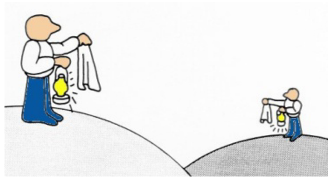
The IVF students went to the Bicocca University of Physics and carried out the measurement of speed of light.

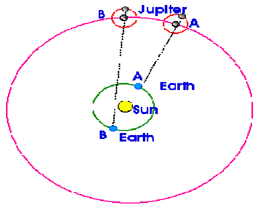
Following a description of their experience and the final result.

MEASURING THE SPEED OF LIGHT

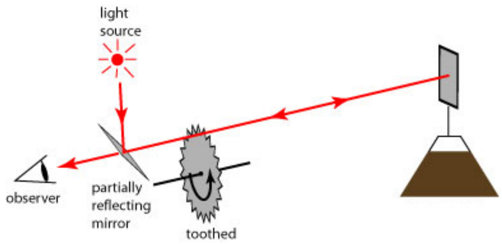
HISTORICAL MEASUREMENTS:



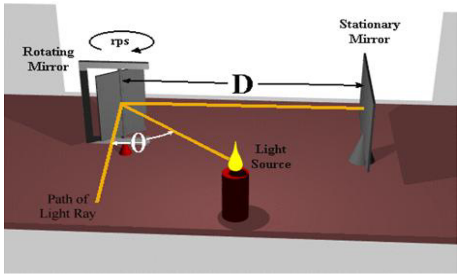
1638 Galileo: at least 10 times faster than sound.
By covering and uncovering two lamps on the top of two different hills, Galileo measured the elapsed time and arrived to the conclusion that "*the speed of light is not instantaneous, it is extraordinarily rapid*".



1675 Ole Roemer: 200000 Km/s
While observing Jupiter's moons, he noticed that the times of the eclipses of the moons seemed to depend on the relative positions of Jupiter and Earth. The apparent change must be due to the extra time for light to travel when Earth was more distant from Jupiter.



1849 Hippolyte Louis Fizeau: 313300 Km/s
Fizeau shone a light between the teeth of a rapidly rotating toothed wheel (whose frequency was known) up to a mirror (more than 5 miles away) which reflected the beam back through the consecutive gap.



1862 Leon Foucault 299796 Km/s
Foucalt perfected Fizeau's method using a rotating mirror instead of the toothed wheel. Now the elapsed time was measured by a slight change of direction of the reflected light beam.

Today: 299792.458 km/s

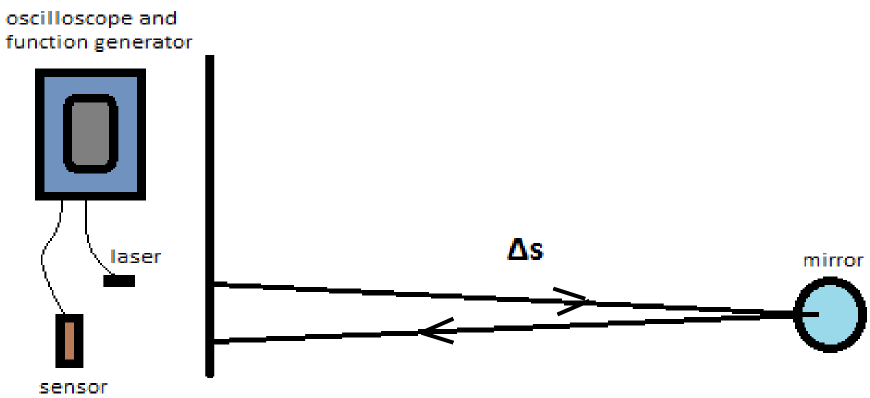
APPARATUS:

- Laser
- Mirror
- Function generator
- Wires
- Sensor

INSTRUMENTS:

- Oscilloscope (sensitivity: 0.01 ns)
- Measuring tape (sensitivity: 0.001 m)

EXPERIMENTAL SETUP:

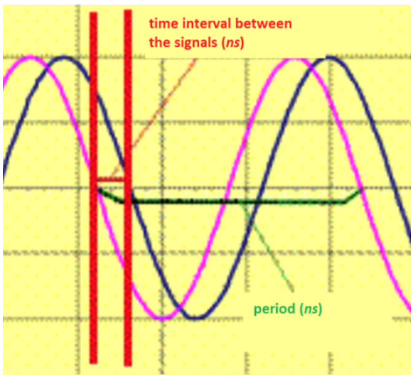


METHOD:

- The mirror was set opposite the laser
- The light was reflected by the mirror and then detected by the sensor, which had been conveniently placed
- The distance from the laser to the mirror was measured with the tape
- Time was measured using the oscilloscope (→ elaboration)
- The experiment was repeated at different distances

ELABORATION:

Each light signal was modulated by the function generator into a function. The first sinus wave represents the output signal, the second wave represents the input signal.



The pointer was set at $y = 0$ and the oscilloscope measured the distance between the two waves and calculated the time.

Due to the electronics, the signal was delayed (not giving the actual value of time), which would result in an underestimated value of the speed of light. This issue was solved by taking two measurements at two different distances and using the differences between two values of both space and time in the formula:

$$c = \frac{\Delta s_2 - \Delta s_1}{\Delta t_2 - \Delta t_1} = \frac{\Delta s_2 - \Delta s_1}{\Delta t_{c2} + \Delta t_w - \Delta t_{c1} - \Delta t_w} = \frac{\Delta s_2 - \Delta s_1}{\Delta t_{c2} - \Delta t_{c1}}$$

Δs represents the distance
Δt represents the time measured
Δt_c represents the actual time
Δt_w represents the delay due to the electronic wires
This allowed to considerably reduce the systematic error due to the electronics.

For each distance, two times were measured: one was obtained from the ascending part of the two waves and the other one from the descending part.

RESULTS:

For the ascending part of the graphs, the final value of c obtained is $2{,}96 \cdot 10^8 m/s$, with a standard deviation of $0{,}34 \cdot 10^8 m/s$ (about the 11% of the result); for the descending part, the value is $2{,}94 \cdot 10^8 m/s$, while the standard deviation is $0{,}37 \cdot 10^8 m/s$ (corresponding to 13% ca.).

The final result of the experiment equals to:

$$\mathbf{(2,95 \pm 0,38) \cdot 10^8}\ \boldsymbol{m/s}$$