EQUINOX

AI&DATA LAB

by ASESOFTWARE

What is this course?

Who is this course for?
Anyone who wants to learn how quantum computing works

What do you need to do this course?
Enthusiasm, knowledge of linear algebra & complex numbers will help a lot

What should you get out of this?
A solid foundation on the theory and practical considerations of quantum computing

What this course is not
This is not a mathematically rigorous course, nor is it a course on quantum mechanics
This course **on its own is not enough to get the most** out of quantum computing

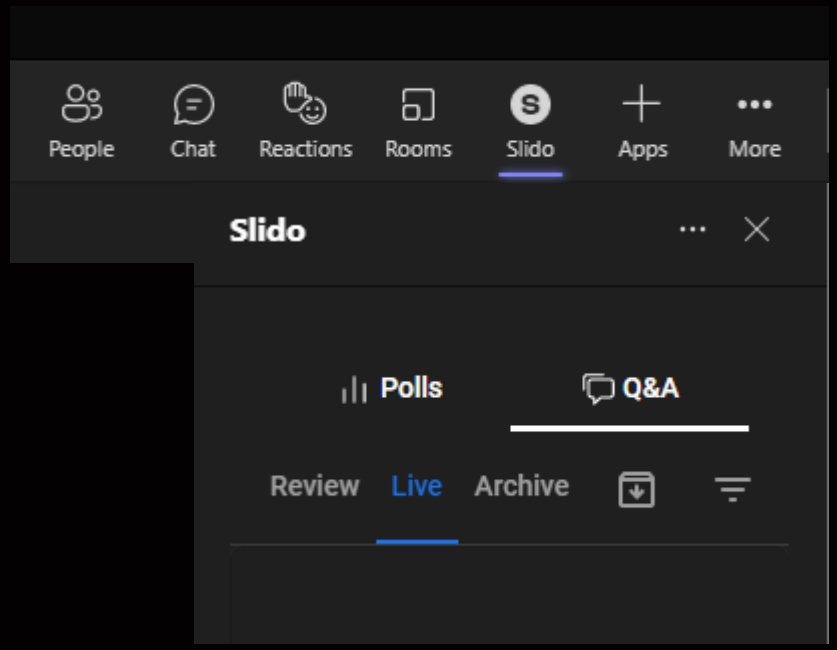
Why learn about quantum computing

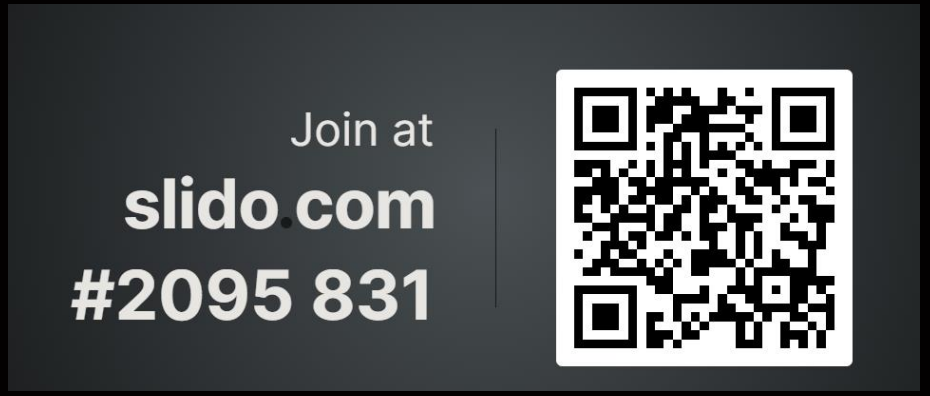
- Our world is based on quantum mechanics
- A completely new way of solving problems
- Moore's law is slowing down
- Commercialisation: potentially $700 billion industry

Source: McKinsey & Company: Quantum computing: An emerging ecosystem and industry use cases, December 2021

QnA

- We use Slido for Q&As and polls
- Add questions at any time, upvote the ones you like
- Teams app users can see Slido at the bottom of the meeting
- Web users can go to slido.com and enter the number **#2095 831**

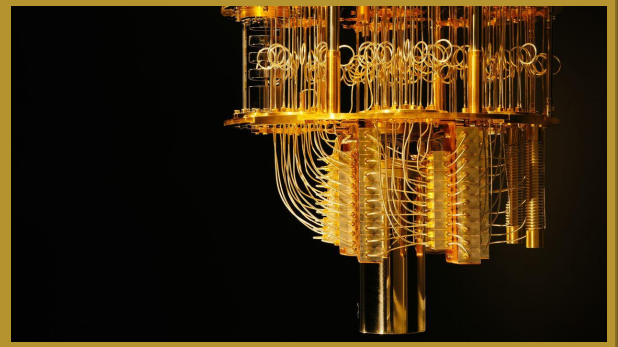




Technical Course Structure

Introduction to QC

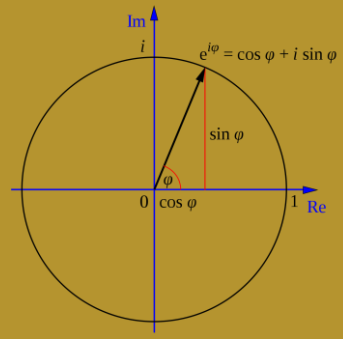
Thursday 25th August



What is QC?
What you should know about QC

Maths for QC

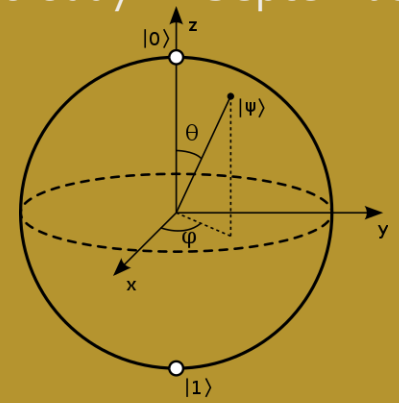
Friday 2nd September



Complex numbers
Linear Algebra

Single Qubits

Thursday 8th September



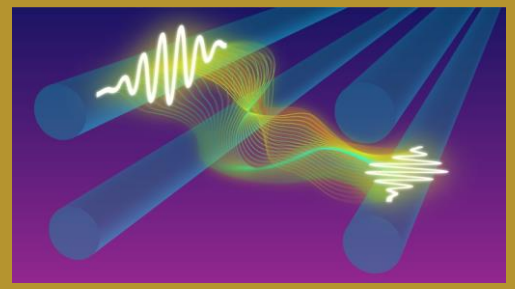
Bloch Sphere
Operators
Single Qubit gates

Assignment 1 Due

Technical Course Structure

Multiple Qubits

Thursday 15th September

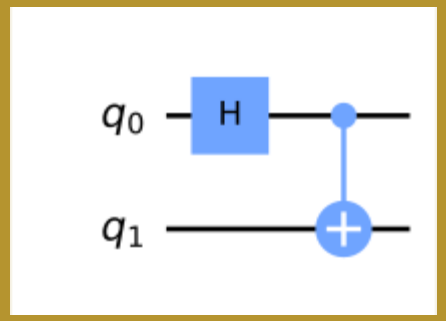


Multi-qubit states
Entanglement revisited
Multi-qubit gates

Assignment 2 Due

Quantum Circuits

Thursday 22nd September

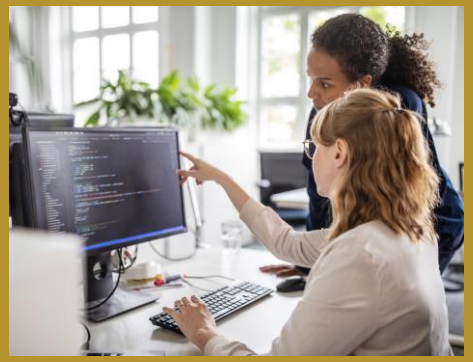


How to program a QC
IBM Quantum Experience

Assignment 3 Due

Quantum Algorithms

Thursday 29th September

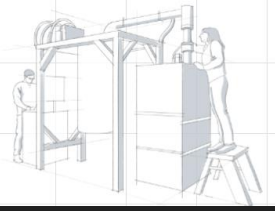


Shor's Algorithm, Grover's algorithm
Practical considerations

Assignment 4 Due

Recommended Reading

Learn Quantum Computation using Qiskit



XANADU QUANTUM CODEBOOK

Quantum Country

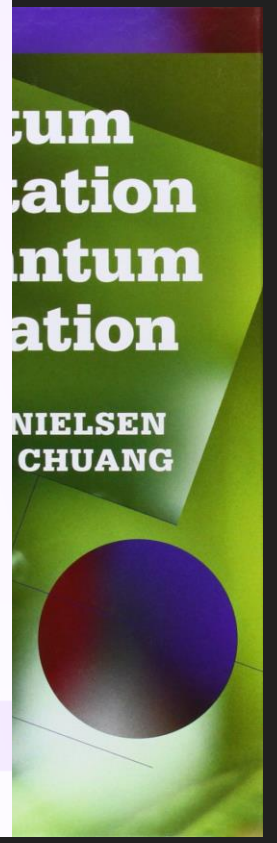
by Andy Matuschak and Michael Nielsen

A free introduction to quantum computing and quantum mechanics

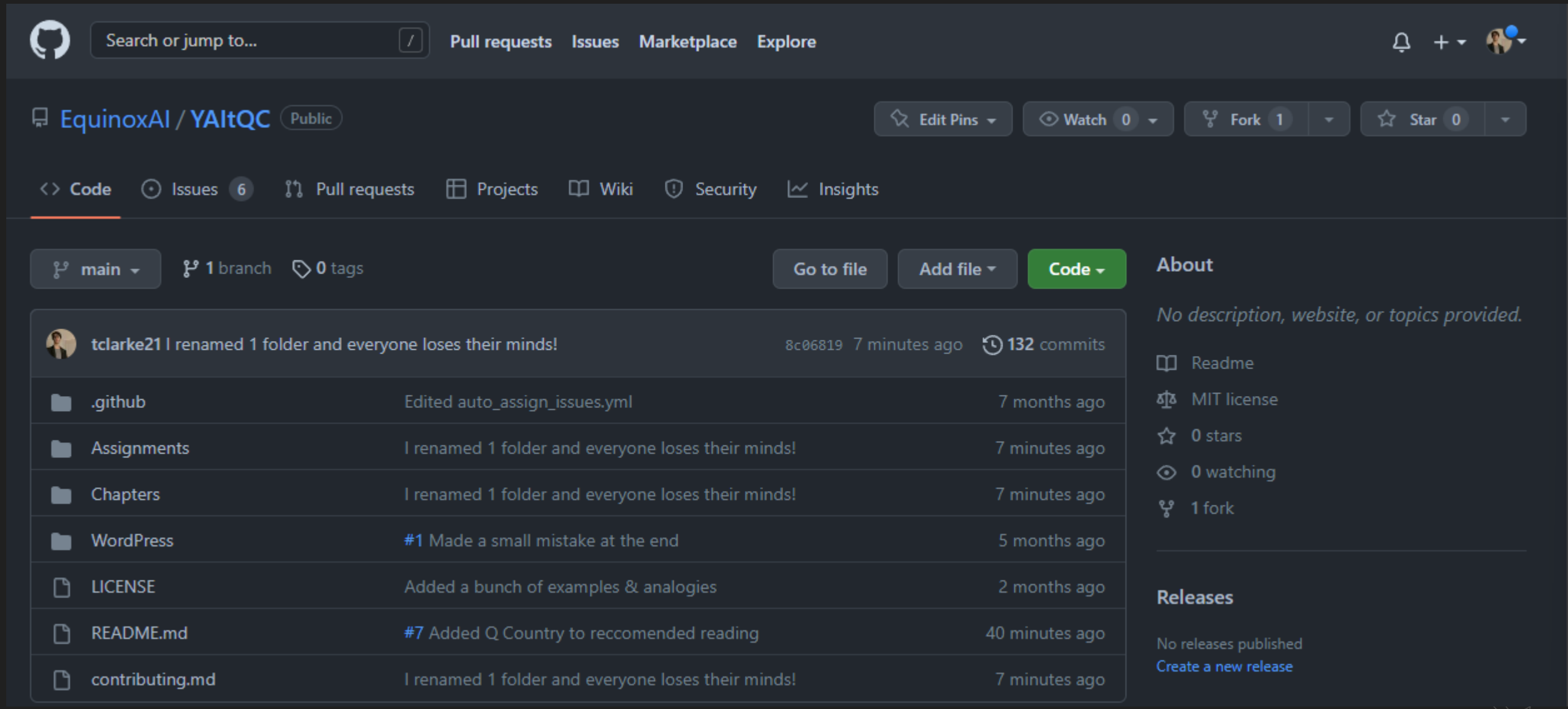
By working through these essays, you will understand in detail all the basic principles of quantum computing and quantum mechanics, plus two important applications: the quantum search algorithm and quantum teleportation.

You'll need familiarity and comfort with the basics of linear algebra and complex numbers. We'll teach you the rest.

Start reading



Course materials



Contributions are welcome!

main YAItQC / Chapters / 0_Acknowledgements.ipynb Go to file ···

tclarke21 I renamed 1 folder and everyone loses their minds! Latest commit 8c06819 8 minutes ago History

2 contributors

43 lines (43 sloc) | 1.43 KB Raw Blame

Acknowledgements

This educational text simply builds upon the inspiring work of a large number of visionaries. In addition, there are many great minds whose generosity in sharing their insights facilitated much of t`his work. It has been a great honour and privilege to have been supported in this endeavour. As an expression of gratitude, what follows is, in no particular order, a list of thanks:

Thanking Eric (Passawis) for his grammatical corrections to chapters 1,2,3... as well as his encouraging feedback.

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For some design suggestions, thanks to Carla Juliana Acosta Zamudio.

As my first student who put up with me rambling through the first two chapters, I'd like to thank Favio Acosta

Introduction to Quantum Computing

What do they do

Introduction to Quantum Computing

Contents

What is Quantum Computing?

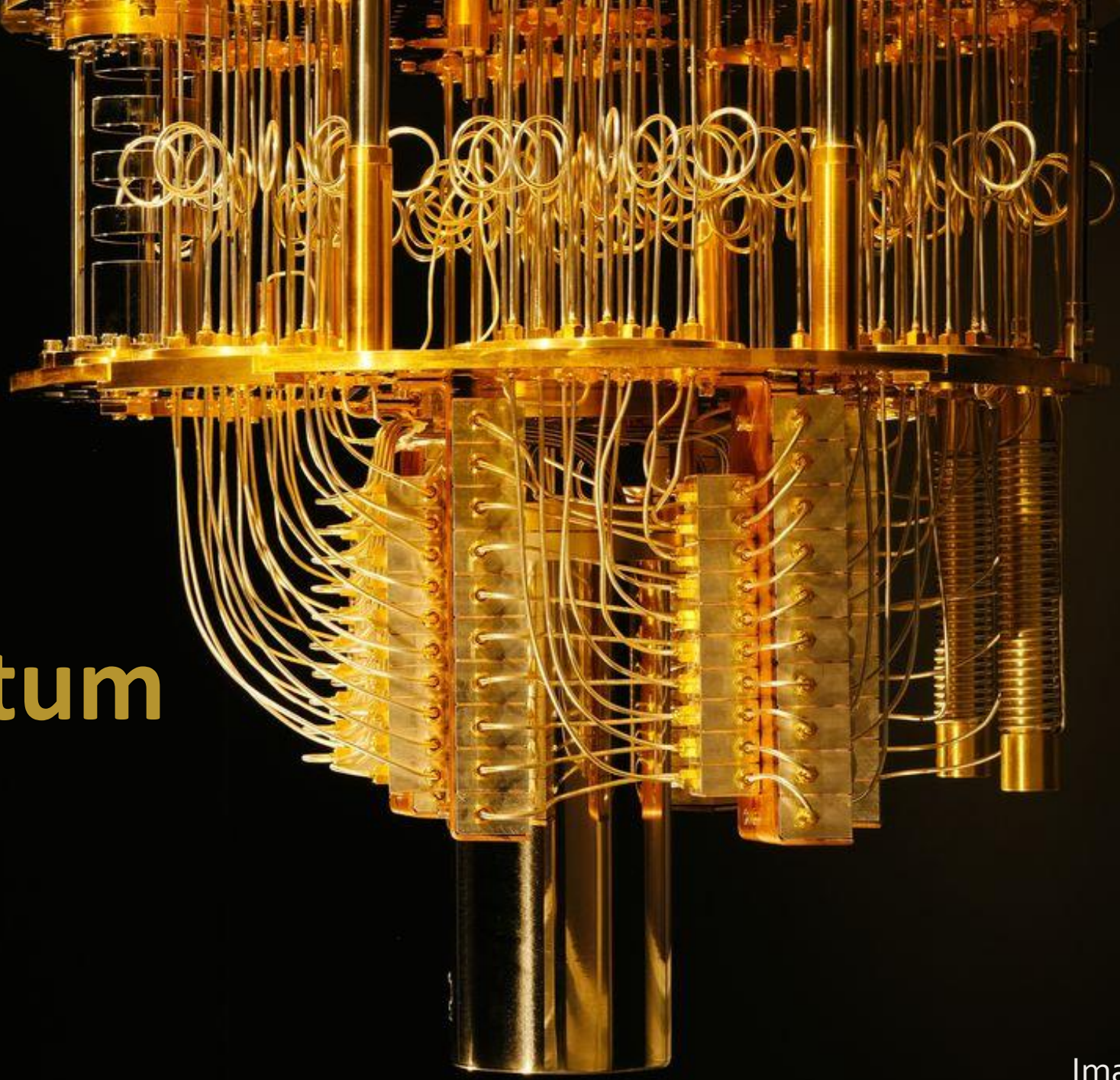
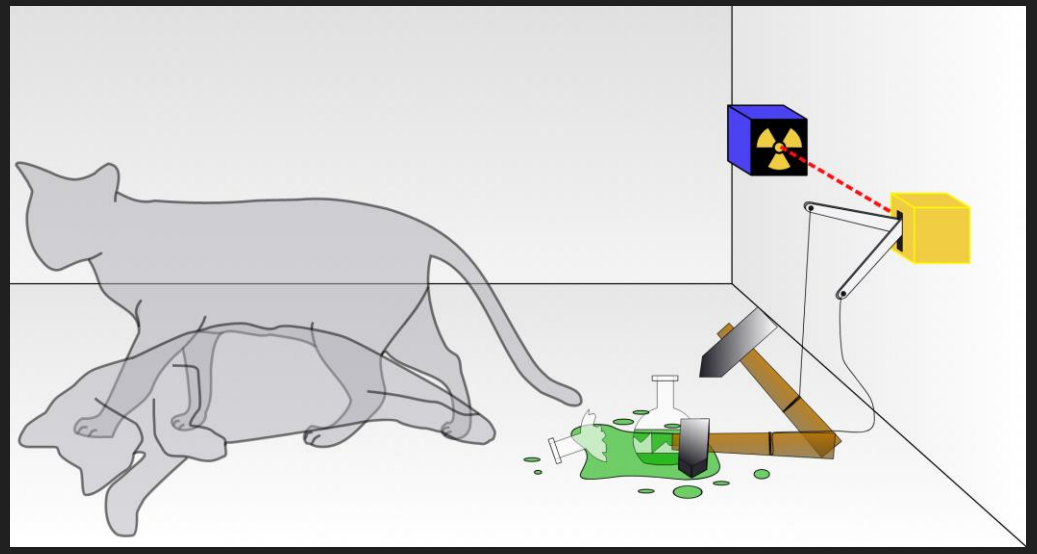


Image: IBM

What is Quantum Computing ?



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What does "quantum" mean?

ⓘ Start presenting to display the poll results on this slide.

quantum

noun [C] • PHYSICS • specialized

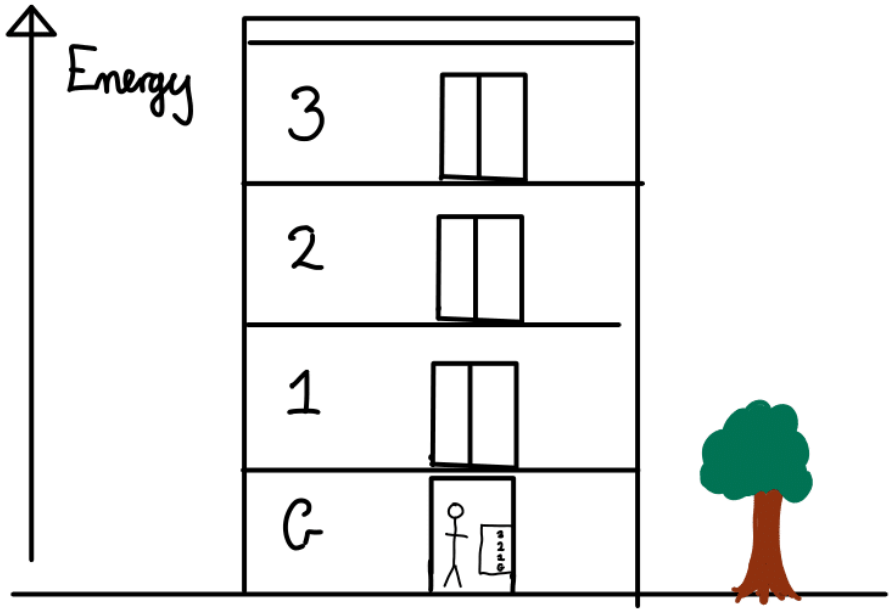
UK /ˈkwɒn.təm/ US /ˈkwɑː.ɳ.ʈəm/

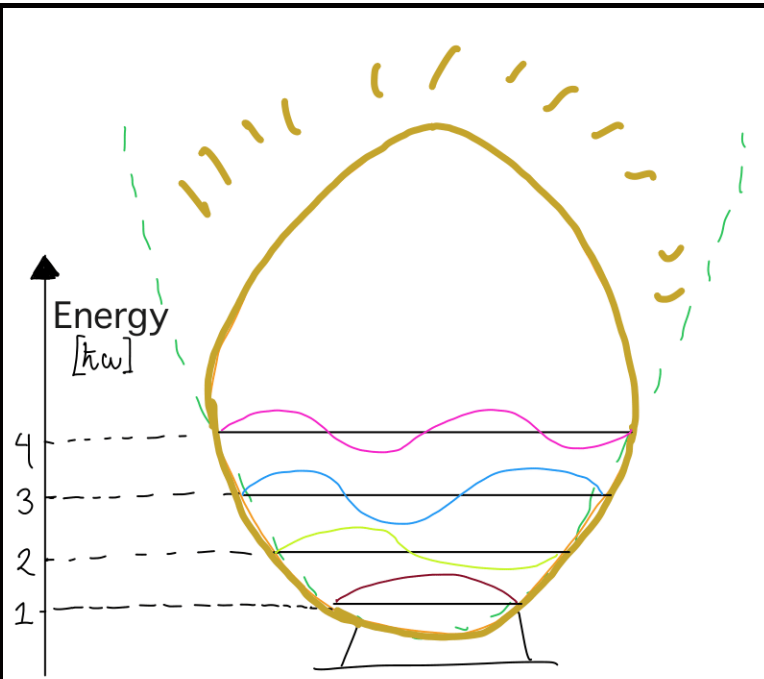
plural **quanta**

the smallest amount or unit of something, especially energy:

- *quantum theory*

Source: Cambridge Dictionary





How is quantum?

$$= \frac{1}{\sqrt{2}} (\quad + \quad)$$

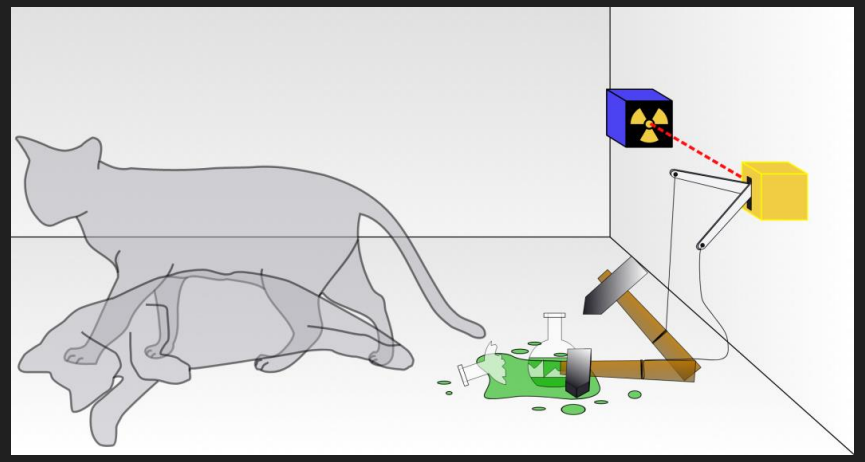


Image: Wikipedia

Number of coins	1	2	3	4	5	n
# possible combinations	2	4	8	16	32	2n

Superposition

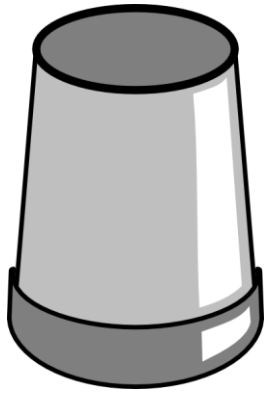
A quantum state (the coins) can be represented as the sum of other quantum states

How is quantum?

What side does the coin on the right have?

slido

Which side does the coin on the right have up?



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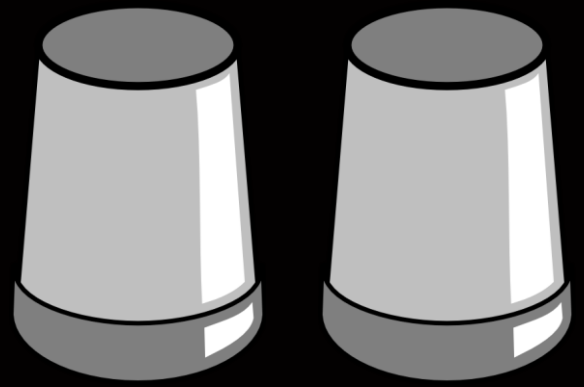
How is quantum?

$$= \frac{1}{\sqrt{2}} \left(\quad + \quad \right)$$

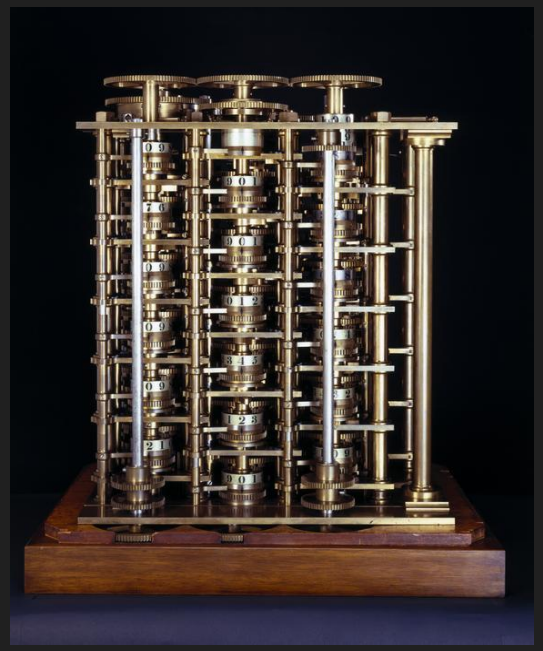


Entanglement

The state of one qubit can't be described independently of the other qubit

How do Computers Work?

Algorithm: Set of instructions that describes how you change the state of the computer



Babbage Difference Engine 1822

IBM Summit 2018

How Quantum Computers Work

Quantum Algorithm: Set of instructions that describes how you change the state of the (quantum) computer

Spin many coins

Many possible coin combinations

Input 1

Input 2

Input N

Quantum Algorithm

Shuffle your coins

Output 1

Output 2

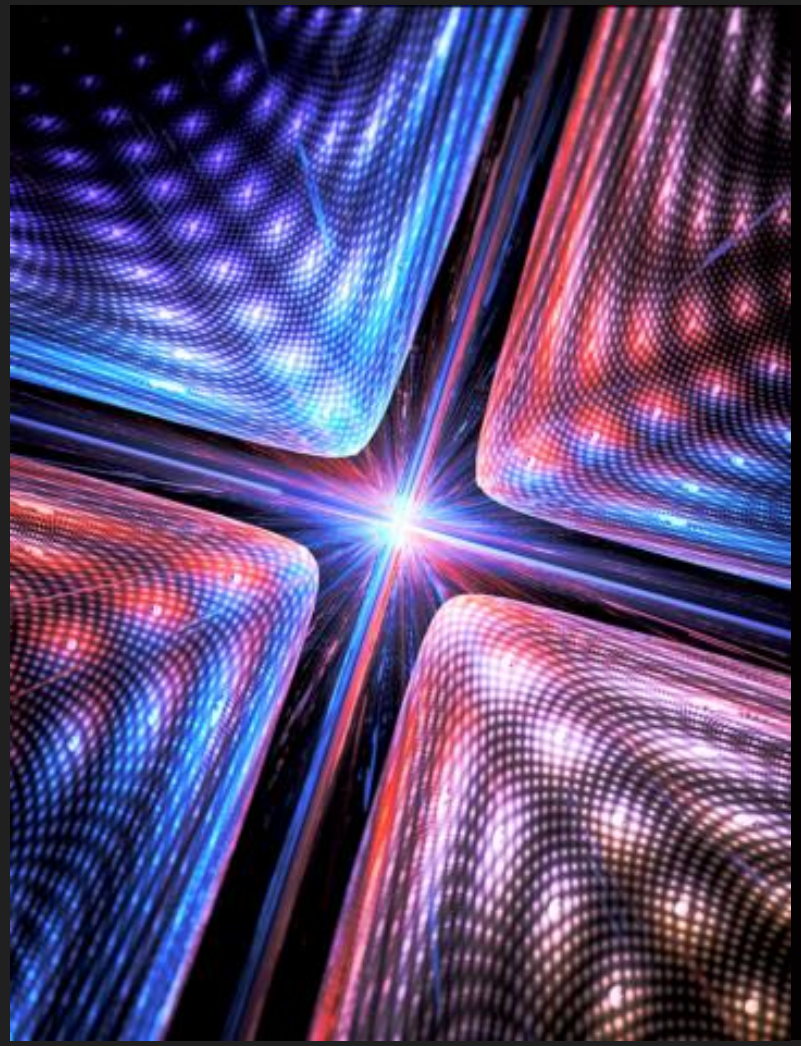
Output N

Reveal coins facing up

Particular Output

Quantum Advantage

Quantum Advantage



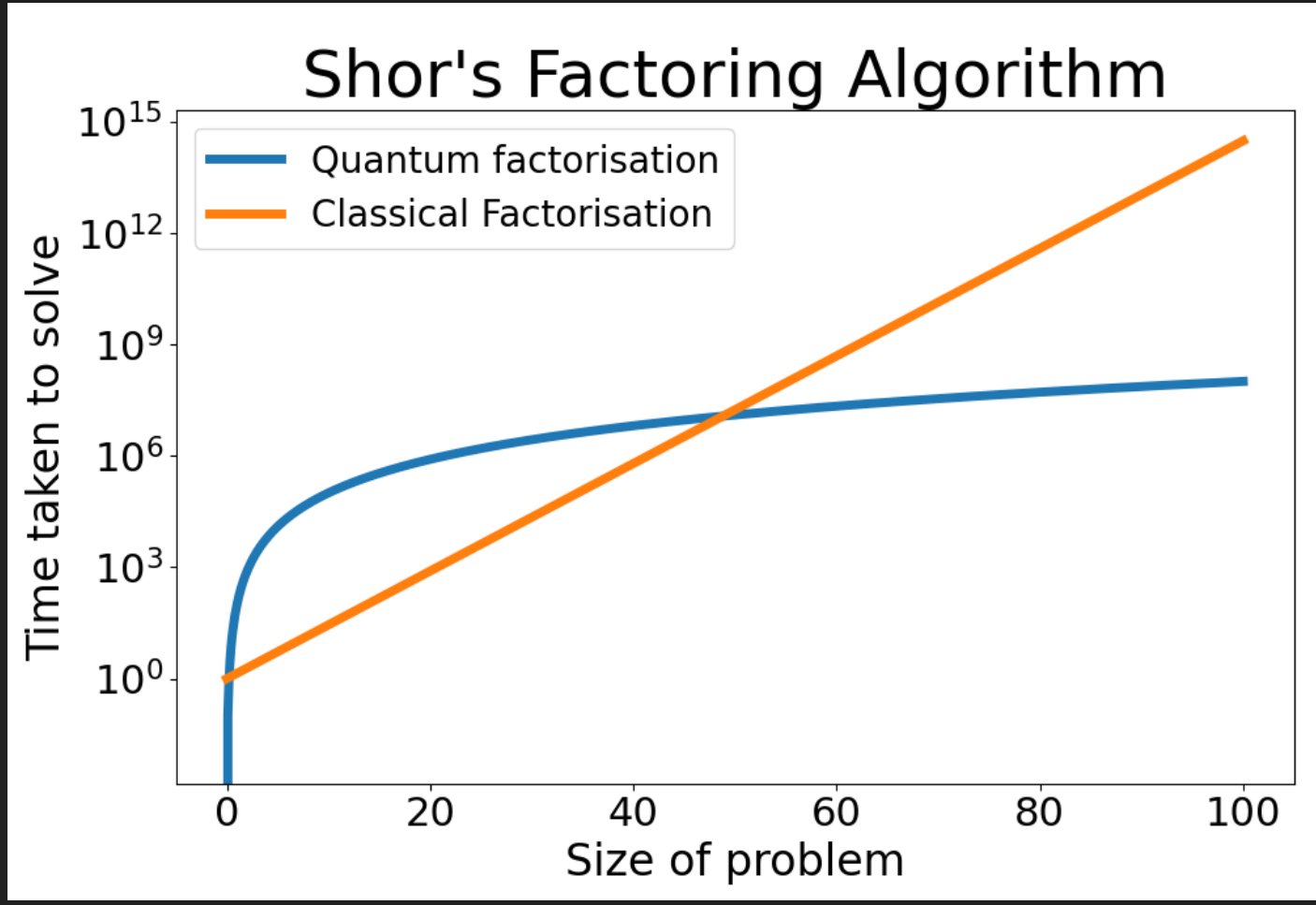
- Faster, more accurate or cheaper than the best classical alternative
- No universal definition of quantum advantage
- Application dependent
- Classical HPC/AI raise the bar each year

What quantum advantage is NOT

- Faster, smaller versions of normal computers
- Apply to every computer problem
- Solving hard problems by trying all solutions at once
- Helping big data problems (for many decades)

What does quantum advantage look like?

Credit: Ars Technica



- 4,100 logical qubits could break current 2048-bit RSA

QC has potential for some problems

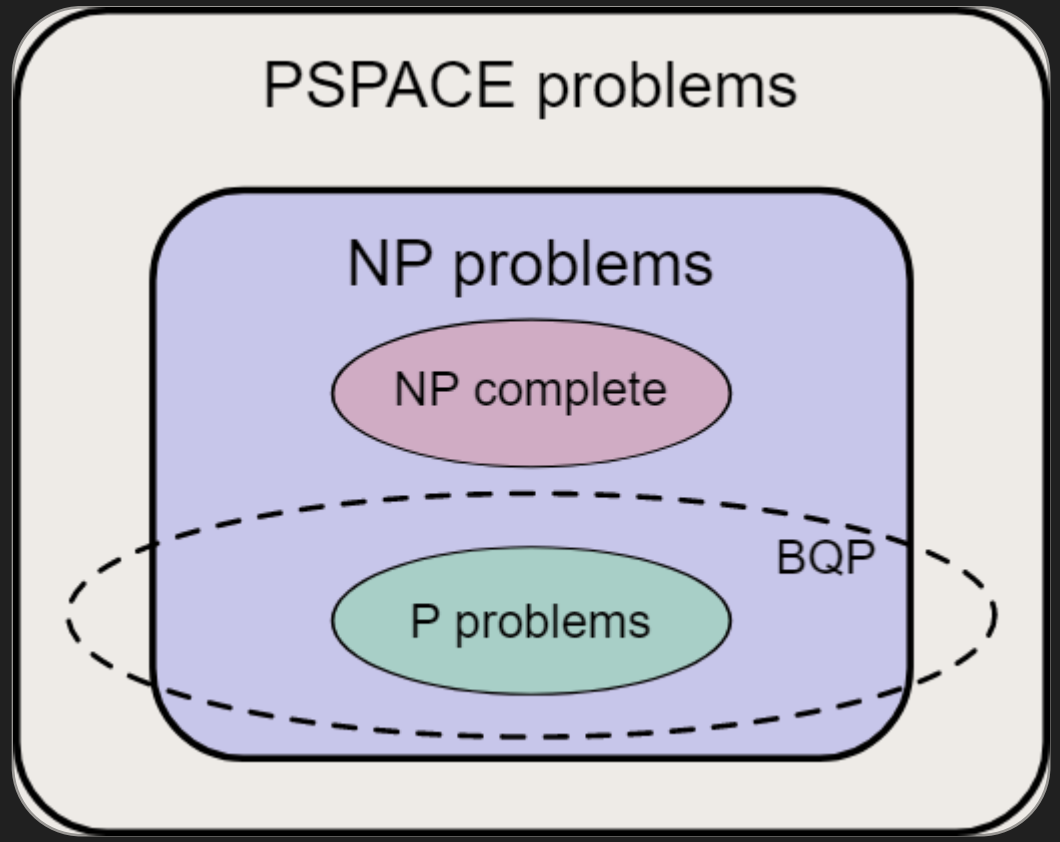
P: Polynomial (classical computer)

BQP: Bounded Quantum Polynomial

NP: Non-polynomial

Example:

Factoring, discrete log, estimating eigenvalues



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Why is it a bad idea to build a computer, quantum or classical, out of coins?

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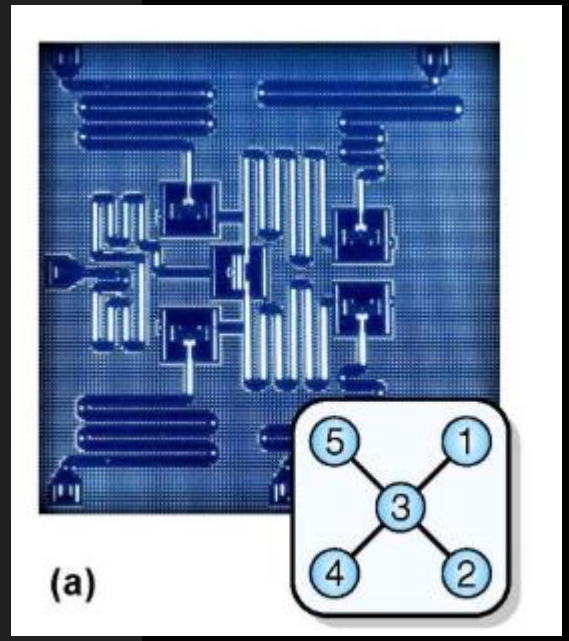
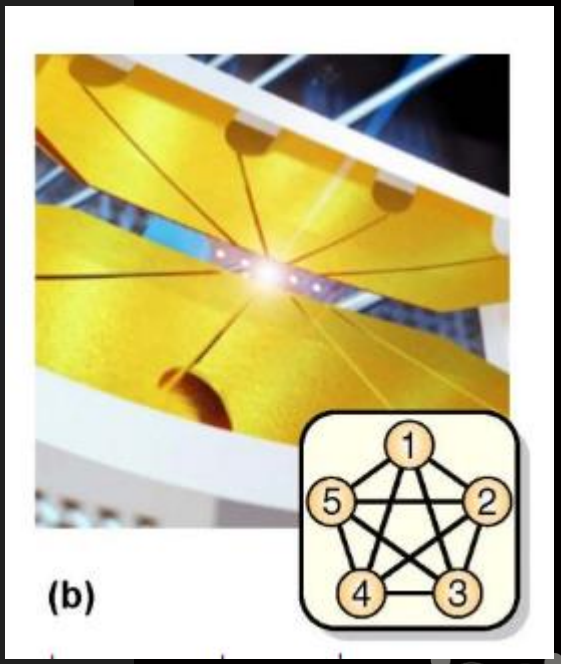
- Spinning coins is not very fast
- Tossing coins can only really be used to generate random numbers
- Sticking coins together is even slower than just flipping them
- We can’t stick together two coins while they are spinning

Qubit

- The qubit is the smallest unit of a quantum computer
- Each qubit is a controlled quantum state
- **Physical qubit**: Today's qubits are physical qubits: irreducible quantum systems that can carry out computation
- **Logical qubits**: Combining many physical qubits to produce higher quality logical qubits that can perform computations with much higher accuracy





Images: University of Maryland

How do you build a qubit?

There is no consensus!

- Superconducting circuits
- Trapped Ions
- Linear/non-linear optics
- Defects in diamond
- Many more

Superconducting Circuits

Building a quantum computer with superconducting qubits (QuantumCasts) - YouTube

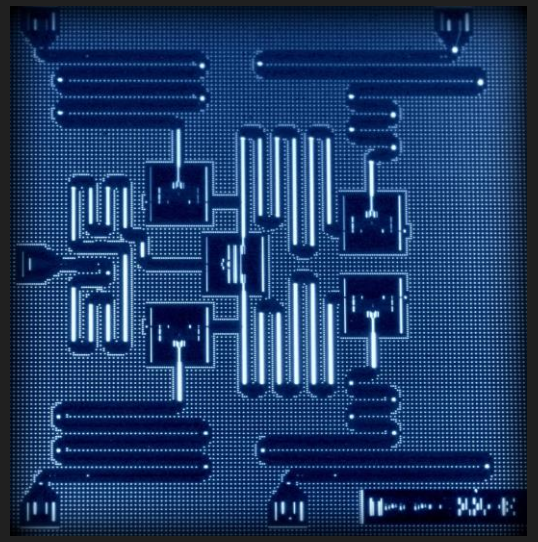
How it works

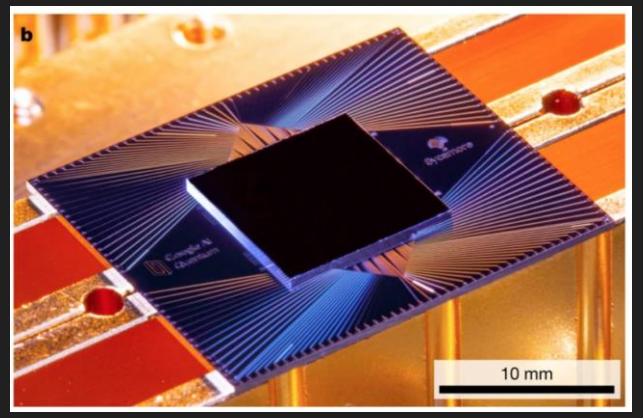
Superconducting circuit (like LC)

Microwave pulses perform quantum gates

Who makes it

IBM, Google, Rigetti, OQC…

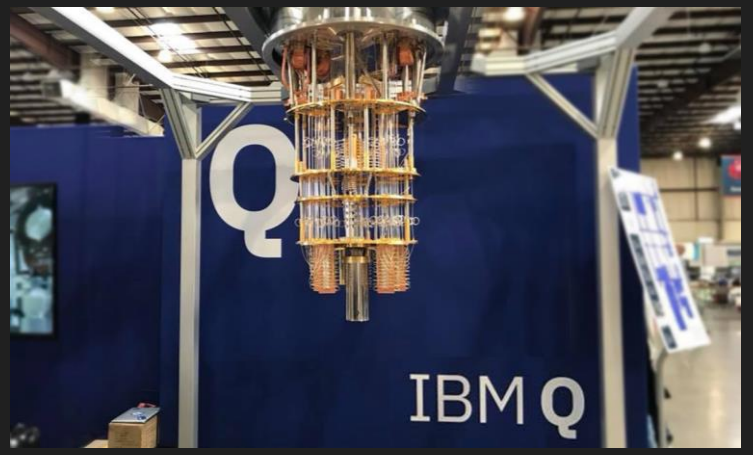




Advantages/Disadvantages

Easy to make qubits, fast

Higher error rates, limited connectivity, difficult to cool



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https://quantum-computing.ibm.com/services/resources

Trapped ions

How it works

Ions held by electric/magnetic fields are qubits

lasers used to perform quantum gates

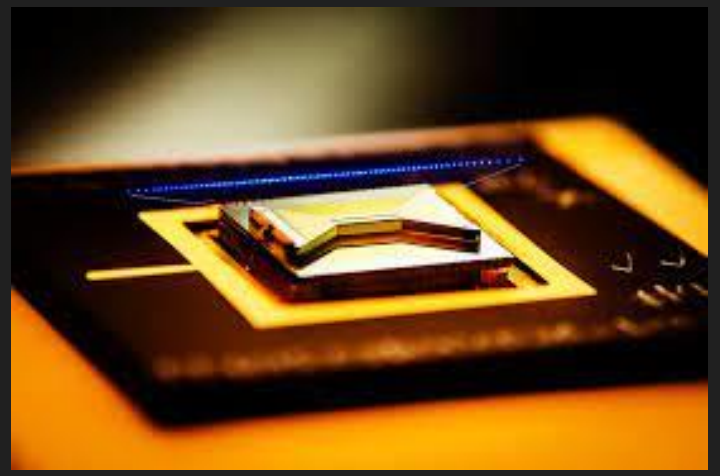
Who makes it

IonQ, Quantinuum, AQT, Universal Quantum,…

Advantages/Disadvantages

Hold many of the records, easy to cool

Very slow



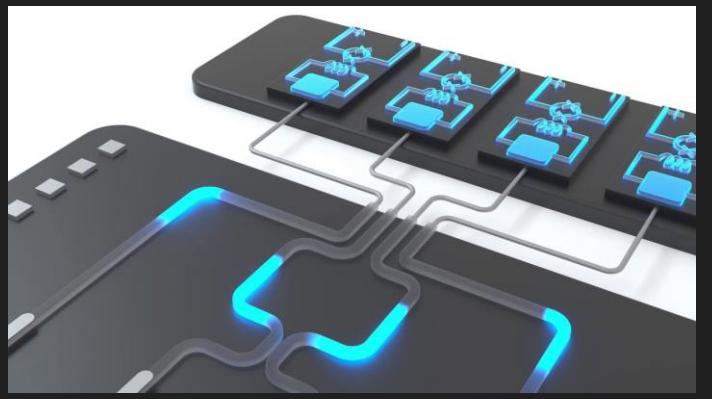
Images: IonQ

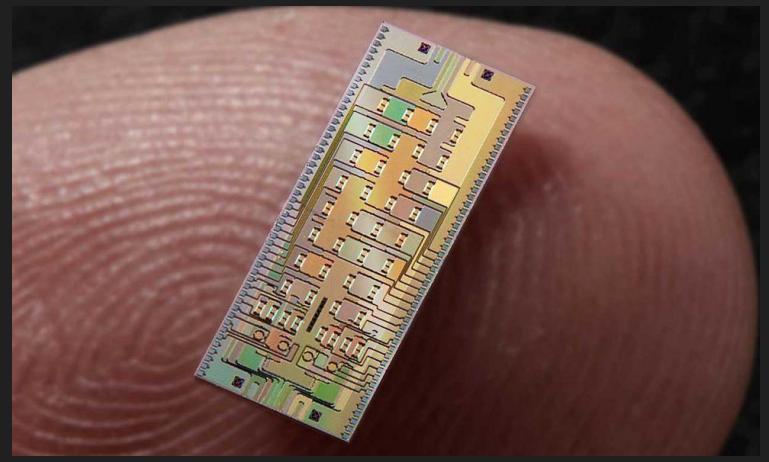
Photonic

How it works
Send single photons through linear/non-linear optics
Measure them with detectors

Who makes it
Xanadu, PsiQuantum, ORCA,…

Advantages/Disadvantages
Very fast, compatible with telecoms (possibly)
Less mature than others





Images: Xanadu

QC Now vs the Future

1: Classically simulatable

2: Noisy Intermediate-Scale Quantum (NISQ)

3: Quantum Computing with error correction

Adapted from AWS

Summary

The first class has introduced core concepts of quantum computing

Next time: Maths to describe this

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Which of these are true?

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Audience Q&A Session

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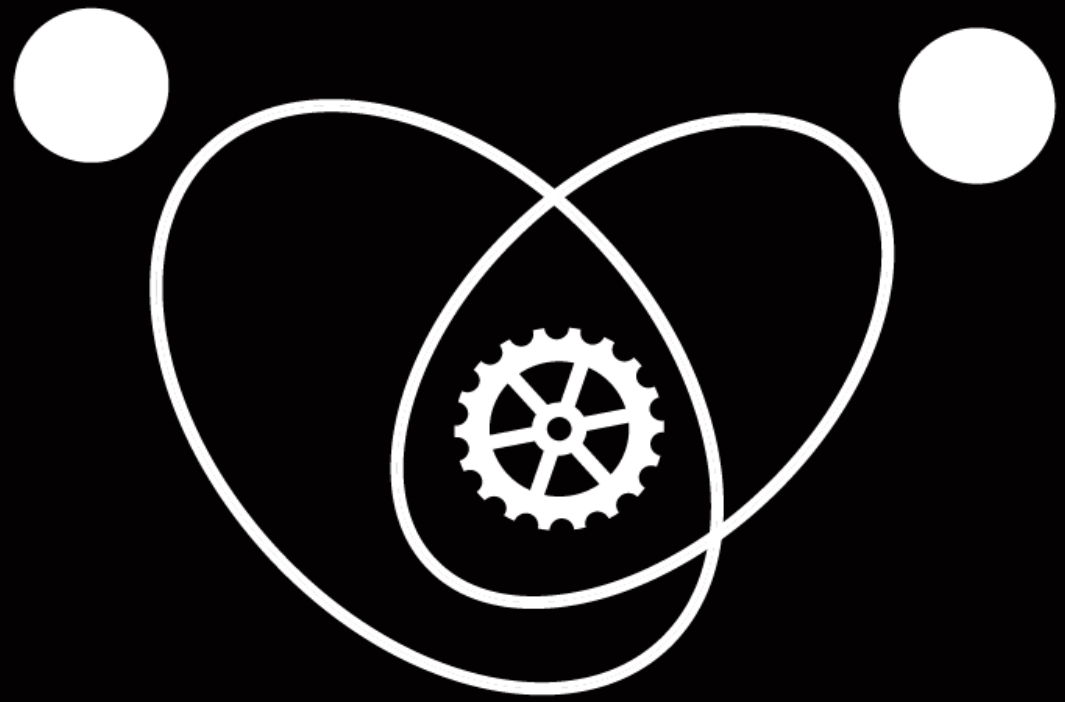
G R A C I A S



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