Superposition

A combination of amplitudes is more than uncertainty about a hidden bit.

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By the end, you'll be able to

- Construct the plus and minus states using H and Z.
- Explain why an equal mixture differs from a coherent superposition.

A useful starting state

Apply H to $|0\rangle$:

$$H|0\rangle = |+\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}}.$$

Both Z outcomes have probability $1/2$. The state is a coherent combination of amplitudes relative to this basis. Superposition is basis-dependent: $|+\rangle$ is itself one basis vector in the X basis.

Why a coin is an incomplete analogy

A classical random bit can also produce equal 0/1 counts. Those counts alone do not distinguish it from $|+\rangle$. The difference appears when you apply another operation.

Applying H again maps $|+\rangle$ to $|0\rangle$ deterministically. An equal classical mixture of $|0\rangle$ and $|1\rangle$ stays 50/50 under H. The coherent state has a stable relative phase; the mixture does not.

Turn a phase into an outcome

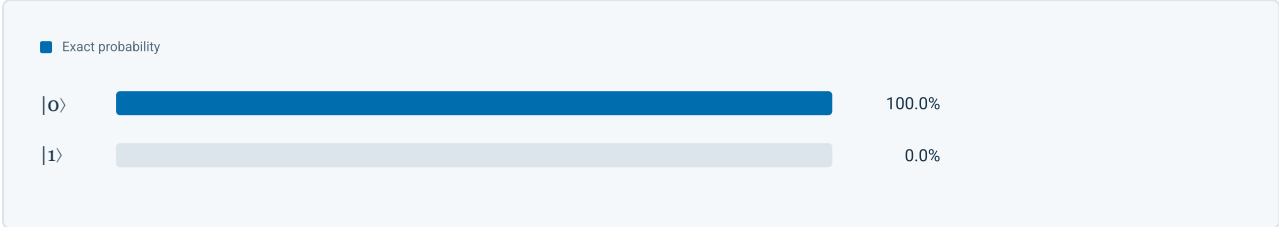
Insert Z between the two H gates. It changes $|+\rangle$ into $|-\rangle$. The second H now gives $|1\rangle$. The intermediate Z-basis probabilities did not change, but the final outcome did.

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Superposition & interference

The two Hadamard gates recombine amplitudes. A relative phase between them changes the result even though the intermediate Z-basis probabilities stay at 50/50.



MODEL · Ideal pure-state vector, complex double precision ORDER · q0 is the leftmost bit

Prediction: H then H returns 0. What do you expect if a Z gate is placed between them? Challenge: Set the phase to 180°. Explain why the final probability of 1 becomes 100%. Open the live experiment studio.

Practise

Compare phase settings 0°, 90° and 180°. Calculate or read the final probability of 1 for each. You should find 0, $1/2$ and 1. Explain the result using amplitudes rather than a claim that measurement reads both possibilities.

Superposition gives algorithms a state space to transform. It does not by itself reveal exponentially many answers, eliminate data-loading costs or guarantee a speedup.

Reference: IBM Quantum — Quantum mechanics basics.