Quantum Mechanics & Quantum Computation

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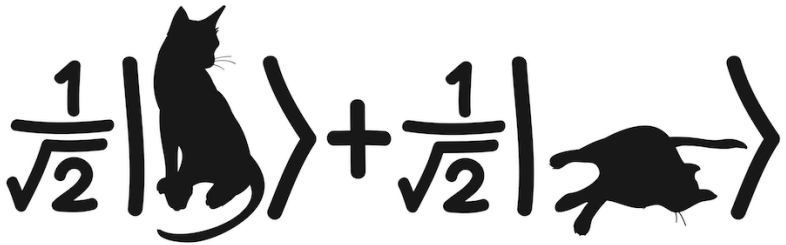


Lecture 3: Two Qubits & Entanglement

Review

Entanglement is the key resource for quantum computation…

“spooky action at a distance”

--Einstein

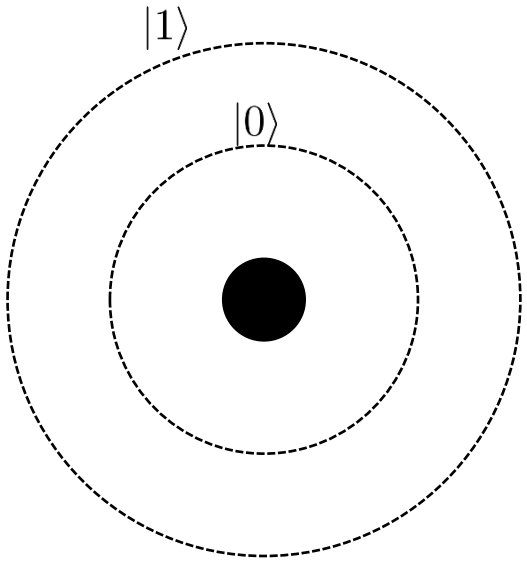
I would not call [entanglement] *one* but rather *the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought.

--Schrodinger

Qubits

- Atomic qubits: electron orbitals.
- Ground state ←→ 0 & Excited state ←→ 1.

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



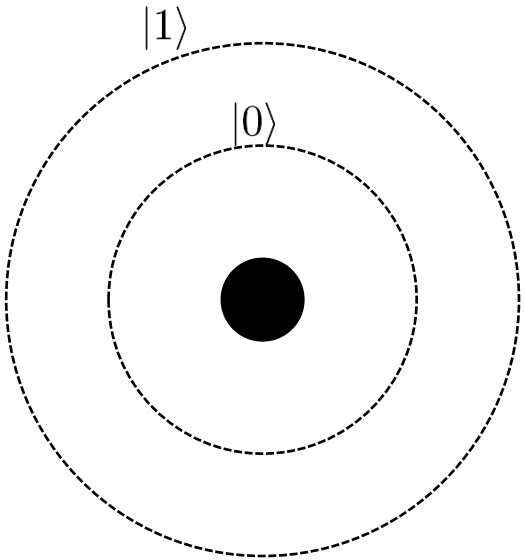
Measurement

- Atomic qubits: electron orbitals.
- Ground state ←→ 0 & Excited state ←→ 1.

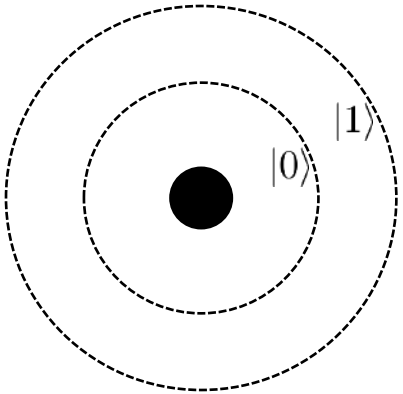
$$|\psi\rangle = \alpha_0|0\rangle + \alpha_1|1\rangle$$

Observe j with probability $|a_j|^2$.
New state = $|j\rangle$.

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

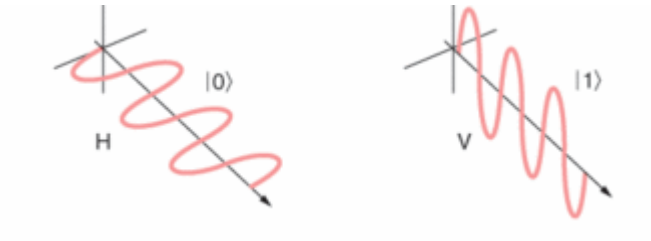


Geometric Interpretation



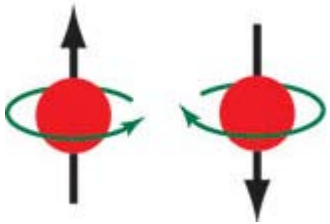
Other Examples of Qubits

Photon polarization



The orientation of electric field oscillations is either vertical or horizontal.

Spin

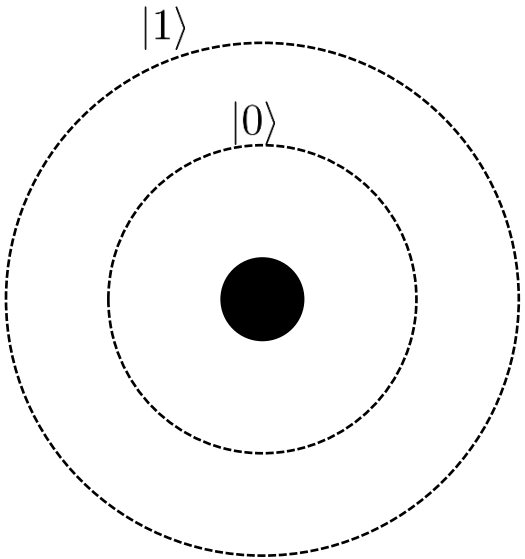


The spin of a particle is either up or down.

Measuring Polarization

Measuring Polarization

Uncertainty principle



Bit: $|0\rangle$ or $|1\rangle$

Sign: $|+\rangle$ or $|-\rangle$

Cannot know both bit and sign of a qubit simultaneously.