Quantum Mechanics & Quantum Computation

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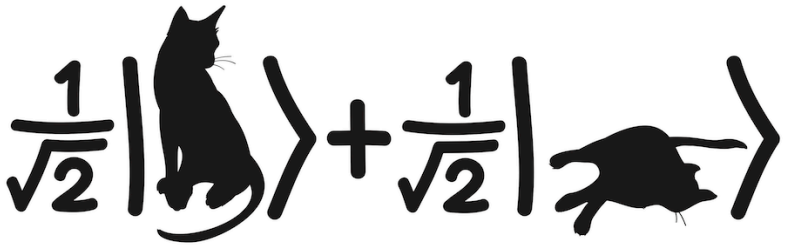
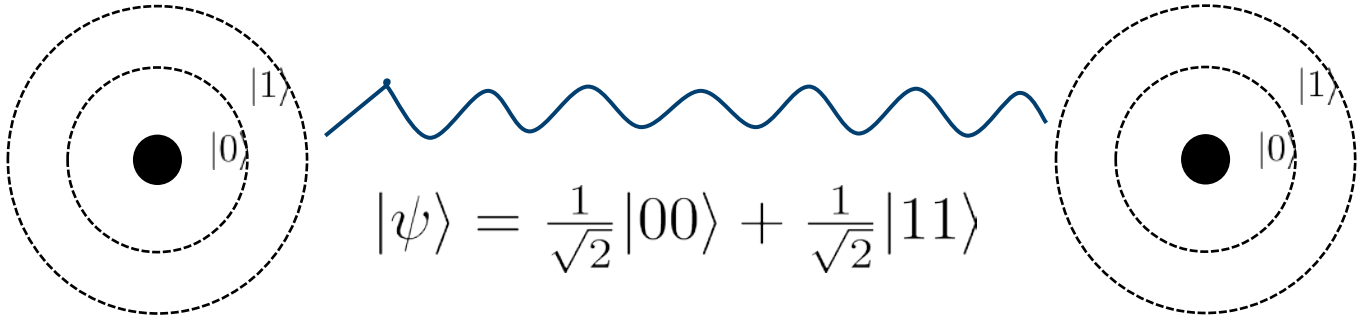


Lecture 3: Two Qubits & Entanglement

EPR Paradox

Measuring the Bell State

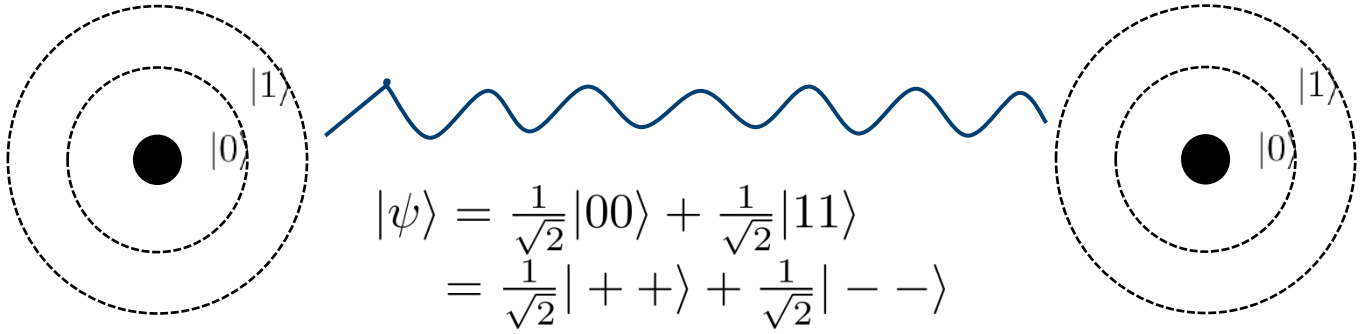


Measure first qubit: see 0 with probability ½ . New state = $|00\rangle$

see 1 with probability ½ . New state = $|11\rangle$

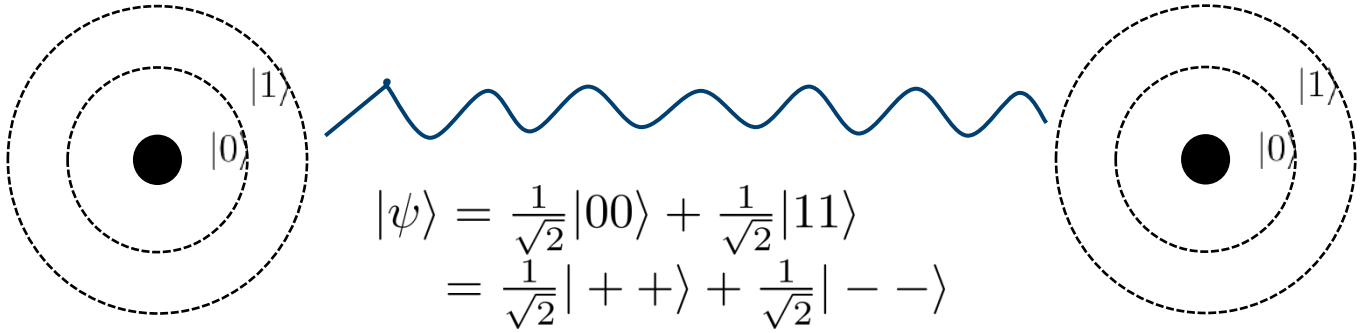
Same result if two particles share a coin flip before they were separated!

Re-writing Bell State in sign basis



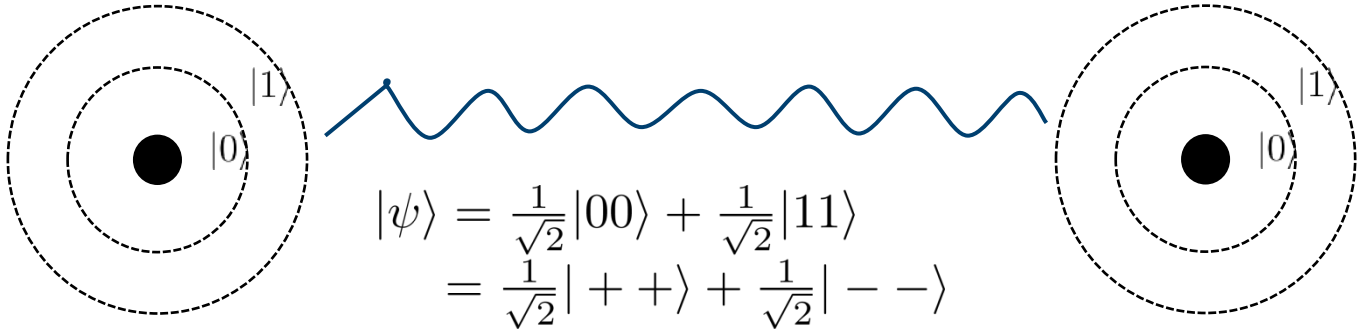
$$|\psi\rangle = \frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|11\rangle$$
$$= \frac{1}{\sqrt{2}}|++\rangle + \frac{1}{\sqrt{2}}|--\rangle$$

Einstein, Podolsky, Rosen (EPR) Paradox (1935)



- Faster than light communication?
- If when the two particles were together they flipped two coins to coordinate how they would answer on bit and sign measurement, then they violate uncertainty principle!!

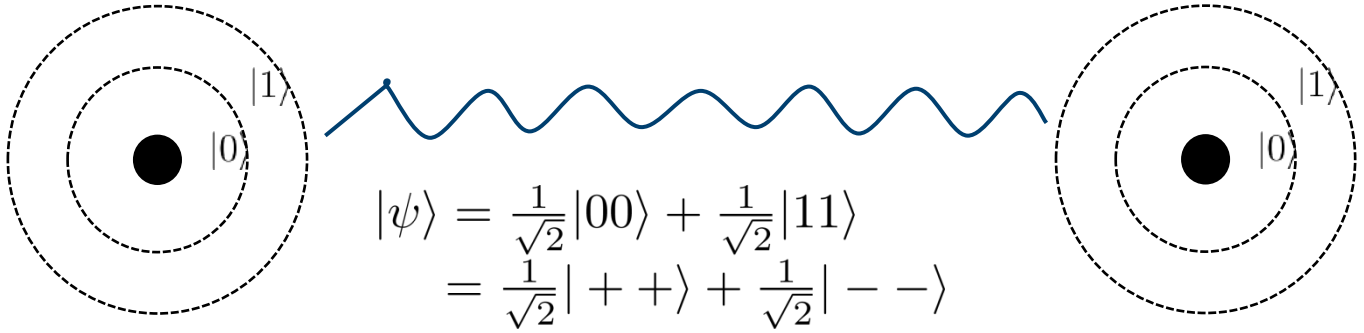
Einstein, Podolsky, Rosen (EPR) Paradox (1935)



- Measure first qubit in bit basis and second qubit in sign basis.

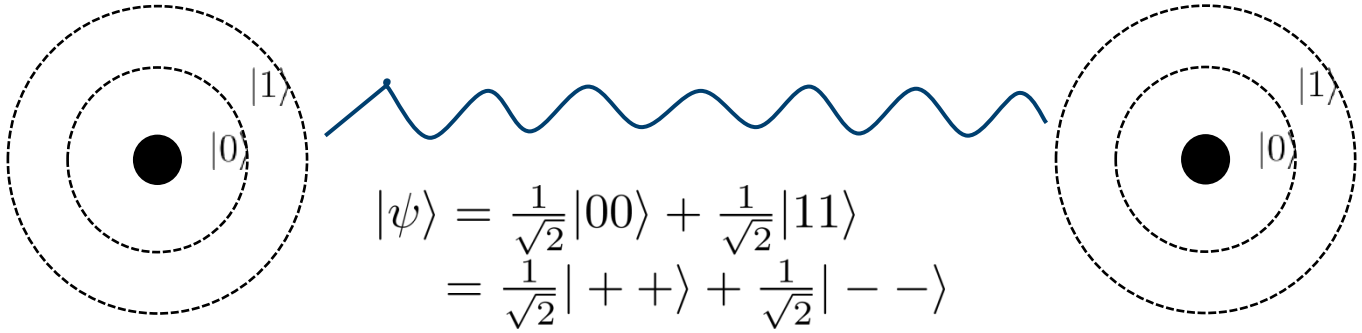
Know both bit and sign for first qubit, contradicting uncertainty principle!!

Einstein, Podolsky, Rosen (EPR) Paradox



Local Hidden Variable Theory: The two particles carry with them all the information necessary to locally decide the outcome of any future measurements.

Einstein, Podolsky, Rosen (EPR) Paradox



Quantum Mechanics: As soon as the first qubit is measured, say in the bit basis, the entanglement between the two qubits is destroyed.
The new state is either |00> or |11>, each of which is unentangled.
Measuring the second qubit in the sign basis no longer reveals any information about the first qubit.

Does not constitute faster than light communication, since no information is communicated.