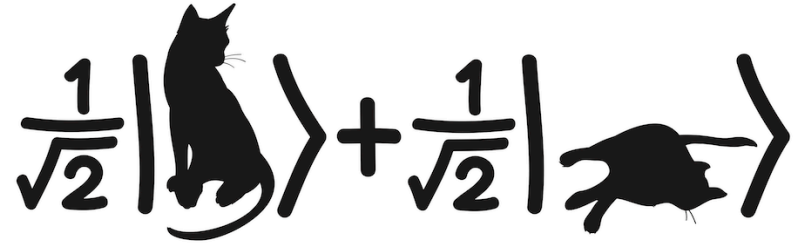


Quantum Mechanics & Quantum Computation

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Lecture 4: Bell's Experiment

Overview

Can we experimentally test whether we live in a quantum World?

- Is all the quantum weirdness an intrinsic property of Nature?
- Or is it possible that quantum mechanics looks so strange because we only know a part of the picture. If we knew more about the gears and mechanism that operate behind the scenes, it might all look more natural. This is what Einstein believed.
- The kinds of gears and mechanism that Einstein was looking for was local and deterministic.
 - local = no action at a distance. No faster than light communication
 - deterministic = “God does not play dice...”

Bell's Experiment (1964)

John Bell devised a remarkable experiment with one of two outcomes:

- Outcome 1 → Nature is inconsistent with quantum mechanics but might be better explained by some local hidden variable theory.
- Outcome 2 → Nature is consistent with quantum mechanics but inconsistent with any local hidden variable theory.

The Bell experiment relies on properties of entangled qubits.

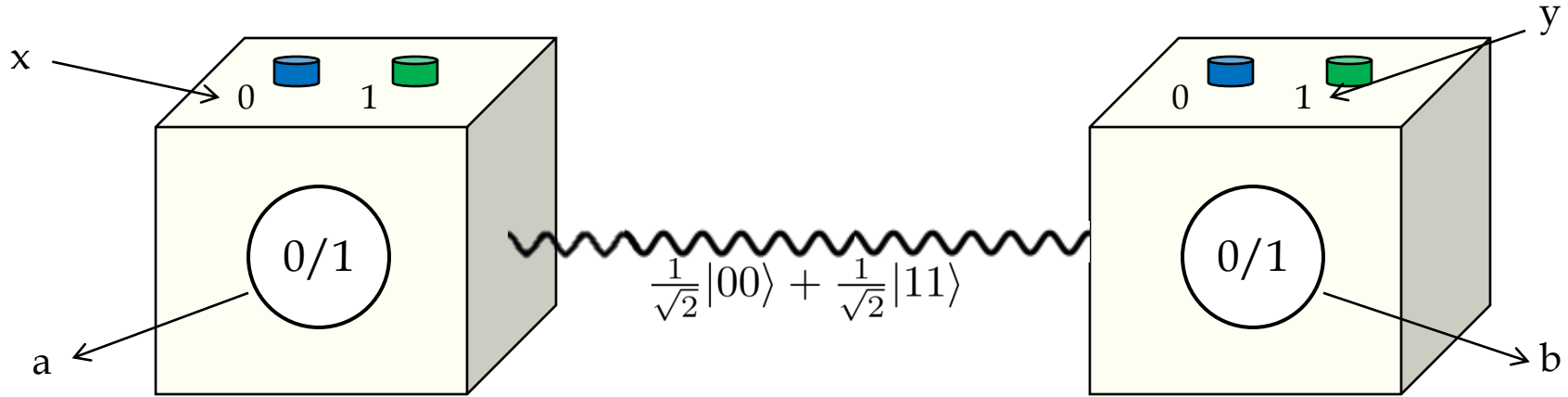
The Bell experiment has been performed numerous times.
The results have always been consistent with quantum mechanics.

Bell's Experiment Setup



- Two boxes are very far apart.
- If both inputs are 1, want output bits to be different
Otherwise, want outputs of the two boxes to be the same.

Bell's Experiment Setup

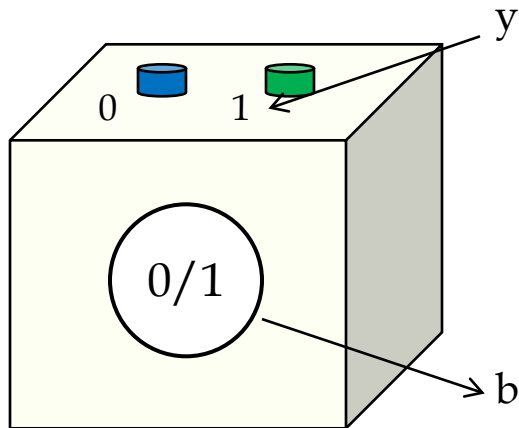
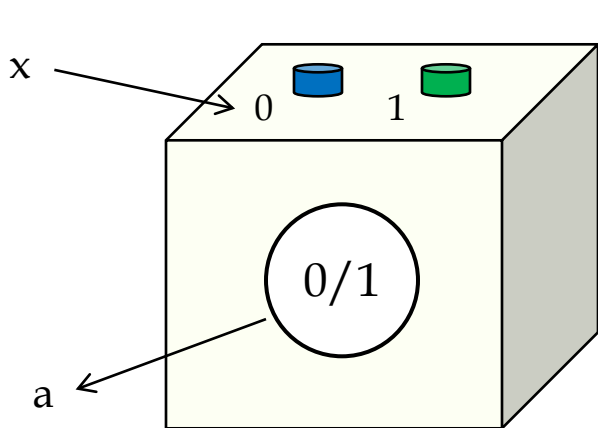


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Boxes described by local hidden variables → succeed with prob $\leq \frac{3}{4} = .75$

Boxes share a Bell state → can succeed with prob as high as .85

Local Hidden Variables



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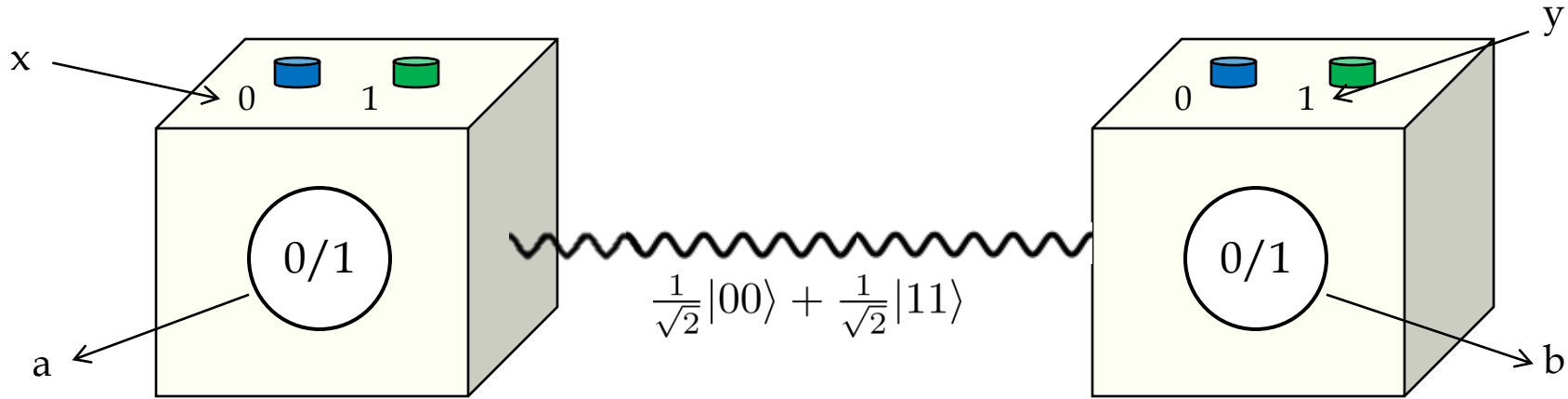
Fail on any of the 4 inputs implies success probability $\leq \frac{3}{4}$

Suppose output on $x=y=0$ is $a=b=0$

By locality, output on $x=0, y=1$ and $x=1, y=0$ must also be $a=b=0$

Finally by locality, output on $x=y=1$ must also be $a=b=0$. Contradiction.

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