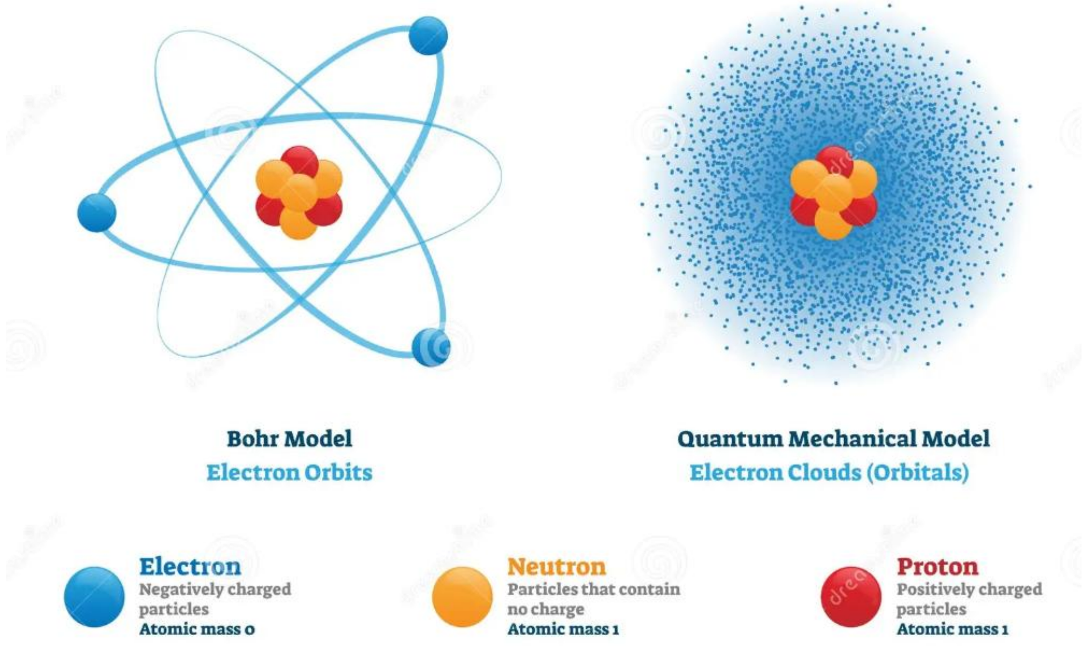
บทที่ 3 INTRO TO QUANTUM MECHANICS



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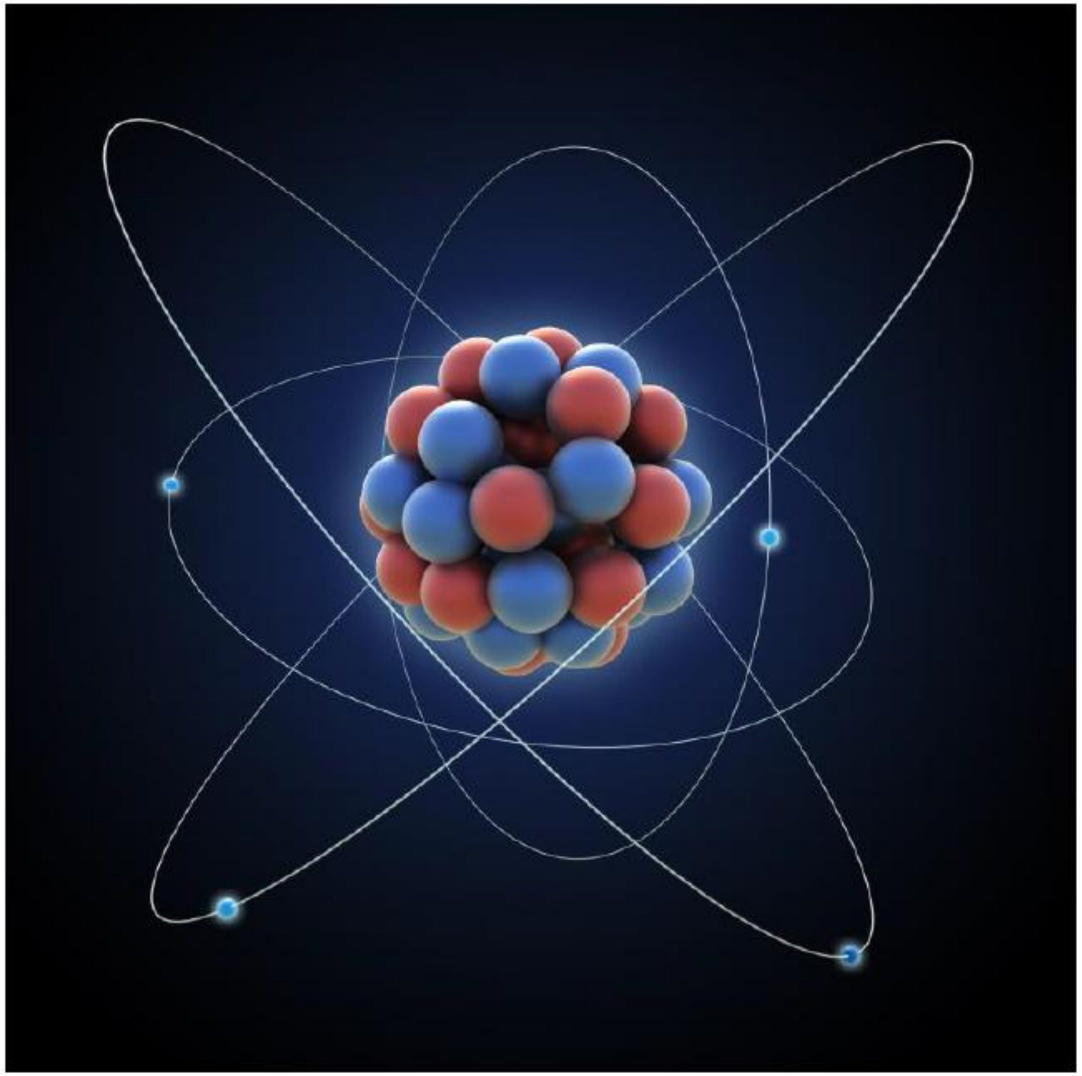
คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยสวนดุสิต

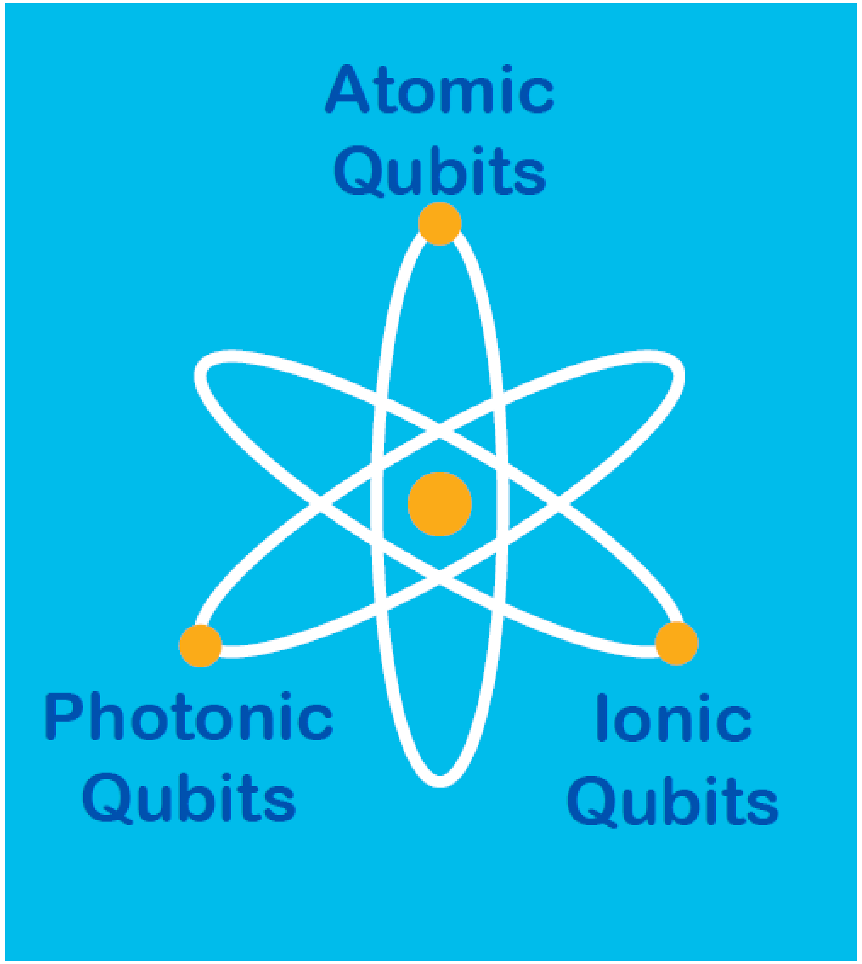
What is Quantum Mechanics?

- Quantum mechanics is the field of physics that explains how subatomic objects simultaneously have the characteristics of both:
  - **Particles**–tiny pieces of matter, and
  - **Waves**–variations that transfer energy



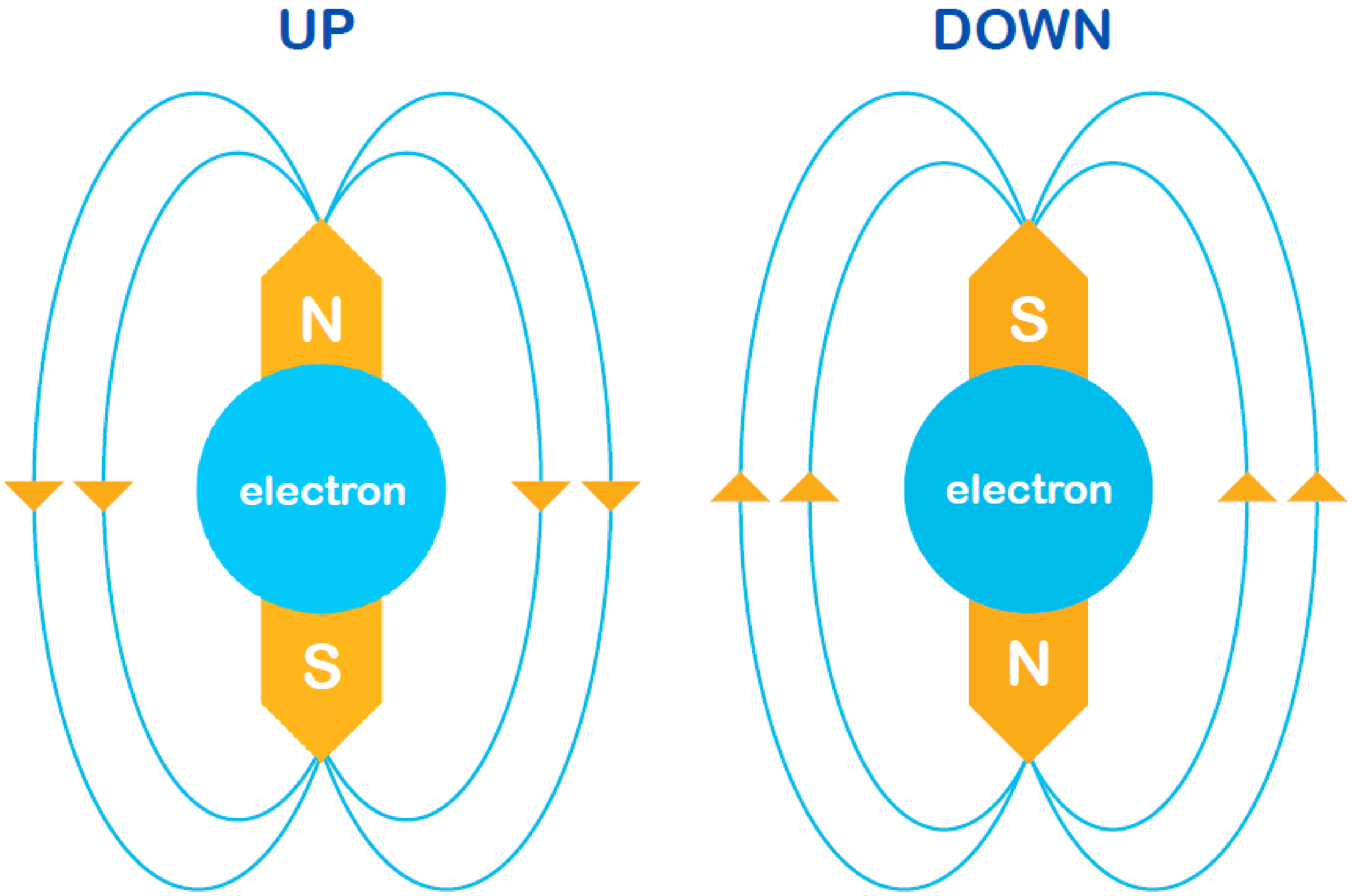
Quantum Bits (Qubits)

- Any quantum particle that can be measured in two discrete states, and as such, could be used to represent information
  - E.g. a 0 or 1



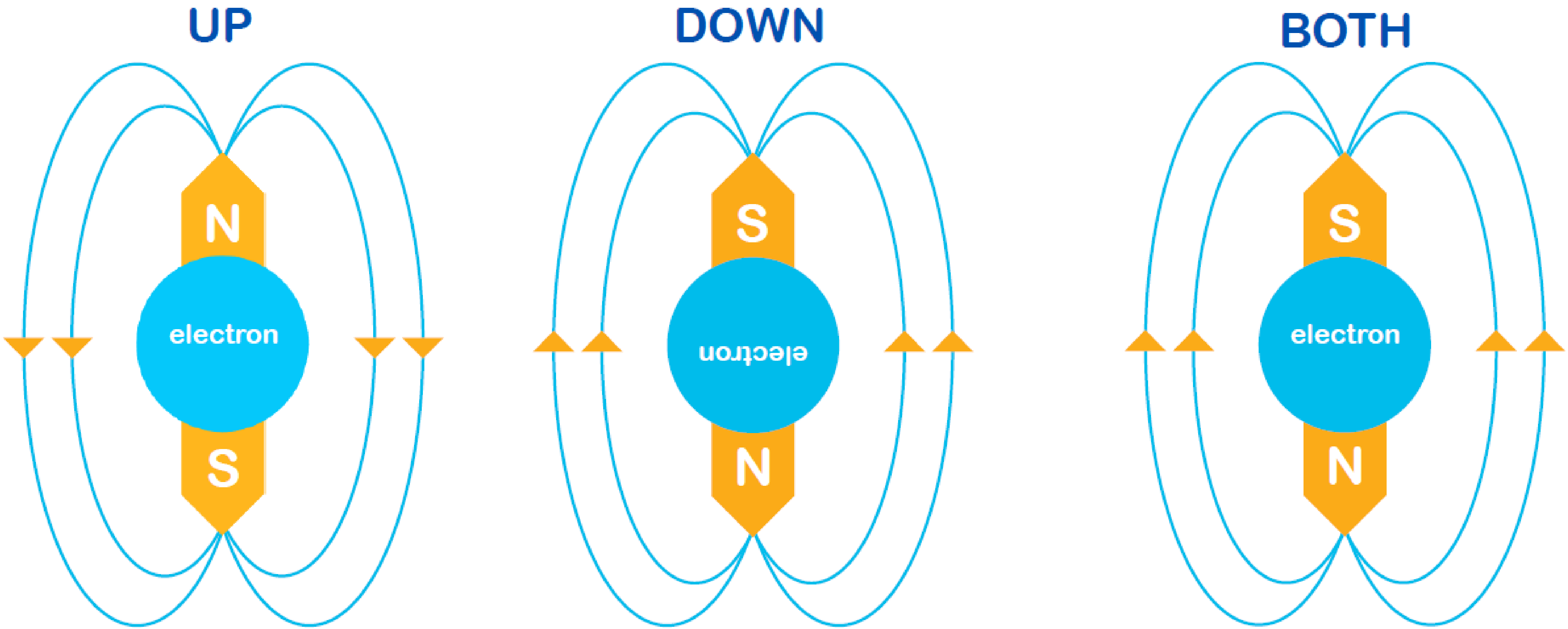
Qubit Example

- The spin of an electron can be used as a Qubit
- For example:
  - An upwards spin could be used represent a 0
  - A downward spin could be used to represent 1



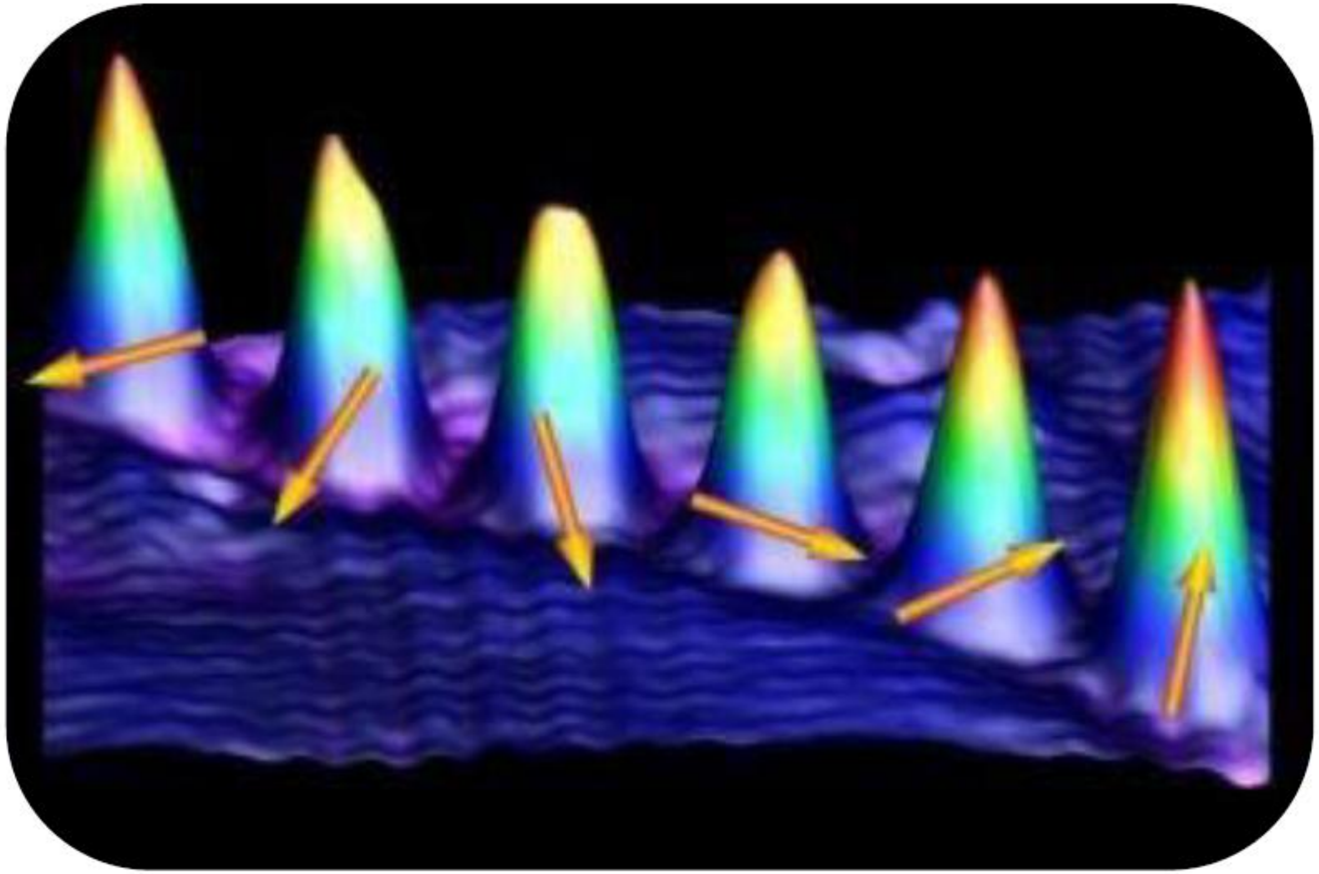
Angular Momentum

- The spin may not always be perfectly up or down, but angular
  - i.e. some *combination* of BOTH up-spin and down-spin



An Electron Microscope View Of Electron Spin

- The pointier the hat, the more upward the spin



General Quantum State Formula

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

Quantum State
represented by Psi

(Psi is the 23rd letter of the Greek alphabet)

Alpha Ket 0
Alpha represents the amplitude of state 0

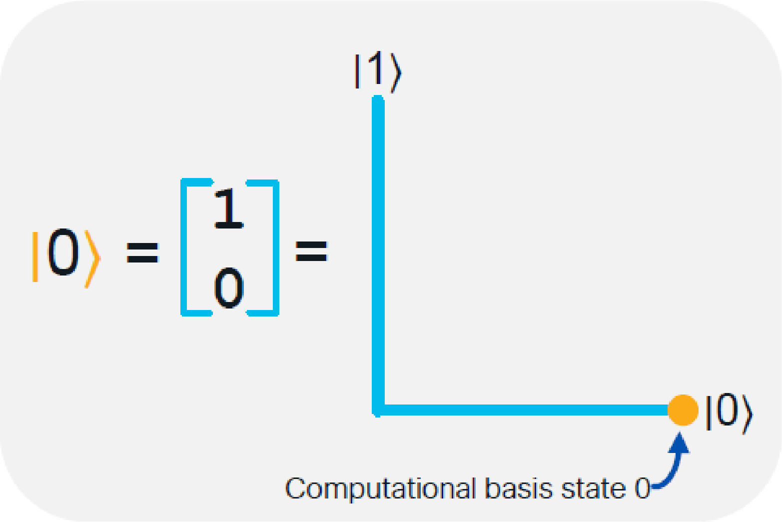
(Alpha is the first letter of the Greek alphabet)

Beta Ket 1
Beta represents the amplitude of state 1

(Beta is the second letter of the Greek alphabet)

Quantum State and Vectors

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



$$\begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

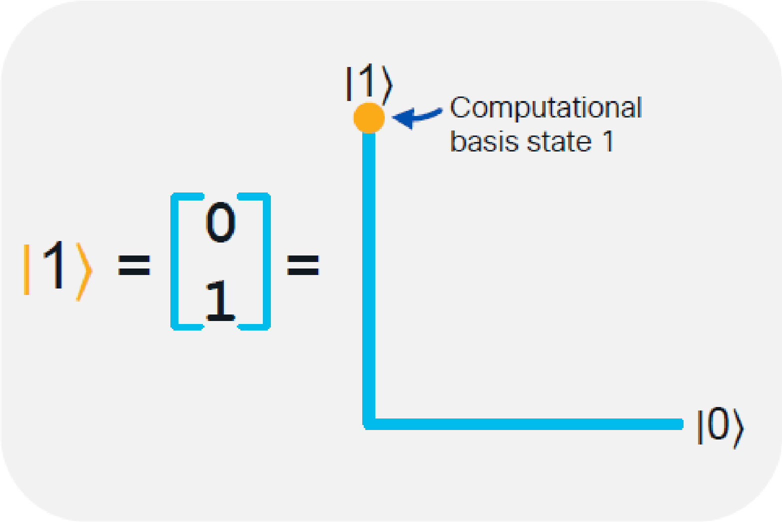
Vector 0

X-Axis Coordinate

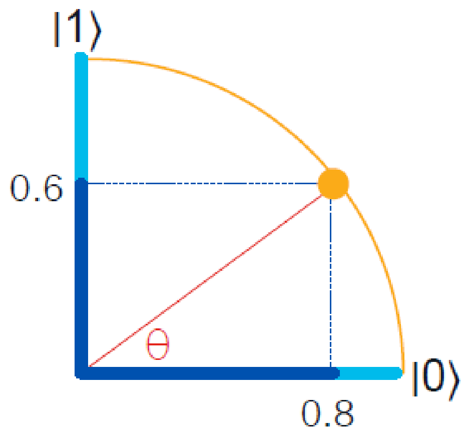
Y-Axis Coordinate

$$\begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

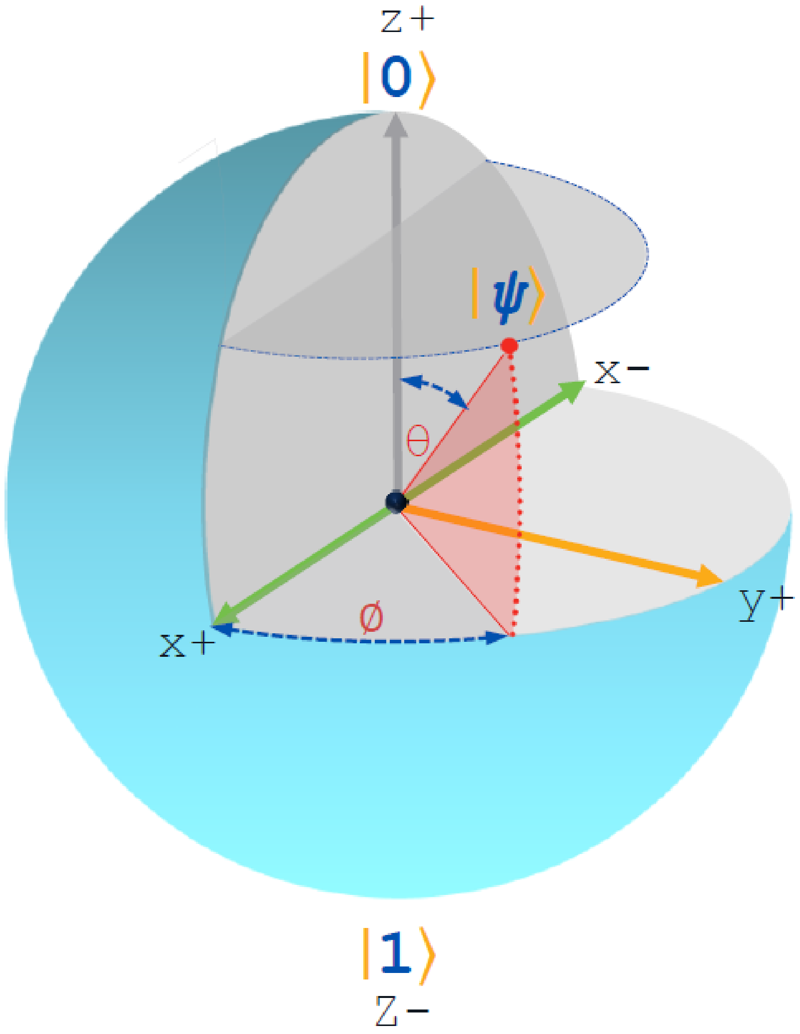
Vector 1

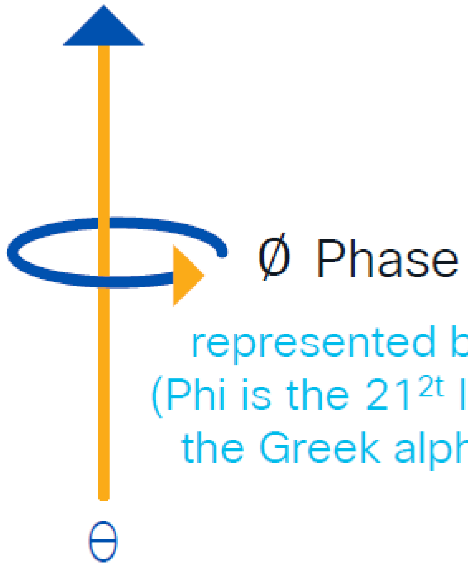


The Bloch Sphere: A 3D Qubit Representation



$|\psi\rangle = 0.8|0\rangle + 0.6|1\rangle$



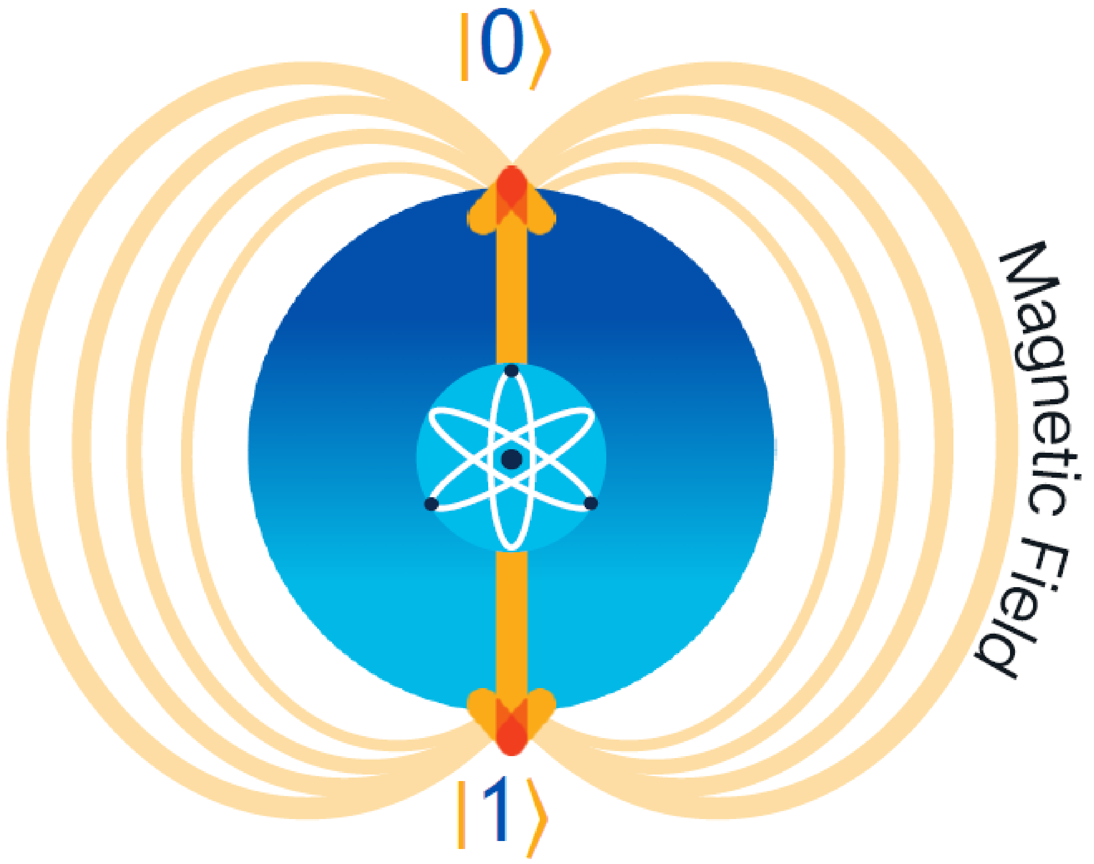


represented by Phi
(Phi is the 21^{2t} letter of the Greek alphabet)

Amplitude
represented by Theta
(Theta is the 8th letter of the Greek alphabet)

Quantum Special Property: Superposition

- As long a Qubit is unobserved (i.e. unmeasured) it is in a "Superposition" of probabilities for 0 and 1

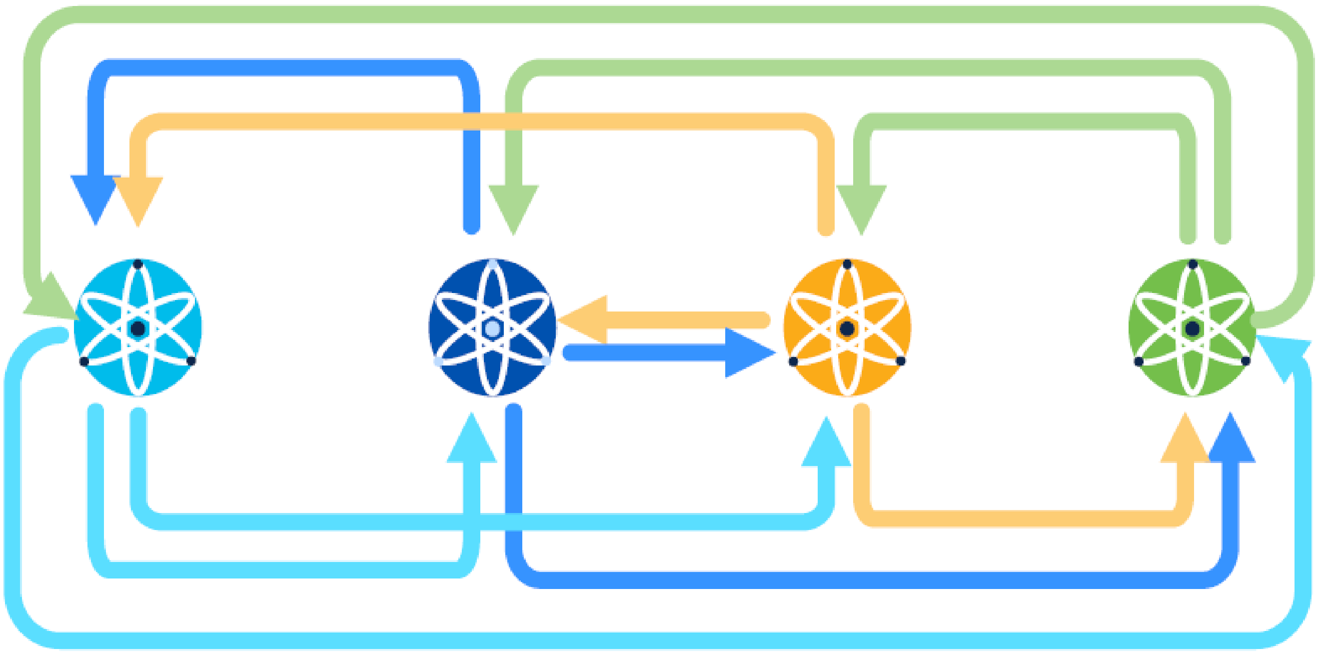


Quantum Special Property: Superposition

- As long a Qubit is unobserved (i.e. unmeasured) it is in a “Superposition” of probabilities for 0 and 1
- The instant a Qubit is measured, the superposition will collapse into one of the two discrete states

Quantum Special Property: Entanglement

- Entanglement is a physical relationship between Qubits where they react to a change in the other(s) state instantaneously regardless of how far they are apart
- Multiple qubits can become entangled with each other
  - The current record is 54



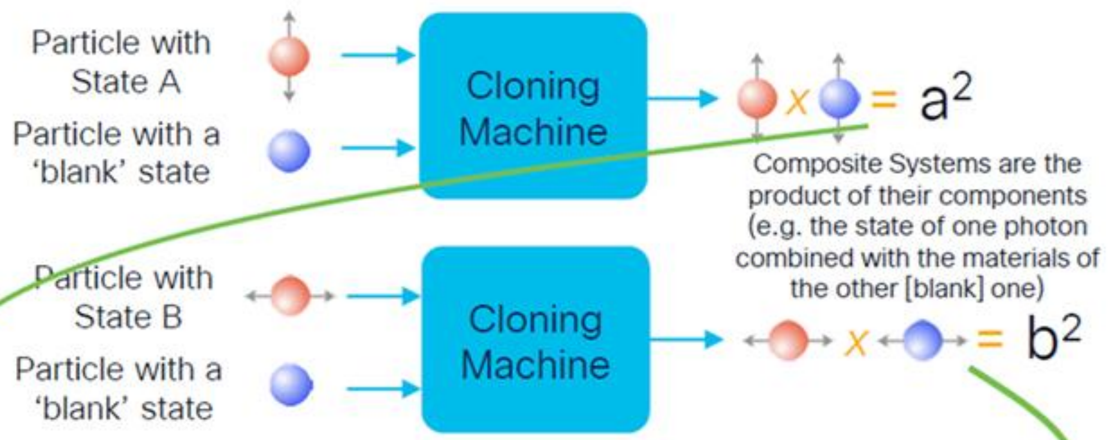
Quantum Special Property: Entanglement

- If an entangled qubit is measured, then entanglement is broken
- The discrete state of the entangled qubit will depend on the entanglement operation that was performed
  - the states may be the same, or
  - the states may be opposite (as shown in this example)
- The important point is that as one entangled qubit changes state, its counterpart(s) will instantaneously reflect that change

Quantum Special Property: No Cloning

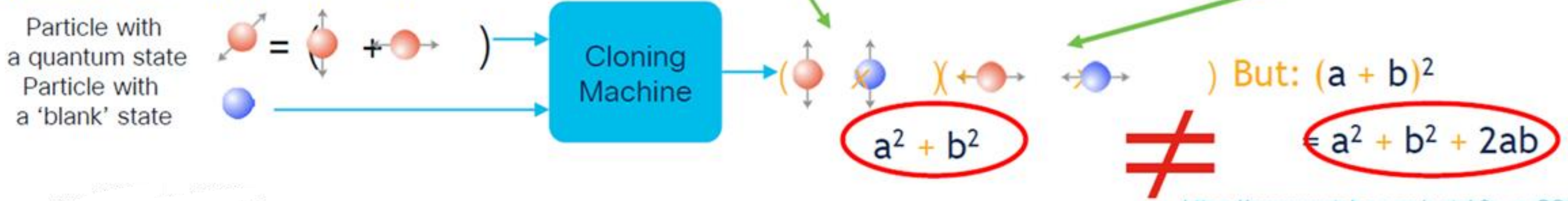
Given: $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$,
Let $a = \alpha|0\rangle$ and $b = \beta|1\rangle$
$|\psi\rangle = (a + b)$

- It can be mathematically proven that it is impossible to clone a qubit
- The proof uses the logical method of "Proof by Contradiction"



Quantum state: $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$
Simplified to: $|\psi\rangle = (a + b)$

For any given Transformation (T): $T(a + b) = T(a) + T(b)$
Let us assume the transformation is a cloning operation



https://www.youtube.com/watch?v=owPC60Ue0BE


QUESTIONS
ANSWERS