Introduction to quantum information

Separate a mathematical state, a physical system and the information a measurement can reveal.

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By the end, you'll be able to

- Separate the quantum state from an observed outcome.
- Explain why copying classical information differs from copying an unknown quantum state.

Information has a physical representation

A bit may be stored as a voltage. A qubit may use two controlled energy levels of a physical system. The abstract model focuses on distinguishable states and allowed operations rather than one particular device technology.

An ideal pure qubit uses a unit vector in a two-dimensional complex vector space. That mathematical description helps us calculate experimental predictions. It is not a list of values we can freely read from the physical system.

A worked comparison

Consider two states:

$$|+\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}}, \qquad |-\rangle = \frac{|0\rangle - |1\rangle}{\sqrt{2}}.$$

Both give 0 and 1 equally often in the Z basis. Yet applying H before measurement makes $|+\rangle$ produce 0 and $|-\rangle$ produce 1. Their relative sign carries a distinction that the first measurement setting does not reveal.

The lesson is practical: a distribution from one basis is not a complete description of an unknown quantum state.

What can be copied?

Known classical basis labels can be copied into another register using reversible logic. An arbitrary unknown quantum state cannot be perfectly copied by one universal operation. This restriction is the no-cloning principle.

Practise

In the qubit explorer, prepare an equatorial state. Keep its polar angle fixed and vary only relative phase. Record what changes in the sphere and what stays fixed in the Z-basis bars. Then use the interference lab to make the phase difference observable.

Reference: IBM Quantum — Single systems.