Physics

https://www.2pennyphysics.it/category/school-labhome/

Two-penny Physics.

Politecnico di Torino

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2 Physics

Agenda

Mechanics

- Linear momentum conservation in 2D
- From the classical experiment to modern physics

Geometrical Optics

- Let's shed some light on coffee

Quantum Mechanics

- Quantum mechanics with a straw

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2 Physics

Mechanics

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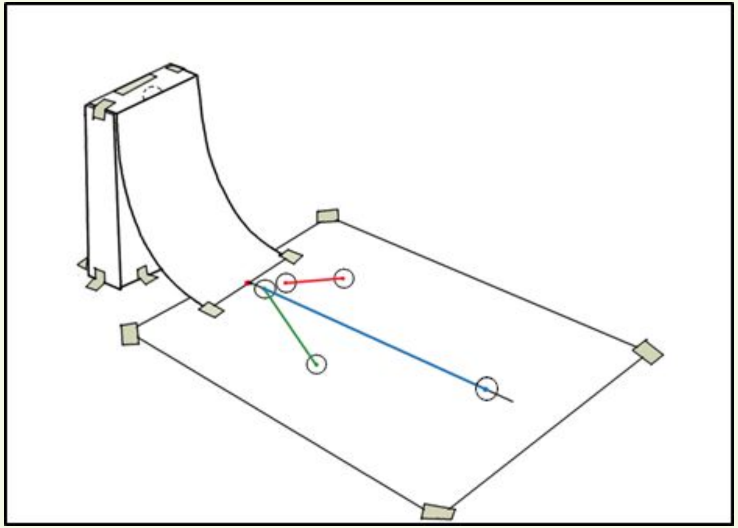
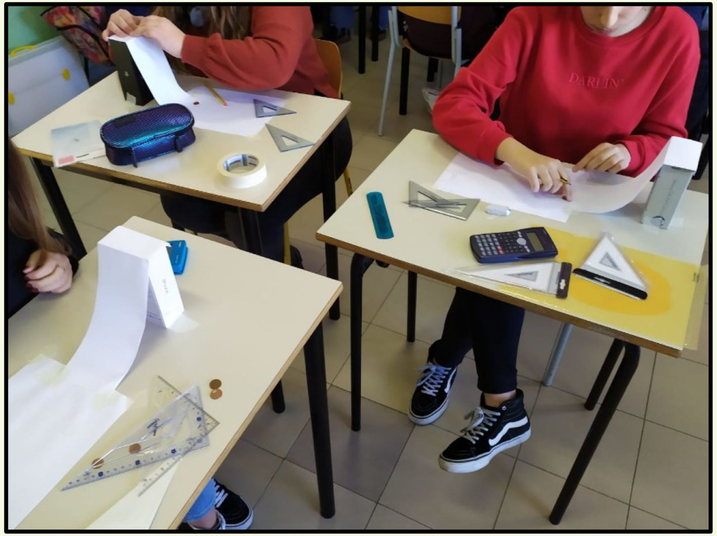
2 Physics

Linear momentum conservation in 2D





Low-cost apparatus to explore the physics of collisions.

Presentation of the activity & Aims

Very versatile apparatus:

1. single student or groups
2. explores of a lot of aspects in collisions
3. students build it and make it effective.
4. can be used to foster creativity.

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Presentation of the activity & Aims

- Discover that in collisions there is a conserved quantity (Linear Momentum) and that the conservation is vectorial in nature

- Introduction to Modern Physics.

  (Particle and Nuclear physics, Special Relativity, Quantum Mechanics)

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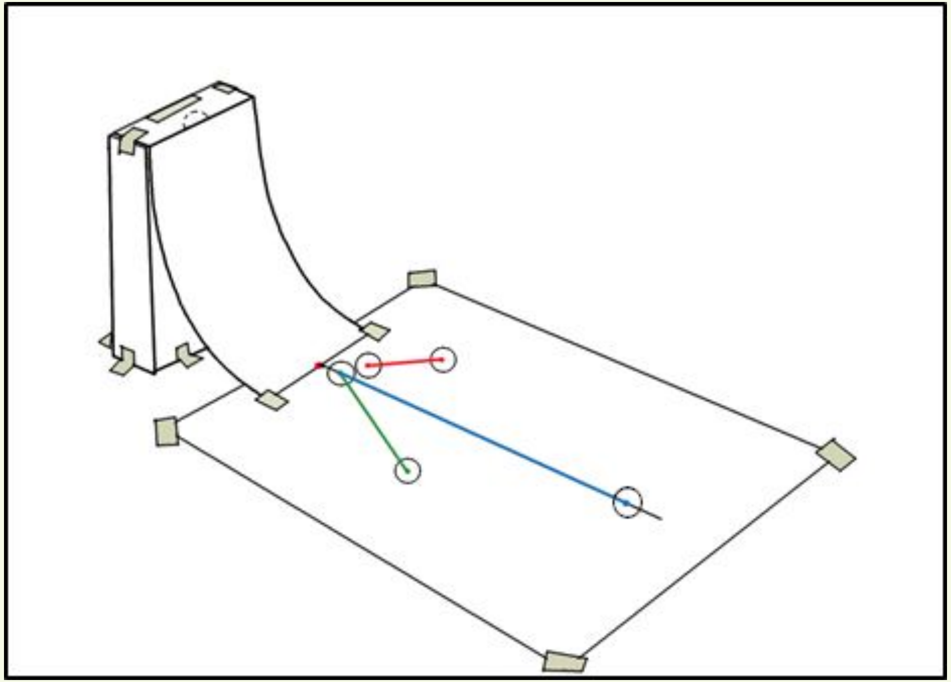
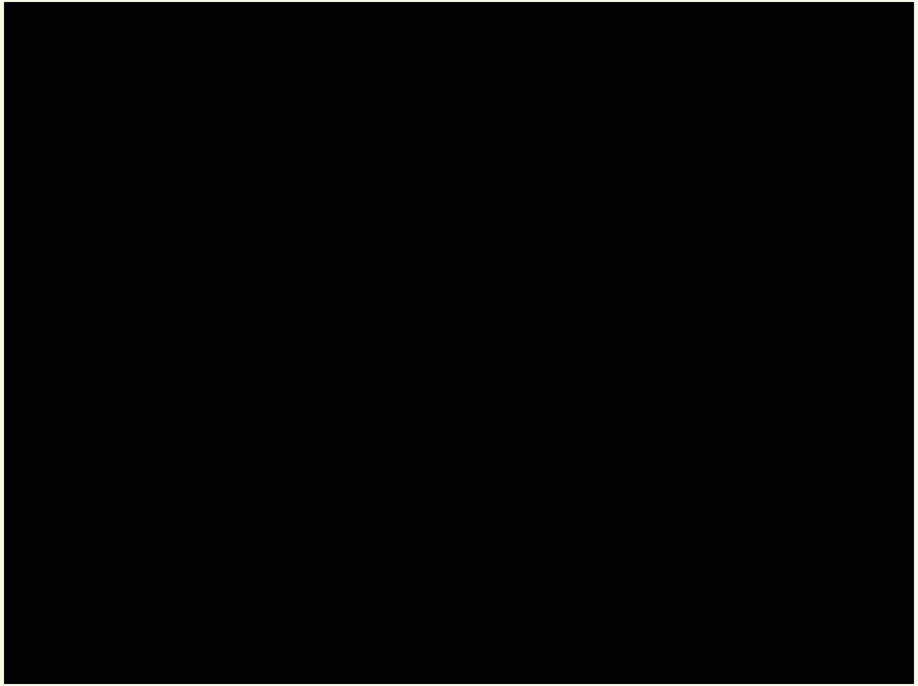
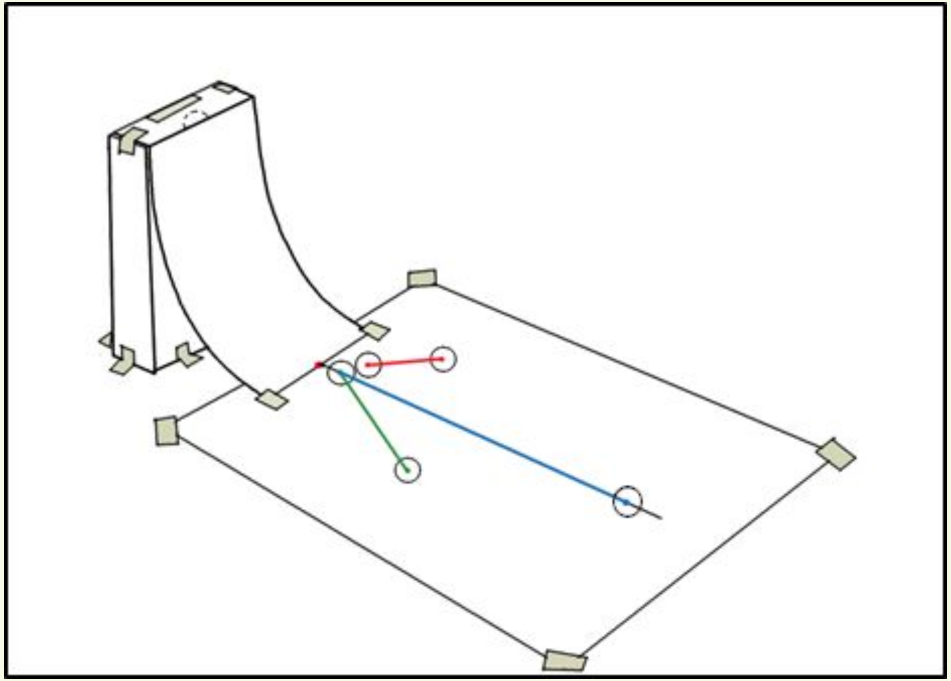
Description of the apparatus





Description of the apparatus



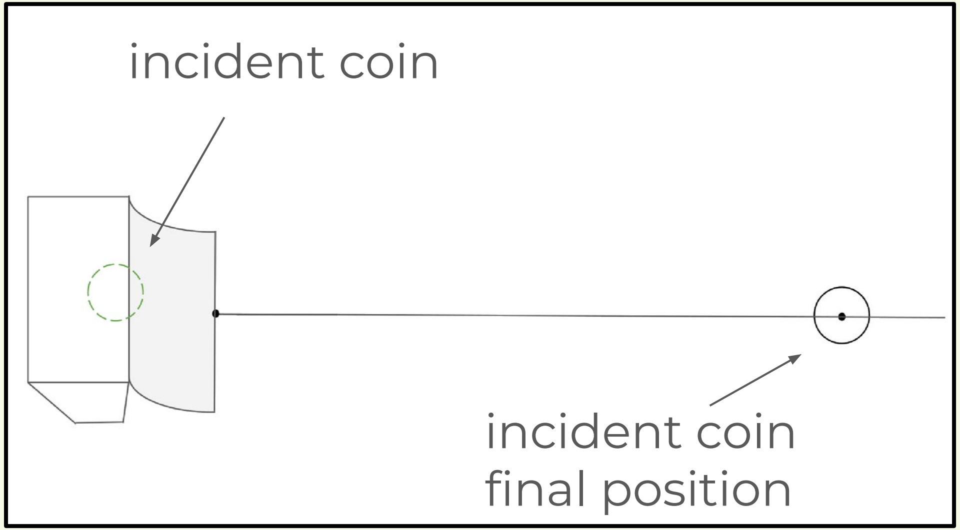
The idea

If we measure the lengths of the tracks of the coins we have information about the velocity vectors involved in the collision.

The friction F acts until the coins come to a stop, so the following relation holds

$$FL = \frac{1}{2}mv^2 \longrightarrow v \propto \sqrt{L}$$

Description of the apparatus



Step 1.

Determine the final position of the incident coin if no collision occurs.

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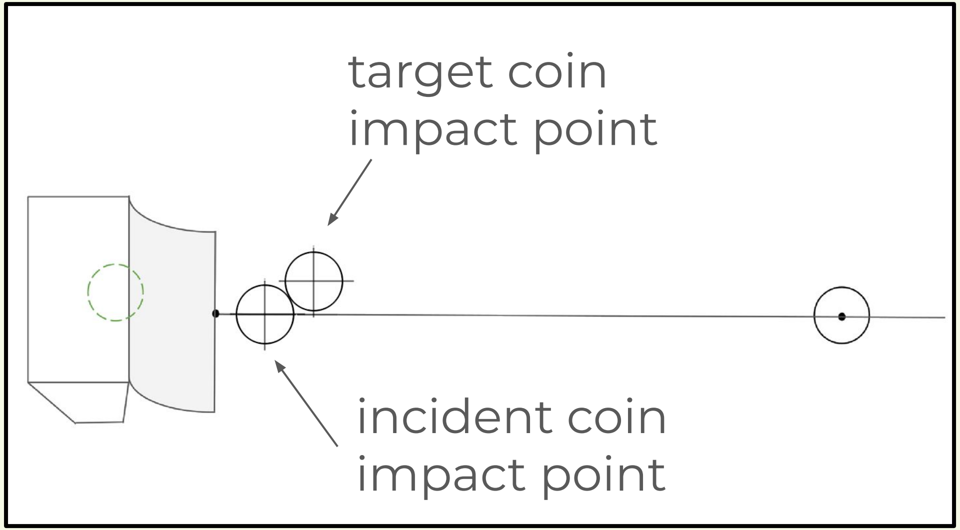
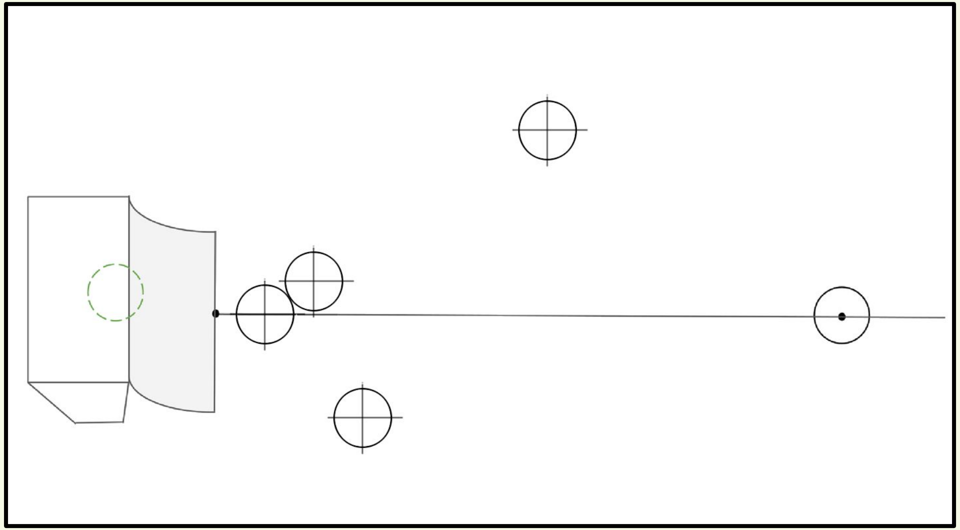
Description of the apparatus



Step 2.

Choose the impact (initial) positions of both the coins.

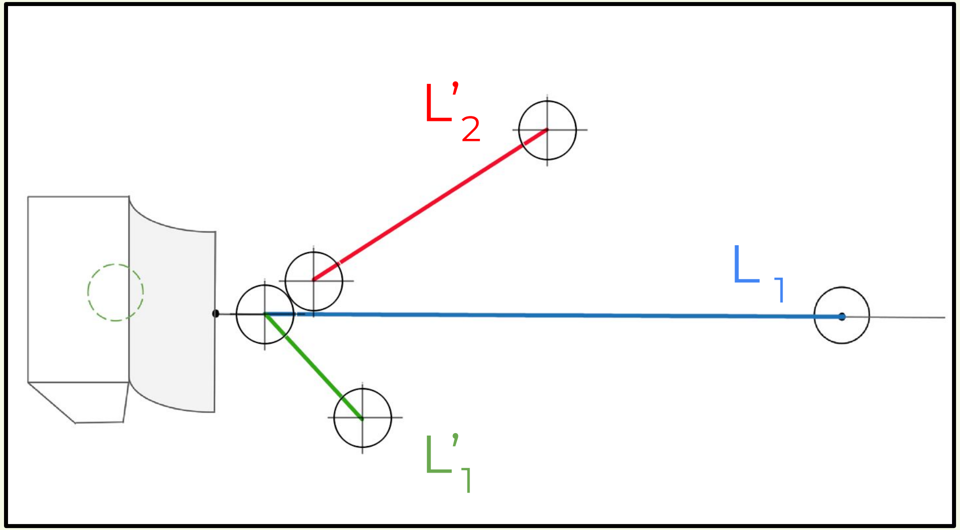
Description of the apparatus



Step 3.

Perform the collision and determine the final positions of the coins.

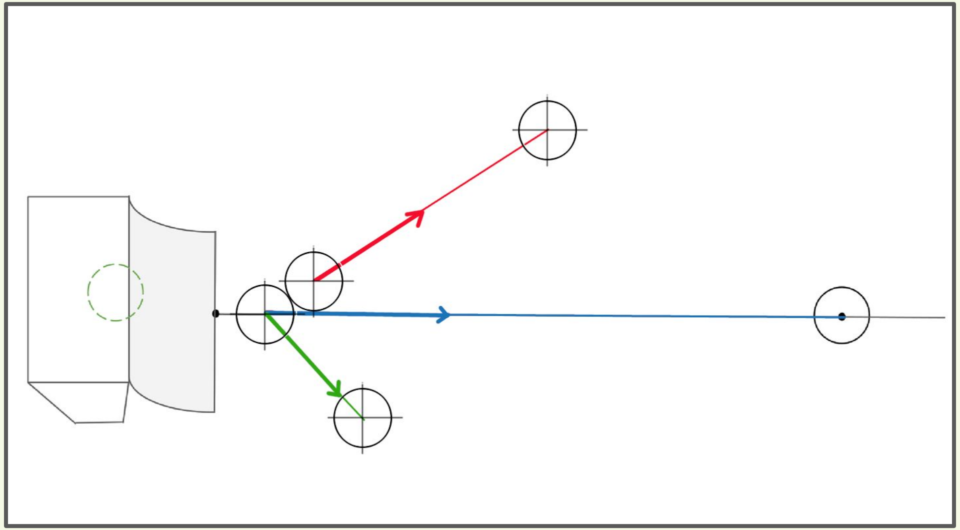
Description of the apparatus



Step 4.

Draw the directions of the tracks and measure the lengths.

Description of the apparatus



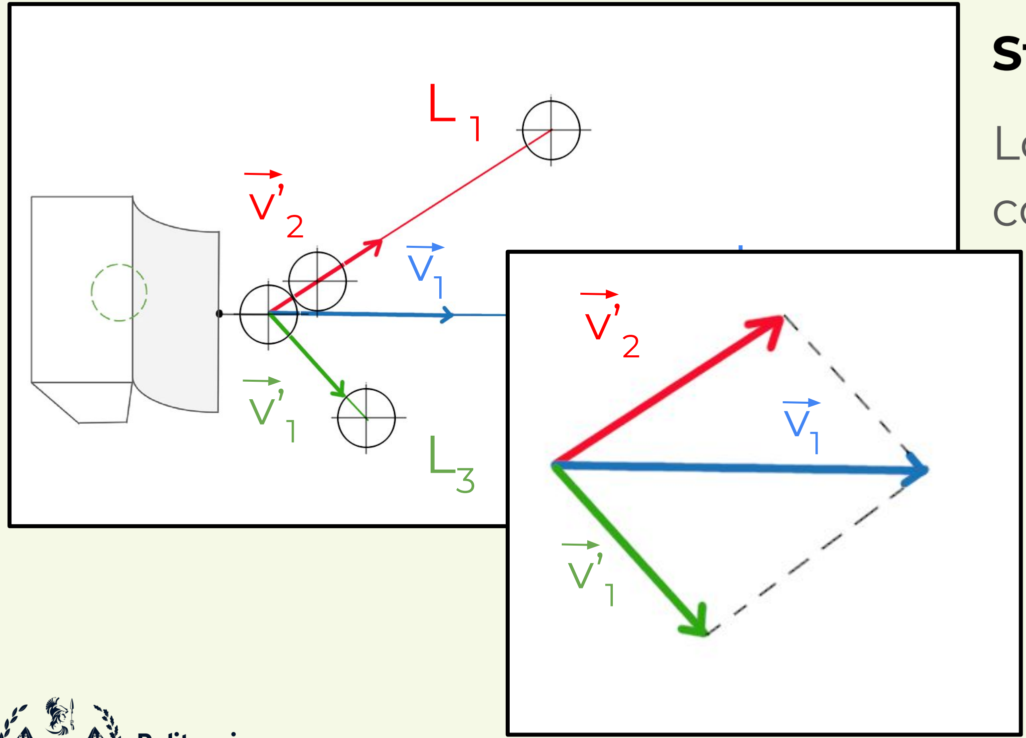
Step 5.

According to the relation

$$v \propto \sqrt{L}$$

Draw the velocity vectors before and after the collision.

Description of the apparatus



Step 6.

Look if the momentum vector is conserved:

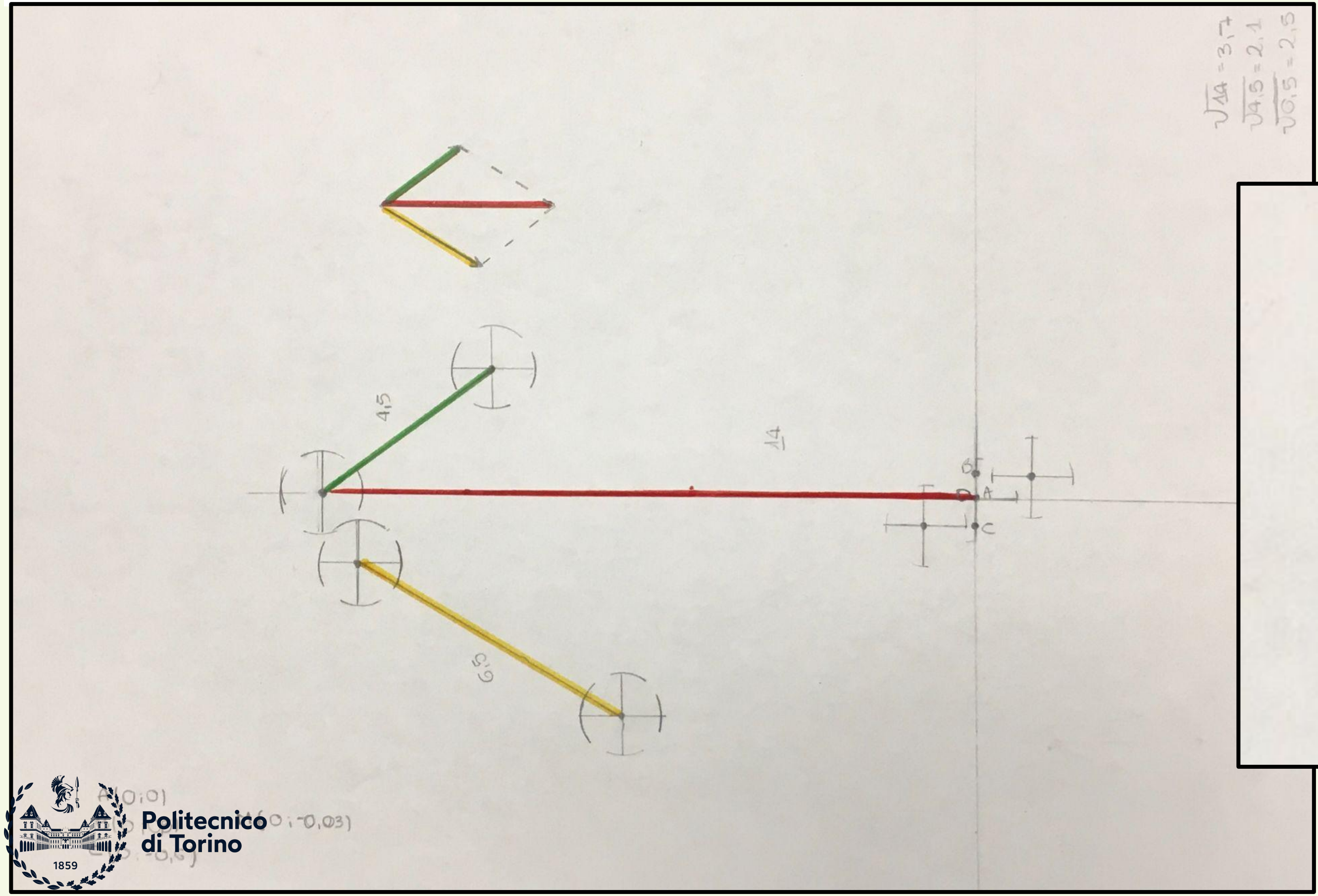
$$m\vec{v}_1 + m\vec{v}_2 = m\vec{v}'_1 + m\vec{v}'_2$$

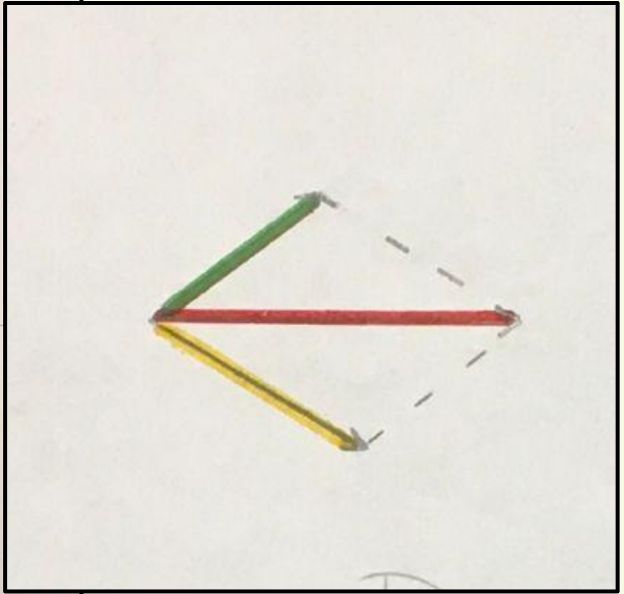
$$\vec{v}_1 + \vec{v}_2 = \vec{v}'_1 + \vec{v}'_2$$

$$\vec{v}_1 = \vec{v}'_1 + \vec{v}'_2$$

2 Physics

Results achieved in the classroom





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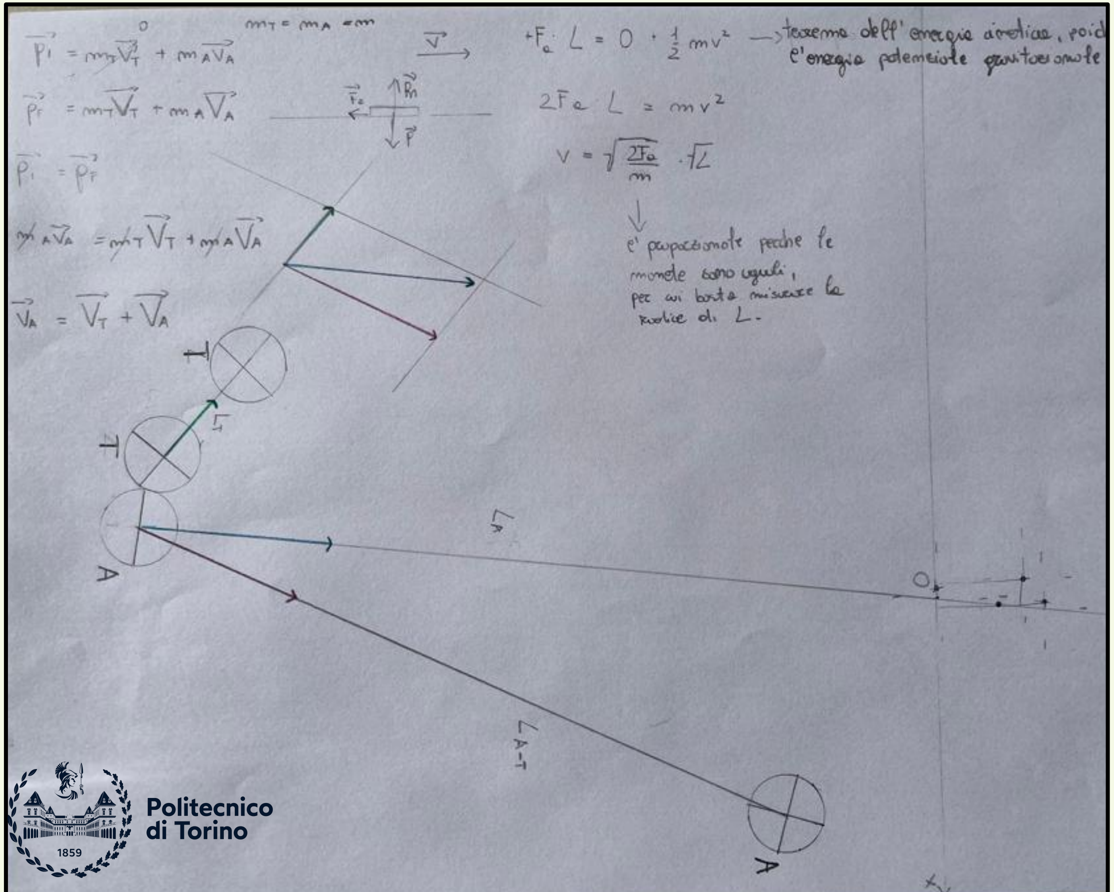
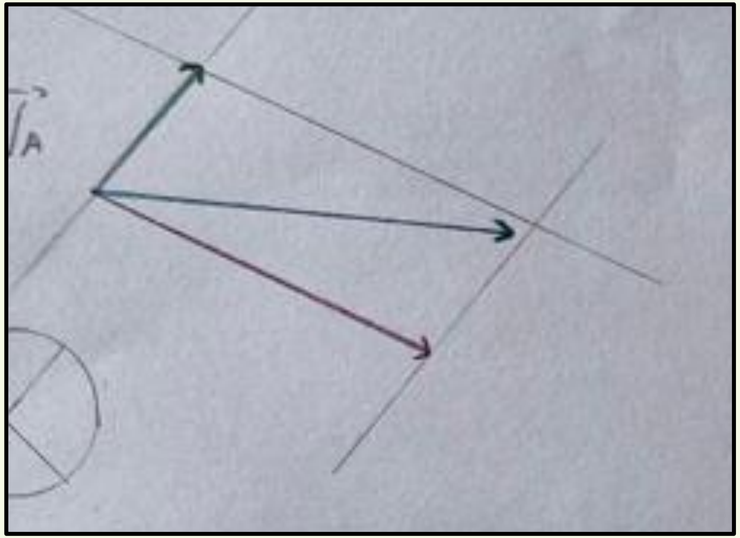
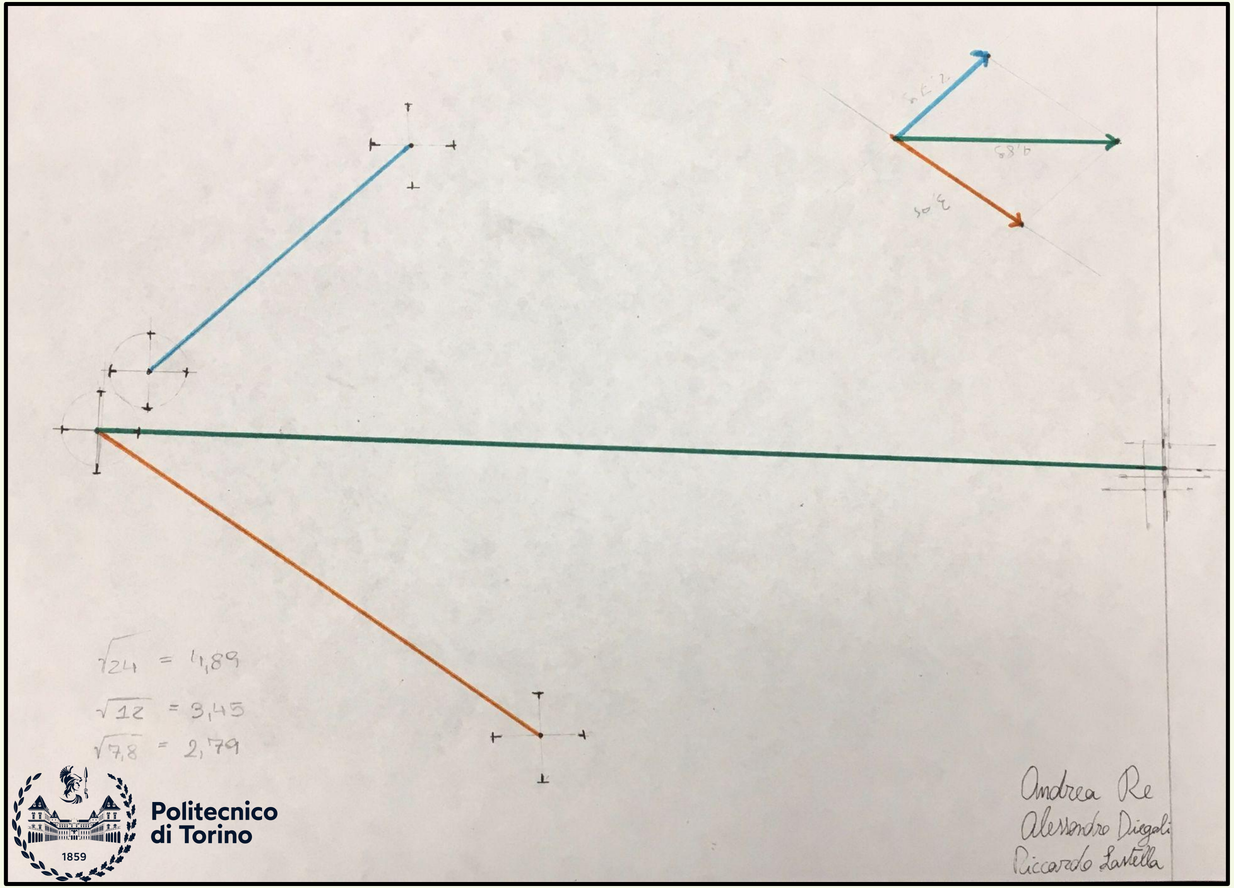
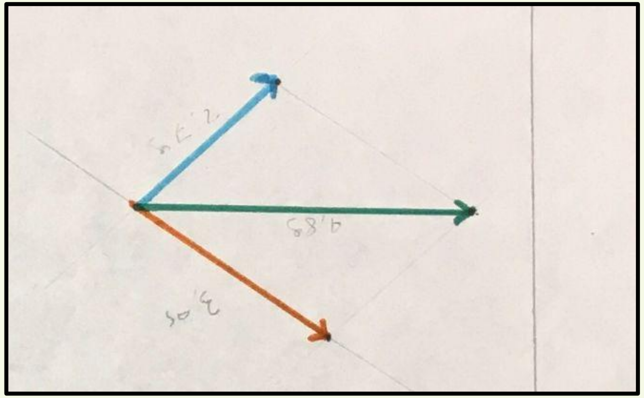




Results achieved in the classroom





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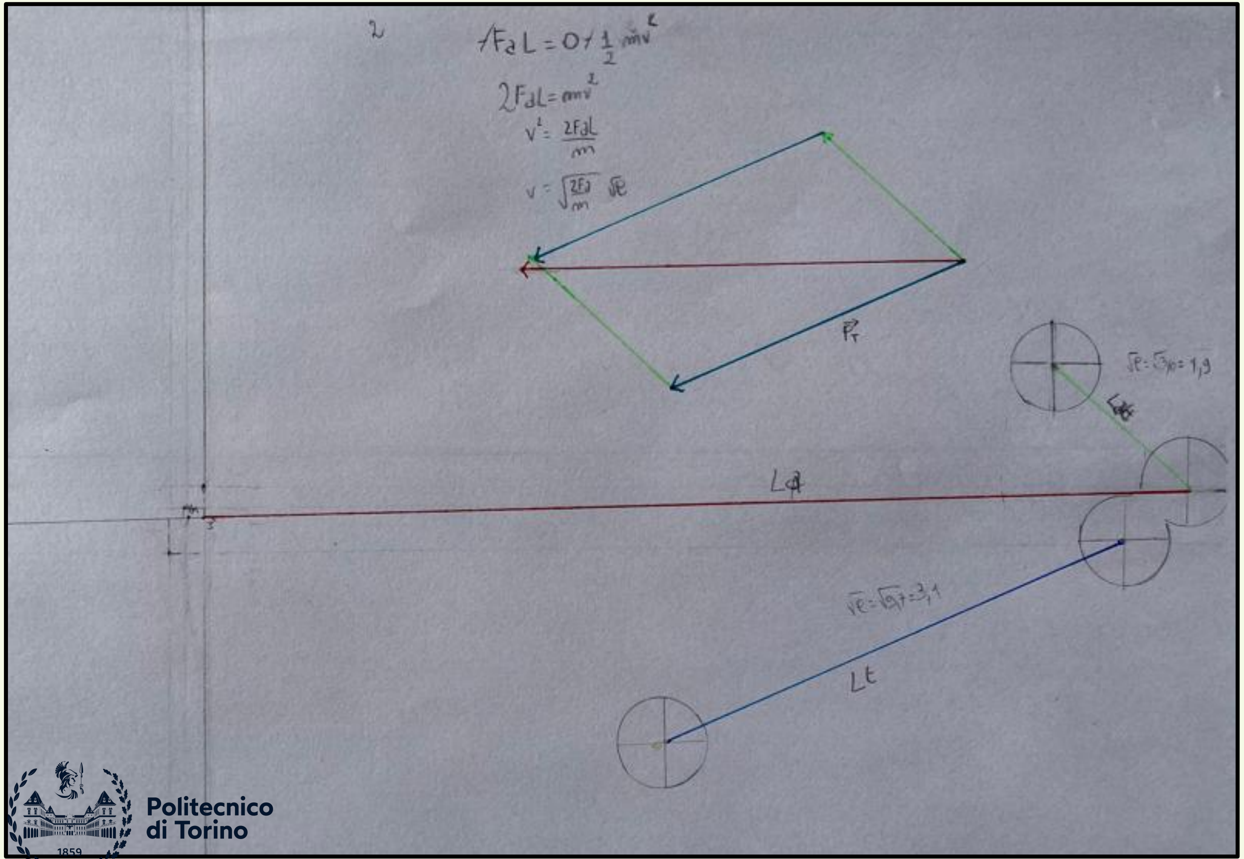
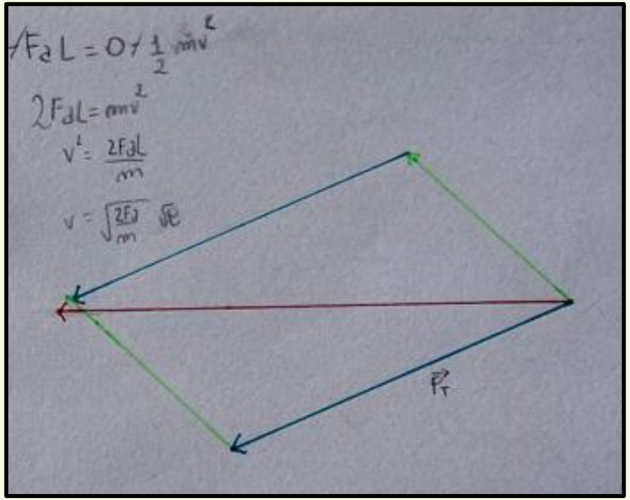
Results achieved in the classroom





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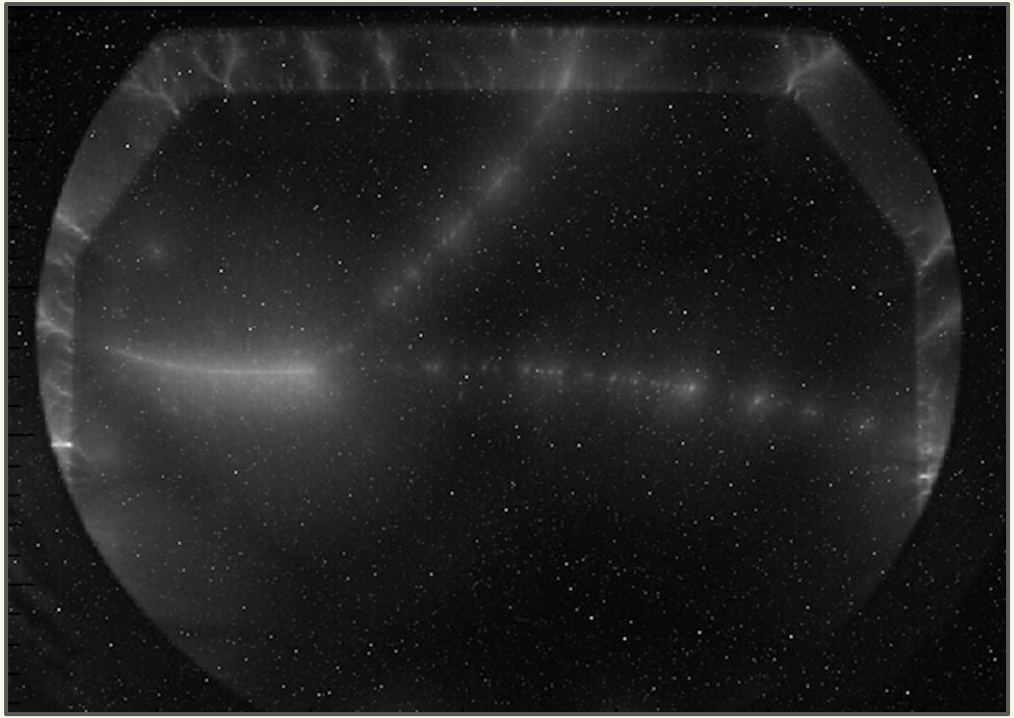
Results achieved in the classroom

Results achieved in the classroom

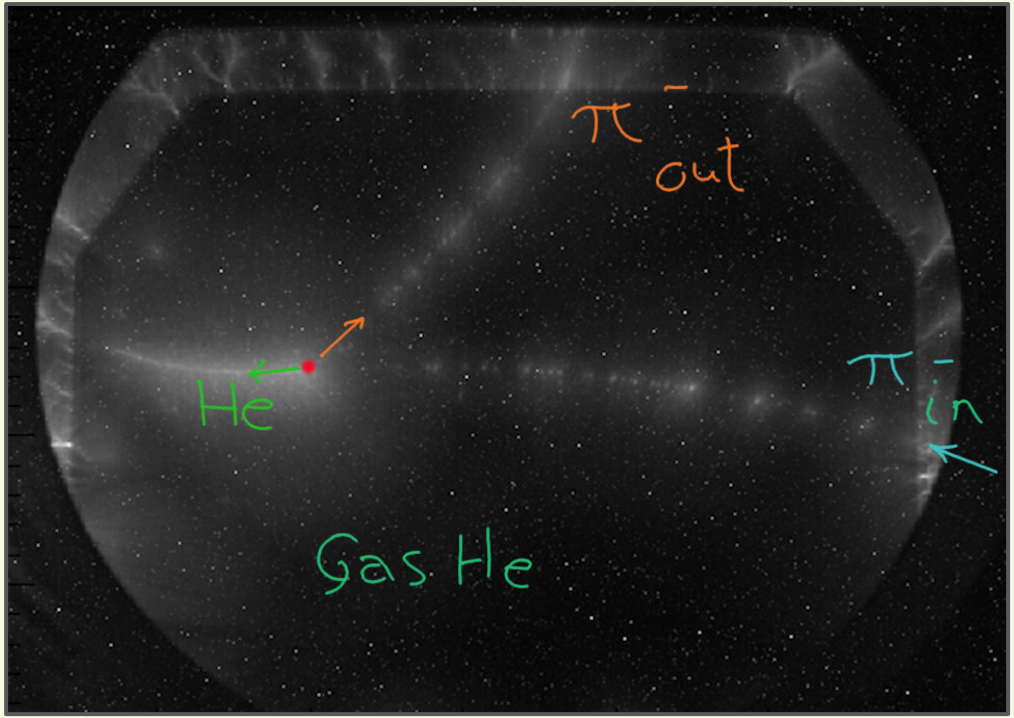
From the experiment to modern physics

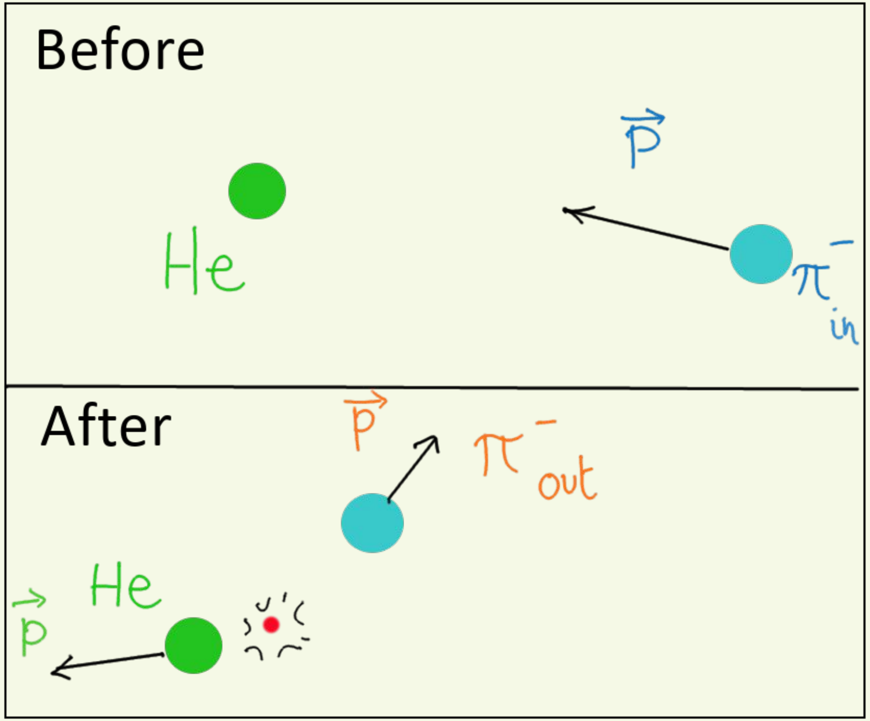


This is a collision event in particle physics experiment.

The situation is exactly the same as the one we had in the coins collision experiment!

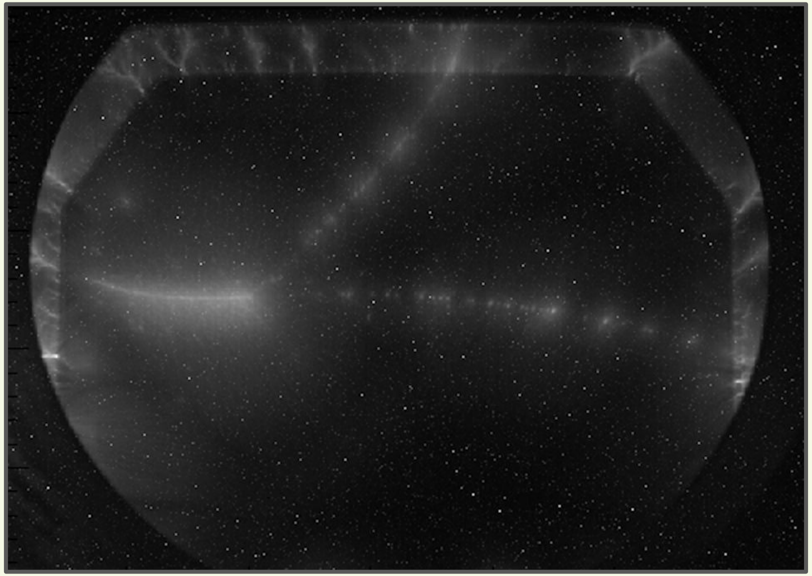
From the experiment to modern physics

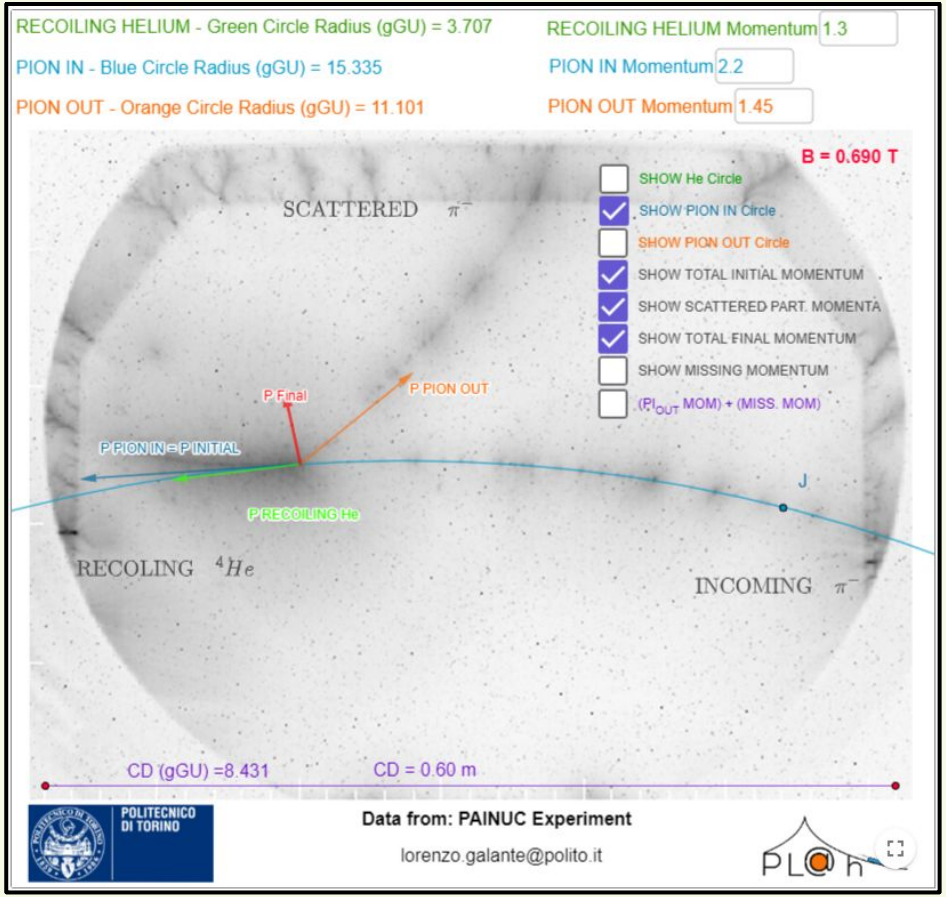




From the experiment to modern physics

Conservation laws as a tool for discovery in nuclear physics





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From the experiment to modern physics

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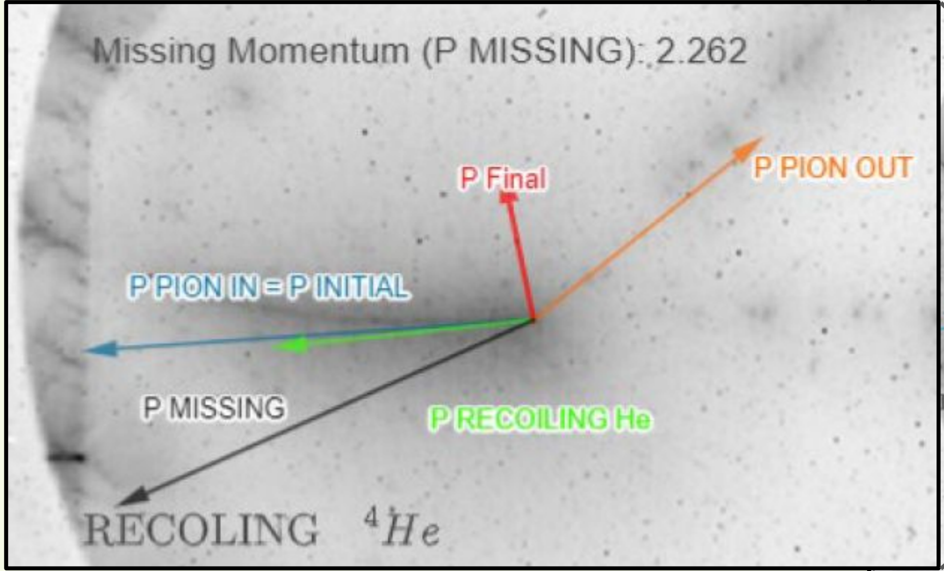

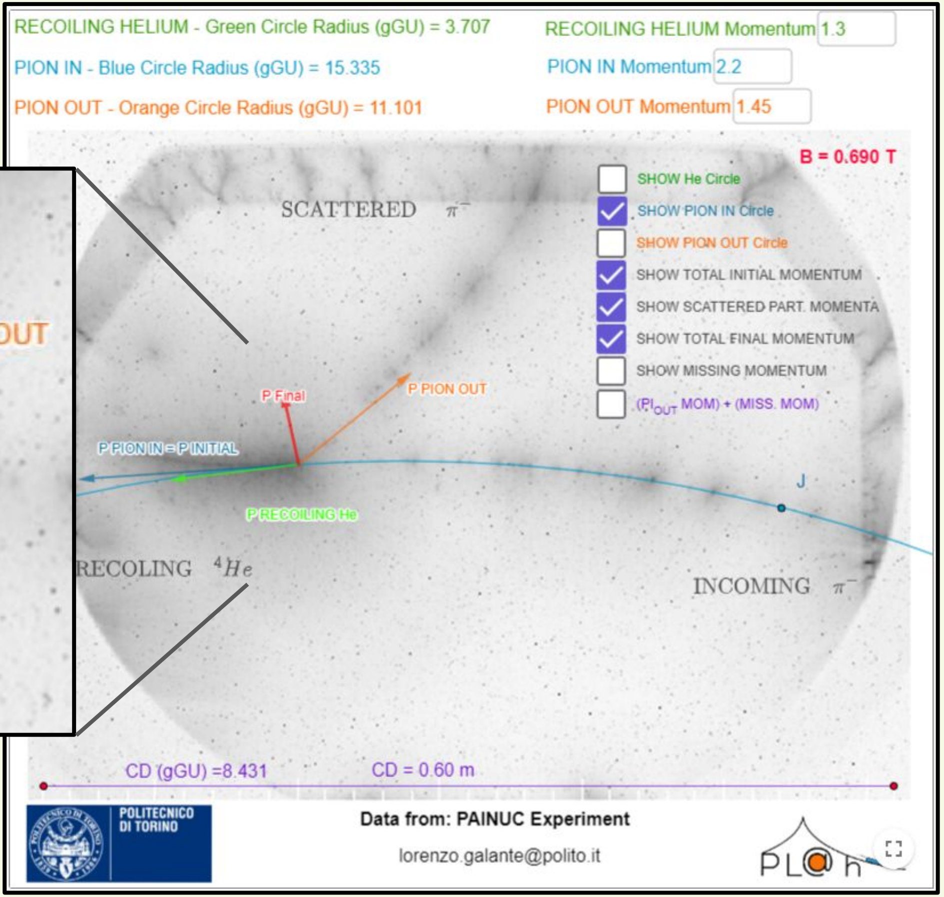

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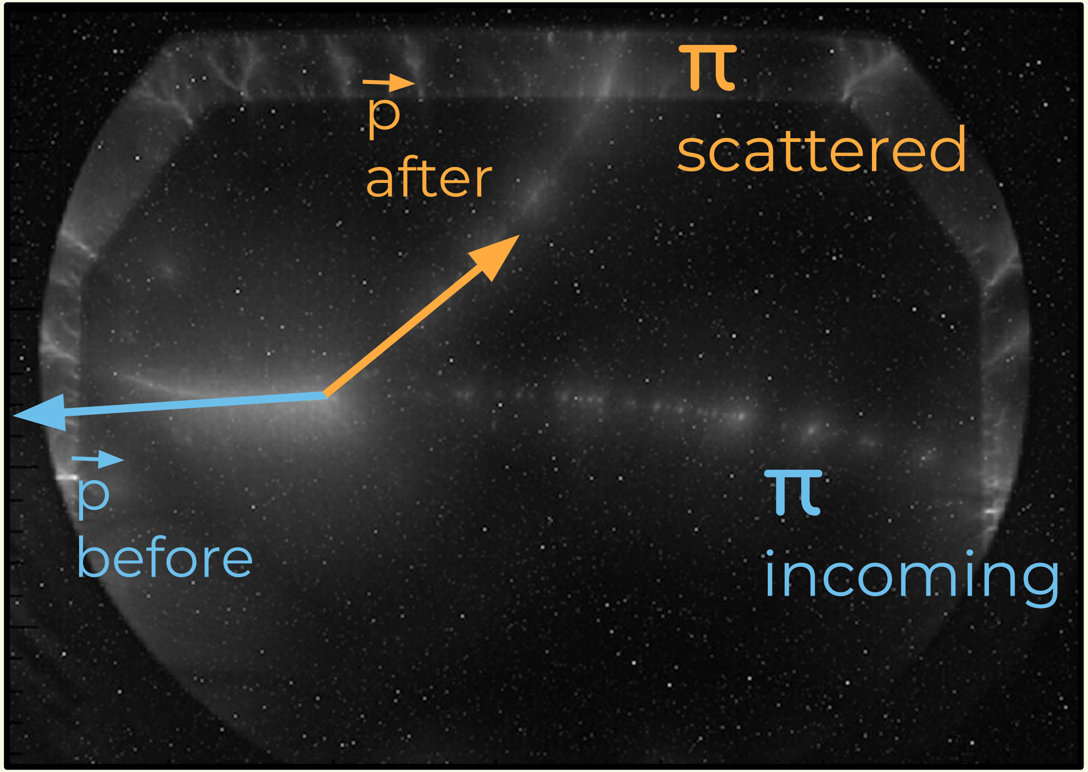
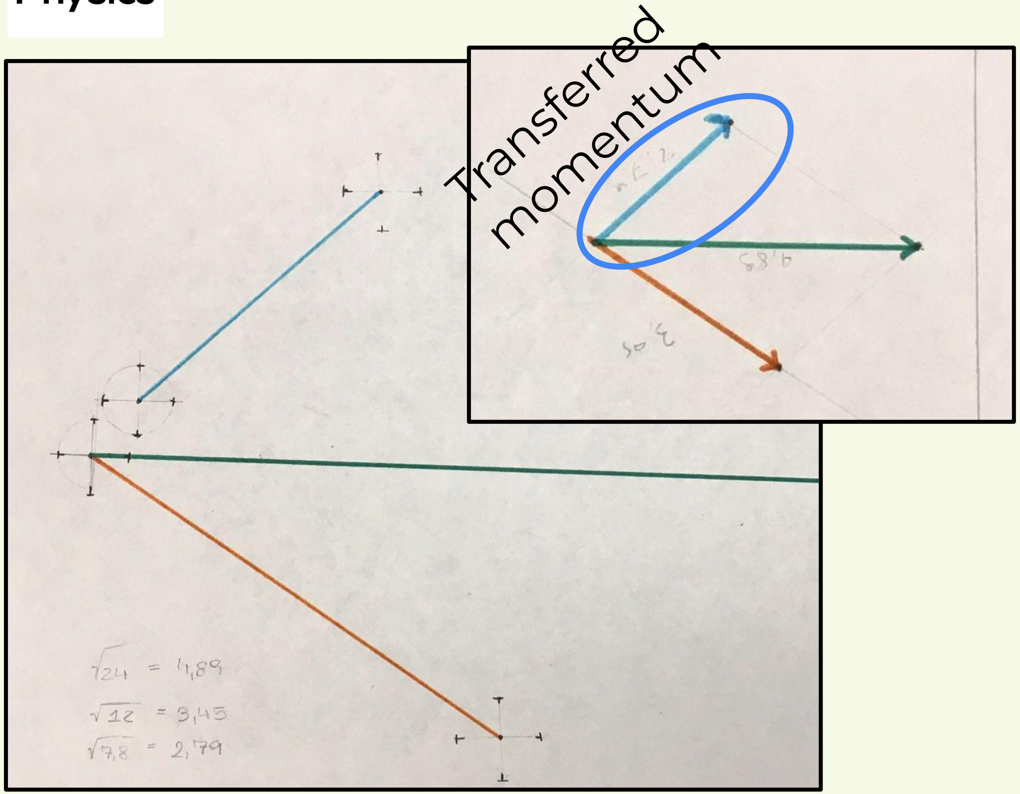
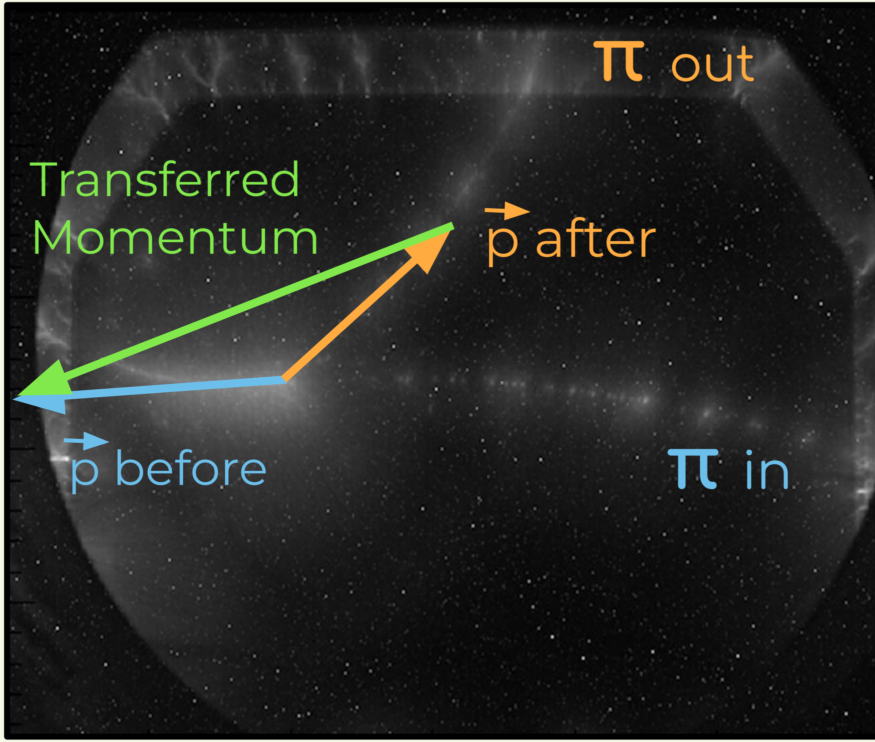
From the experiment to modern physics

Transferred Momentum



The same occurs in the coin collision …





From the experiment to modern physics

Transferred Momentum

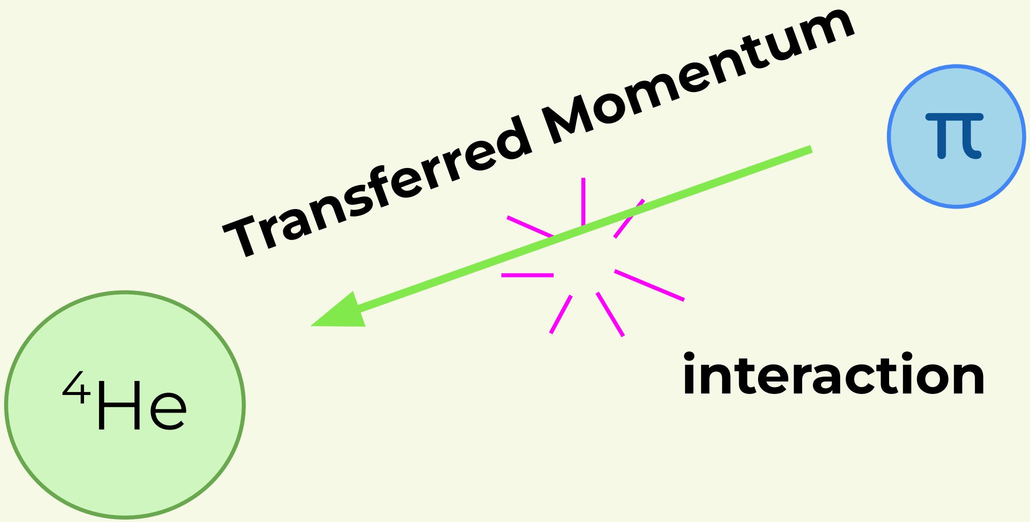
QUANTUM THEORY OF INTERACTIONS

Force Carrier

Spatial Scales of the Interaction

From the experiment to modern physics

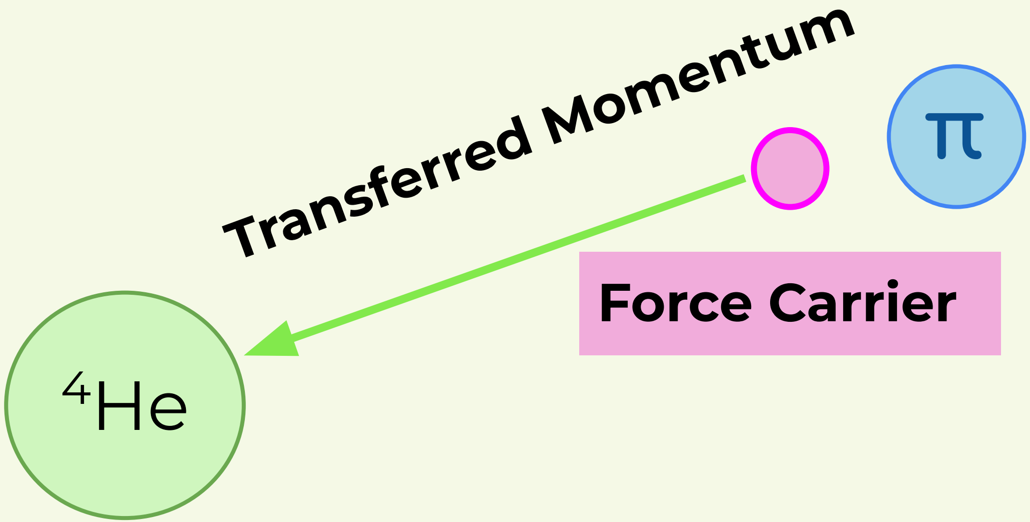
Force Carrier



... What carries this momentum?

From the experiment to modern physics

Force Carrier



A “particle”. The force carrier !

From the experiment to modern physics

Spatial Scales of interaction

Heisenberg Relation for the quantum system

$$\Delta p \cdot \Delta x \sim \hbar/2$$

Force Carrier:

We assume: $\Delta p \sim p$

Therefore $$\Delta x \sim \frac{\hbar}{2p}$$

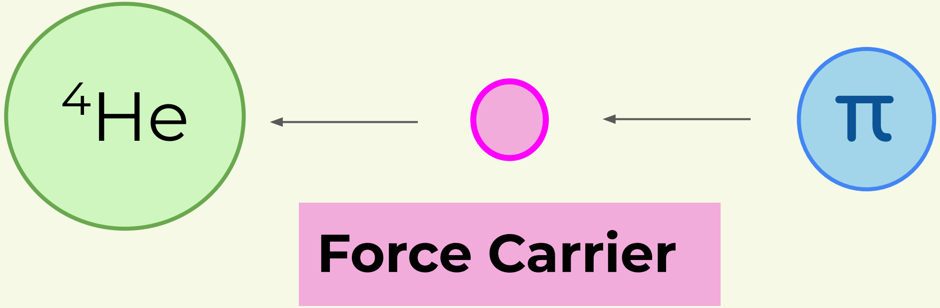
From the experiment to modern physics

Spatial Scales of interaction → $$\Delta x \sim \frac{\hbar}{2p}$$

Δx is the Dispersion in Space of the Force Carrier (FC).

It tells us about "how big" the FC is.

Therefore, it tells at what scales the interaction occurs



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Geometrical Optics

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Let's shed some light on coffee!

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Quantum Mechanics

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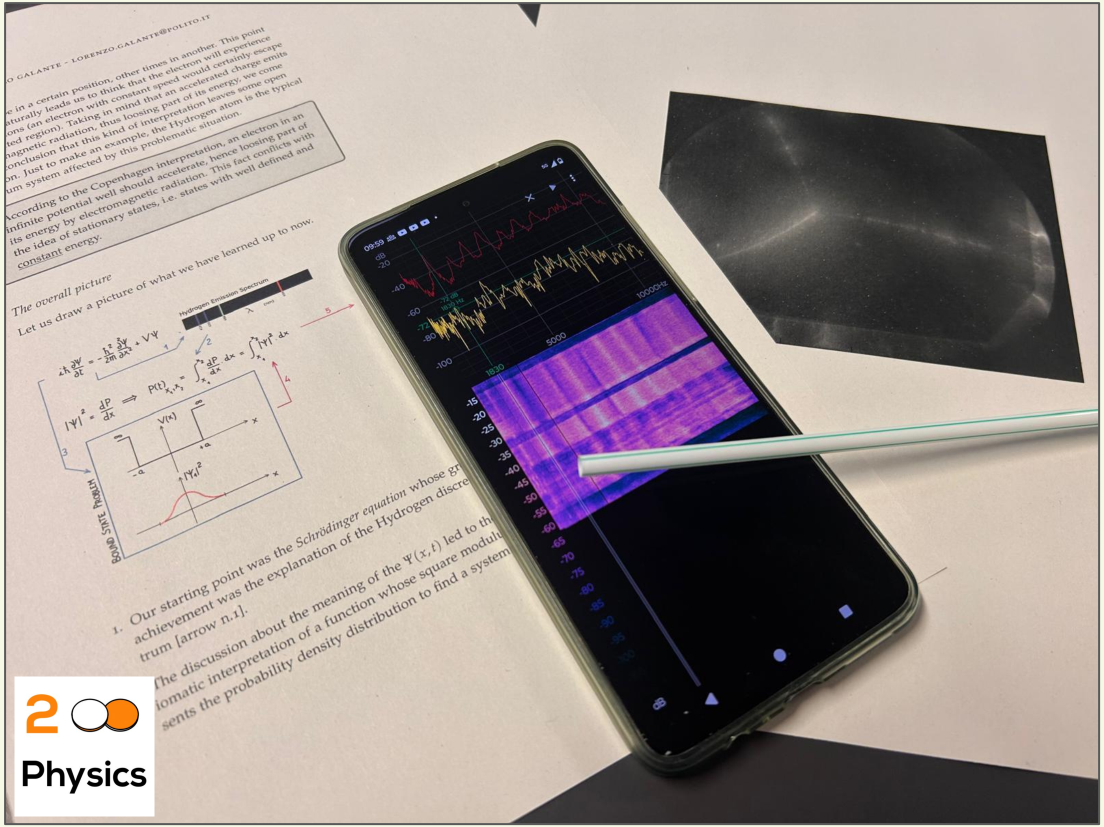
Quantum mechanics with a straw



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Quantum mechanics with a straw

Theoretical model

L = 0.208 m

C = 340 m/s

$f_1 = c/(2L) = \mathbf{817\ Hz};$

$f_2 = 2 f_0; \quad f_3 = 3f_0 \quad \ldots$

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Quantum mechanics with a straw

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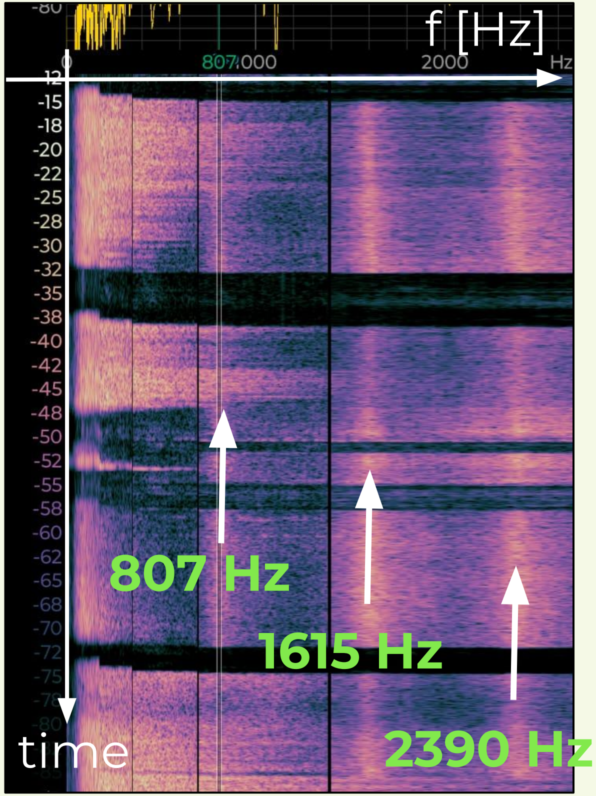
Measurements



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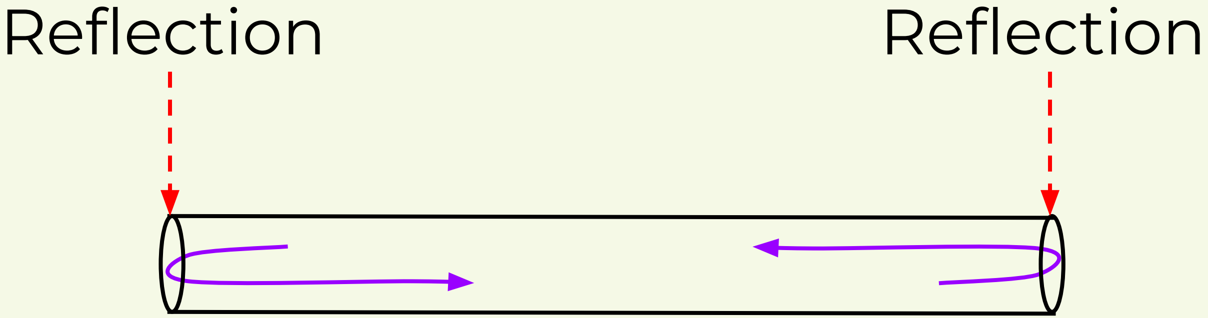
What’s happening in the straw?



Wave confined in

Space!

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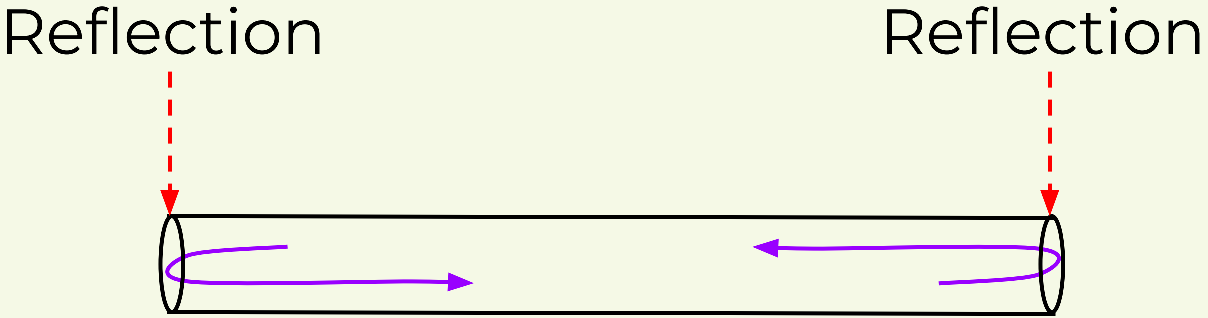
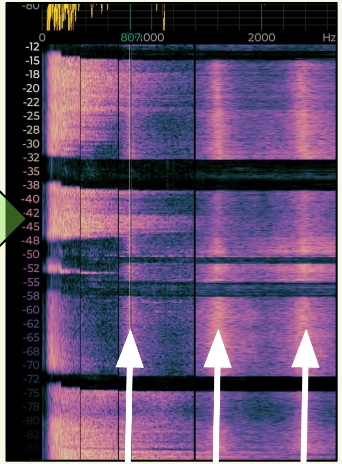
What’s happening in the straw?



Wave confined in Space



Quantization!

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What’s happens in the atom?

The same thing

2 Physics

What's happens in the atom?

The same thing

1.

The **Schroedinger** equation tells us quantum systems are described by a **wave function**

2.

An atom is a quantum systems **confined in space**

3.

Waves

+

confined in space

=

quantization

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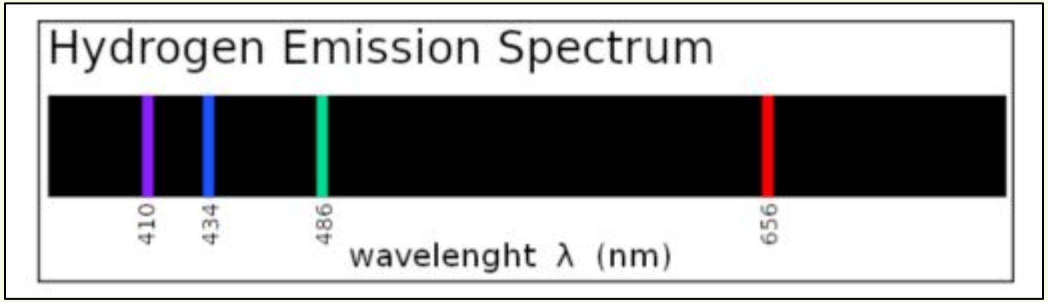
What's happens in the atom?

Quantization of

the Energy levels



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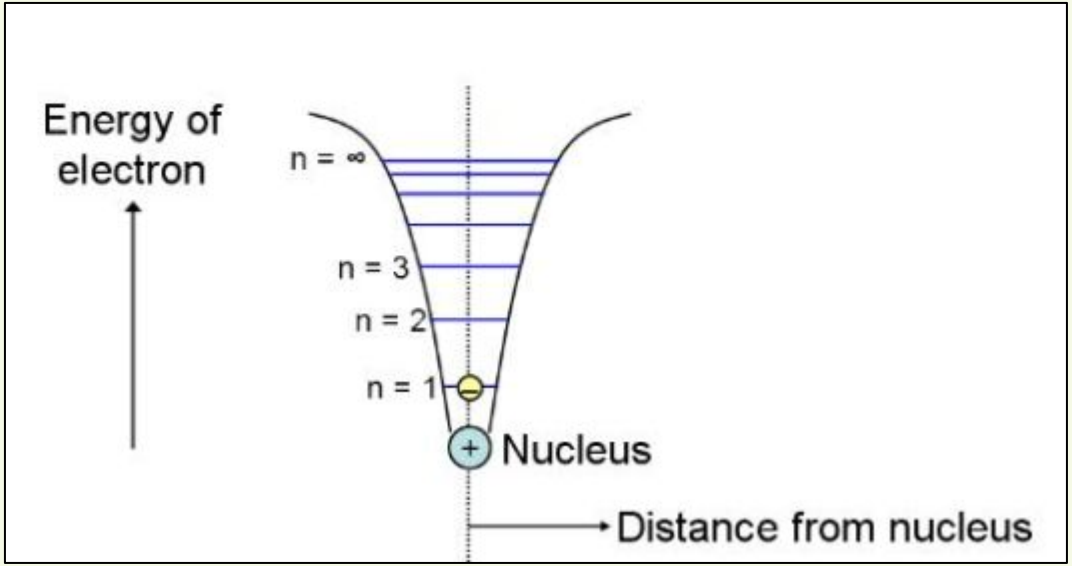
The straw also explains the decreases of the spacing of the energy levels



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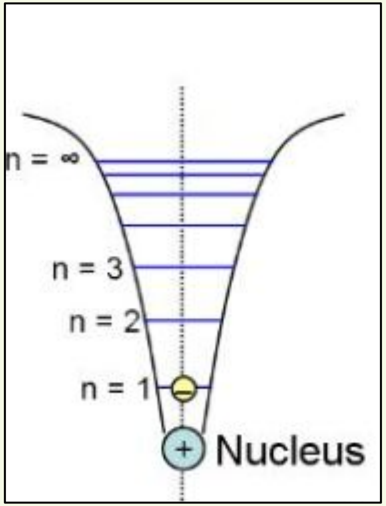
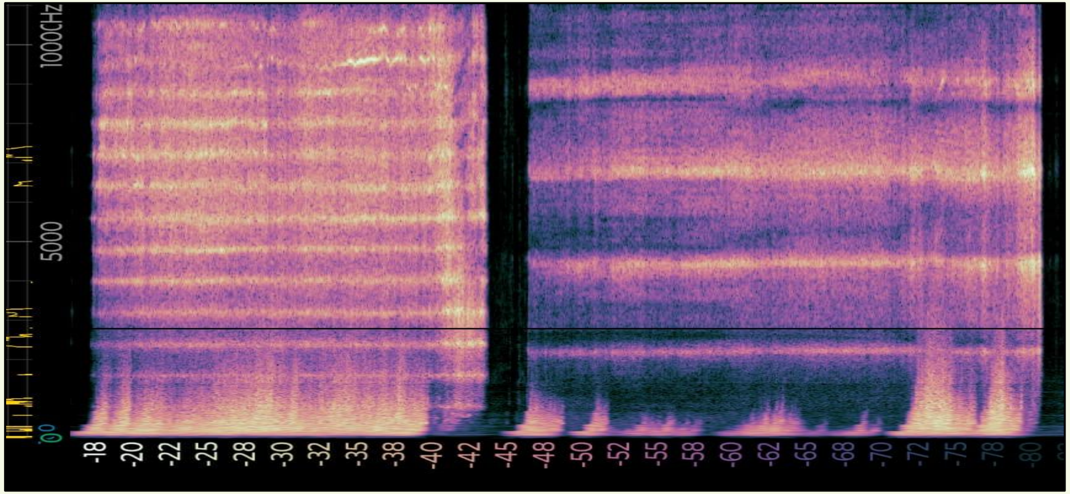
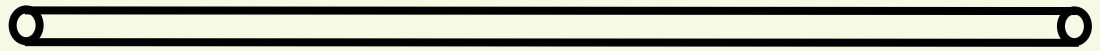
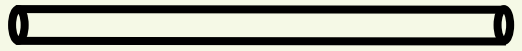
The straw also explains the decreases of the spacing of the energy levels







L = 20 cm



L = 7 cm

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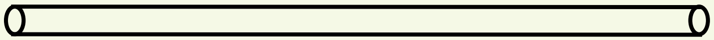
The analogy stands on the equations

Straw



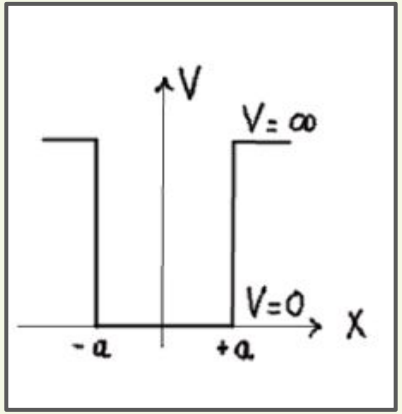
D'Alembert wave equation

$$\frac{\partial^2 y}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 y}{\partial t^2} = 0$$

that for harmonic solutions becomes …

$$\frac{\partial^2 y}{\partial x^2} = -k^2\, y$$

Quantum system in an infinite potential well



Schroedinger stationary wave equation

$$-\frac{\hbar^2}{2m}\frac{\partial^2 \Psi}{\partial x^2} = E\,\Psi$$

That may be rewritten …

$$\frac{\partial^2 \Psi}{\partial x^2} = -k^2\, \Psi$$

Quantum mechanics with a straw

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V\Psi$$