QUANTUM COMPUTING HACKATHON

2023

Qiskit

مقر المبرمجين
coders(hq)

جامعة زايد
ZAYED UNIVERSITY

AGENDA

- Opening Keynote
- Guest Speakers - CodersHQ
- Quantum Mechanics Fundamentals
- Quantum Games!
- Lunch + Prayer Break
- Guest Speaker - QF (Quantum Formalism)
- Qiskit Fundamentals
- Hackathon Details!

KEYNOTE SPEAKER

- Full Professor @ CIS
- PhD (Computer Engineering)
- Senior Member Of IEEE

Prof. Jamal Al Karaki

GUEST SPEAKERS

CodersHQ Ambassadors


جامعة زايد
ZAYED UNIVERSITY
البرنامج الوطني للمبرمجين
NATIONAL PROGRAM FOR CODERS
مقر المبرمجين
coders(hq)

CODING AMBASSADORS

Amna Al Hammadi
Interface & Frontend Team

Bashayer Al Salami
Interface & Frontend Team

Maryam Al Mansoori
Backend Team

Husayn Gokal
Bounties Team

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الإمارات تبتكر

UAE INNOVATES

February 2023 فبراير

Agenda

1. What is CodersHQ?
2. Who created CodersHQ?
3. Our initiatives
4. CodersHQ Roadshow
5. Our ambassadors

1 What is CodersHQ?

2

Who created CodersHQ?

Omar Sultan Al Olama is Minister of State for Artificial Intelligence in the United Arab Emirates.

3

Our initiatives

(hq) get inspired

(hq) conferences

(hq) hackathons

(hq) internship

CODERSHQ INITIATIVES

(hq) meetups

(hq) 021

(hq) assessment

(hq) learn

(hq) challenges

(hq) ambassador

4

CodersHQ Roadshow

4 CodersHQ Roadshow

Our ambassadors

JOIN OUR COMMUNITY

Coders HQ is a community for all coders in the UAE to come and empower their skills and mindset with the power of code.

GUEST SPEAKER

- Founder @ SiddiquiAcademy
- 2021 Diana Award Recipient
- TEDx Youth Speaker

AISHA SIDDIQUI

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Review and History of Quantum Computing and Quantum Mechanics

Aisha Siddiqui

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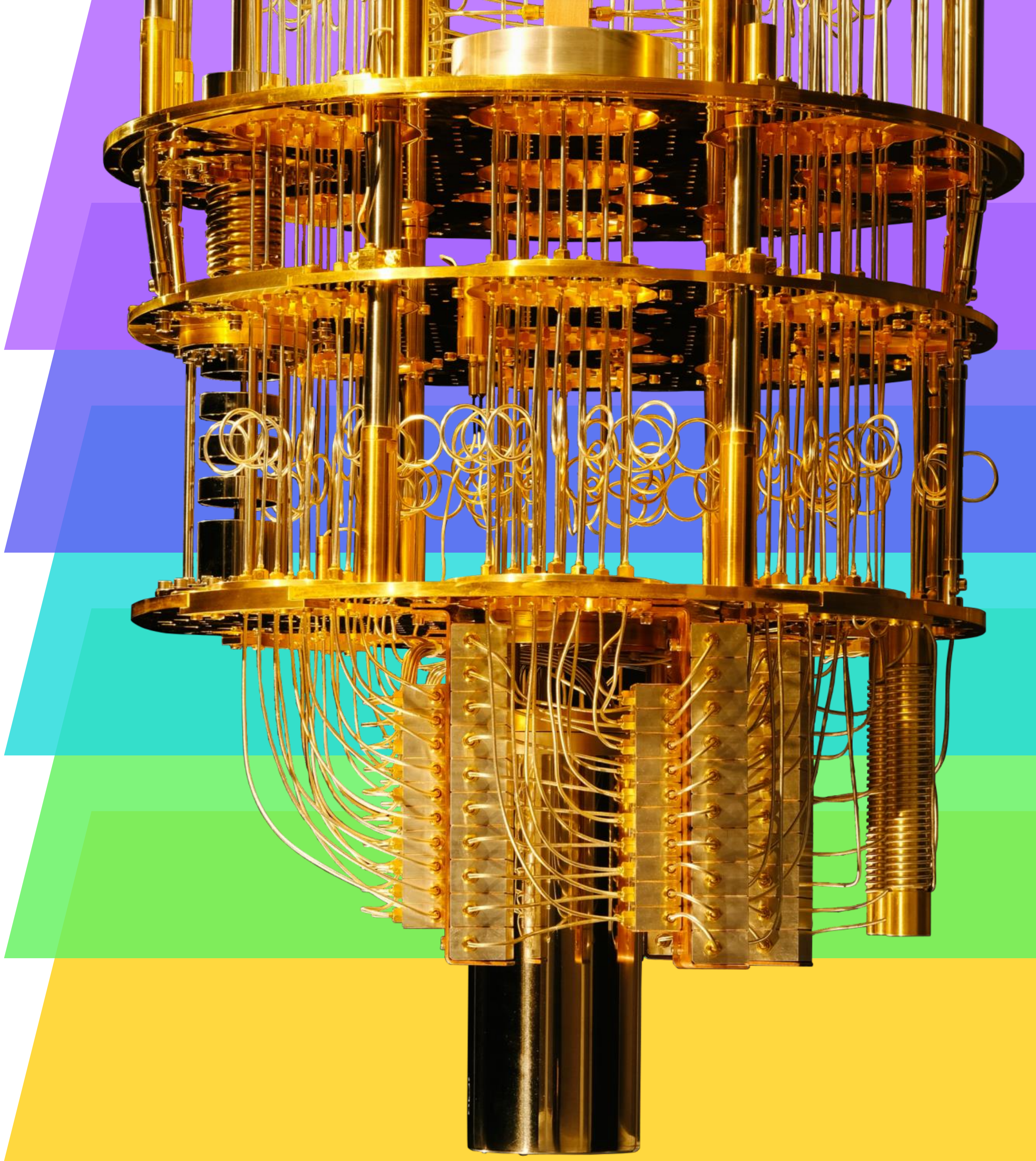

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Quantum Computing

Computing through the generations

1ST

First Generation

1940 - 1956 | Vacuum Tubes

2ND

Second Generation

1956 – 1963 | Transistors

3RD

Third Generation

1964 – 1971 | Integrated Circuits

4TH

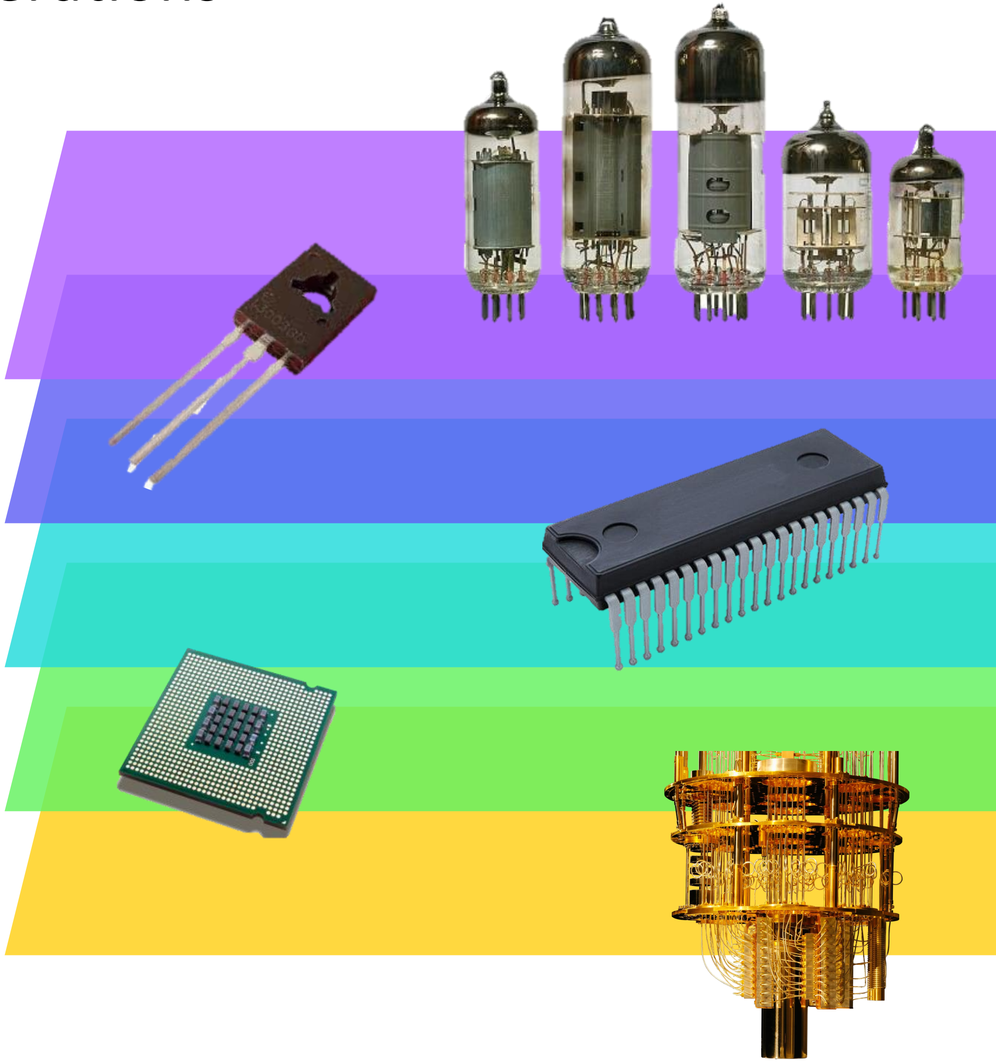
Fourth Generation

1971 – Present | Microprocessors

5TH

Fifth Generation

Present and Beyond | Artificial Intelligence and Quantum Computing



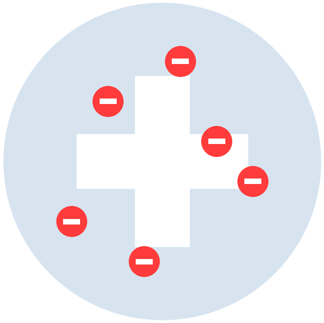
Quantum Mechanics

History of the atom

1803

Dalton

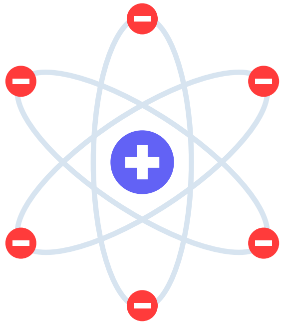
+ Recognized atoms of a particular element differ from other elements.
- Atoms aren't indivisible – they're composed from subatomic particles



1904

Thomson

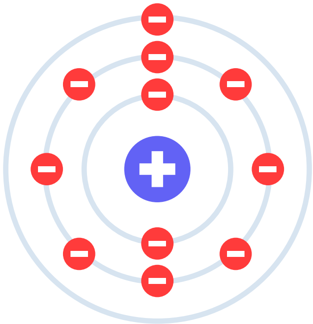
+ Realized positive charge was localized in the nucleus of an atom
- Did not explain why electrons remain in orbit around the nucleus



1911

Rutherford

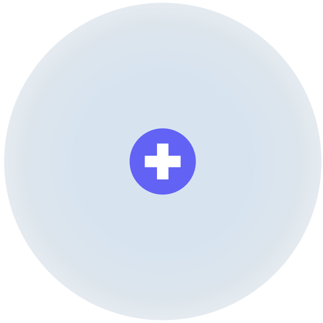
+ Realized positive charge was localized in the nucleus of an atom
- Did not explain why electrons remain in orbit around the nucleus.



1913

Bohr

+ Proposed stable orbits; explained the emission spectra of some elements.
- Moving electrons emit energy and collapse into the nucleus, model did not work well for heavier atoms.



1926

Schrödinger

+ Shows electrons don't move around the nucleus in orbits, but in clouds where their position is uncertain.
+ Still widely accepted as the most accurate model of the atom

Introduction

Quantum Computers use quantum mechanical phenomena:

- Entanglement
- Superposition

- Today's computers, called "classical" computers, store information in binary; each bit is either on or off.
- Quantum computation use qubits, which, in addition to being possibly on or off, can be both on and off, which is a way of describing superposition, until a measurement is made.
- The state of a piece of data on a normal computer is known with certainty, but quantum computation uses probabilities.
- Only very simple quantum computers have been built, although larger designs have been invented. Quantum computation uses a special type of physics, quantum physics.

Logic and Representation

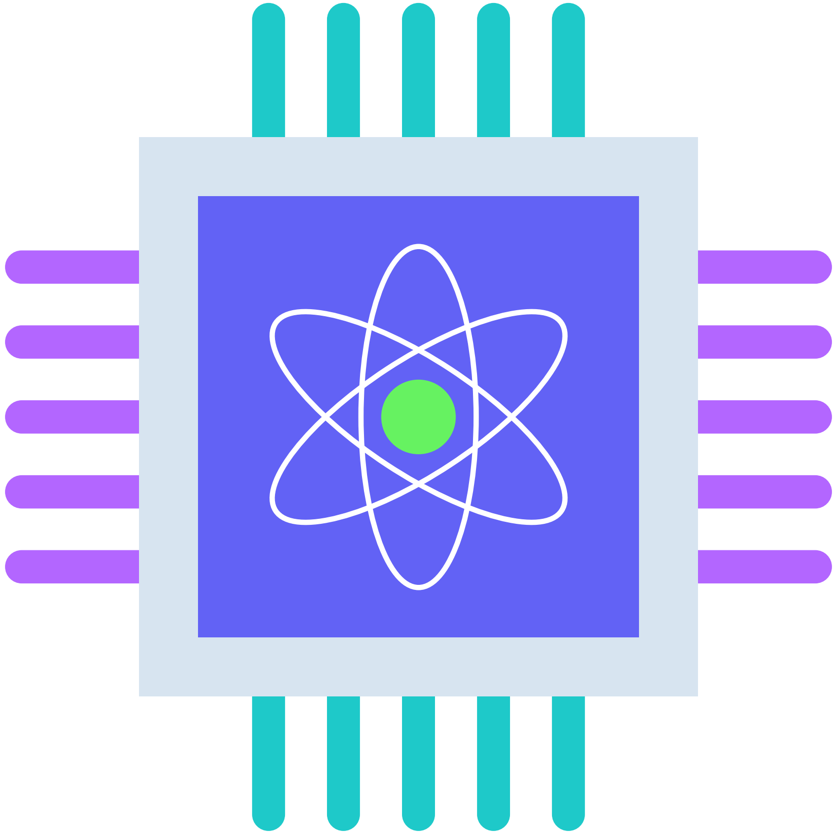
Classical Computer		Quantum Computer
A classical computer has a memory made up of bits.	A	A quantum computer maintains a sequence of qubits.
A bit is a binary digit, the smallest increment of data on a computer.	B	A single qubit can represent a one, a zero, or crucially, any quantum superpositions of these.
A normal computers can only be in one these states – 1 or 0. Therefore, base 10	C	Quantum Computer with n qubits in an arbitrary superposition of up to 2^n different states simultaneously. Therefore base 2

What is a Quantum Computer?

Exploits properties of quantum physics

Built around “qubits” rather than “bits.”

Qubits are 1 or 0 and both simultaneously,

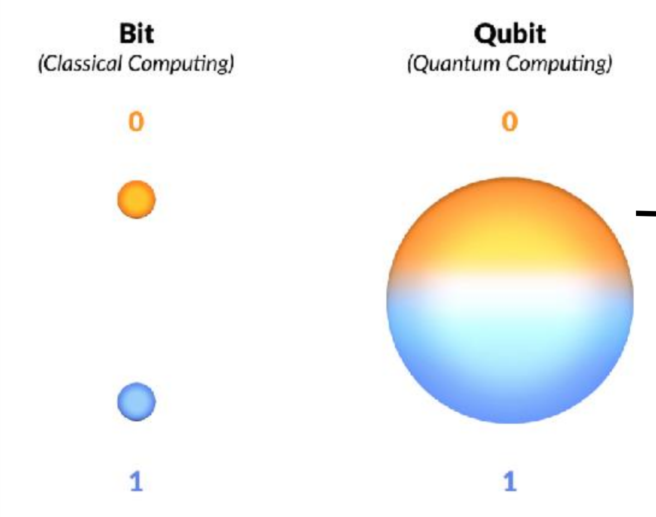


Operates in an extreme environment:

- 150X colder than interstellar space
- Shielded to 50000X less than Earth’s magnetic field
- Very low pressure: 10B times lower than atmospheric pressure.

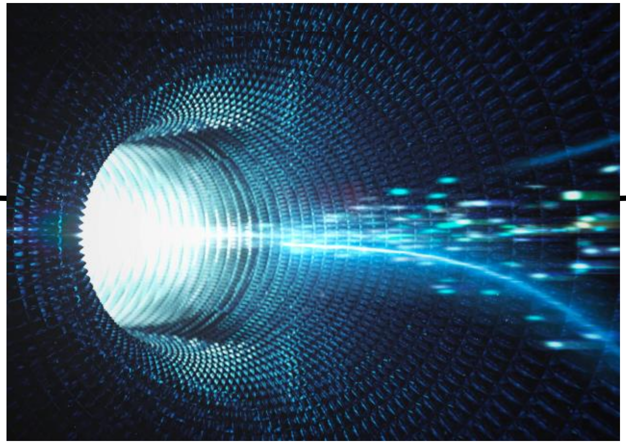
Key Quantum Effects

1



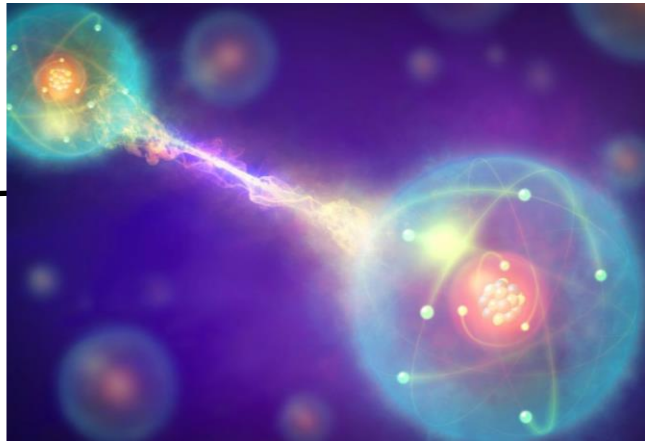
Superposition

2



Quantum Tunneling

3



Entanglement

Schrodinger’s Cat Thought Experiment

Understanding Schrodinger's Cat

Quantum Theory

In quantum theory, quantum particles can exist in a superposition of states at the same time and collapse down to a single state upon interaction with other particles.

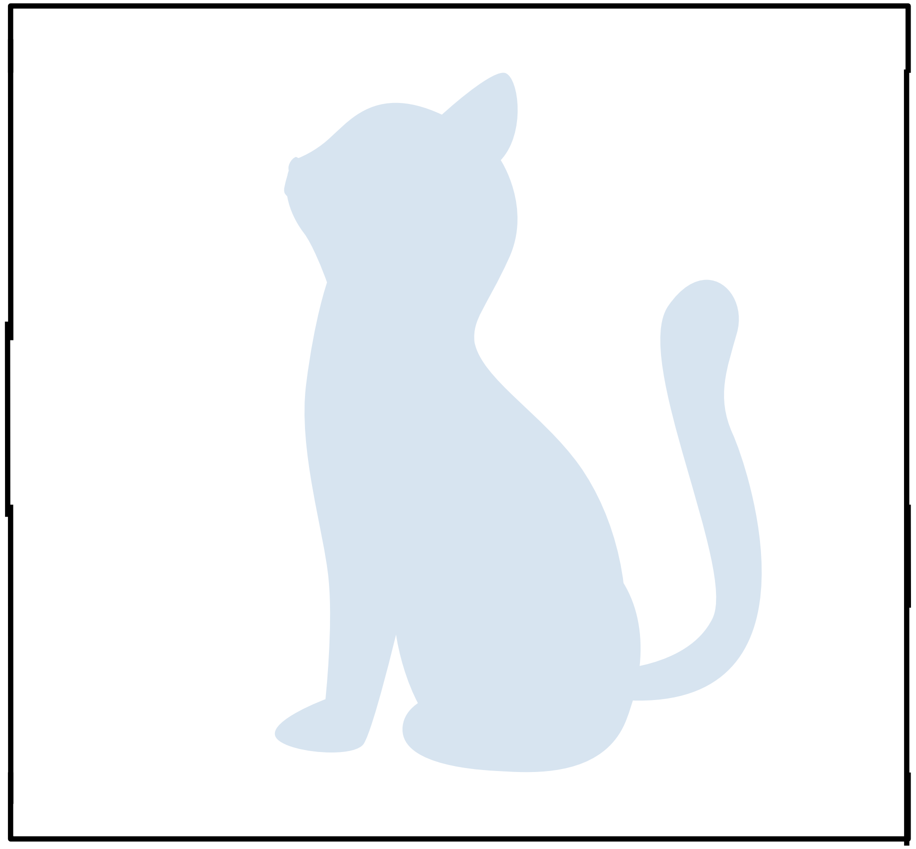
How does it work?

- First, a cat is placed inside a sealed box for one hour.

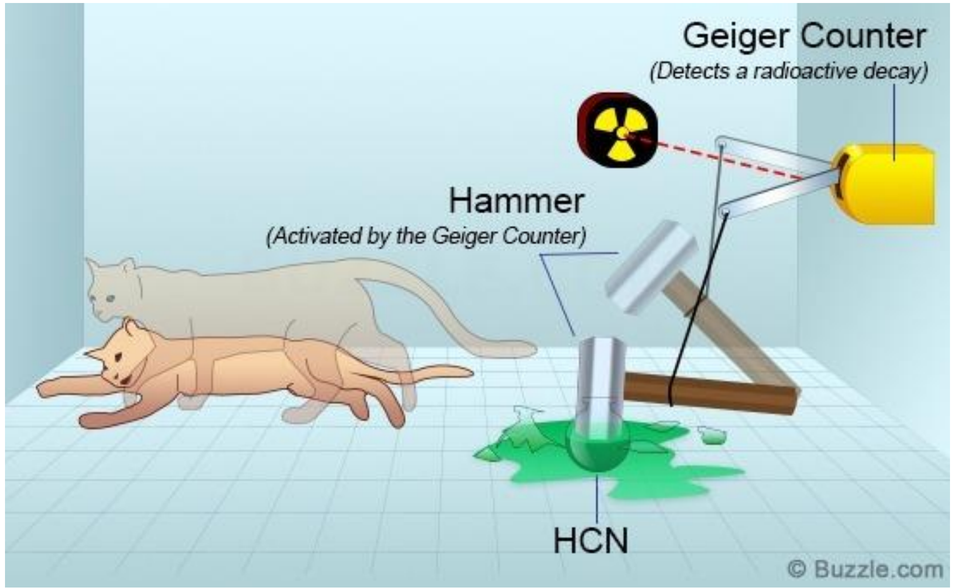
Also, inside the box are:

- A container of radioactive material
- A Geiger Counter (a simple machine that detects radioactive particles)
- A hammer
- A container of deadly cyanide

Using the correct radioactive material allows a precisely 50/50 chance that a single radioactive particle will be emitted within one hour.



Results of Schrodingers Experiment



- In Schrodinger's imaginary experiment, you place a cat in a box with a tiny bit of radioactive substance.
- When the radioactive substance decays, it triggers a Geiger counter which causes a poison or explosion to be released that kills the cat. Now, the decay of the radioactive substance is governed by the laws of quantum mechanics.
- This means that the atom starts in a combined state of "going to decay" and "not going to decay". If we apply the observer-driven idea to this case, there is no conscious observer present (everything is in a sealed box), so the whole system stays as a combination of the two possibilities.
- The cat ends up both dead and alive at the same time. Because the existence of a cat that is both dead and alive at the same time is absurd and does not happen in the real world, this thought experiment shows that wavefunction collapses are not just driven by conscious observers.

Quantum Properties

Interference

- The possible states of quantum objects can add up or cancel out.
- An example of interference is noise cancelling headphones, which produce sound waves that cancel out external noise through interference.
- The fact that atoms and molecules show similar behavior hints at their wave-like nature.

Superposition

- Quantum objects can be in a combination of multiple possible states.
- For example, in an atom, electrons are in a superposition of many possible positions.

Discretization

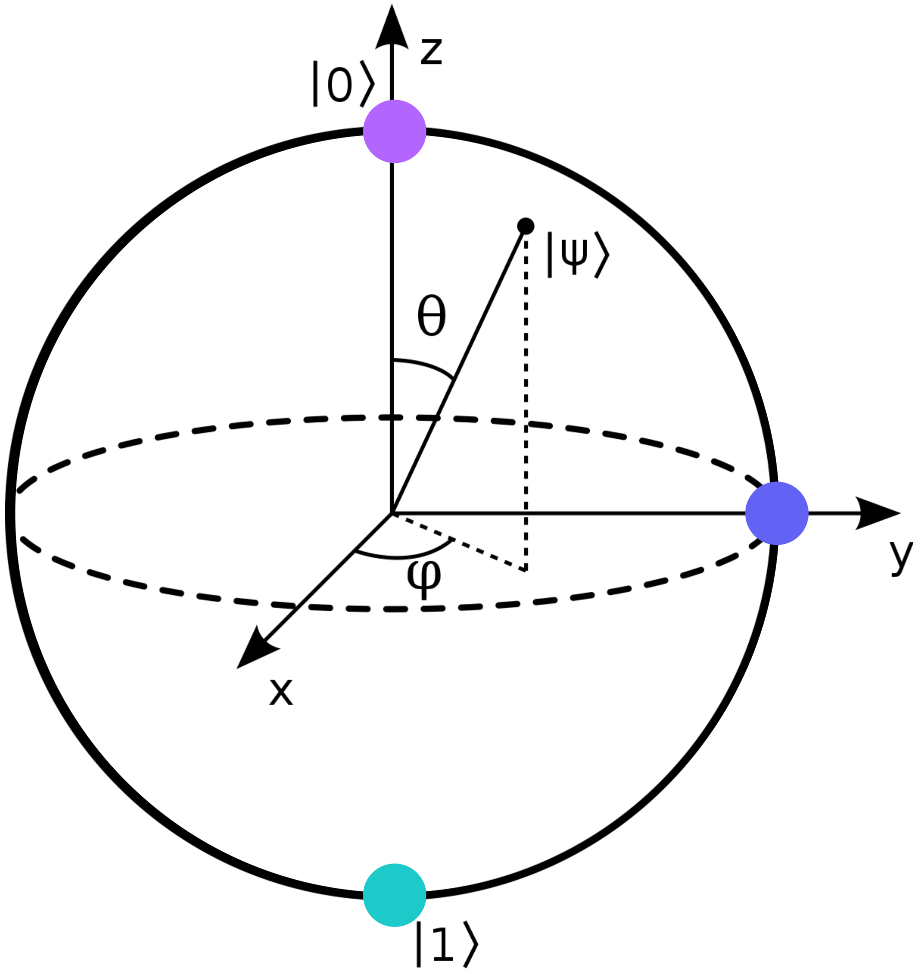
- In atoms and molecules, energy is discrete. This means that only some values of energy are allowed.
- These allowed values of energy are also called energy levels. Discretization allows quantum objects to be used for computing - their energy levels can be used as 0 and 1.

Entanglement

- Two quantum objects are entangled if the state of one object depends on the state of another. If you know the state of one quantum object, you know the state of the other.
- Entanglement doesn’t depend on distance - entangled quantum particles remain entangled if they are separated by millions of miles.
- Entanglement is a property of multiple quantum objects, unlike the earlier properties which can happen with one object.

The Qubit

Basic unit of quantum information



Bloch Sphere Representation

Is a way to visually represent qubit states. It overcomes the limitations of the arrow notation that we've used so far to visualize qubit states, which is not very good for representing superposition states.

How it works

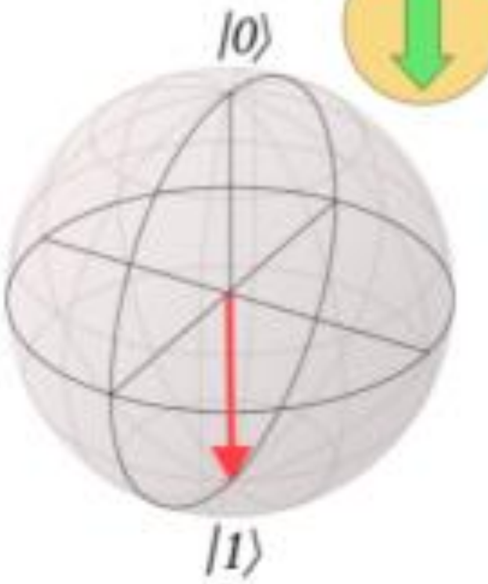
Ket notation: The ket notation is used to represent the state of qubits. Putting a "0" or a "1" inside a ket shows that it represents a quantum state.
Bloch sphere: Any qubit state can be represented on the Bloch sphere.

- The |0> state is located at the top of the Bloch sphere, and the |1> state at the bottom.

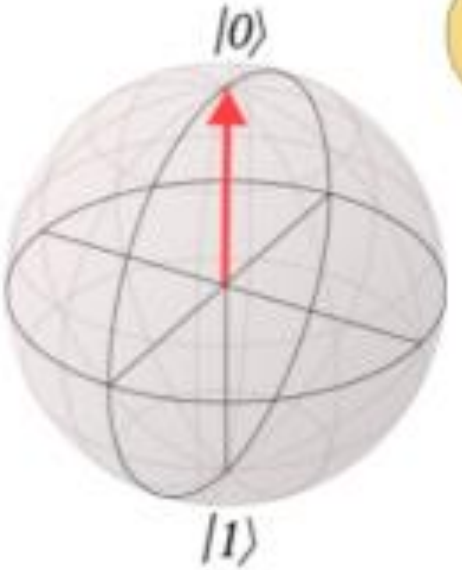
$|1\rangle$ $|0\rangle$ Superposition of $|0\rangle$ and $|1\rangle$

These are called kets.

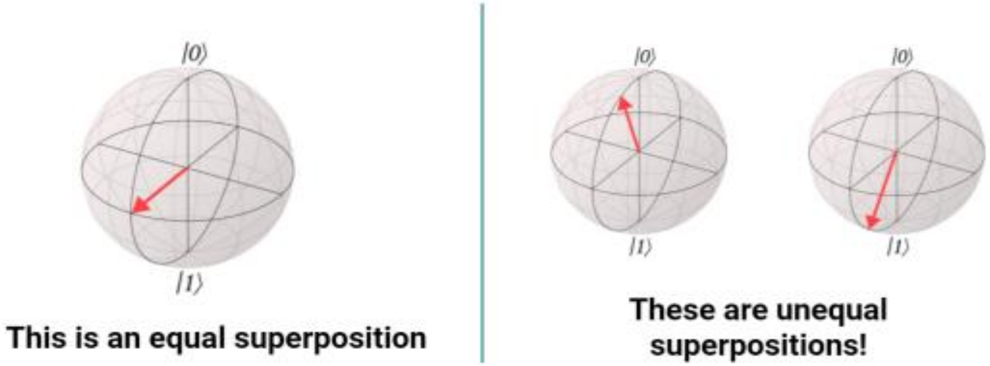
And this to be the $|1\rangle$ state.

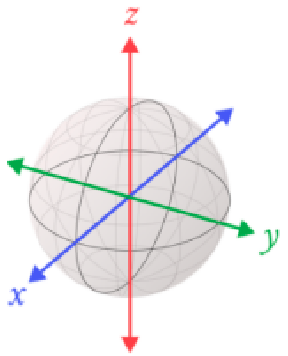


We define this to be the $|0\rangle$ state.



Bloch Sphere Representation





Any other state on the Bloch sphere represents a superposition of |0> and |1>. A superposition can be equal, meaning that |0> and |1> contribute equally to the state, or unequal, meaning that either |0> contributes more or |1> does. If the state is closer to |0>, it has a greater contribution from |0>. If it is closer to |1>, it has a greater contribution from |1>.

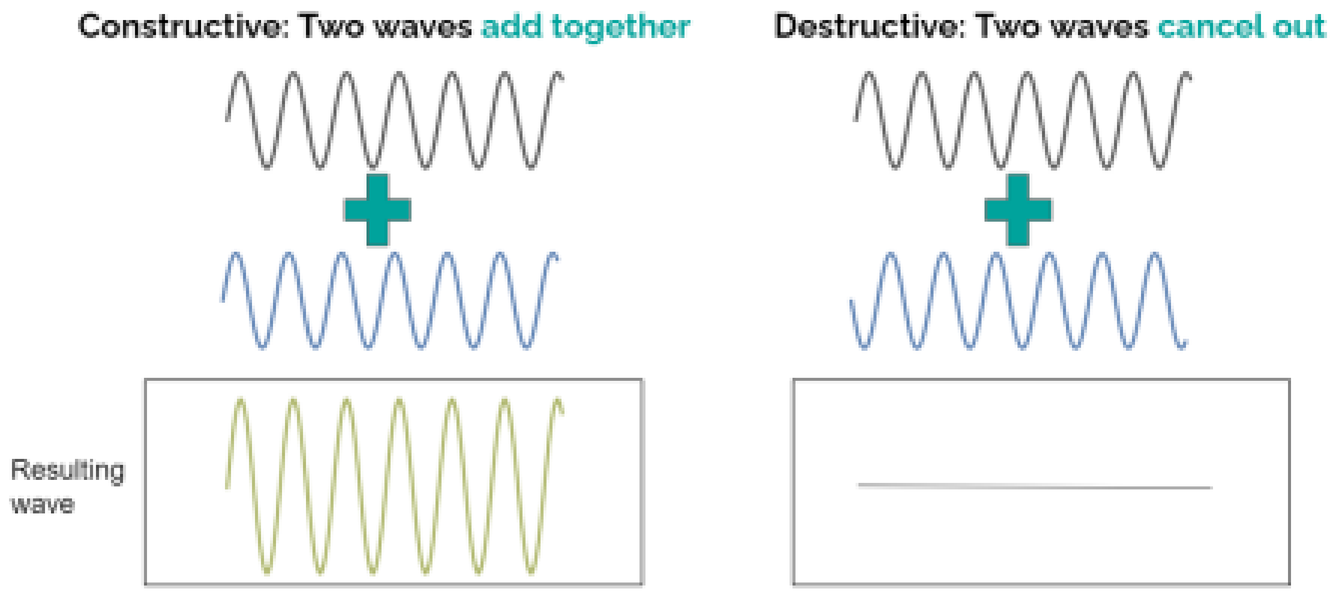
Quantum Gates: Quantum gates manipulate or change the state of qubits. Gates are how we create superposition, interference, and entanglement! The operation of gates on qubits can be visualized as rotations on the Bloch sphere.

- To visualize these rotations, we need to associate a coordinate system with the Bloch sphere. Here is the conventional coordinate system:

Quantum Mechanics

Wave properties

Waves, such as sound waves and water waves, travel with a certain velocity. Further, waves interact with each other to form complex patterns in a process called interference. Sometimes waves can add onto each other to create a bigger wave (constructive interference), and sometimes waves can cancel each other out (destructive interference)



Quantum Mechanics

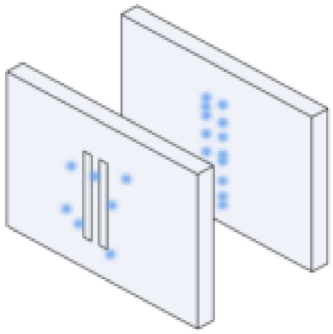
Particle Properties

Particles, such as soccer balls, have mass, have a definite, discrete location, and also travel with a certain velocity

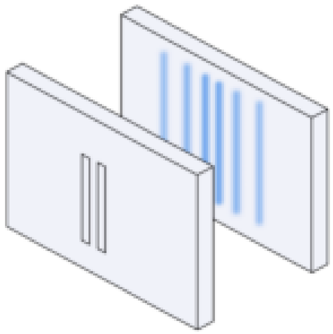
Double Slit Experiment

The double-slit experiment helps differentiate between waves and particles. In this experiment, the wave or particle is aimed at two slits (two openings in an opaque barrier), behind which is a plain wall. Particles pass through either the left or the right slit, and create two lines of discrete spots on the wall. Waves passing through the slits interfere with each other and create a pattern of bright and dark lines on the wall.

With particles: no interference
Discrete spot for each particle, two lines



With waves: interference
Multiple lines



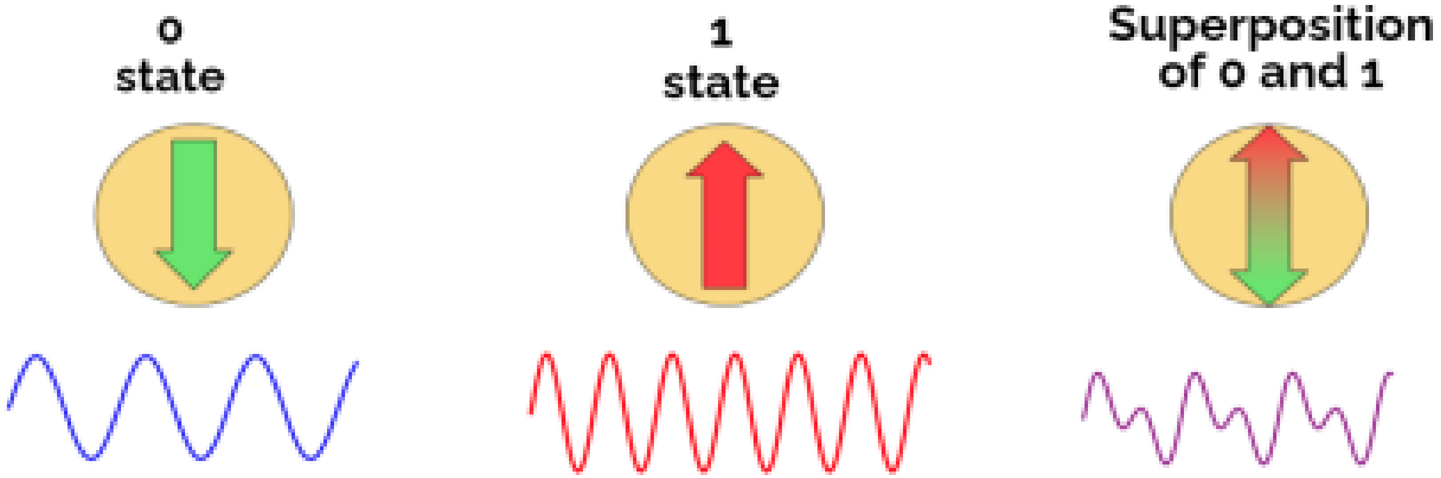
Quantum Mechanics

Wave-particle duality: Quantum objects show both wave-like and particle-like properties.

When quantum objects, such as electrons or photons (particles of light), are used in a double slit experiment, they create discrete spots (like particles) but the spots are arranged in an interference pattern (like waves). Because of wave-particle duality, we can think of qubits as both waves and particles.

Superposition with waves

Superposition is a consequence of wave-particle duality. Using the wave nature of qubits, we can represent the two states of the qubit (0 and 1) with two waves. To create a superposition state, we can combine these waves.



Quantum Mechanics

Interference with waves

Interference is also a consequence of wave-particle duality and can be described as the addition or subtraction of the waves representing qubit states. Both superposition and interference involve overlap between waves.

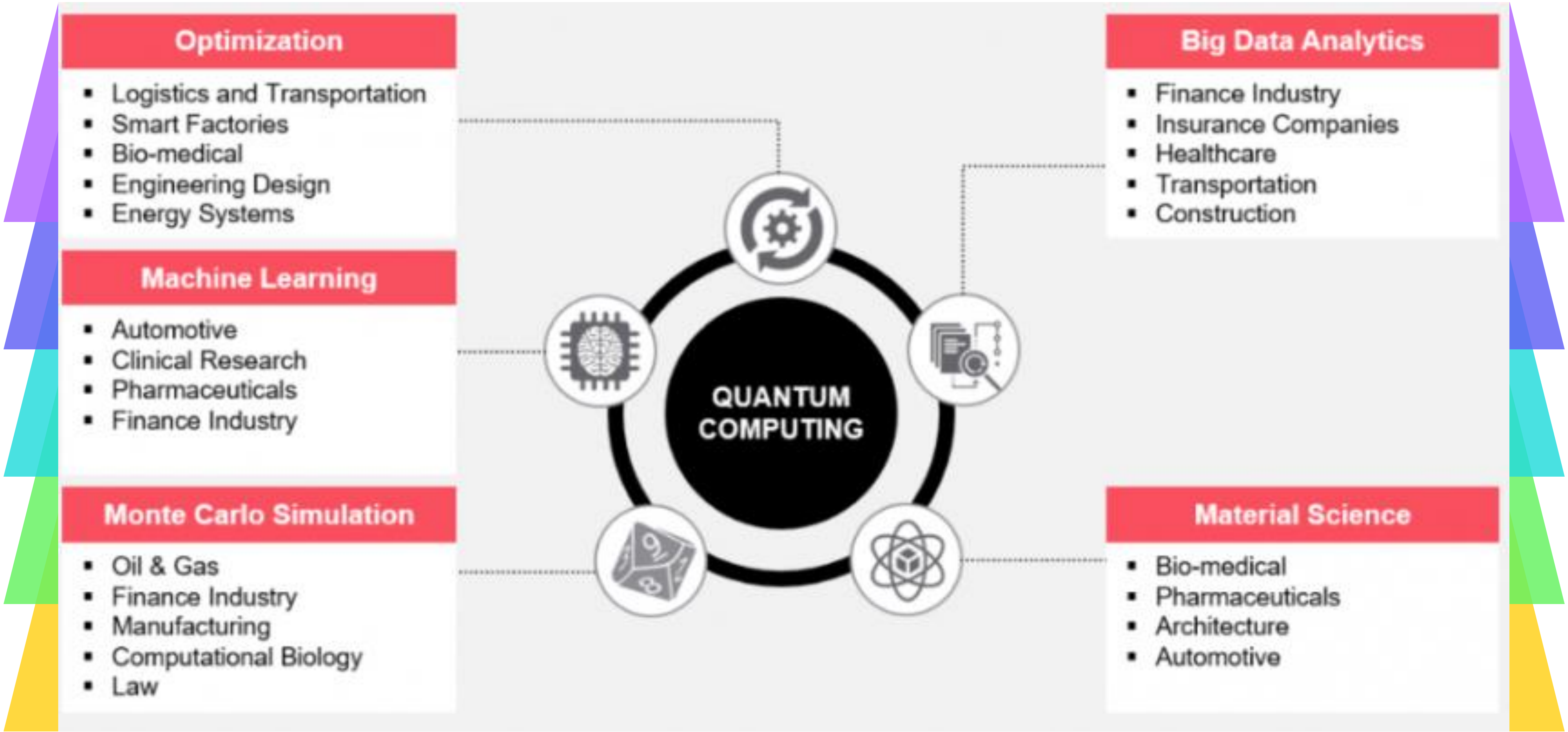
Discretization with waves

The discreteness of the quantum world arises when quantum objects are confined. Confinement of waves forces them to only take certain shapes or energies, much like the waves on the string of a musical instrument fixed at two ends. In the quantum world, confinement can exist naturally (for example, in a trapped ion qubit, where the negatively charged electron is confined by the positively charged nucleus) or be created artificially (such as through electric circuits in superconducting qubits).

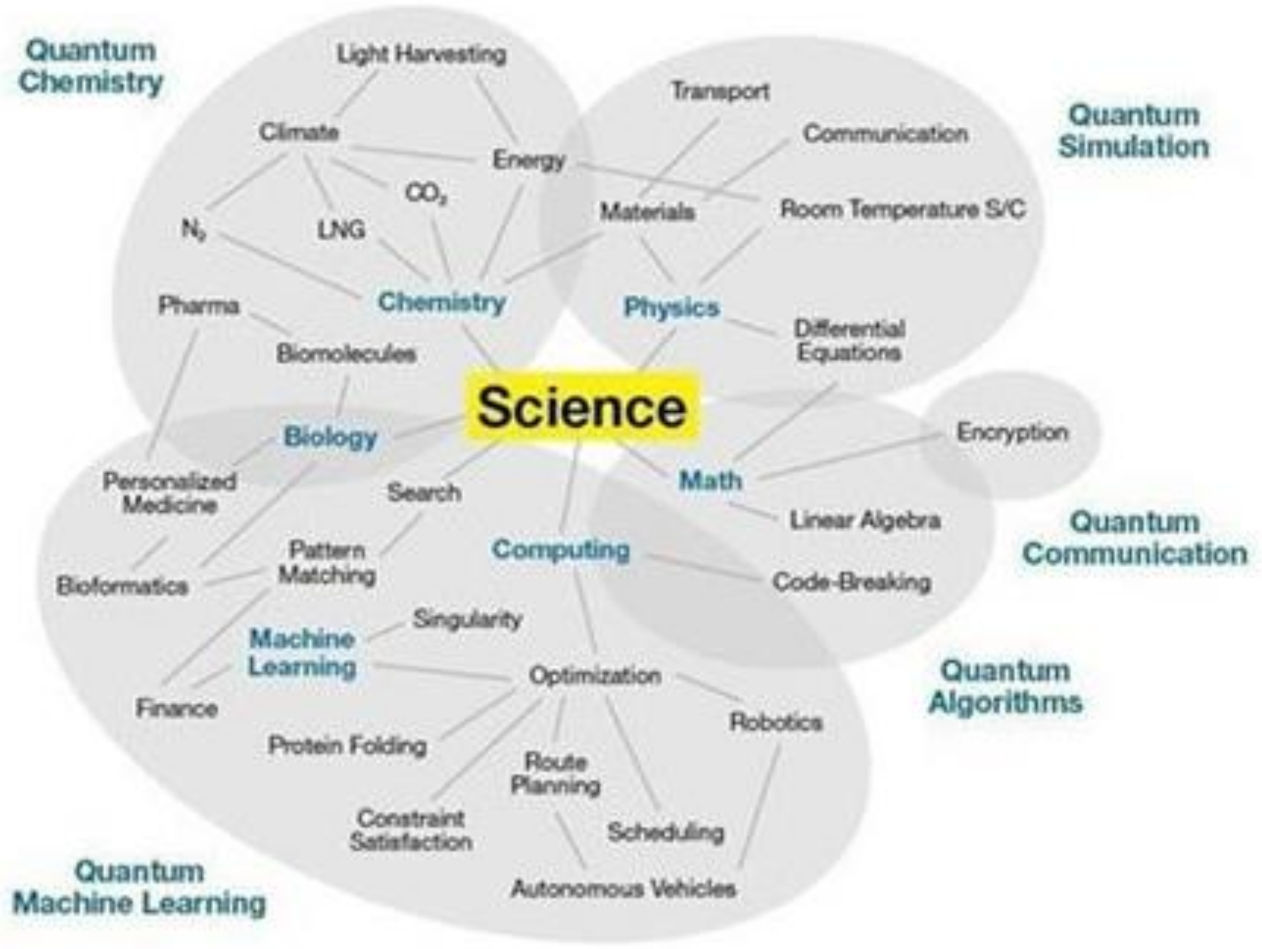
Open Questions

There are lots of unresolved questions in quantum mechanics. We do not understand why the result of quantum measurement can be random, and we also do not know if there is an unexplained link between two entangled qubits. Attempts to answer such questions lead to different interpretations of quantum mechanics

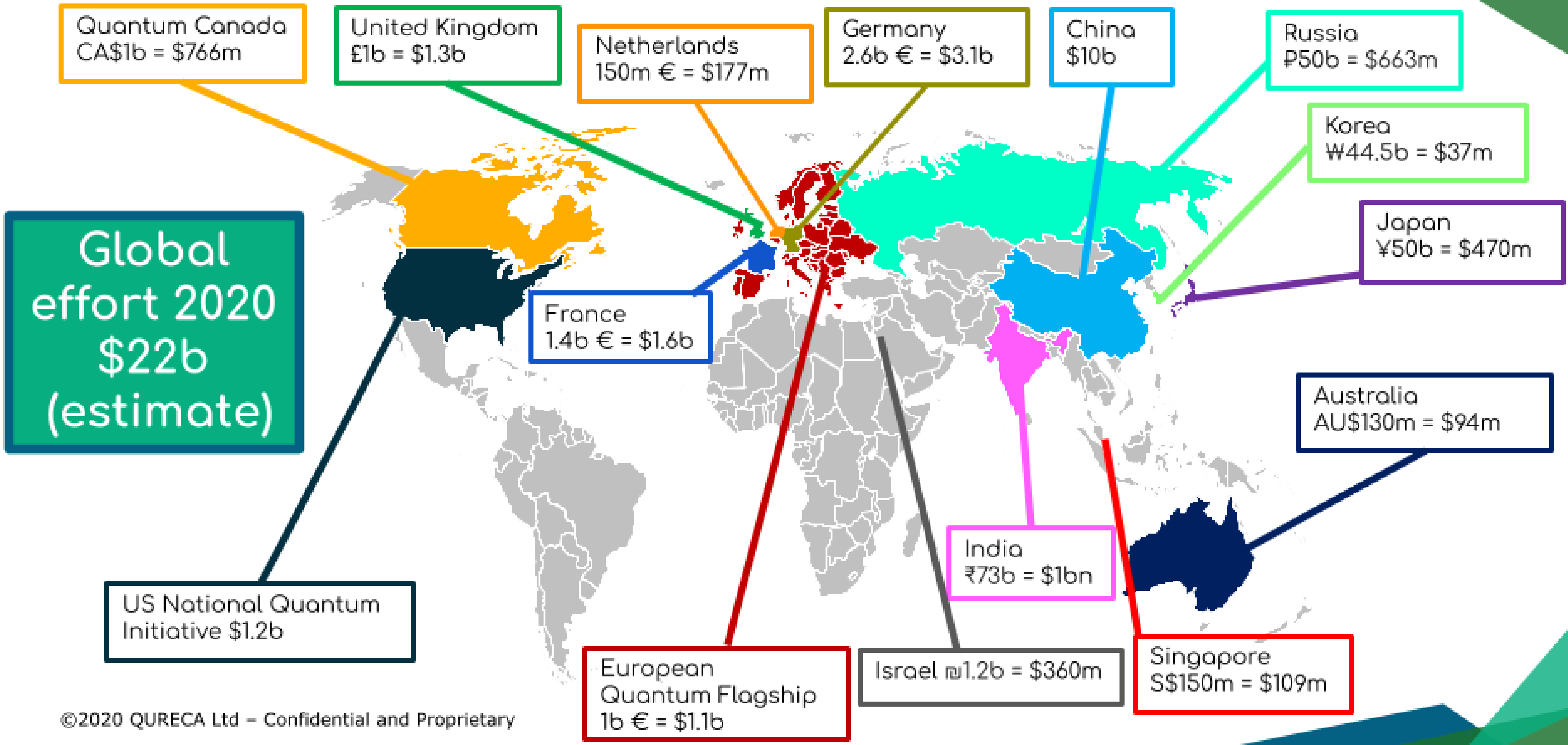
Quantum as a growing field



Quantum Computing Cases



Quantum effort worldwide



Big O Notation

Big O Notation is a metric for determining an algorithm's efficiency. Big O is also known as the algorithm's upper bound since it analyses the worst-case situation.

The best-case scenario usually tells us nothing — we'll possibly solve the problem on the first try. That’s why we employ worst-case scenarios to get meaningful input. It tells us that the algorithm will always perform equal to or better than the worst-case scenario.

Now, the algorithm & data structure you employ while programming code is critical. Big O notation makes it easier to compare the performance of different algorithms and figure out which one is best for your code.

In computer science, Big O Notation is a mathematical function used to determine the difficulty of an algorithm. It defines the time it takes to execute an algorithm. It will also help you determine how your algorithm's performance will change as the input size grows.

Big O Notation

But why do we need Big O?

The world we live in today consists of complicated apps and software, each running on various devices and each having different capabilities. Some devices like desktops can run heavy machine learning software, but others like phones can only run apps. So when you create an application, you'll need to optimize your code so that it runs smoothly across devices to give you an edge over your competitors.

The Quantum Advantage

By exploiting the power of Quantum Mechanics, Quantum Computers are able to solve O(2N) computations in O(N) time or less by using a concept called Superposition. This makes previously "intractable" problems on a Classical Computer manageable on a Quantum Computer!

This phenomenon is termed Quantum Advantage, as a Quantum Computer can do something faster and more efficiently than a Classical Computer.

The Bits of Computation

A Bit is like the world's simplest alphabet.

You can represent any piece of information with just 2 characters - 0 and 1, which means that it's a Base 2 System!
In a Base 10 System, each number represents how many times it contains a certain power of ten by its place.

This is the number system we use in day-to-day life!

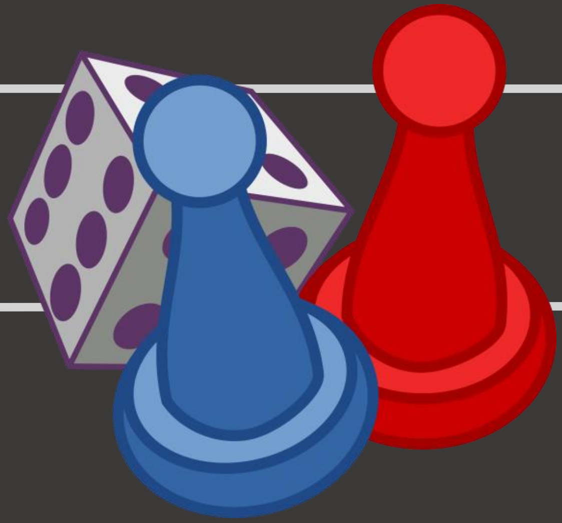
In a Base 2 System, each number represents how many times it contains a certain power of two by it's place.

This is the number system that computers use, including Quantum Computers!

Quantum Logic Gates (or Quantum Gates for conciseness) are the quantum equivalent of classical Logic Gates, but are designed for operations on Qubits instead of Classical Bits. Just like classical logic gates, Quantum Gates perform operations on qubits to transform their state. The difference between these gates and their classical counterparts lies in the way they operate on the quantum mechanical properties of Qubits.

QUANTUM GAMES!

- Hello Quantum (Android | iOS)
- Quantum Flytrap (Online)



BREAK TIME!

- Lunch Is Served!
- Prayer Rooms Are Available!
- Feel Free To Chat With Us!
- Be Back By 1 PM!

GUEST SPEAKER

- Co-Founder @ Zaiku Group
- Head of Mathematical Sciences @ Zaiku Group

BAMBORDÉ BALDÉ

GUEST SPEAKER

- 15 Year Old
- Event Manager
- CodersHQ Ambassador

HUSAYN GOKAL

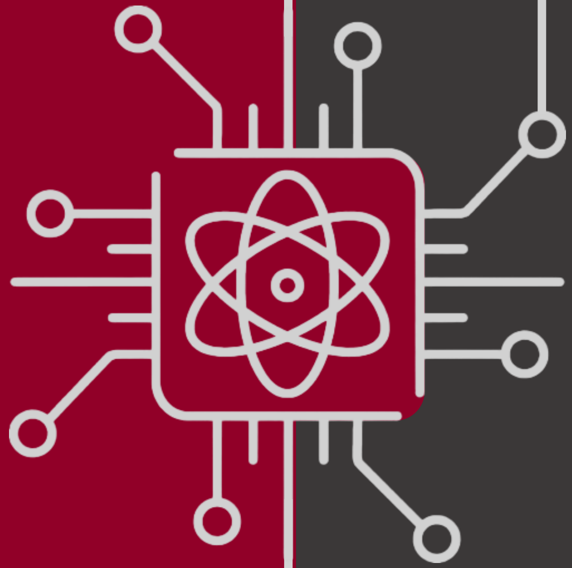
JUPYTER NOTEBOOK

HACKATHON DETAILS

- Teams Of 3 - 5 People
- Deadline - Feb 19 Midnight
- 3 Awards - Best Innovation, Best Application, Best Creation

HACKATHON DETAILS

- Code required for submission
- Only open source code
- Must give appropriate references
- Only commercially-allowable material



MORE DETAILS COMING SOON!

THANK YOU VOLUNTEERS!

Amna
Alhammadi

Bashayer
Alsalami

Maryam
Almansoori

THANK YOU VOLUNTEERS!

Miqdad Khimji

Musab Bin Umair

Aisha Siddiqui

JOIN US ON DISCORD!