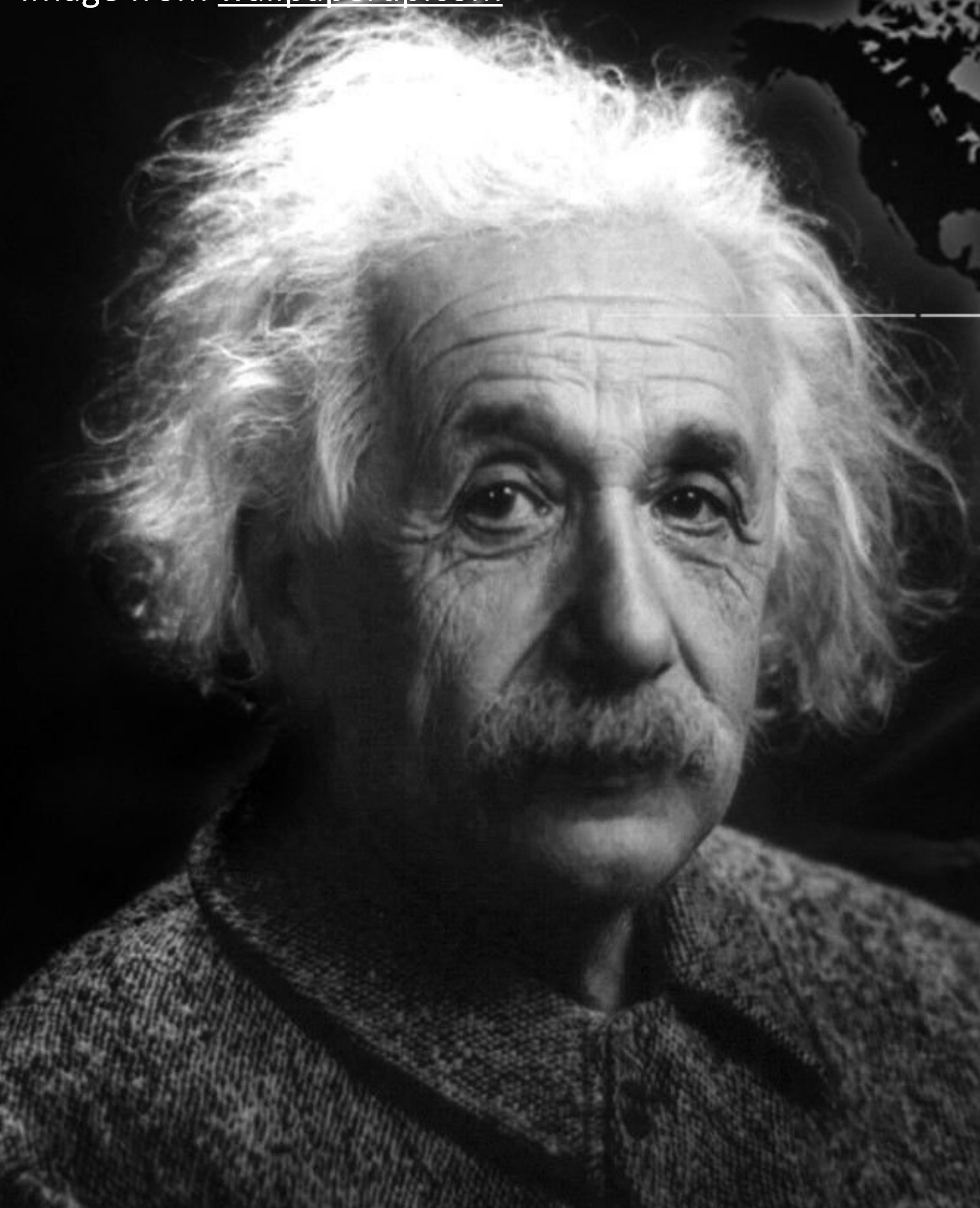

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2304104: GEN PHYS II
2304154: PHYS ELEC ENGS

Update: April 9, 2022

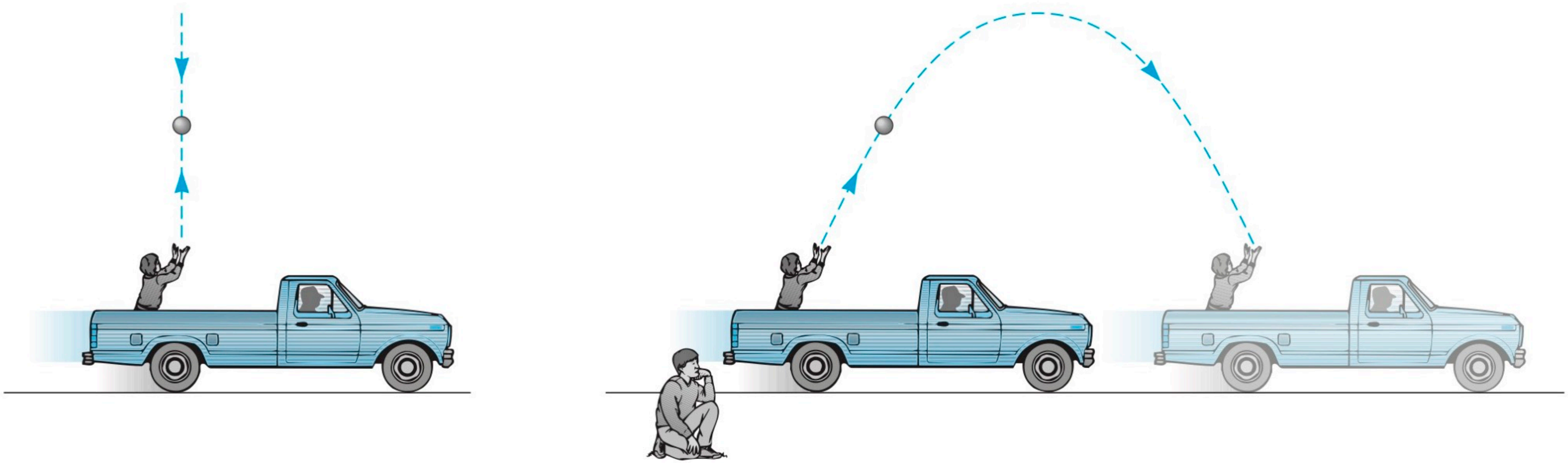
Special theory of relativity

- The principle of Galilean relativity
- The Michelson–Morley experiment
- Einstein's principle of relativity
- Consequences of the special theory of relativity
- The Lorentz transformation
- The Lorentz velocity transformation
- Relativistic linear momentum
- Relativistic energy
- The general theory of relativity

Phat Srimanobhas (phat.s@cern.ch)
https://twiki.cern.ch/twiki/bin/view/Main/PhatSrimanobhasTeaching

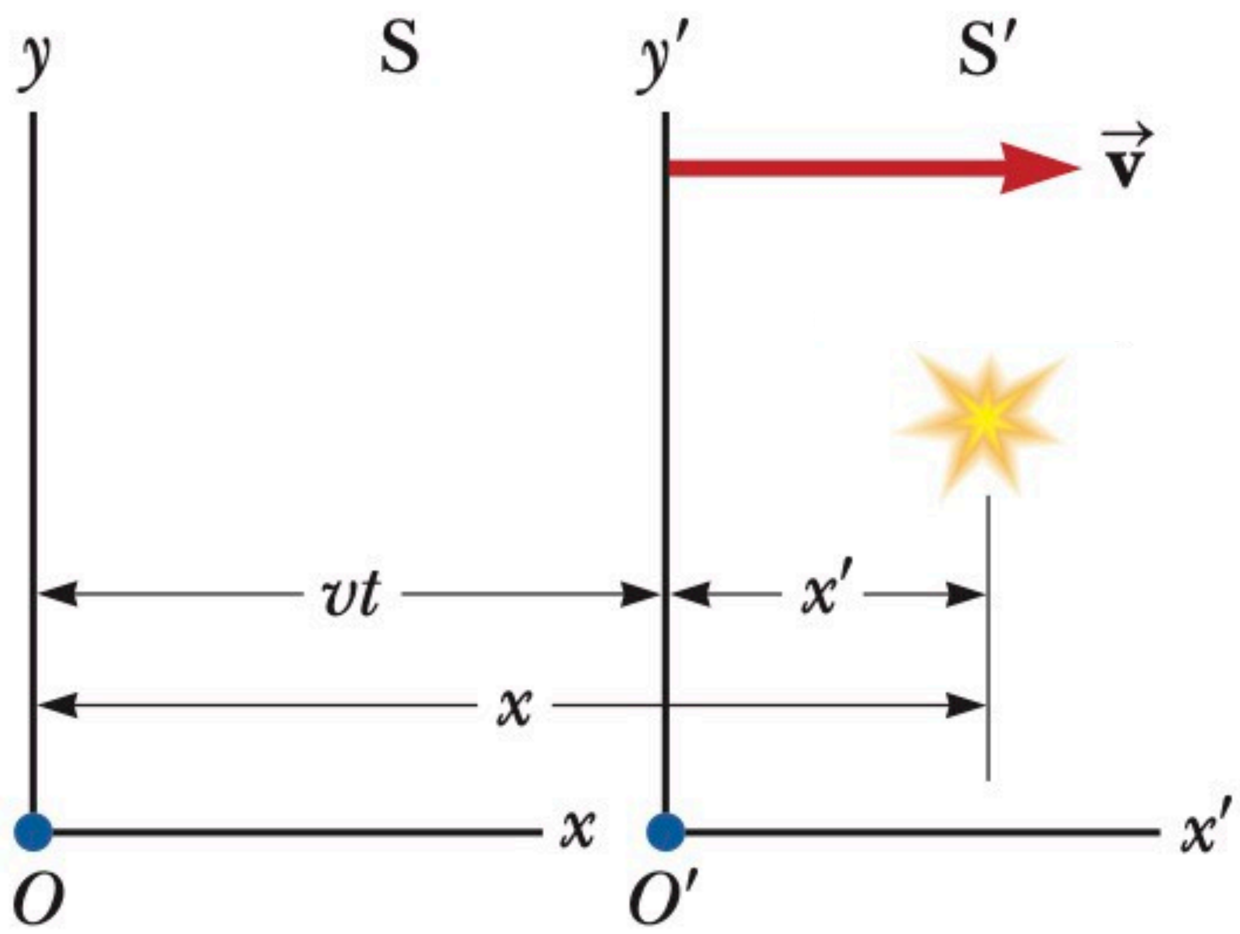
The principle of Galilean relativity

The principle of Galilean relativity



- A passenger in the truck throws a ball straight up. If we neglect the air resistance, the passenger observes that the ball moves in a vertical path.
  ➡ Same as if the ball were thrown by a person at rest on the Earth.
- The observer on the ground sees the path of the ball as a parabola.
- Although, the two observers disagree on certain aspects of the situation, they agree on the validity of Newton's laws.
  ➡This agreement implies that **no mechanical experiment can detect any difference between the two inertial frames**. The only thing that can be detected is the relative motion of one frame with respect to the other.

Event and Galilean transformation



Event:

1st event: when 2 frames cross

2nd event: fire cracker

Note that the fourth coordinate, **time**, is assumed to be the same in both inertial frames. That is, *in classical mechanics, all clocks run at the same rate regardless of their velocity*, so that the time at which an event occurs for an observer in S is the same as the time for the same event in S'. Consequently, the time interval between two successive events should be the same for both observers.

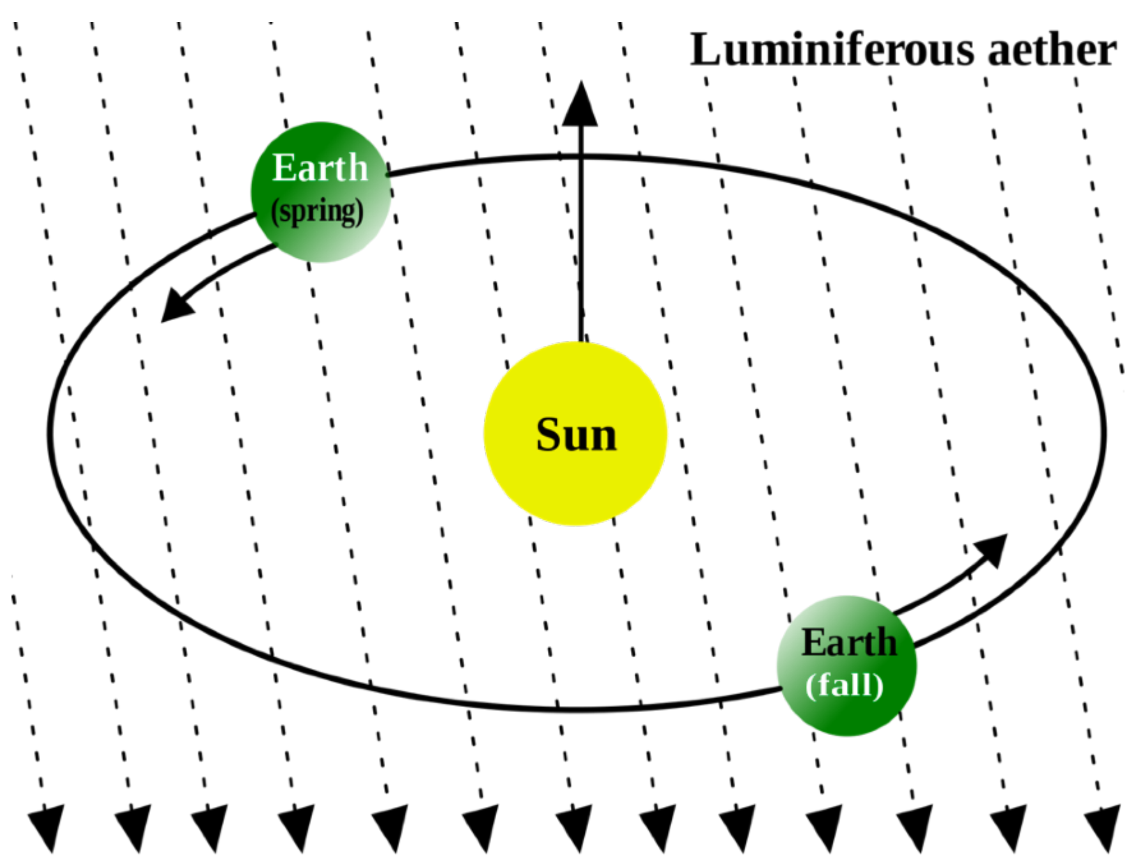
Maxwell's equations and idea of Aether

James Clerk Maxwell

$$\oint \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0} \qquad \oint \vec{B} \cdot d\vec{A} = 0$$

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 (I + I_d) = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$



Maxwell's equations are based on the idea that light travels through a sea of molecular vortices known as the **aether**. The speed of light has to be respective to the reference frame of this aether:

- the aether is stationary and only partially dragged by Earth,
- the aether is completely dragged by Earth and thus shares its motion at Earth's surface.

Michelson–Morley experiment

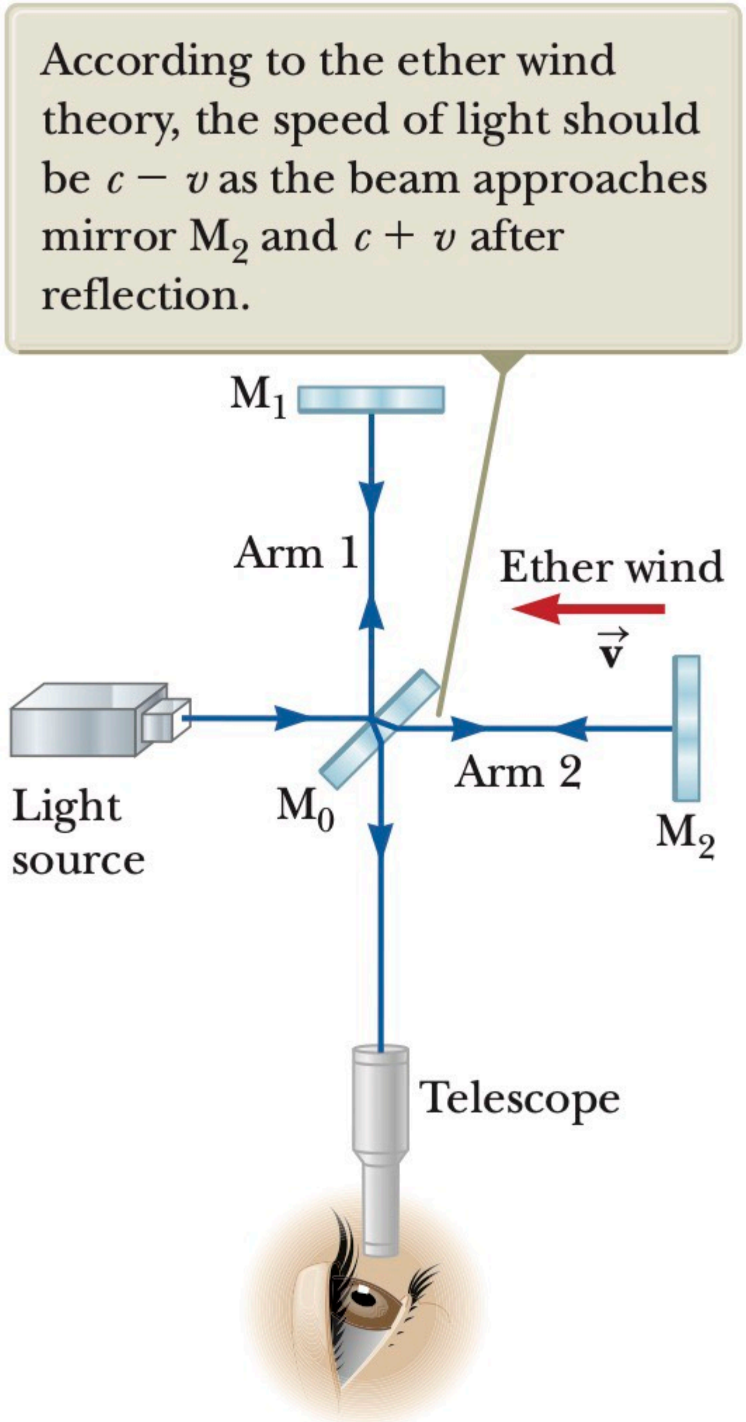
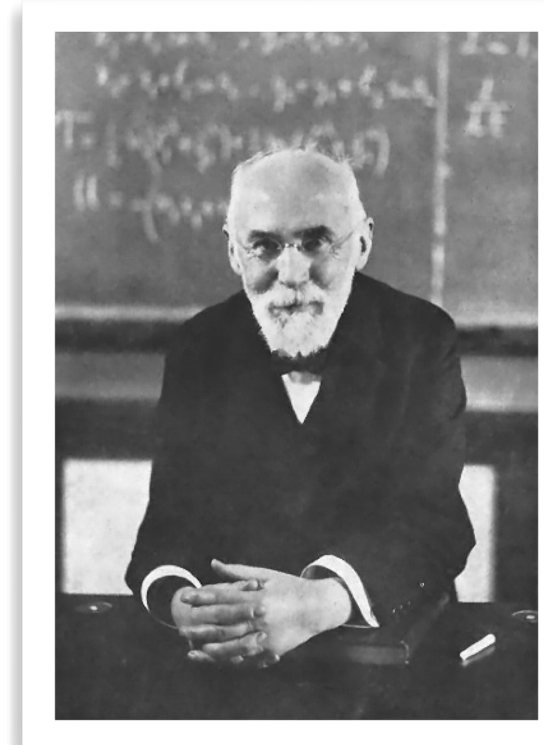


Figure 39.4 A Michelson interferometer is used in an attempt to detect the ether wind.

No aether, what next?

Maxwell's equations were invariant: a theoretical approach suggested by **Hendrik Lorentz** along with **George FitzGerald** and **Joseph Larmor**. Both Larmor (1897) and Lorentz (1899, 1904) derived the Lorentz transformation (so named by **Henri Poincaré**).



Hendrik Lorentz

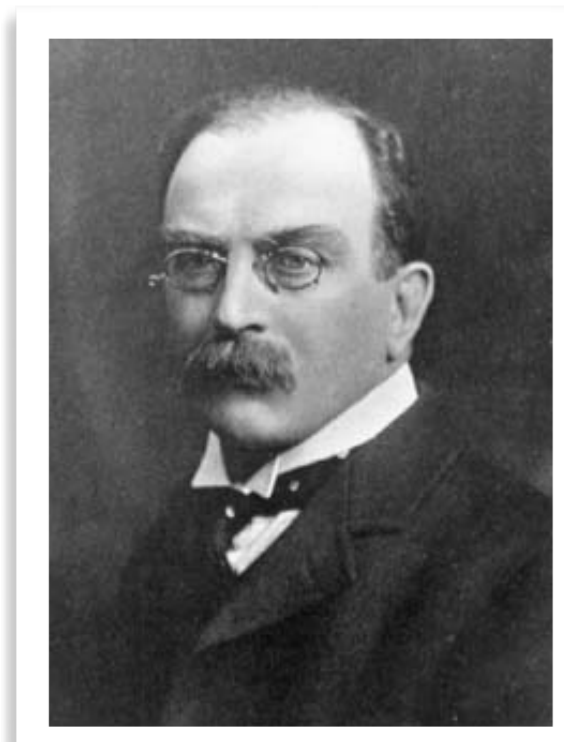
Le point essentiel, établi par Lorentz, c'est que les équations du champ électromagnétique ne sont pas altérées par une certaine transformation (que j'appellerai du nom de *Lorentz*) et qui est de la forme suivante

$$(1)\qquad x' = kl(x + \varepsilon t), \qquad y' = ly, \qquad z' = lz, \qquad t' = kl(t + \varepsilon x),$$

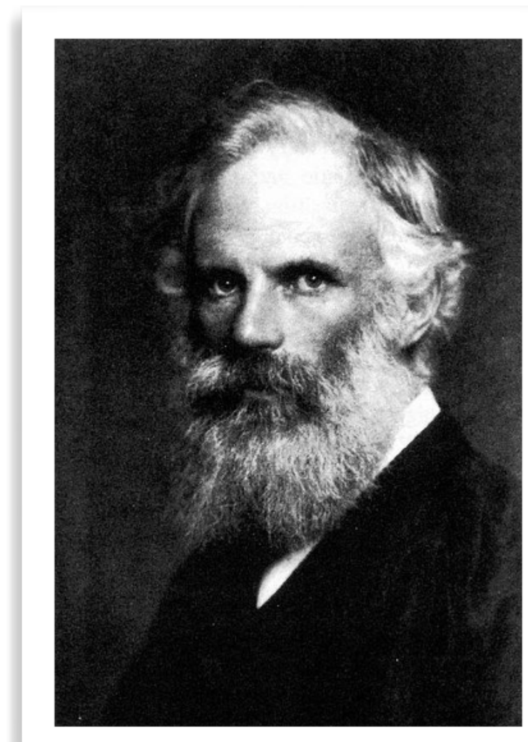
x, y, z sont les coordonnées et t le temps avant la transformation, x', y', z' et t' après la transformation. D'ailleurs ε est une constante qui définit la transformation

$$k = \frac{1}{\sqrt{1 - \varepsilon^2}}$$

Henri Poincaré



Joseph Larmor



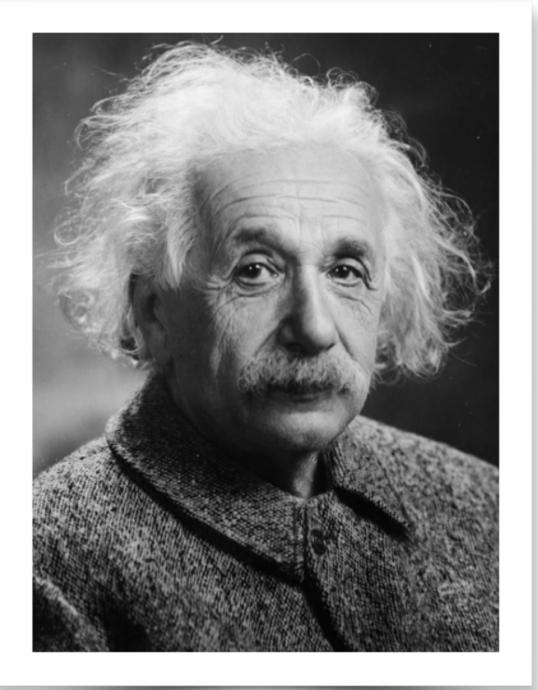
George FitzGerald

Postulates in special theory of relativity

Albert Einstein dismissed the notion of the aether as an unnecessary. His conclusion was that Maxwell's equations predicted the existence of a fixed speed of light, independent of the velocity of the observer. This was a starting point of the special theory of relativity.

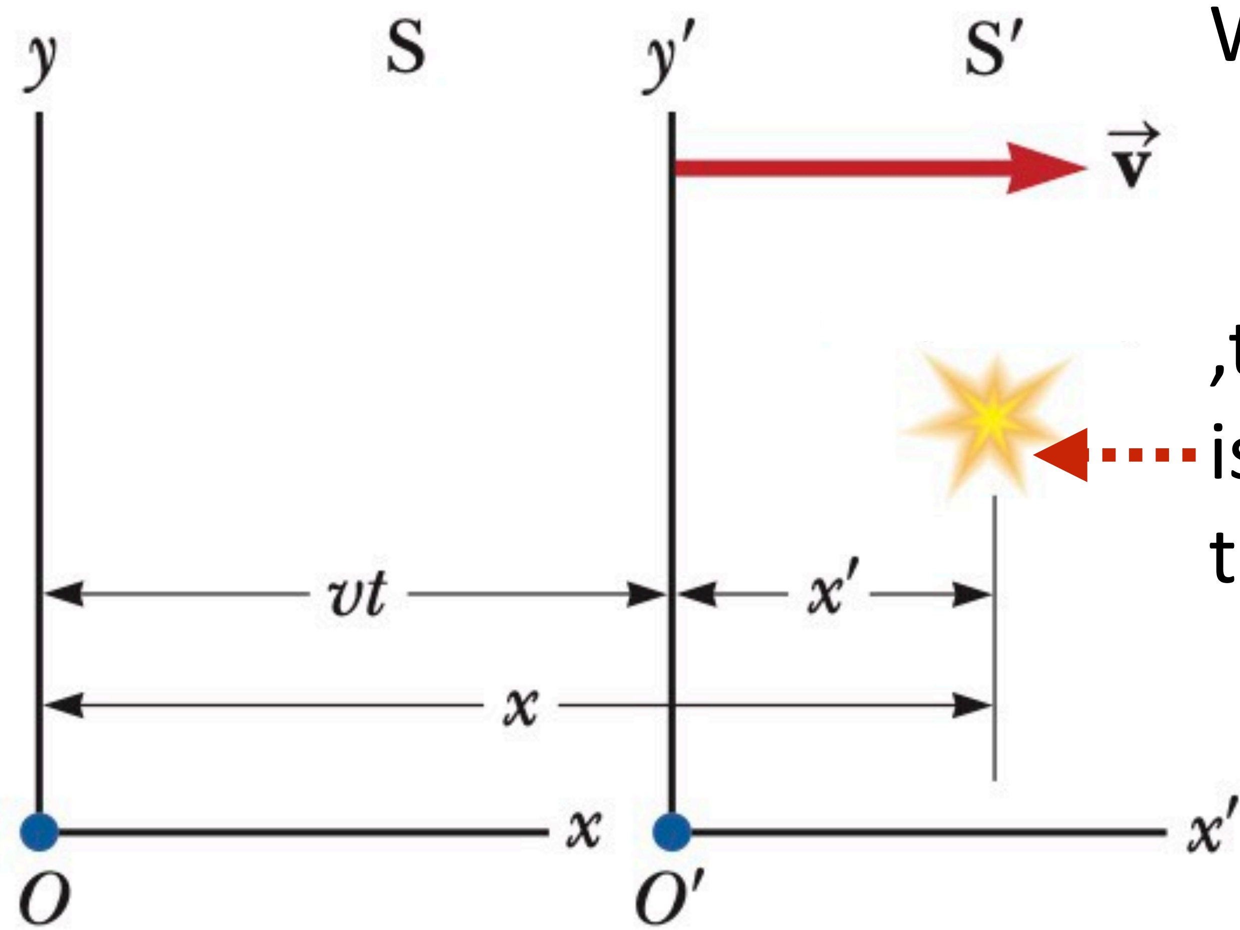
The special theory of relativity bases on Einstein's two postulates:

1. **The principle of relativity**: The laws of physics must be the same in all inertial reference frames.
2. **The constancy of the speed of light**: The speed of light in vacuum has the same value, $c = 3 \times 10^8$ m/s, in all inertial frames, regardless of the velocity of the observer or the velocity of the source emitting the light.



Albert Einstein

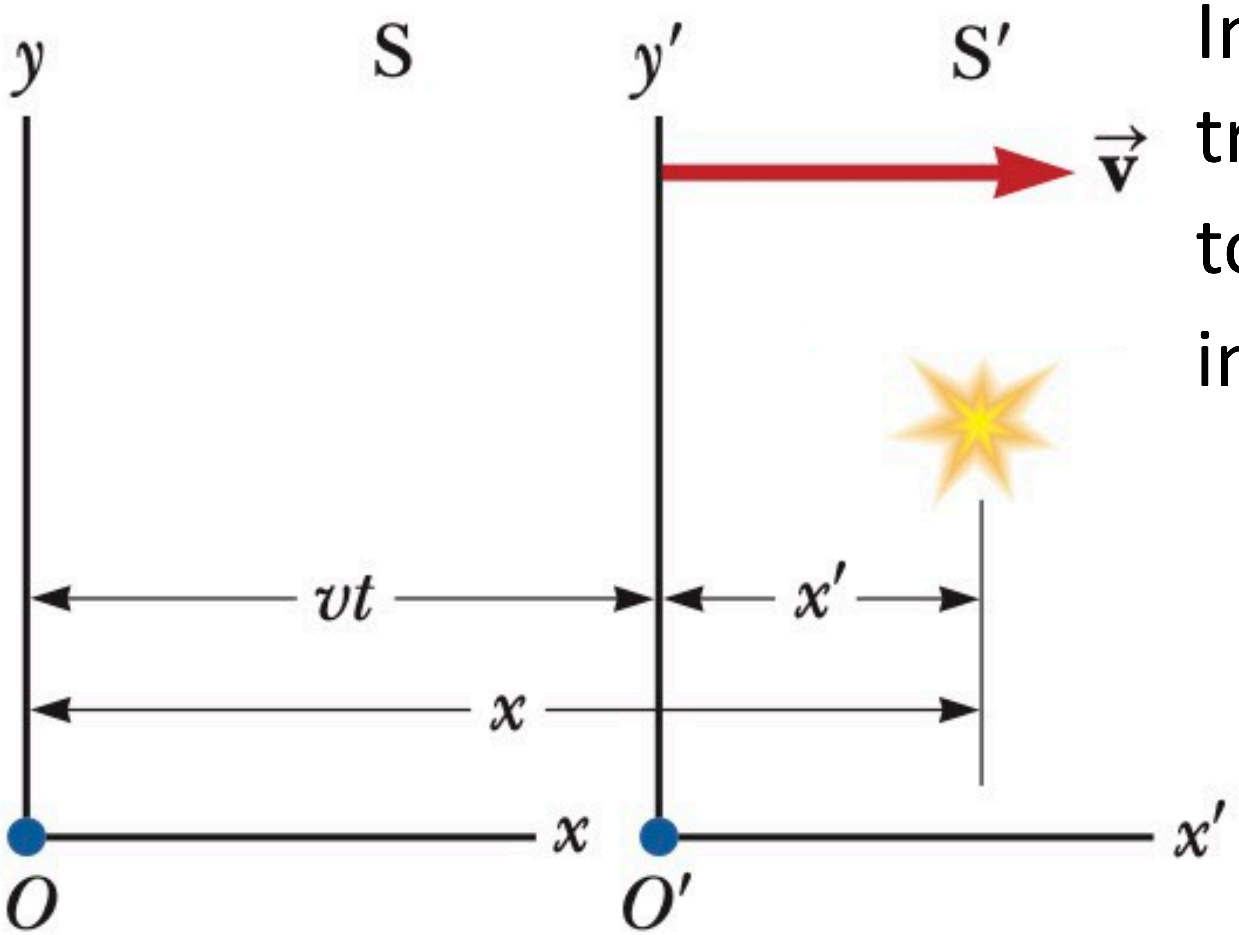
Lorentz transformation



We start when S and S' cross,

,the light is emitted. Then the light signal is detected. Start by Galilean transformation and then modify it:

Lorentz transformation



In summary, the complete coordinate transformations between an event found to occur at (x, y, z, t) in S and (x', y', z', t') in S' are

To obtain the inverse Lorentz transformation of any quantity, simply interchange primed and unprimed variables and reverse the sign of the frame velocity.

Lorentz velocity transformation

Now let's interpret the "event" as the object's motion.

Lorentz velocity transformation: Example

Imagine a motorcycle rider moving with a speed of 0.8c past a stationary observer. If the rider tosses a ball in the forward direction with a speed of 0.7c with respect to himself, what is the speed of the ball as seen by the stationary observer?