

Mise à niveau Astroparticules
M2 ASEP
Key concepts of special relativity

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Bibliography

- R. Feynman, R. B. Leighton, M. Sands, The Feynman lectures on Physics, Vol I, chapters 15-17
- A. Beiser, Concepts of modern Physics, chapter 1

Genesis

- Galileian relativity principle: the laws of motion have the same form in all inertial* reference frame
- Maxwell's equations: the speed of light is a constant
- Inconsistent!

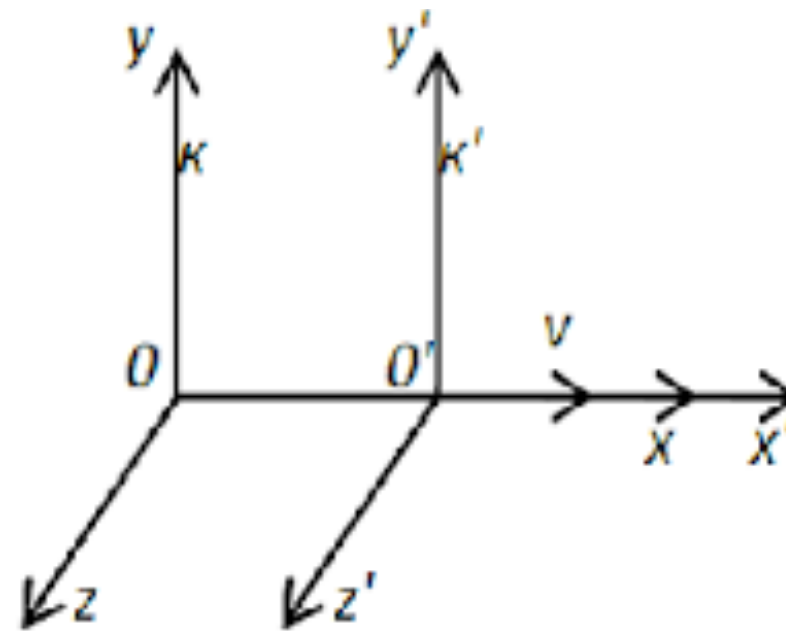
*move with constant speed with respect to one another 3 of 10

Einstein's solution

The special relativity postulates:

- the laws of physics have the same form in all inertial reference frames
- the speed of light in vacuum c has the same value in all inertial reference frames

Lorentz transformations



$$ct' = \gamma(ct - \beta x)$$

$$x' = \gamma(x - \beta ct)$$

$$\beta = \frac{v}{c}$$

$$\gamma = \frac{1}{\sqrt{1 - \beta^2}}$$

Implications (I)

- c is a limit speed in any reference frame
- simultaneity depends on the reference frame

- length contraction
$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}} = \frac{L_0}{\gamma}$$

- time dilation
$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}} = T_0 \gamma$$

Spacetime, events, intervals, causality

- Space and time form an unicum called spacetime
- An event is a physical occurrence associated with a point in spacetime
- Interval between two infinitely close events

$$ds^2 = c^2 dt^2 - |d\vec{x}|^2$$

- Causality only possible for time ($ds^2 > 0$) or light ($ds^2 = 0$) intervals

Energy and momentum

momentum

$$p = \gamma m v$$

energy

$$E = \gamma m c^2$$

rest energy

$$E_0 = m c^2$$

kinetic energy

$$T = E - m c^2$$

With this definition energy and momentum transform between reference frames as time and space according to Lorentz transformations.

Energy so defined is verified to be conserved in microscopic processes.

useful identities

$$m^2 c^4 = E^2 - p^2 c^2$$

$$\gamma = \frac{E}{m c^2} \quad \beta = \frac{p c}{E}$$

Invariant mass for system of bodies

- Units of mass (square)
- Lorentz invariant
- Equivalent of mass for the center of mass reference frame

$$s = \left(\sum_i E_i \right)^2 - \left| \sum_i \vec{p}_i c \right|^2$$