⇒ Erasing 1 bit releases $\Delta Q = kT \ln 2$ heat.

⇒ "Information is physical"

(i.e.: we cannot think about information processing in physical systems without the physics)

Other motivation: "Moore's law" → # transistors/chip doubles every 18 months

→ transistor size approaches atomic size!

→ must take into account q.m. effects

⇒ better to use them!

Basic ideas of Q.Info:

- Quantum bits (qubits):

Classical info:

basic unit: Bit $b = 0, 1$ (2 possibilities)

N bits: bit string $b_1 \ldots b_N = 0\ldots0, 0\ldots01, 0\ldots10, \ldots$

2^N possibilities!

Quantum information:

basic unit: quantum bit $|b\rangle = |0\rangle, |1\rangle$
(qubit)

quantum mechanics: any superposition possible!

$$|b\rangle = \alpha|0\rangle + \beta|1\rangle$$

$\alpha, \beta \in \mathbb{C}$ → "infinitely many possibilities!"

N qubits:

$$|\underline{b}\rangle = \underbrace{\alpha_{0\ldots0}|0\ldots0\rangle + \alpha_{0\ldots01}|0\ldots01\rangle + \ldots}_{2^N \text{ complex parameters!}}$$

→ Can we store/extract "infinitely much" information?

→ How to quantify amount of information?

- Cloning: Can we copy information?

Classically: $b \to$ [copy] $\to b, b$: works! ✓

Q. Mech: NO!

Why? $|0\rangle \xrightarrow{\text{copy}} |0\rangle \otimes |0\rangle$ (a)

$|1\rangle \xrightarrow{\text{copy}} |1\rangle \otimes |1\rangle$ (b)

$\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \xrightarrow{\text{copy}} \frac{1}{2}(|0\rangle + |1\rangle) \otimes (|0\rangle + |1\rangle)$

But linearity: (1)+(2):

$\frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \xrightarrow{(1)+(2)} \frac{1}{\sqrt{2}}(|0\rangle \otimes |0\rangle + |1\rangle \otimes |1\rangle)$

No-cloning theorem

Quantum information cannot be cloned!

⇒ Questions: How can we then store/transmit q. info? How can we deal w/ errors?