@Brendan_In_Byte

# Quantum Computing

*A new type of computing using principles of quantum mechanics to solve problems too complex for classical computers.*

## Classical

*Classical computers store and process information in binary **bits**.*

*Each bit represents one unit of information.*

*N bits = 2N units of information*

## Quantum

$|\Psi\rangle = a|0\rangle + b|1\rangle$

*Quantum computers store data in **qubits**, which are a weighted combination of zero and one at the same time.*

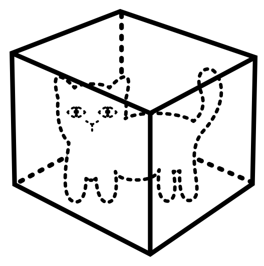
$|\Psi\rangle = a|0\rangle + b|1\rangle$

$|\Psi\rangle = a|00\rangle + b|11\rangle + c|01\rangle + d|10\rangle$

*Entangled qubits exponentially increase the amount of information that can be stored.*

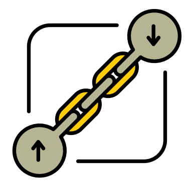
*N bits = $2^N$ units of information*

## Three key principles:



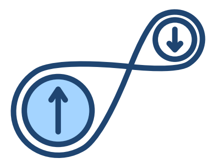
### Superposition

*A quantum particle or system represents a combination of multiple possibilities, fluctuating until observed. When measured, this superposition collapses into a single state.*



### Entanglement

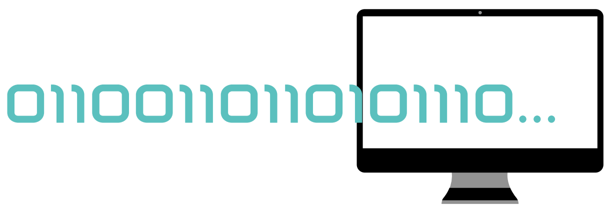
*Multiple quantum particles can correlate their measurement results beyond regular probability. Measurements from one qubit can inform conclusions about the others.*



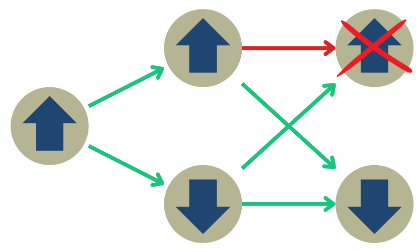
### Interference

*The intrinsic behaviour of a qubit to influence the probability of it collapsing one way or another.*

## Quantum computing approaches computing differently




*Classical computing processes data **sequentially**, working through one step at a time.*



*Quantum computing processes data **simultaneously** - probability amplitudes overlap to provide efficient paths to a solution.*

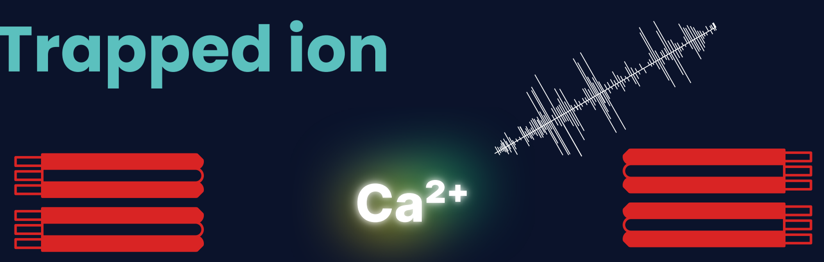
***Quantum computing is less efficient for "simple" problems but better for complex problems** (e.g. optimization, factorization etc.)**, as it finds efficient paths to a solution while scaling qubit information density rapidly.***

## What exactly is a qubit?

*A qubit ("quantum bit") is not a single physical object - rather, a general term referring to a quantum system that can produce the desired characteristics.*

### Examples of qubits include...

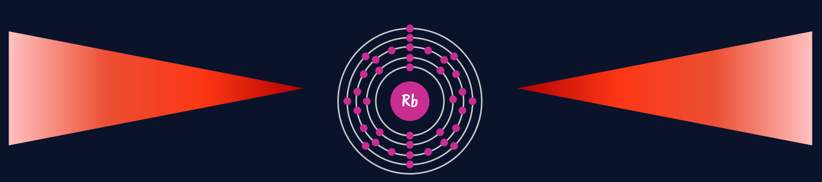
### Trapped ion




*Electromagnetic fields are used to trap entangled ions and provide signals to change qubit states.*

QUANTINUUM
Universal Quantum
IONQ
oxford ionics
AQT

### Neutral atoms

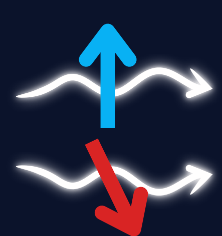



PASQAL
QuEra
Infleqtion
atom computing

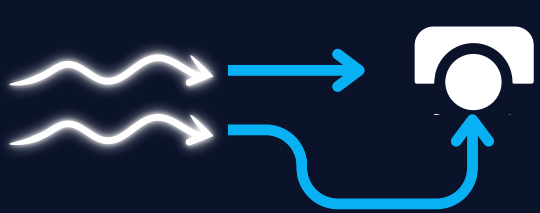
*Arrays of neutral atoms (e.g. Rb) are entangled by exciting them to high-energy Rydberg states, being held in place and excited between energy levels using lasers.*

### Photons

*More than one way of making a qubit:*



*Encode polarization states as "0" or "1"*



*Using two distinct paths ("modes"): arrival times dictate which path a photon took and hence qubit state*

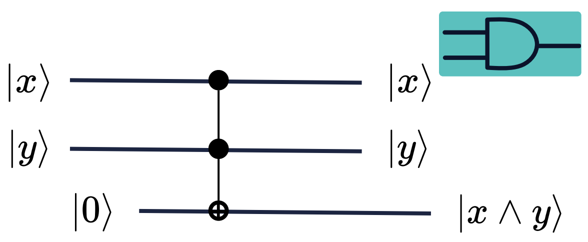
XANADU
ORCA COMPUTING
QUANDELA
PsiQuantum
QUIX QUANTUM
nu

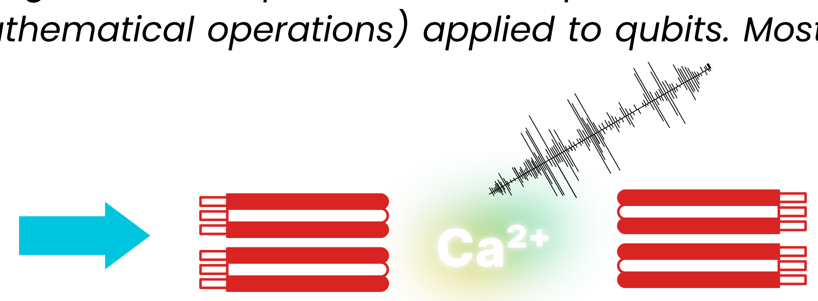
## How exactly does a quantum computer work?

*Just as there are many ways to make a qubit , there are multiple ways to make a quantum computer.*

### Circuit model

*Analogous to classical computing circuits: represents a computation as a sequence of quantum gates (mathematical operations) applied to qubits. Most common model.*

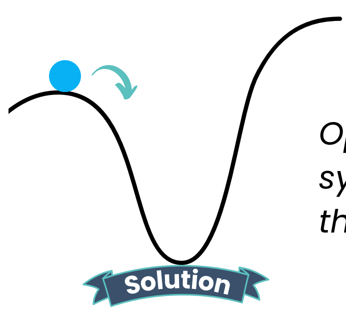



*EM waves replicate the mathematical operators physically.*

### Quantum annealing

*Uses specialised purpose-built hardware - excels at solving optimisation problems. Already commercially available (e.g. D-Wave)*

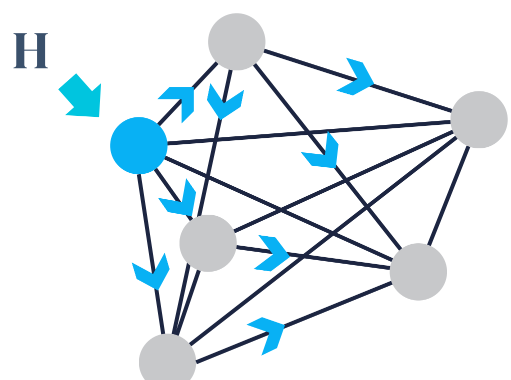



*Optimisation problem is mapped to an energy landscape and system is guided to find the lowest energy state, which represents the solution.*

### Measurement-based quantum computation

***(one-way quantum computation)***

*Uses a cluster state as a computational resource. to serve as a resource for computation. Instead of actively controlling qubits, get to the answer by measuring them.*




*Computation driven by single-qubit measurements, adapting based on prior outcomes.*

@Brendan_In_Byte