Introduction to Quantum Computing

Week 1: Quantum World

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Quantum Talent and Learning Center
Amsterdam University of Applied Sciences

Week 1
March 15th, 2024

Agenda for today:

- 14:00-14:30 Setting up the workshop + Introduction + round of introductions from other teachers/TLCs.
- 14:30-14:45∼15:00 Marten Teitsma will give a short presentation on the quantum software applications and the ecosystem.
- 15:00-15:30 ∼ 15:45 Starting the first part of the presentation.
- 15:45-16:00 Bernardo will give a short presentation about the minor of applied quantum computing at HvA.
- 16:00-16:30 Continue with the workshop's presentation, ending the workshop with outline for the upcoming session next week.

Workshop scheme

Every 30 min or so we will have a feed from other QTLC groups.

Feel free to ask questions at any time!

It is an **interactive** workshop, we all learn from each other!

Session is **recoded** and will be shared with you.

We will use **Discord** for communication.

Meet the other TLC hubs!

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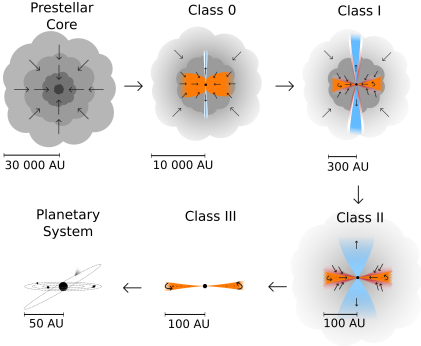
- Hogeschool Fontys -Fontys University of Applied Sciences, Dr. Mohammad-Amin Moradi (TLC Eindhoven).

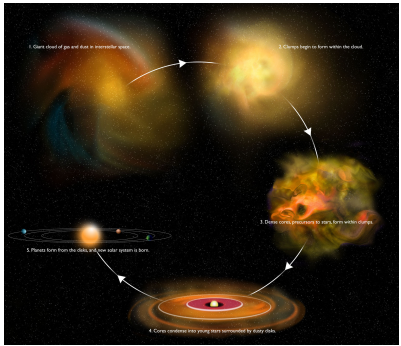
Presentation, Marten Teitsma, professor of applied quantum computing at HvA

The quest to understand the formation of planets and origin of life!

Circumstellar/Protoplanetary Disks



– Persson, Magnus Vilhelm (2014)



– Bill Saxton, NRAO/AUI/NSF

Quantum chemistry and quantum dynamics simulations

During my PhD work: computationally expensive simulations of molecular interactions.

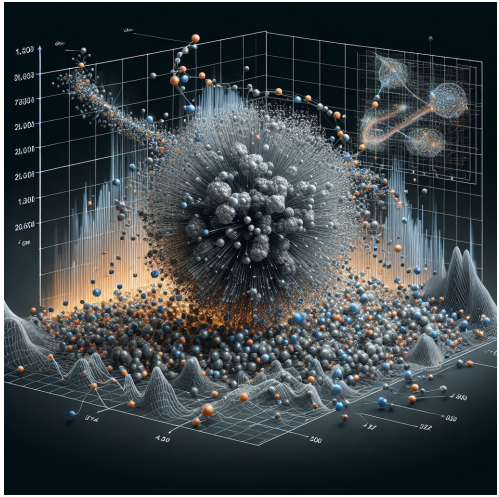


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Image credit: Taha Selim, AI-generated image.

Quantum chemistry and quantum dynamics simulations

Would quantum computing help in performing these simulations?

Applications include: material design, drug discovery, $\cdots$.

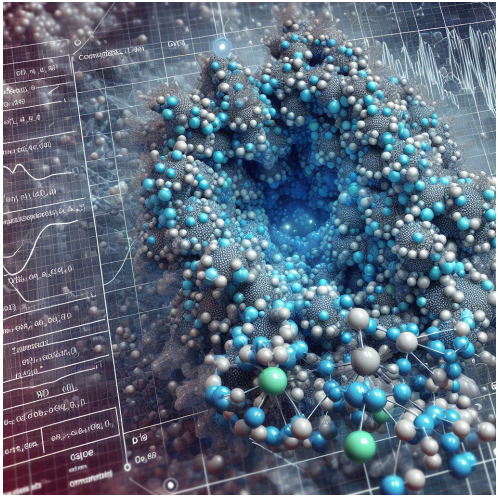


Image credit: Taha Selim, AI-generated image.

It is all about computing!

The need for digital twin, performing simulations and design

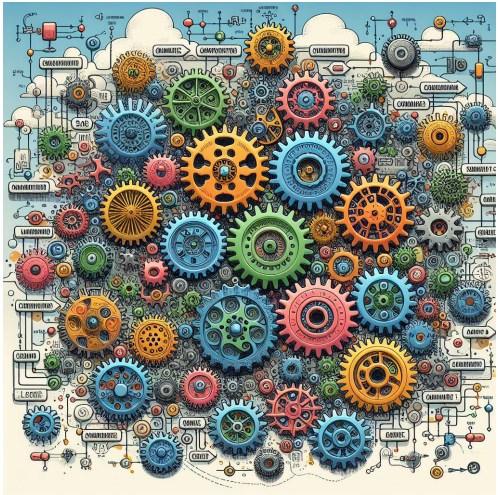


Image credit: Taha Selim, AI-generated image.

Curious Questions!

- What is the fastest computer in the world?
- What is the difference between classical and quantum computing?
- Why do we need Quantum Computing?
- What do you expect to have from quantum computing?
- Can Quantum Computing solve all problems?
- Can Quantum Computing break all encryptions?
- Can current AI be improved by Quantum Computing?
- Which one wins, AI or Quantum Computing?
- What is the future of Quantum Computing?

What is Quantum Mechanics?

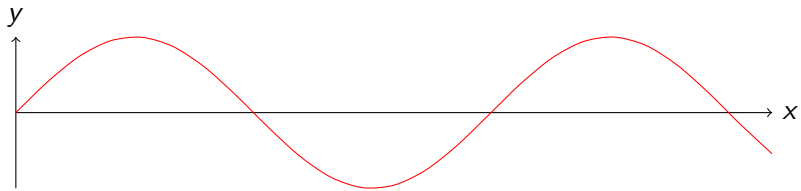
Quantum mechanics is the language of the microscopic world!

With the language of quantum mechanics, we can do:

- Make designs of quantum sensors.
- Send and encrypt information.
- Design quantum systems to do computations.

Classical vs quantum superposition

What is the functional form of the following wave?



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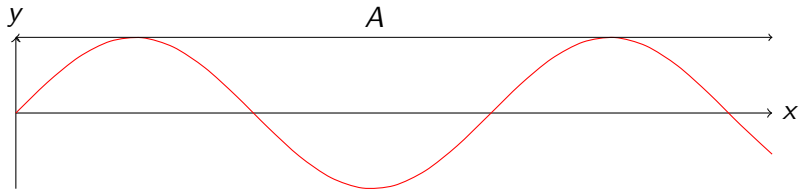
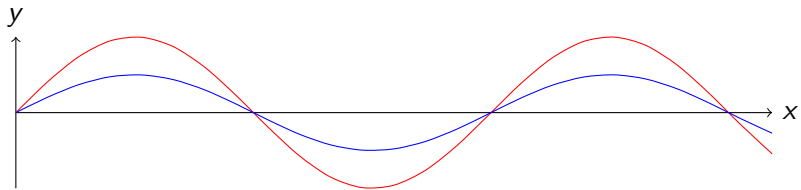


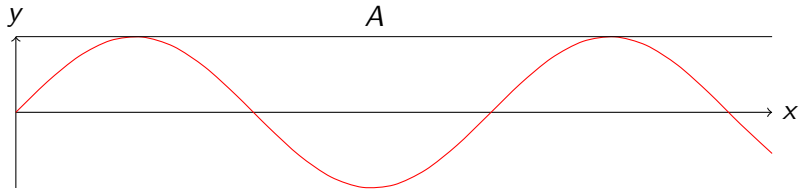
$$y = A\sin(x)$$

Classical vs quantum superposition

Classical or Quantum superposition?



Classical superposition:
Two physical quantities are added together to make another third physical quantity.



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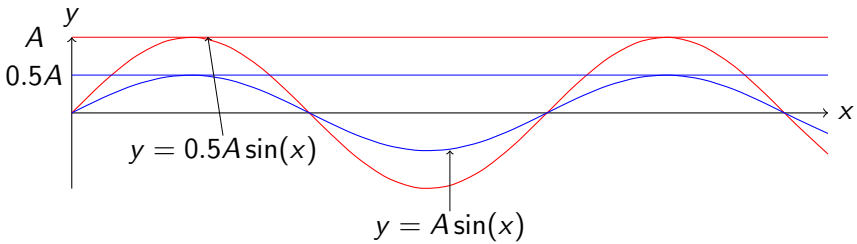
Classical vs quantum superposition

Example of constructive and destructive interference of two waves.



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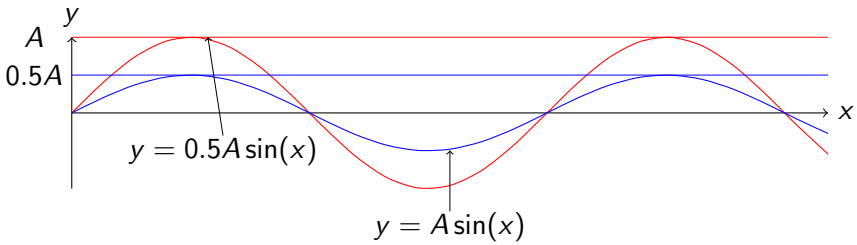
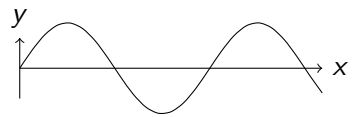


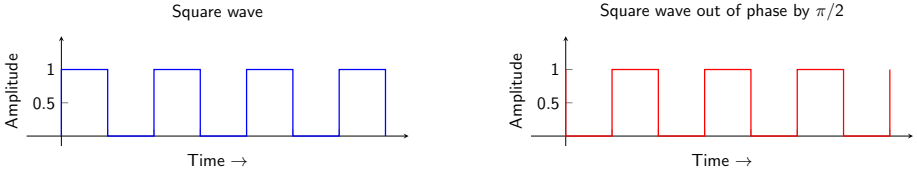
The superposition of two waves: constructive interference,

$$y(x) = A\sin(x) + 0.5A\sin(x)$$



Classical vs quantum superposition

Example of constructive and destructive interference of two square waves.



The result of the superposition of the two waves: destructive interference,

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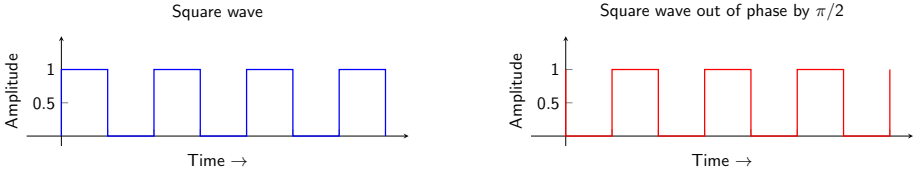

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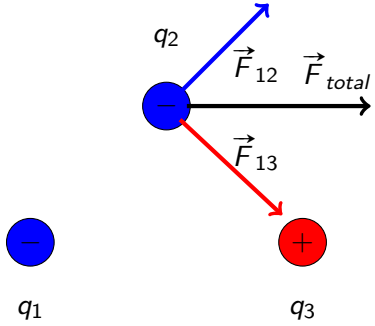
Example of classical superposition in electrostatics.



The resultant force acting on the upper electric charge:

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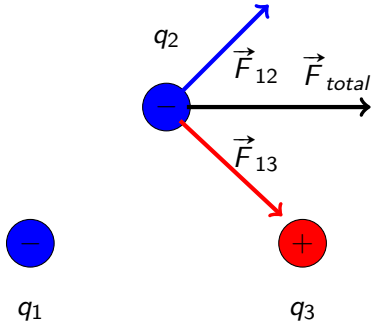

The resultant force acting on the upper electric charge:

$$\vec{F}_{total} = \vec{F}_{12} + \vec{F}_{13}$$

Classical vs quantum superposition

Quantum superposition:
A quantum system can be in a superposition of two or more states. We can explain it using the following analogy:

A coin has a 50/50 probability of landing as either heads or tails:

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After the coin is tossed, it is in a superposition of heads and tails. Only when it fails on the ground, we will know the outcome:

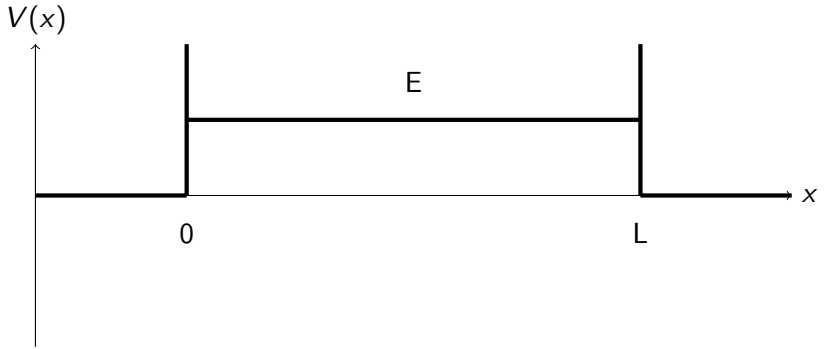
Probability of landing on heads $P(H) = 0.5$

Probability of landing on tails $P(T) = 0.5$

Energy quantization

Quantum superposition:

Example: Particle (electron) trapped in a box

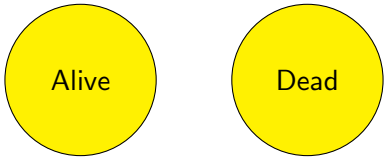


Quantization of energy levels which a trapped particle in 1D well can have.

Classical vs quantum superposition

Quantum superposition:

Schrödinger's cat:



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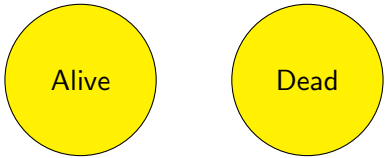

Measurements: destroy the superposition of states.

Let's play!

Tik Tok Toe game:

https://tiqtaqtoe.com/

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https://tiqtaqtoe.com/

Who wins? How did you win?

Refreshing 1

Discuss among yourselves whether the following quantities are quantized or continuous:

1. electric charge.
2. time.
3. length.
4. energy.
5. cash.
6. paint color.

Question source: Hughes et al. (2021), Springer. Quantum Computing for the Quantum Curious.

Refreshing 2

Question:

An ink is created by mixing together 50% red ink and 50% yellow ink. An artist uses it to stamp a picture of a sun. If the ink behaves like a quantum system in a half-yellow, half-red quantum superposition, what are the different options for what the resulting picture could look like? Some options are shown in the figure.

Question source: Hughes et al. (2021), Springer. Quantum Computing for the Quantum Curious.

Refreshing 3

Question:
If this controversial picture of a dress is always seen as blue/black by Student A and always seen as white/gold by Student B, is the dress in a quantum superposition?
`https://en.wikipedia.org/wiki/The_dress`

Question source: Hughes et al. (2021), Springer. Quantum Computing for the Quantum Curious.

Questions?

Intro to Quantum Computing workshop: Taha Selim, t.i.m.m.selim2@hva.nl

Minor of Applied Quantum Computing @HvA, Dr. Bernardo Villalba Frias, b.r.villalba.frias@hva.nl

Quantum Software ecosystem and applications, Dr. Marten Teitsma, m.teitsma@hva.nl

Thank you!