Putting the rhythm in quantum algorithms!

Learn quantum programming basics with the 2-Qubit Dance

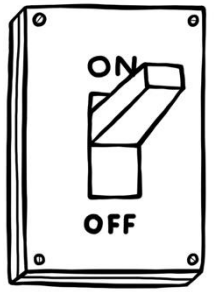
INSTITUT QUANTIQUE UDS

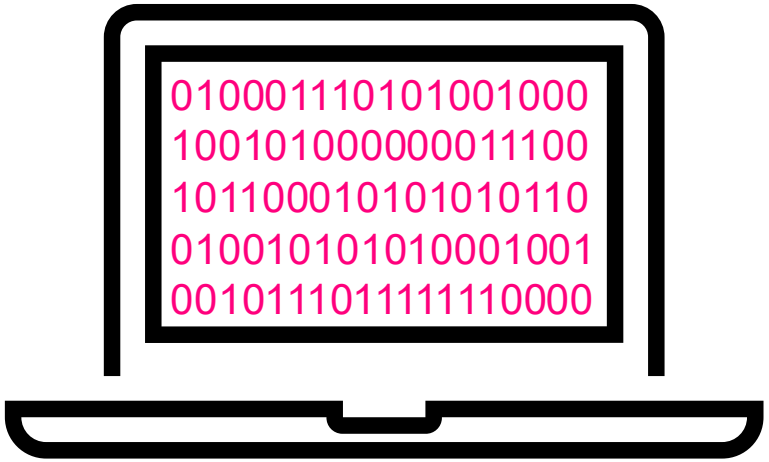
QUANTUM CURIOUS

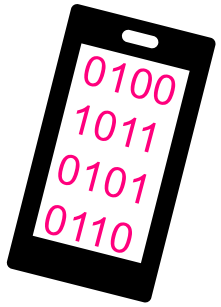
How do classical computers work?

Inside classical computers: transistors coding 0s and 1s

- Their hardware is made of billions of transistors
- For example, if a transistor allows current to flow, it means 1; if not, it means 0







Your time to shine!

Activity 1: Experimenting with binary codes

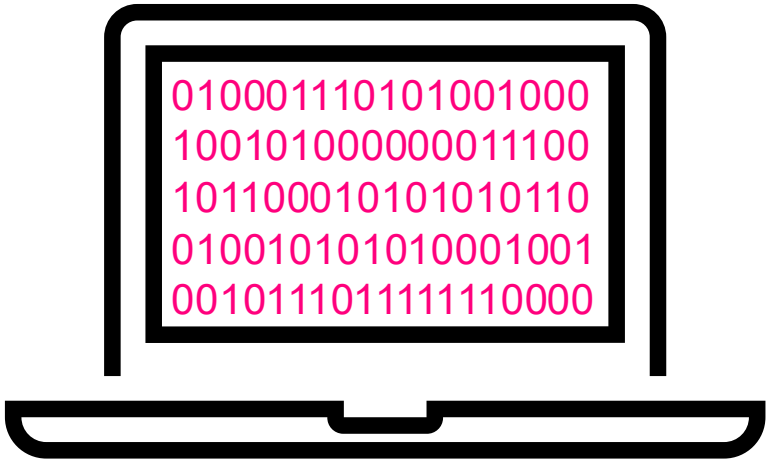
Observations from this activity

- Information can be coded with conventions (for example, up means “yes” and down means “no”);
- The conventions can vary (left/right; up/down);
- Classical computers work in a similar way, where they use series of 0s and 1s coded by transistors.

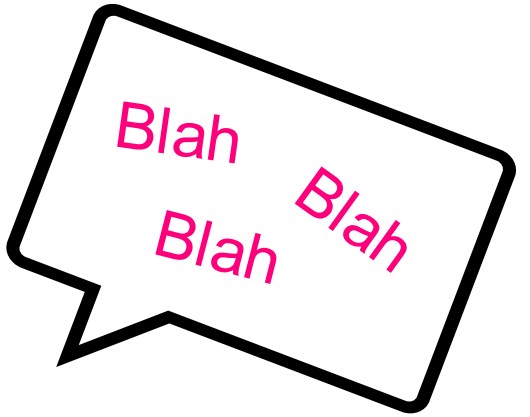
How can 0s and 1s encode complex information like words?

ASCII : a code translating series of 0s and 1s into letters

- Different codes can be used to translate 0s and 1s into words
- A well-known one is the ASCII code, where each pack of 8 binary digits (bits) corresponds to a letter

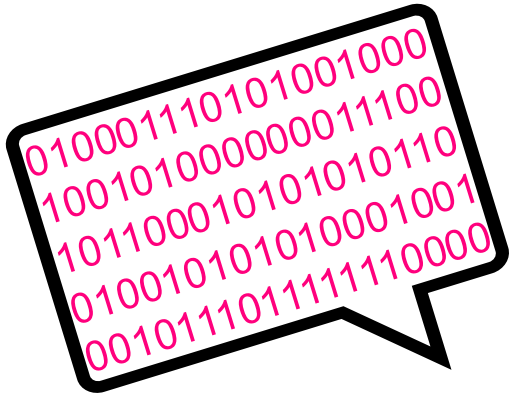


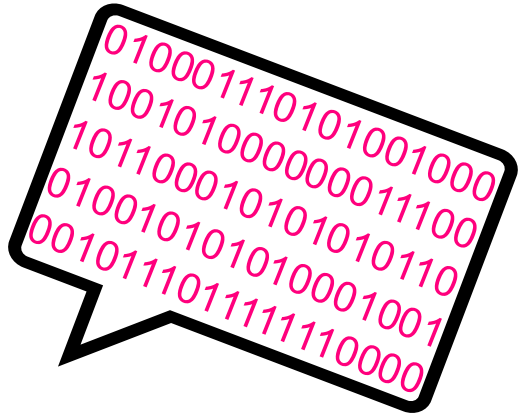
01000010 = B
01001100 = L
01000001 = A
01001000 = H



Your time to shine!

Activity 2 : Communicating with the ASCII code





ASCII code for the capital letters

01000001	A	01001010	J	01010011	S
01000010	B	01001011	K	01010100	T
01000011	C	01001100	L	01010101	U
01000100	D	01001101	M	01010110	V
01000101	E	01001110	N	01010111	W
01000110	F	01001111	O	01011000	X
01000111	G	01010000	P	01011001	Y
01001000	H	01010001	Q	01011010	Z
01001001	I	01010010	R		

01000001	A	01001010	J	01010011	S
01000010	B	01001011	K	01010100	T
01000011	C	01001100	L	01010101	U
01000100	D	01001101	M	01010110	V
01000101	E	01001110	N	01010111	W
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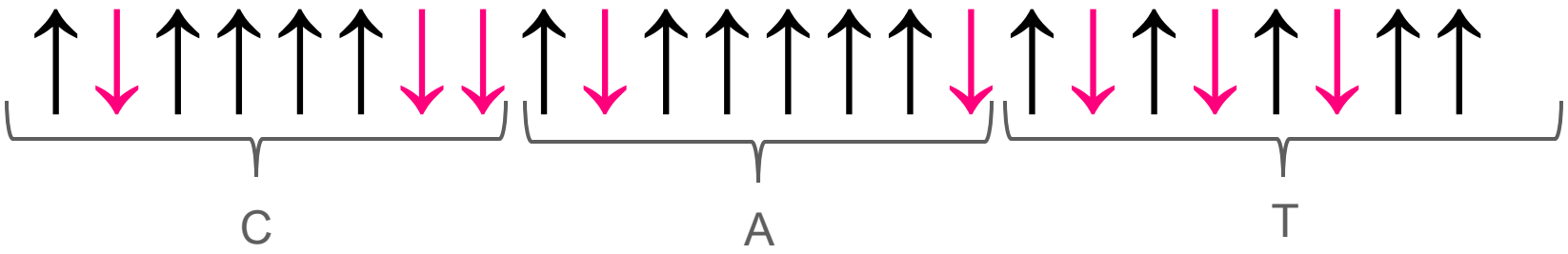
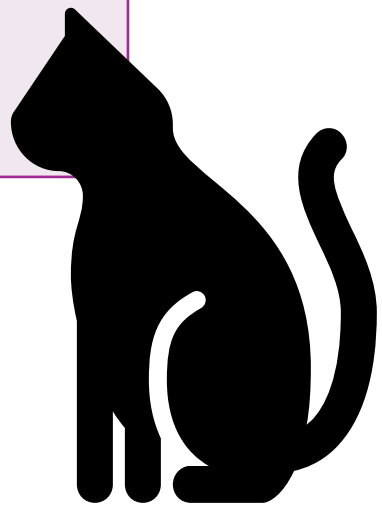




Observations from this activity

- Classical computers work in a similar way to what you just did, where they use consecutive « packs » of 0s and 1s;
- Both the transmitter and the receiver need to use the same convention to understand each other;
- If only the transmitter and receiver know the convention, they can communicate in secret, because observers can't decode what they intercept. (That's cryptography!)

Welcome to the quantum realm!... But what is quantum physics?

It’s the study of physics at the subatomic scale!

- Quantum physics studies the energy and the behavior of matter at an infinitely small scale
- The name "quantum" comes from the Latin word "quantus" meaning "how much"
- Surprising and counterintuitive phenomena happen at this scale

Compared to classical computers, do you think quantum computers …:

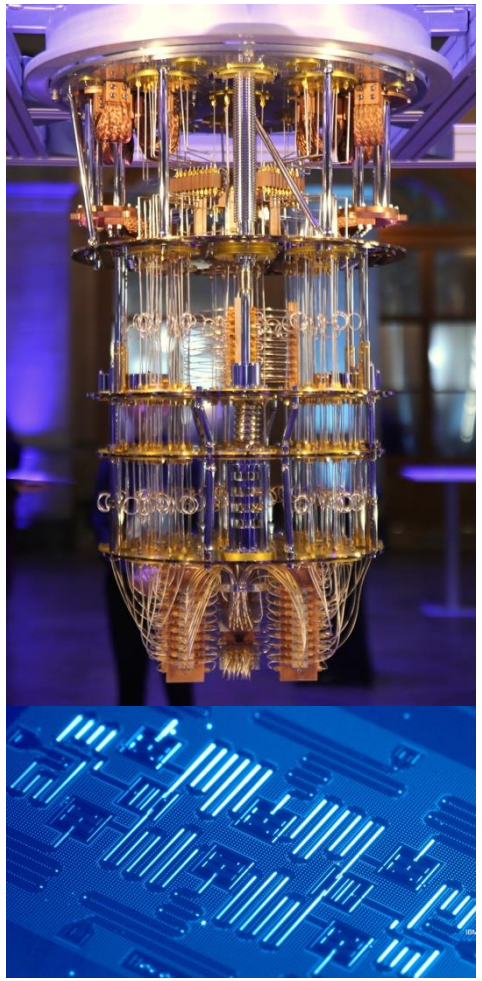
A) work the same, but faster?

OR

B) work differently?

Quantum computers work differently!

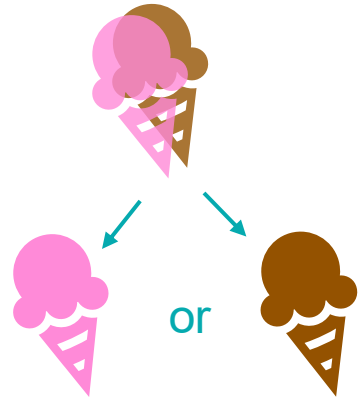
- Instead of transistors encoding bits, quantum hardware uses qubits (quantum bits)
- Qubits can encode 0 or 1 (like classical computers), but also 0 and 1 at the same time (unlike classical computers!)
- They use quantum properties such as:
  - Superposition of states
  - Entanglement



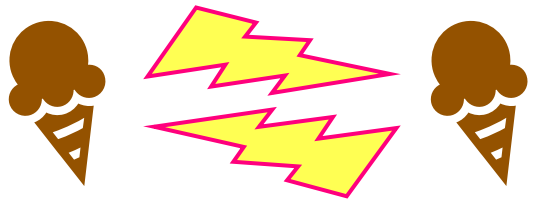
Credit (both photos) : IBM quantum

What happens in relation to those quantum properties

- Superposition of states
  - Allows to encode 2 states at the same time
  - At measurement, the superposition of state collapses : you'll measure 1 of the 2 states (follows rules of probability)



- Entanglement
  - Links the states of 2 qubits
  - If you mesure one qubit, you then know the state of the other one without measuring it

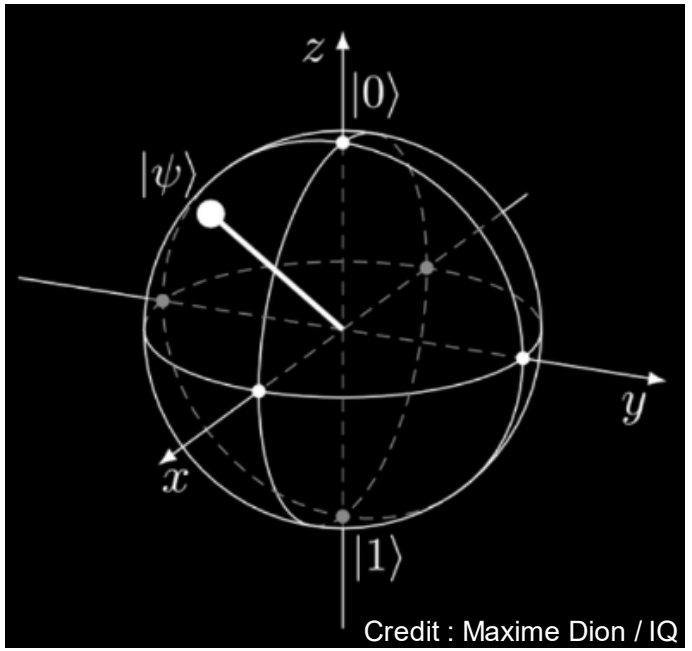


Quantum properties, quantum programming!

- Since quantum computers work in a completely different way, the way they are programmed is also different

- Quantum algorithms are programmed with quantum logic gates (Y, Hadamard…)

- There's a useful tool to represent a qubit : the Bloch sphere



Credit : Maxime Dion / IQ

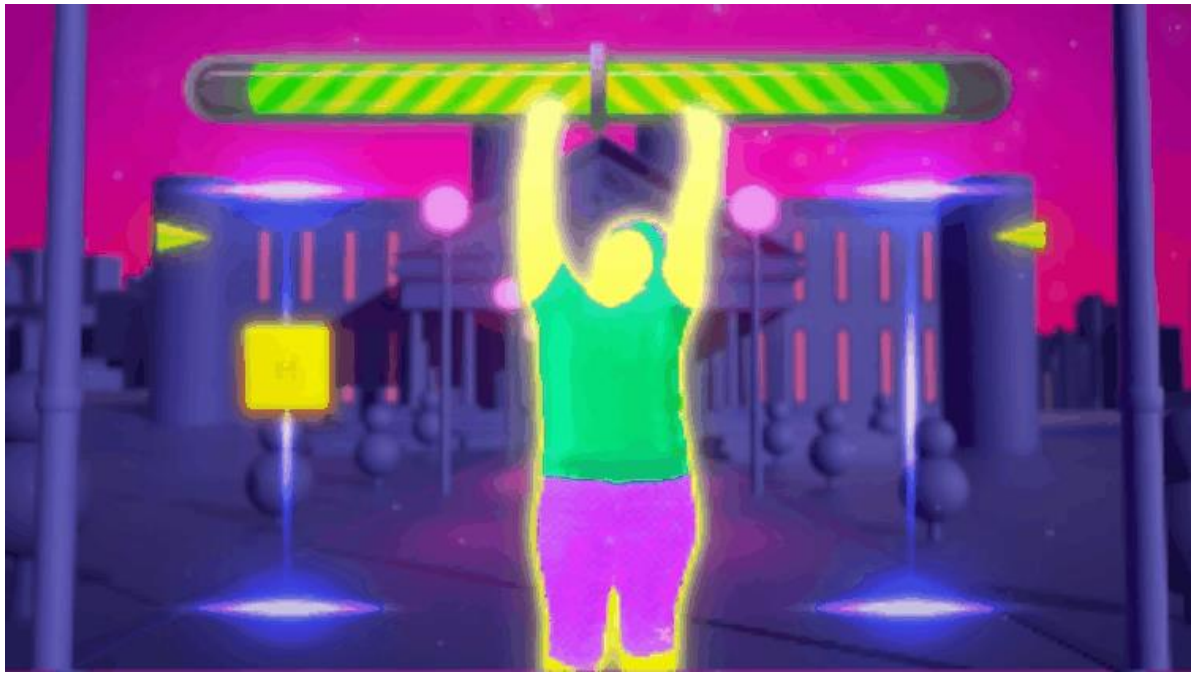
Your time to shine!

Activity 3 : Dancing quantum logic gates


2UBIT
DANCE
LA DANSE À 2 QUBITS

Have you noticed this?

- Superposition of states
- Entanglement
- Measurement

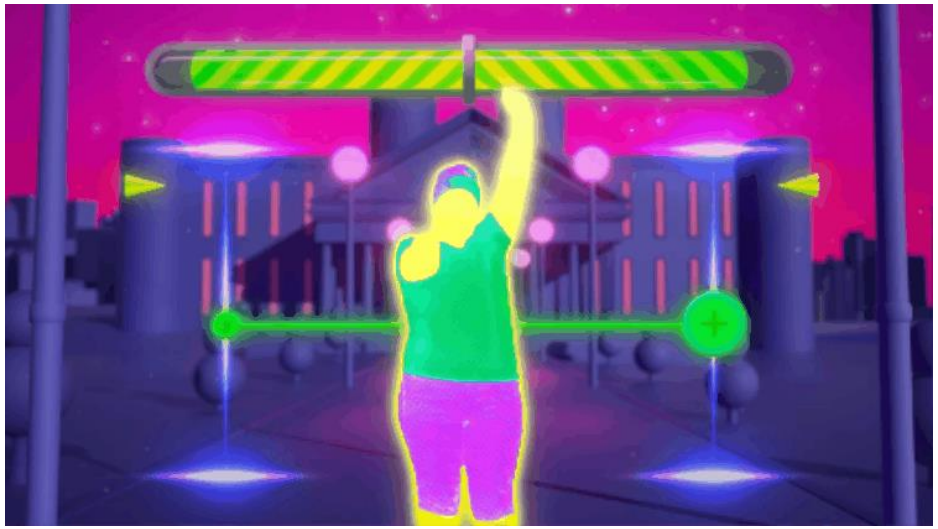


Have you noticed this?

- Superposition of states
  - With Hadamard gate
  - The qubit is 50% in the 1 state 1 and 50% in the 0 state
- Entanglement
- Measurement

Have you noticed this?

- Superposition of states
- Entanglement
  - Before CNOT application: the control qubit is in superposition of states
  - CNOT application : the NOT gate is both applied and not applied at the same time
  - After CNOT application: the 2 qubits are now entangled and their superposed states are "0 and 0" and "1 and 1"
- Measurement



Have you noticed this?

- Superposition of states
- Entanglement
- Measurement
  - Measuring any superposed state will make it collapse
  - With the entangled qubits of this example, when either is measured, both collapse the same way: "0 and 0" or "1 and 1"

2QUBIT DANCE

LA DANSE À 2 QUBITS

What to do next!

THE QUANTUM ENIGMAS

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