

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

⇒ "Information is physical"

(i.e.: we cannot think about information processing in physical systems w/out the physics)

Other motivations: "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 $s_1 \dots s_N = 0\dots 0, 0\dots 01, 0\dots 10, \dots$

2^N possibilities!

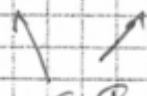
Quantum information:

(3)

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

quantum mechanics: any superposition possible!

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



$\in \mathbb{C} \rightarrow$ "infinitely many" possibilities!

N qubits:

$$|b\rangle = \underbrace{\alpha_{0\dots 0}|0\dots 0\rangle + \alpha_{0\dots 1}|0\dots 01\rangle + \dots}_{2^N \text{ complex parameters!}}$$

2^N complex parameters!

\rightarrow Can we store/extract "infinitely much" information?

\rightarrow How to quantify amount of information?

Cloning: Can we copy information?

Classically: $b \rightarrow \boxed{\text{copy}} \rightarrow \begin{matrix} b \\ b \end{matrix}$: works! \checkmark

Q. Tech: NO!

(4)

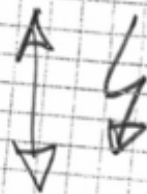
Why?

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

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

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

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!

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