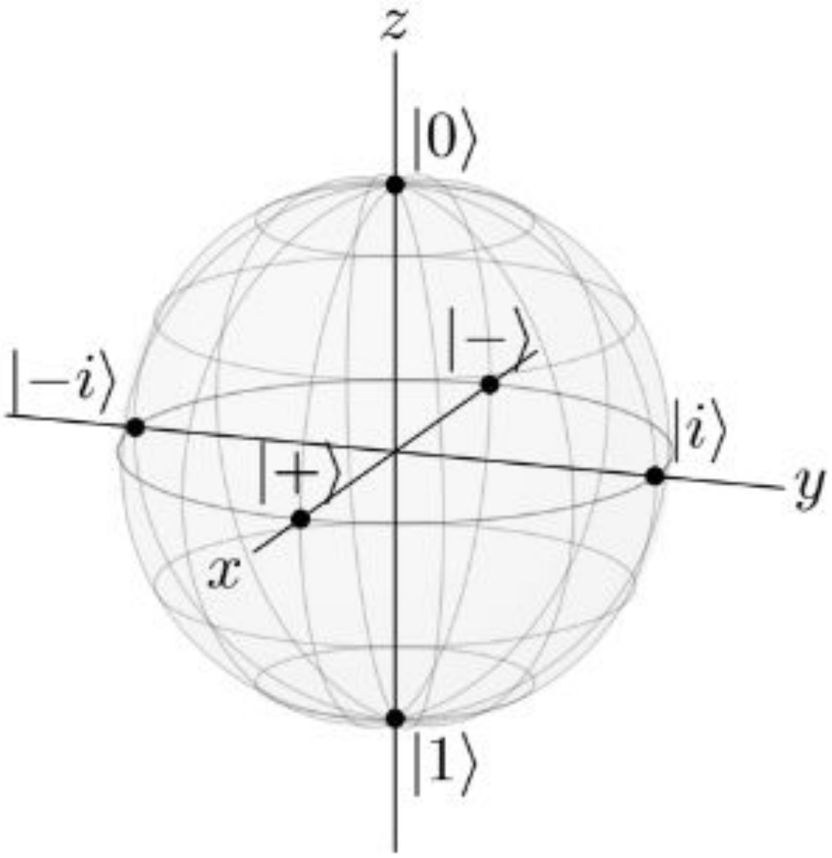


Bloch Sphere



Bloch Sphere

$$|+\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle + |1\rangle\right),$$
$$|-\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle - |1\rangle\right),$$
$$|i\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle + i|1\rangle\right),$$
$$|-i\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle - i|1\rangle\right).$$



Example 1

1. The quantum state of a spinning coin can be written as a superposition of heads and tails. Using heads as $|1\rangle$ and tails as $|0\rangle$, the quantum state of the coin is

$$|\text{coin}\rangle = \frac{1}{\sqrt{2}}\left(|1\rangle + |0\rangle\right). \tag{2.3}$$

What is the probability of getting heads?

The amplitude of $|1\rangle$ is $\beta = 1/\sqrt{2}$, so $|\beta|^2 = \left(1/\sqrt{2}\right)^2 = 1/2$. So the probability is 0.5, or 50%.

Example 2

A weighted coin has twice the probability of landing on heads vs. tails. What is the state of the coin in “ket” notation?

Example 2

A weighted coin has twice the probability of landing on heads vs. tails. What is the state of the coin in "ket" notation?

$$P_{\text{heads}} + P_{\text{tails}} = 1 \quad \text{(Normalization Condition)}$$

$$P_{\text{heads}} = 2P_{\text{tails}} \quad \text{(Statement in Example)}$$

$$\rightarrow P_{\text{tails}} = \frac{1}{3} = \alpha^2$$

$$\rightarrow P_{\text{heads}} = \frac{2}{3} = \beta^2$$

$$\rightarrow \alpha = \sqrt{\frac{1}{3}},\ \beta = \sqrt{\frac{2}{3}}$$

$$\rightarrow |\text{coin}\rangle = \sqrt{\frac{1}{3}}|0\rangle + \sqrt{\frac{2}{3}}|1\rangle.$$

Electron as a quantum system

Electron as Qubit

An electron is a prototype for a qubit.

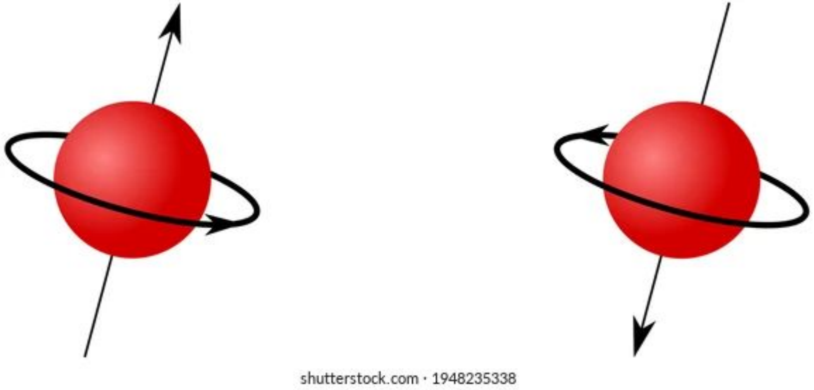
An electron has many measurable properties such as energy, mass, momentum.

But, for the purposes of creating a qubit, we want to focus on a property with only two measurable values. An electron has a two-state property which is called **spin**.

Electron as Qubit

The property was called spin because it can be described mathematically just like orbital momentum (angular momentum), but spin does not actually correspond to the electron physically rotating.

Just like a lot of quantum phenomena, spin can be confusing at first.



Electron Spin

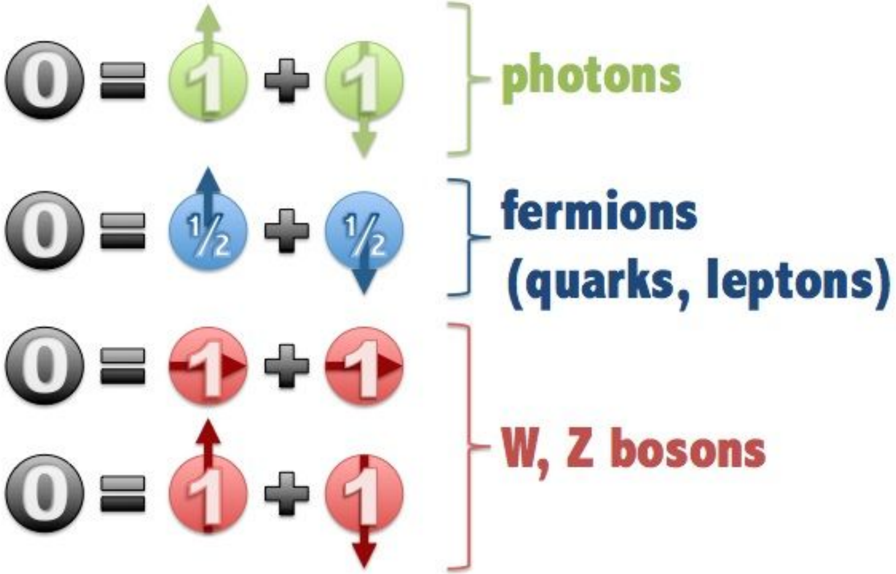
$|\uparrow\rangle$ = spin up → clockwise

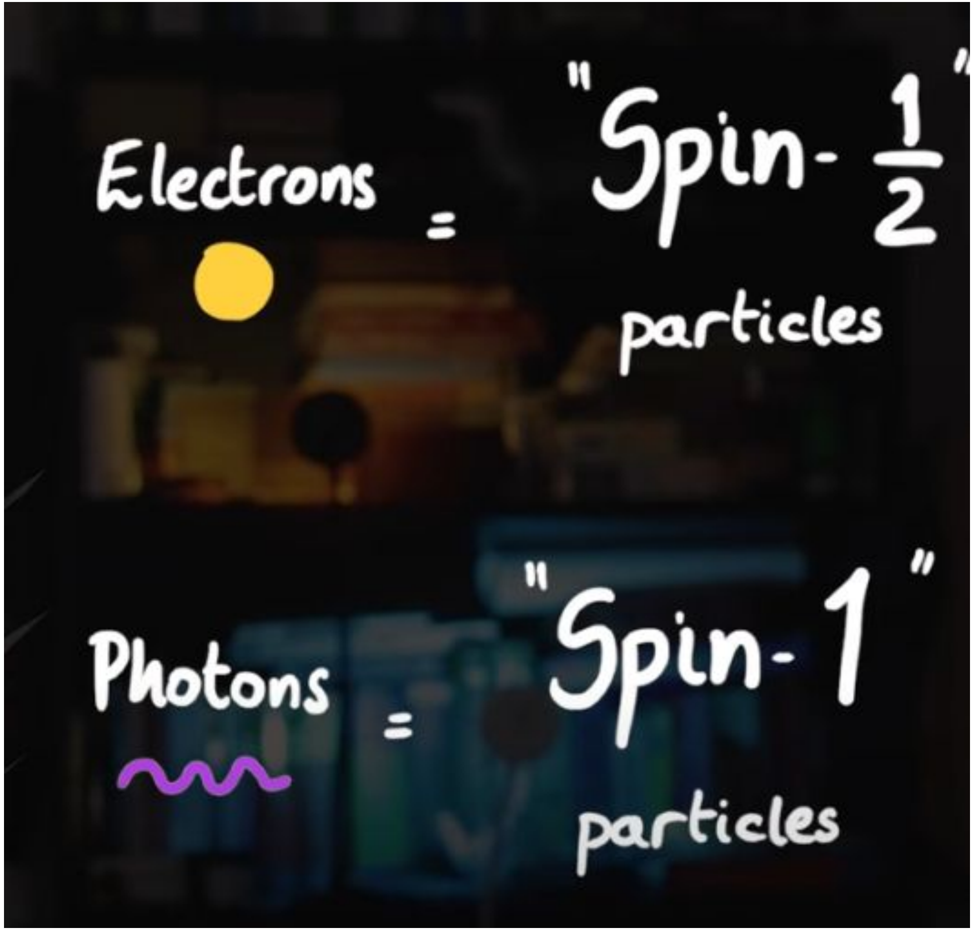
$|\downarrow\rangle$ = spin down → anticlockwise

If our electron — our quantum system — is just left alone then it is said to be in a superposition of both these states, In other words, the electron isn't $|\uparrow\rangle$ or $|\downarrow\rangle$, it's $|\uparrow\rangle$ and $|\downarrow\rangle$.

Spin -n

n= 0, 1/2 ,1, 3/2 ,2 …..




Electrons = "Spin-1/2" particles
Photons = "Spin-1" particles

If $n = \frac{1}{2}$ (e.g. electron ●):

Maximum spin $= +\frac{1}{2}\hbar$

Direction of spin: ↑

Magnitude of spin: $\frac{1}{2}\hbar$

Other possible states: $n - 1 = \left(-\frac{1}{2}\right)$

Spin $= -\frac{1}{2}\hbar$ ("spin down")

If $n = \frac{3}{2}$:

$\uparrow \quad +\frac{3}{2}\hbar$

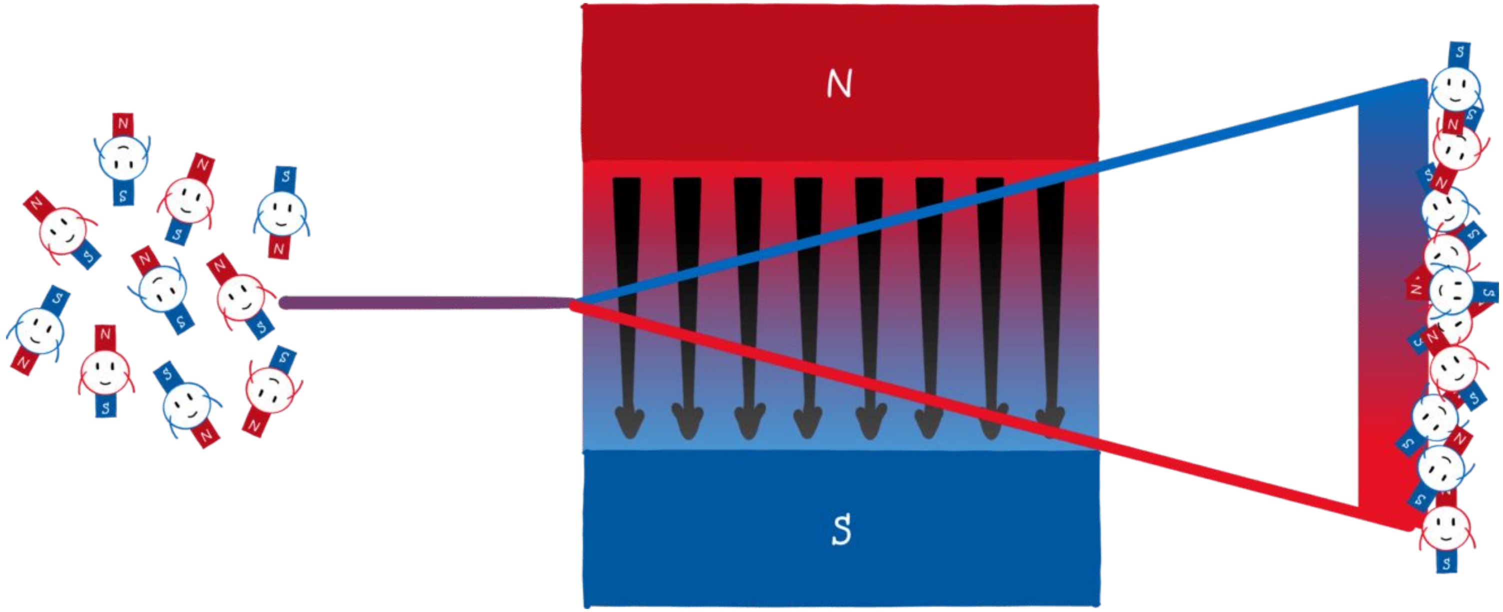
$\uparrow \quad +\frac{1}{2}\hbar$

$\downarrow \quad -\frac{1}{2}\hbar$

$\downarrow \quad -\frac{3}{2}\hbar$

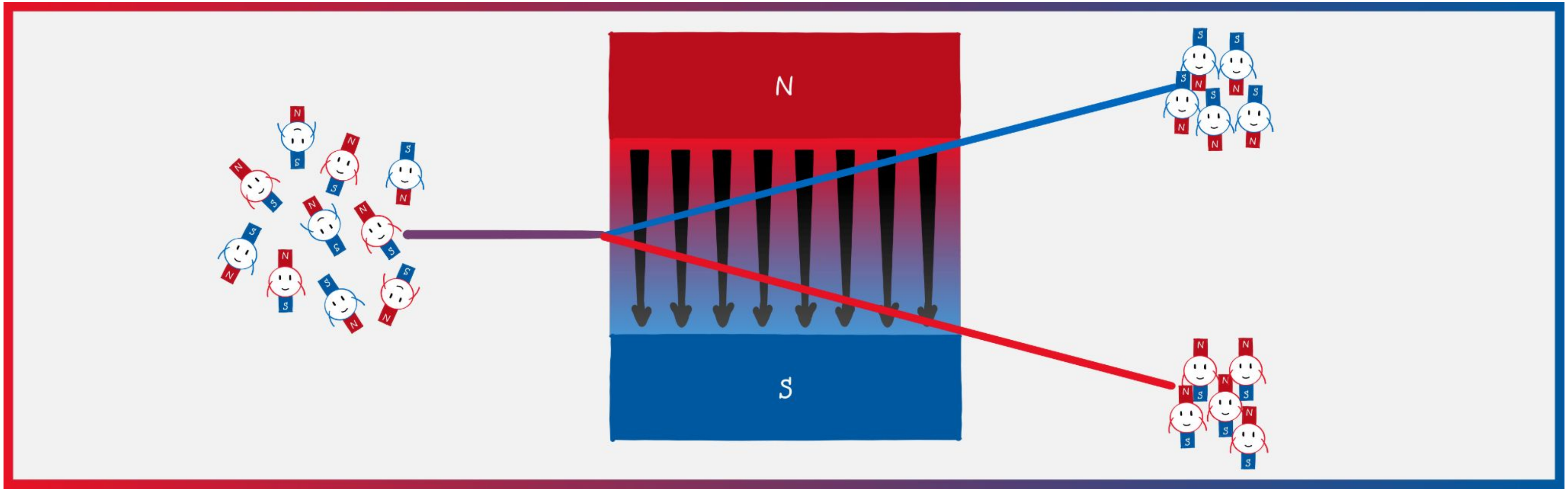
Stern-Gerlach Experiment

Atoms behave like mini-magnets



Stern-Gerlach Experiment

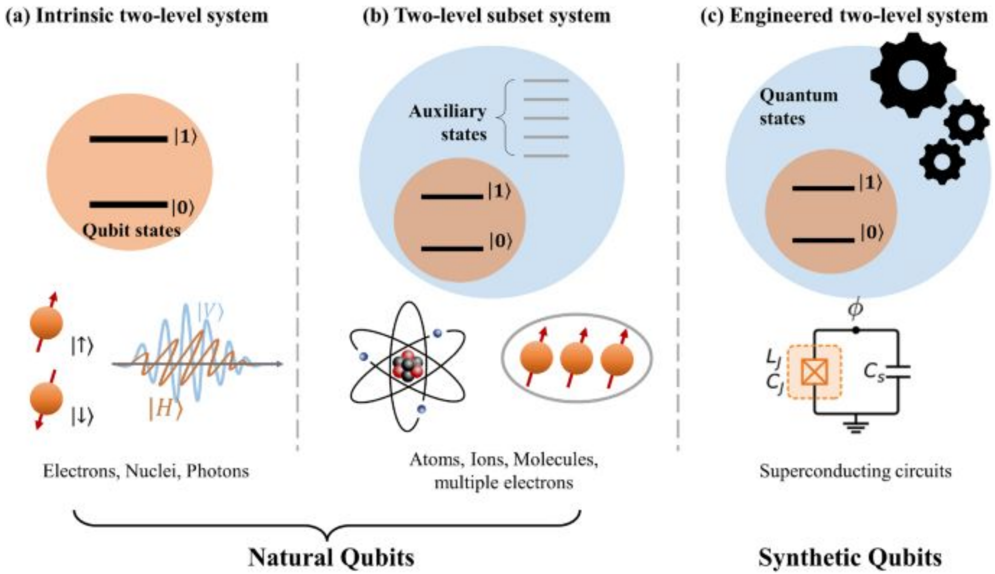
Atoms behave like mini-magnets



Types of Qubits

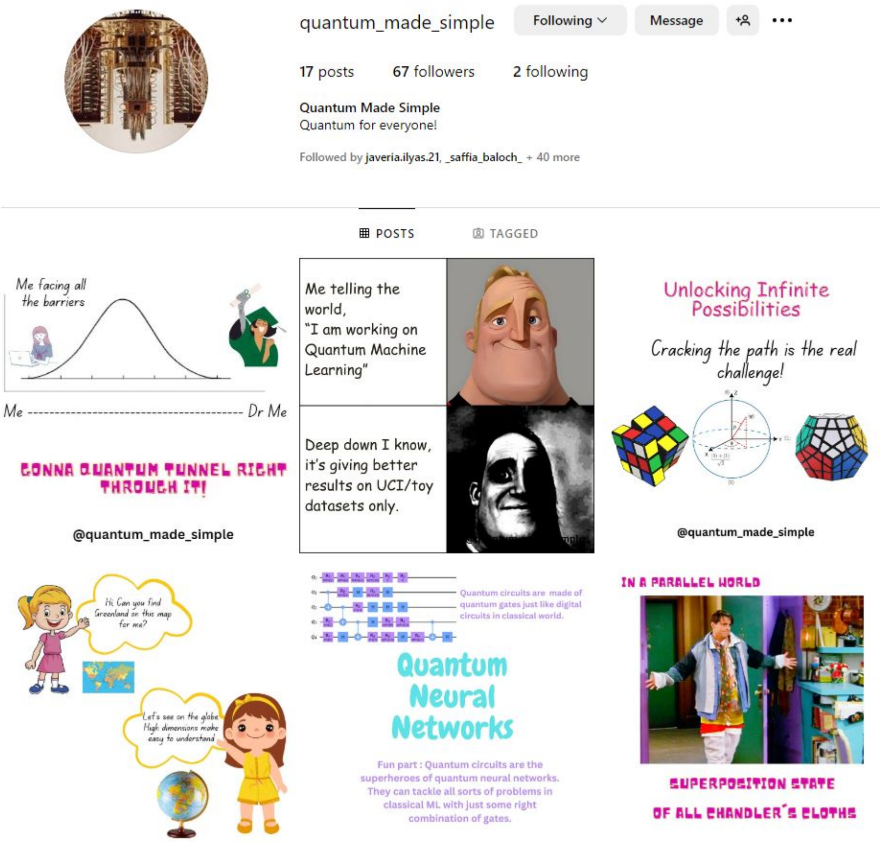
There are many kinds of qubits, some occurring naturally and others that are engineered. Some of the most common types include:

- Spin
- Trapped Atoms and Ions
- Photons
- Superconducting Circuits



What technologies are used to build quantum computers?

	Superconducting loops	Trapped ions	Silicon quantum dots	Topological qubits	Diamond vacancies
Company support	Google, IBM, Quantum Circuits	ionQ	Intel	Microsoft, Bell Labs	Quantum Diamond Technologies
Pros	Fast working. Build on existing semiconductor industry.	Very stable. Highest achieved gate fidelities.	Stable. Build on existing semiconductor industry.	Greatly reduce errors.	Can operate at room temperature.
Cons	Collapse easily and must be kept cold.	Slow operation. Many lasers are needed.	Only a few entangled. Must be kept cold.	Existence not yet confirmed.	Difficult to entangle.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Following
Message
17 posts
67 followers
2 following
Quantum Made Simple
Quantum for everyone!
Followed by javeria.ilyas.21, _saffia_baloch_ + 40 more
POSTS
TAGGED
Me facing all the barriers
Me -- Dr Me
GONNA QUANTUM TUNNEL RIGHT THROUGH IT!
@quantum_made_simple
Me telling the world, "I am working on Quantum Machine Learning"
Deep down I know, it's giving better results on UCI/toy datasets only.
Unlocking Infinite Possibilities
Cracking the path is the real challenge!
@quantum_made_simple
Hi, Can you find Greenland on this map for me?
Let's see on the globe High dimensions make easy to understand
Quantum circuits are made of quantum gates just like digital circuits in classical world.
Quantum Neural Networks
Fun part : Quantum circuits are the superheroes of quantum neural networks. They can tackle all sorts of problems in classical ML with just some right combination of gates.
IN A PARALLEL WORLD
SUPERPOSITION STATE
OF ALL CHANDLER'S CLOTHS

References

https://www.youtube.com/watch?v=UjaAxUO6-Uw

https://physicus-minimus.com/en/the-stern-gerlach-experiment/