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A new approach to relativity

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A new approach to relativity
based on the understanding
of
Hendrik Lorentz (1853-1928)

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Declaration of authorship

I, Simon FOSSAT, declare that this independant research “A new approach to relativity”, its french version "Le principe de relativité revisité" and the work presented in it are my own.

Abstract

This article aims at interpreting over the physics concept of relativity. It sets on giving an alternative meaning to the one that has been commonly understood since the works of Einstein (1879-1955) on special relativity.

At the crux of our thinking; we will challenge one of the central tenets of special relativity, the one which consists in positing invariance in speed of light in every Galilean reference frame and its consequence of the relativity of time and space.

To reach our conclusion, we shouldn't consider space as a geometrical locus, but rather as a physical environment to which one can apply geometry's rule. We shall call this space the Wave middleware. Speed of light would be an intrinsic property of the Wave middleware.

As everything is in movement in the universe, the privileged position of the still observer in the Wave middleware may not be achievable, we will then assume it a priori. The observations and measures one can make in his associated mobile reference frame would thus be relative, as opposed to the absolute nature of the observed phenomena.

We will see that this seemingly gratuitous, even out of date assumption in regard of the discussions of the last century, will enable us to come up with a renewed principle of special relativity that will give us a new way of describing physical phenomena.

I wish to stress now that this article stems from the reinterpretation and summary of some of the works of of the independant researcher Gabriel Lafréniere (1942-2012) [1]

As a tribute to Hendrik Lorentz (1853-1928) and his works upon which I build mine, I will name mobile reference frames "Lorentz reference frames".

Note: See also the french original version: "Le principe de relativité revisité"

[1] http://web.archive.org/web/20110901222346/http://glafreniere.com:80/matter.htm

Acknowledgements

- To Paul Meier [2] , whose epistemologic works drove me to explore again the fascinating history of the ideas in science

- Special thanks to the administrators of the General Science Journal [3] , and the enthusiastic reception of Thierry De Mees in particular.

[2] http://sys.theme.free.fr/
[3] http://www.gsjournal.net/

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Chapter 1

Lorentz reference frame

1.1 Overview

From Newton's time up to Albert Einstein's special relativity in the early 20th century, scientists were admitting the existence of a middleware for wave propagation, called ether. It was considered to have some physical properties making propagation possible, like an acoustic wave needs the atmosphere, for example.

The Michelson and Morley interferometer, aiming at showing the influence of ether on light's movement, failed for it. A consensus was established on the non-existence of ether, as Albert Einstein's theories could explain these experimental results without ether. Thus, the assumption of its non-existence was accepted, even if the question was not really definitively decided [2]

The Dutch physicist Hendrik Lorentz, who lived at the same era, had other intuitions and was supposing that matter could be influenced by speed like light was [3] . He had to let his intuitions down, as he hadn't any ways or facts to prove it.

Nevertheless, this assumption became relevant again with the works of the French physicist Louis De Broglie (1892-1987), and his theories on wave mechanics [4] . If matter was made of waves, then we should consider again the Lorentz assumptions mentioned above and postulate that matter - and thus the interferometer itself - was influenced by movement like would be light.

[2]Albert Einstein - Ether and the Theory of Relativity (1920)

[3]Hendrik Lorentz - The Michelson-Morley Experiment and the Dimensions of Moving Bodies (1921)

[4]Louis de Broglie - Recherches Sur La Théorie Des Quanta (1925)

1.2 Schematic presentation of the Michelson and Morley interferometer

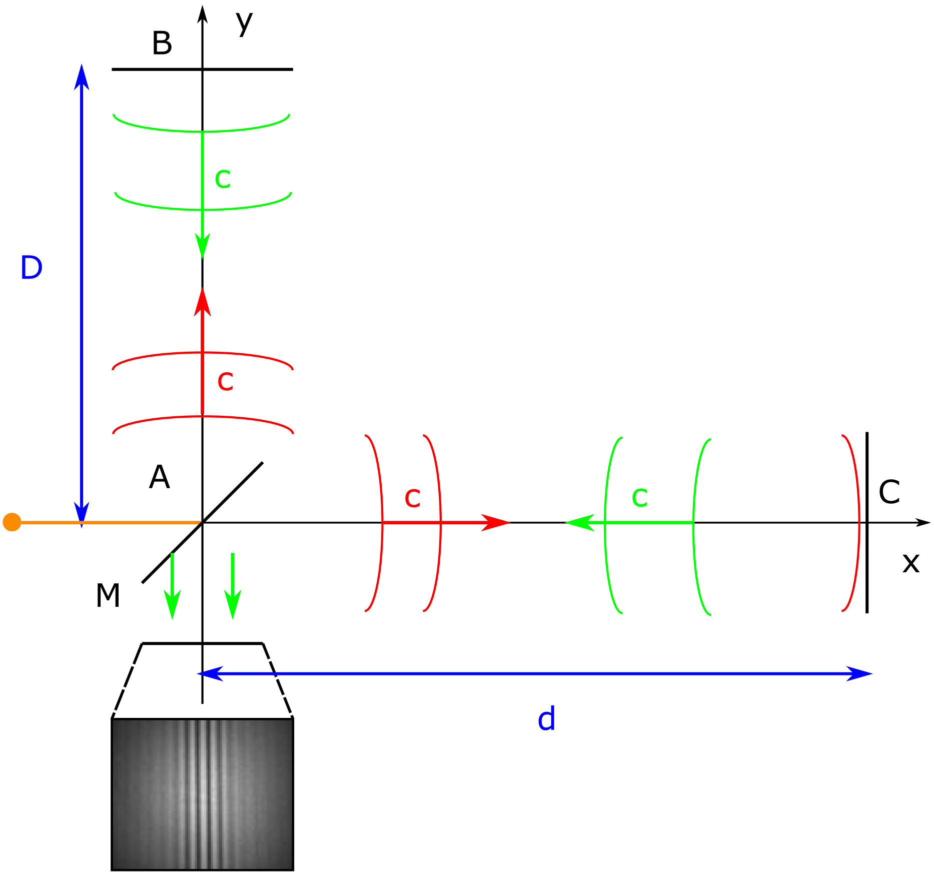

Figure 1.1: The Michelson and Morley experiment

The Michelson and Morley experiment features two paths for light, represented by [AB] and [AC). A semi-reflecting mirror split the light source into two beams having the same frequency and in phase. As they go back to the semi-reflecting mirror after their whole course within the two interferometer's arms, they are driven to a screen where they form an interferometric pattern.

Once the optical bench has been finely tuned, the pattern turns to a typical one for two beams in phase. Then we have to make the optical bench turning, we have to observe the resulting pattern at different times in order to highlight the influence of the position or movement of the optical bench on light's movement.

The Michelson and Morley experiment always failed to prove such an influence. A conclusion was made about light and its speed being the same in any direction, whatever the speed of the emitter. As the experiment couldn't prove the existence of ether, a consensus was made about its non-existence, although not proving its existence was not synonymous with proving its non-existence. However, the whole special relativity theory was built, compatible with the results of the experiment and avoiding to refer to the existence of an ether.

1.3 Lorentz equations and transformations

1.3.1 Overview

We willl now present an alternative expression of the historical Lorentz equations and transformations [5] , and consider the meaning of the variables representing space and time like Hendrik Lorentz and Henri Poincaré did. We will expose how this interpretation makes us consider the Lorentz equations a different way than Albert Einstein and his successors did.

Our alternative expression of the Lorentz equations is given by:

$$x' = g.x + \beta.t$$
$$t' = g.t - \beta.x$$
$$y' = y$$
$$z' = z$$

Where:

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

β : c normalized speed or speed ratio

$$g = \sqrt{1 - \beta^2}$$

g : Lorentz factor

The variable x is the spatial coordinate of a material object in a resting reference frame. The variable x' then, represents the coordinate of the same material object but moving at the c normalized speed of $\beta = v/c$.

In terms of a full reference frame's representation, we can consider the moving reference frame R' as the one for which the spatial and time units are weighted by the g Lorentz factor, as it is moving at the c normalized speed of β in relation to the resting reference frame R.

Let us use the following notations:

u_x : length unit of measure in the resting reference frame

u_t : time unit of measure in the resting reference frame

$g.u_x$: length unit of measure in the moving reference frame at the speed of β

$g.u_t$: time unit of measure in the moving reference frame at the speed of β

[5] Hendrik Lorentz - Electromagnetic Phenomena in a System Moving with Any Velocity Smaller than that of Light (1904)

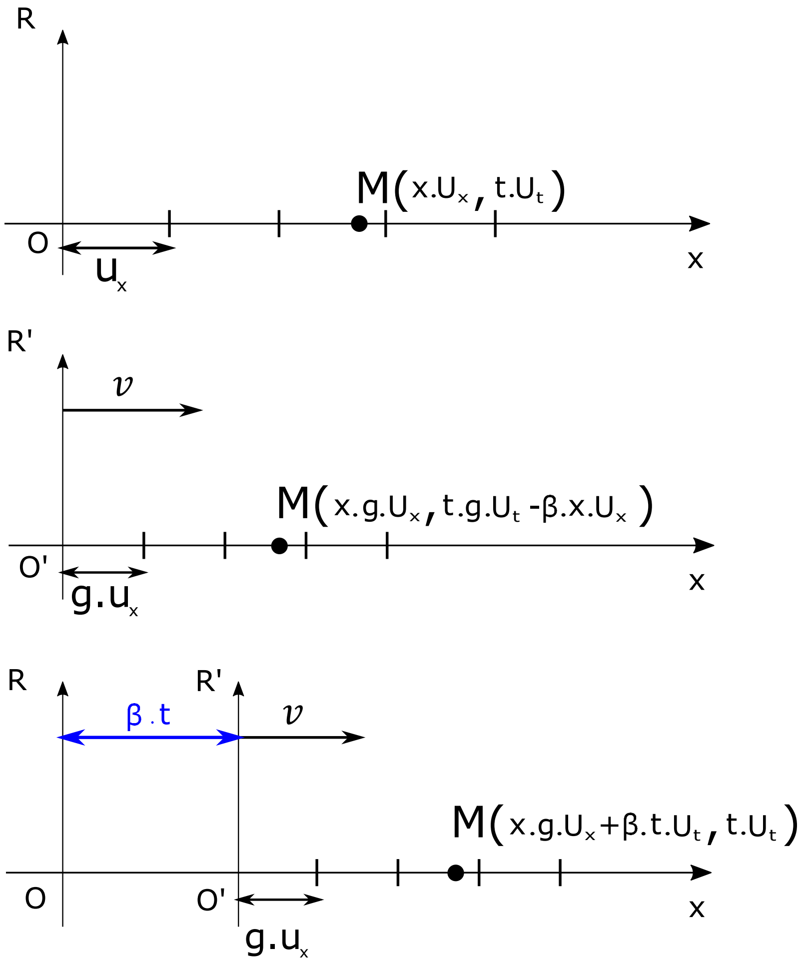

Figure 1.2:
1.2.1: Coordinates of M at rest in the resting reference frame R
1.2.2: Coordinates of M in the R′ reference frame moving at β
1.2.3: Coordinates of M moving at β in the resting reference frame R

Comments

- The length unit is normalized to the speed of light c, then we will express it in light-seconds

- β is the Lightspeed ratio of the material object

- Time is basically in seconds

If we consider a material object as a set of n material dots physically connected to each other, having (x_n) for spatial coordinates when it is at rest then we have, according to the Lorentz equations, a set of n material dots with the (x'_n) coordinates in a resting reference frame when the object is in movement. The variable t corresponds to the time for the x coordinate of a material dot of the object. The variable t' also represents the measurement of time that can be made by an observer associated with the movement of the material dot and object.

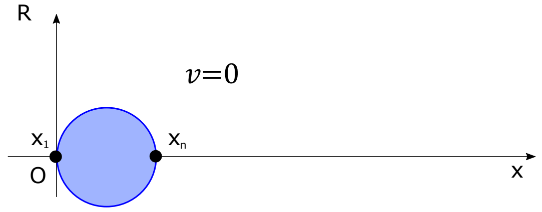

Figure 1.5:
$t = 0$
$(x_1, t) = (0, 0)$
$(x_n, t) = (x_n, 0)$

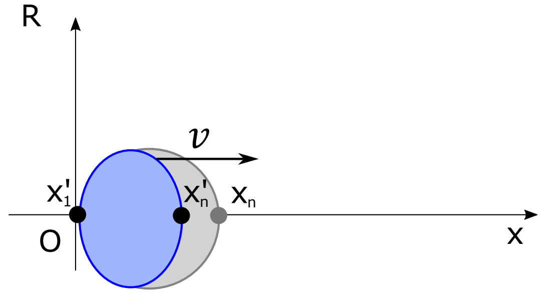

Figure 1.6:
$t = 0$
$(x'_1, t') = (0, 0)$
$(x'_n, t') = (g.x_n, -\beta.x_n)$

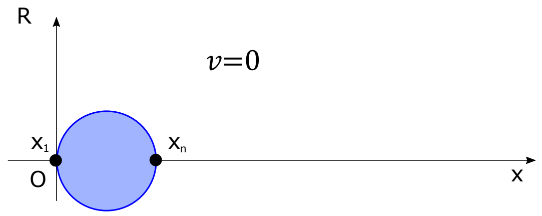

Figure 1.7:
For any t
(x_1, t)
(x_n, t)

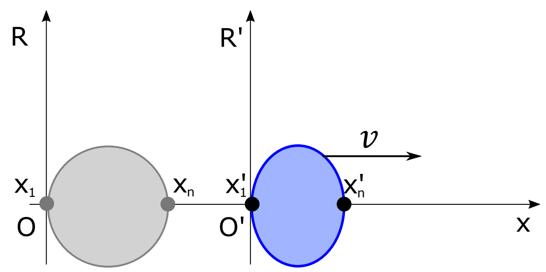

Figure 1.8:
For any t
$(x'_1, t') = (\beta.t, g.t)$
$(x'_n, t') = (g.x_n + \beta.t, g.t - \beta.x_n)$

Coordinates of a moving material dot in the resting reference frame:

$$(x'_n, t)$$

Coordinates of a moving material dot in the moving reference frame:

$$(g.x_n, t')$$

The length of the object in the resting reference frame is given by:

$$x'_n - x'_1 = g.x_n + \beta.t - (g.x_1 + \beta.t)$$
$$x'_n - x'_1 = g.(x_n - x_1)$$

The length of the object in the moving reference frame is also given by:

$$g.x_n - g.x_1 = g.(x_n - x_1)$$

The length of the moving object is then :

$$d' = g.d$$

We won't consider that space contracts or dilates, but rather more basically that the dimensions of the material object itself are influenced by its movement, more precisely contracted in the direction of its movement [6]

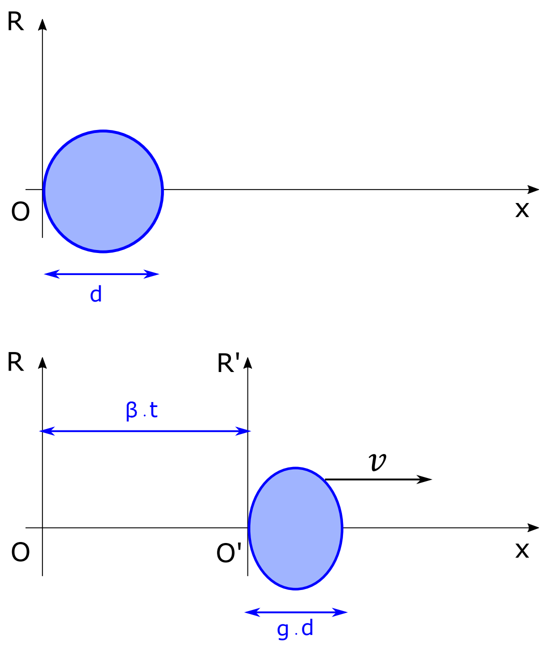

Figure 1.9: Object's contraction with its movement

[6] Henri Poincaré - The New Mechanics (1913)

Regarding time measurement, its expression in the moving referential frame is given by:

$$t'_{x'_n} - t'_{x'_1} = g.t - \beta.x_n - g.t$$
$$t_{x'_n} - t_{x'_1} = -\beta.x_n$$

There should be a time delay between two clocks positioned in two different locations of the object. This time delay is synonymous with a phase difference between the time count of the two clocks, and given by the following expression if we consider the entire length of the material object:

$$\phi = -\beta.d$$

Then we won't consider that time contracts or dilates, but rather more basically that the physical mechanisms within matter slow down when it is in movement [7] .

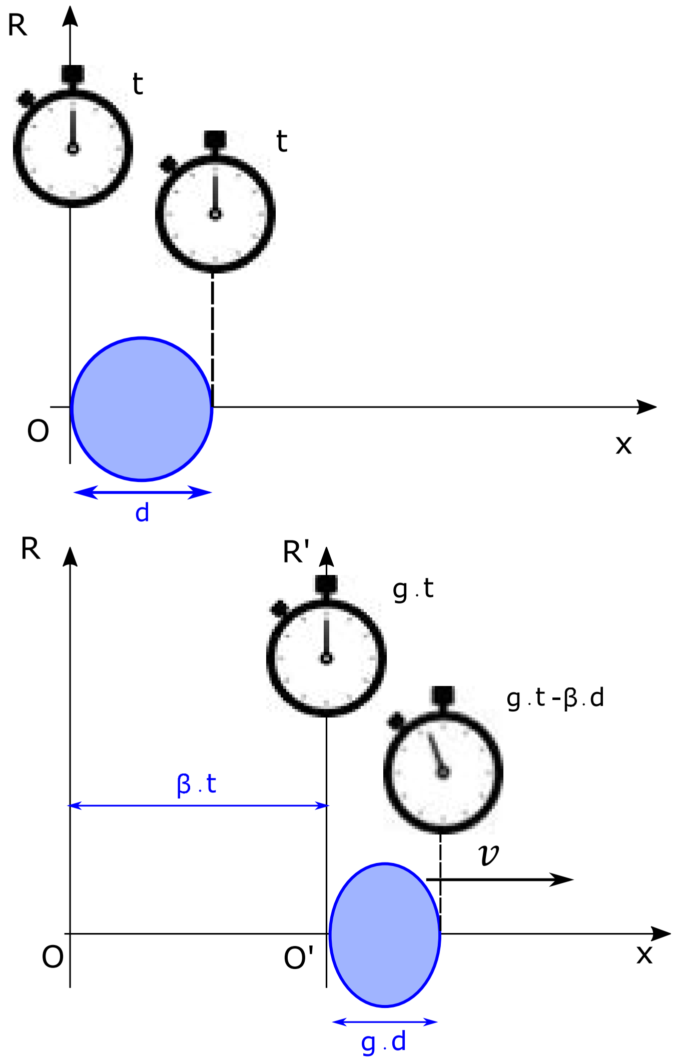

Figure 1.10:
Shift of phase between two clocks located at two different points the object

[7]Gabriel Lafrénière - Lorentzian Relativity (2011)

As a consequence of the mechanisms slowdown within matter, we will assume that the frequency of an emitter given by f when it is at rest, should be given by $g.f$ when it is in movement, g being the Lorentz factor.

$$f' = g.f$$

The corresponding wavelength is then given by:

$$\lambda' = \lambda/g$$

1.3.2 Reverse Lorentz equations

The Lorentz equations are given by:

$$x' = g.x + \beta.t$$
$$t' = g.t - \beta.x$$

Their reverve forms are then given by:

$$x = g.x' - \beta.t'$$
$$t = g.t' + \beta.x'$$

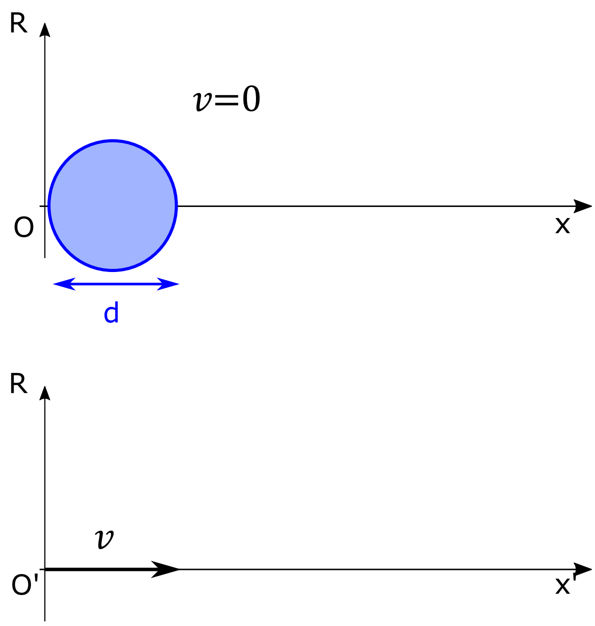

Figure 1.11: Case where the observer is moving and the object is at rest

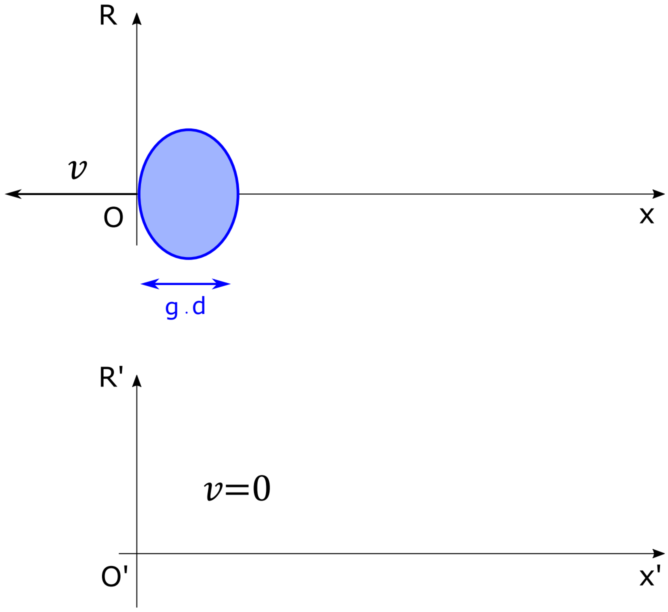

Figure 1.12:
Observer's point of view, located at O' and considering himself to be at rest

Let us express, like said before, the distances in light-seconds. Then for a moving observer O' at the speed of β, the time needed to cover the entire object is given by:

$$t = d/\beta$$

This gives the following time expression for O' in his own moving reference frame:

$$t' = g.t = (g.d)/\beta$$

From the moving observer's point of view, the resting reference frame is moving at the same speed of β as he actually does, but in the opposite way. The two speeds, one absolute, the other one relative to the moving observer, are related by the following expression:

$$v' = v$$

$$\beta' = \beta$$

For a moving observer, the apparent length of the object is then given by:

$$d' = g.d$$

Here is our first highlight on the relativity principle according to our alternative understanding of the Lorentz equations. From the point of views of the observers:

- A resting observer is considering the length of a moving object contracted to $g.d$

- A moving observer is allowed to consider, in the name of the relativity principle, that he is at rest whereas the object is moving away from him and is contracted to the length $g.d$

More over:

- A moving object actually contracts to the length $g.d$

- An object keeps its length unchanged when it is at rest, whatever the moving observer would measure and consider

=> Beyond the equivalence of the two different points of views, the reality of the phenomenon is not the same.

1.3.3 Differential study of the Lorentz equations

In order to express the relation between the relative speeds, we will make a differential study of the Lorentz equations

$$x' = g.x + \beta.t(1)$$
$$t' = g.t - \beta.x(2)$$

$$x = g.x' - \beta.t'(3)$$
$$t = g.t' + \beta.x'(4)$$

Using (1) and (2) leads to:

$$x = \frac{1}{g}.(x' - \beta.t)(5)$$

and:

$$t = \frac{1}{g}.(t' + \beta.x)(6)$$

Using (3) and (4) leads to:

$$x' = \frac{1}{g}.(x + \beta.t')(7)$$

and:

$$t' = \frac{1}{g}.(t - \beta.x')(8)$$

The differential expression of (7) followed by a factorization by dt' gives:

$$dx' = \frac{1}{g}.(\frac{dx}{dt'} + \beta).dt'$$

The differential expression of (6) followed by a factorization by dt' gives :

$$dt = \frac{1}{g}.(1 + \beta.\frac{dx}{dt'}).dt'$$

Making the ratio of the two last expressions leads to:

$$\frac{dx'}{dt} = \frac{\frac{dx}{dt'} + \beta}{1 + \beta.\frac{dx}{dt'}}$$

This differential equation can be simplified as one of the two reference frame is at rest, that is $dx = 0$, whatever the time reference may be considered

$$\frac{dx}{dt'} = 0$$

This leads to:

$$\frac{dx'}{dt} = \beta$$

This confirms the value of β for the speed of an object when it is related with a resting reference frame.

By using the same approach than before:

The differential expression of (5) followed by a factorization by dt' gives:

$$dx = \frac{1}{g}.(\frac{dx'}{dt} - \beta).dt$$

The differential expression of (8) followed by a factorization by dt' gives :

$$dt' = \frac{1}{g}.(1 - \beta.\frac{dx'}{dt}).dt$$

Making the ratio of the two last expressions leads to:

$$\frac{dx}{dt'} = \frac{\frac{dx'}{dt} - \beta}{1 - \beta.\frac{dx'}{dt}}$$

This differential equation can be simplified as one of the two reference frames is at rest, that is $dx = 0$, whatever the time reference may be considered

$$\frac{dx}{dt'} = 0$$

This leads to:

$$\frac{dx'}{dt} = \beta$$

This confirms again the following speed value for a moving and contracted object : β.

1.3.4 Transformation between two Lorentz reference frames

Let us consider an object with the (x_n, t) coordinates in a resting reference frame. Let us consider its (x'_{n1}, t) coordinates when it is in movement at the speed of $\beta_1 = v_1/c$. Let us also consider its (x'_{n2}, t) coordinates when it is in movement at the speed of $\beta_2 = v_2/c$.

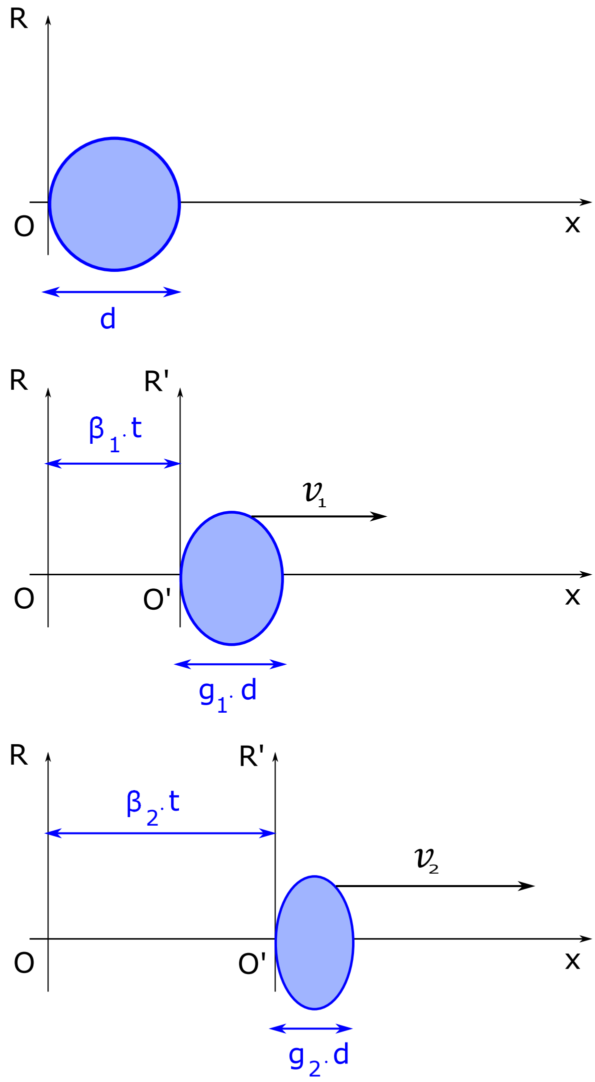

Figure 1.13:
The same object is moving at the speed of β_1 in a first time, and at the speed of β_2 in a second time

Regarding the dimensions of the object, we can write as a first result:

$$d'_1 = g_1.d$$
$$d'_2 = g_2.d$$
$$d'_1 = \frac{g_1}{g_2}.d'_2$$

We can relate the coordinates of the object moving at the speed of β_1 with the coordinates of the same object when it is at rest, like we can do the same for the object moving at the speed of β_2.

According to the Lorentz equations, we can write the following equations:

$$x'_1 = g_1.x + \beta_1.t(1)$$
$$t'_1 = g_1.t - \beta_1.x(2)$$

$$x'_2 = g_2.x + \beta_2.t(3)$$
$$t'_2 = g_2.t - \beta_2.x(4)$$

According to their reverse forms, we can write then the following equations:

$$x = g_1.x'_1 - \beta_1.t'_1(5)$$
$$t = g_1.t'_1 + \beta_1.x'_1(6)$$

$$x = g_2.x'_2 - \beta_2.t'_2(7)$$
$$t = g_2.t'_2 + \beta_2.x'_2(8)$$

Where:

$$\beta_1 = \frac{v_1}{c}$$
$$g_1 = \sqrt{1 - \beta_1^2}$$

And:

$$\beta_2 = \frac{v_2}{c}$$
$$g_2 = \sqrt{1 - \beta_2^2}$$

Using (1) and (7), and also (2) and (8) leads to:

$$x'_1 = g_1.(g_2.x'_2 - \beta_2.t'_2) + \beta_1.(g_2.t'_2 + \beta_2.x'_2)$$
$$t'_1 = g_1.(g_2.t'_2 + \beta_2.x'_2) - \beta_1.(g_2.x'_2 - \beta_2.t'_2)$$

$$x'_1 = (g_1.g_2 + \beta_1.\beta_2).x'_2 + (\beta_1.g_2 - \beta_2.g_1).t'_2$$
$$t'_1 = (g_1.g_2 + \beta_1.\beta_2).t'_2 - (\beta_1.g_2 - \beta_2.g_1).x'_2$$

Using (5) and (3), and also (6) and (4) leads to:

$$x'_2 = g_2.(g_1.x'_1 - \beta_1.t'_1) + \beta_2.(g_1.t'_1 + \beta_1.x'_1)$$
$$t'_2 = g_2.(g_1.t'_1 + \beta_1.x'_1) - \beta_2.(g_1.x'_1 - \beta_1.t'_1)$$

$$x'_2 = (g_1.g_2 + \beta_1.\beta_2).x'_1 + (\beta_2.g_1 - \beta_1.g_2).t'_1$$

$$t'_2 = (g_1.g_2 + \beta_1.\beta_2).t'_1 - (\beta_2.g_1 - \beta_1.g_2).x'_1$$

As a physical interpretation of these equations, we will say that:

* A β_1 moving object whose length is d when it is at rest gets its length like follows:

- Its length in a resting reference frame, which actually corresponds to its real length, is given by:

$$d'_1 = g_1.d$$

- Its apparent length in a β_2 moving reference frame is given by :

$$(g_1.g_2 + \beta_1.\beta_2).d$$

* A β_2 moving object whose length is d when it is at rest a length like follows: - Its length in a resting reference frame, which actually corresponds to its real length, is given by:

$$d'_2 = g_2.d$$

- Its apparent length in a β_1 moving reference frame is given by :

$$(g_1.g_2 + \beta_1.\beta_2).d$$

Note: the perceived length of an object moving at the speed of β_1 from the point of view of a reference frame moving at the speed of β_2 equals to the perceived length of an object moving at the speed of β_2 from the point of view of a reference frame moving at the speed of β_1

1.3.5 Differential study of the Lorentz equations for two moving reference frames

In order to make the relation between two reference frames at the speeds of β_1 and β_2, we will use the same approach than the one to compare a resting reference frame with a moving one.
Let us write a composite expression for the equivalence of the Lorentz factor and the speed ratio in the case of two moving reference frames. This will help to simplify the writing of the next equations.

$$G_{12} = g_1.g_2 + \beta_1.\beta_2$$
$$B_{12} = \beta_1.g_2 - \beta_2.g_1$$

We can write the former equations like follows :

$$x'_1 = G_{12}.x'_2 + B_{12}.t'_2(1)$$
$$t'_1 = G_{12}.t'_2 - B_{12}.x'_2(2)$$

$$x'_2 = G_{12}.x'_1 - B_{12}.t'_1 (3)$$
$$t'_2 = G_{12}.t'_1 + B_{12}.x'_1 (4)$$

(3) leads to:

$$x'_1 = \frac{1}{G_{12}}.(x'_2 + B_{12}.t'_1)(5)$$

(4) leads to:

$$t'_1 = \frac{1}{G_{12}}.(t'_2 - B_{12}.x'_1)(6)$$

(1) leads to:

$$x'_2 = \frac{1}{G_{12}}.(x'_1 - B_{12}.t'_2)(7)$$

(2) leads to:

$$t'_2 = \frac{1}{G_{12}}.(t'_1 + B_{12}.x'_2)(8)$$

The differential expression of (7) and factorization by dt'_2 leads to:

$$dx'_2 = \frac{1}{G_{12}}.(\frac{dx'_1}{dt'_2} - B_{12}).dt'_2$$

The differential expression of (6) and factorization by dt'_2 leads to:

$$dt'_1 = \frac{1}{G_{12}}.(1 - B_{12}.\frac{dx'_1}{dt'_2}).dt'_2$$

Making the ratio between the two last expressions leads to:

$$\frac{dx'_2}{dt'_1} = \frac{\frac{dx'_1}{dt'_2} - B_{12}}{1 - B_{12}.\frac{dx'_1}{dt'_2}}$$

$$\frac{dx'_2}{dt'_1} = \frac{\frac{dx'_1}{dt'_2} - (\beta_1.g_2 - \beta_2.g_1)}{1 - (\beta_1.g_2 - \beta_2.g_1).\frac{dx'_1}{dt'_2}}$$

The differential expression of (5) and factorization by dt'_1 leads to:

$$dx'_1 = \frac{1}{G_{12}}.(\frac{dx'_2}{dt'_1} + B_{12}).dt'_1$$

The differential expression of (8) and factorization by dt'_1 leads to:

$$dt'_2 = \frac{1}{G_{12}}.(1 + B_{12}.\frac{dx'_2}{dt'_1}).dt'_1$$

Making the ratio between the two last expressions leads to:

$$\frac{dx'_1}{dt'_2} = \frac{\frac{dx'_2}{dt'_1} + B_{12}}{1 + B_{12}.\frac{dx'_2}{dt'_1}}$$

$$\frac{dx'_1}{dt'_2} = \frac{\frac{dx'_2}{dt'_1} + (\beta_1.g_2 - \beta_2.g_1)}{1 + (\beta_1.g_2 - \beta_2.g_1).\frac{dx'_2}{dt'_1}}$$

1.3.6 Physical interpretation of the equations relating relative speeds

Physical meaning of the previous values

* β_1 : Absolute speed of the R1 moving reference frame in the resting reference frame

* β_2 : Absolute speed of the R2 moving reference frame in the resting reference frame

* $\frac{dx'_2}{dt'_1}$: Relative speed of the R2 moving reference frame from the R1 reference frame point of view, which we will call v'_{r2}

* $\frac{dx'_1}{dt'_2}$: Relative speed of the R1 moving reference frame from the R2 reference frame point of view, wich we will call v'_{r1}

* It is not possible to measure the speeds β_1 and β_2 as far as these values imply the absolute speeds of the reference frames, that one can't reach as far as it is impossible to reach the resting position by any ways or experiment. The only measurable speeds are the relative ones, in concordance with Henri Poincaré on the subject [8]

[8]Henri Poincaré - On the Dynamics of the Electron (1905)

Summary table of the relative speeds - Table 1

(β_2, g_2) \ (β_1, g_1)	$(1,0)$	$(0,1)$	(β_1, g_1)
(1,0)	$B_{12} = 0$ $v'_{r1} = v'_{r2}$ $v'_{r2} = v'_{r1}$	$B_{12} = -1$ $v'_{r1} = 1$ $v'_{r2} = -1$	$B_{12} = -g_1$ $v'_{r1} = \frac{v'_{r2}-g_1}{1-g_1.v'_{r2}}$ $v'_{r2} = \frac{v'_{r1}+g_1}{1+g_1.v'_{r1}}$
(0,1)	$B_{12} = 1$ $v'_{r1} = -1$ $v'_{r2} = 1$	$B_{12} = 0$ $v'_{r1} = v'_{r2} = 0$ $v'_{r2} = v'_{r1} = 0$	$B_{12} = \beta_1$ $v'_{r1} = \frac{v'_{r2}+\beta_1}{1+\beta_1.v'_{r2}}$ $v'_{r2} = \frac{v'_{r1}-\beta_1}{1-\beta_1.v'_{r1}}$
(β_2, g_2)	$B_{12} = g_2$ $v'_{r1} = \frac{v'_{r2}+g_2}{1+g_2.v'_{r2}}$ $v'_{r2} = \frac{v'_{r1}-g_2}{1-g_2.v'_{r1}}$	$B_{12} = -\beta_2$ $v'_{r1} = \frac{v'_{r2}-\beta_2}{1-\beta_2.v'_{r2}}$ $v'_{r2} = \frac{v'_{r1}+\beta_2}{1+\beta_2.v'_{r1}}$	$B_{12} = \beta_1.g_2 - \beta_2.g_1$ $v'_{r1} = \frac{v'_{r2}+(\beta_1.g_2-\beta_2.g_1)}{1+(\beta_1.g_2-\beta_2.g_1).v'_{r2}}$ $v'_{r2} = \frac{v'_{r1}-(\beta_1.g_2-\beta_2.g_1)}{1-(\beta_1.g_2-\beta_2.g_1).v'_{r1}}$

Relative speeds

Discussion

- A relative speed reaching the value of 1 means that it's reaching 1 light-second, that is the Lightspeed *c*.

- When a moving reference frame reaches the speed of light, the relative speed between the two moving reference frames can't go further than the speed of light. It is quite easy to demonstrate with a short mathematical study of the following functions $y = \frac{x+g}{1+g.x}$ and $y = \frac{x-g}{1-g.x}$ with the variable x ranging from 0 to 1 and the parameter g ranging between 0 and 1.

- For $\beta_1 = 0$ ($g_1 = 1$) and any β_2 speed ratio, we can write again the formula relating the speed of a moving reference frame with a resting one :

$$\frac{dx'_2}{dt'_1} = \frac{\frac{dx'_1}{dt'_2} + \beta_2}{1 + \beta_2.\frac{dx'_1}{dt'_2}}$$

$dx'_1 = 0$ (Resting reference frame) leads to:

$$\frac{dx'_2}{dt'_1} = \frac{dx'_2}{dt} = \beta_2$$

- For $\beta_2 = 0$ ($g_2 = 1$) and any β_1 speed ratio, we can write again the formula relating the speed of a moving reference frame with a resting one :

$$\frac{dx'_2}{dt'_1} = \frac{\frac{dx'_1}{dt'_2} - \beta_1}{1 - \beta_1.\frac{dx'_1}{dt'_2}}$$

$dx'_1 = 0$ (Resting reference frame) leads to:

$$\frac{dx'_1}{dt'_2} = \frac{dx'_1}{dt} = \beta_1$$

1.4 Using the Lorentz equations for the Michelson and Morley interferometer

In the former paragraphs, we have already established the following considerations:

- The length of an object at rest

- The length of an object when it is in movement

- The apparent length of an object from the point of view of a resting reference frame

- The apparent length of an object at rest from the point of view of a moving reference frame

- The apparent length of a moving object from the point of view of a moving reference frame having a different speed

We basically didn't focus on the height of an object (its transversal dimension compared to its movement) as far as we have, according to the Lorentz equations:

$$y' = y = D$$

This means that the height of an object is not influenced by its longitudinal speed. Moreover, we can write the following expression:

$$dy' = dy = 0$$

The longitudinal speed has basically no influence on the transversal movement of the object.

We now have to study how the dimensions of an object are seen and measured from the point of view of an observer associated with its movement. We will then use again the Lorentz transformations for the following cases:

- Times and distances for an optical signal within the transversal path of the interferometer when it is at rest
- Comparison with the interferometer when it moves
- Times and distances for an optical signal within the longitudinal path of the interferometer when it is at rest
- Comparison with the interferometer when it moves

1.4.1 Transversal path when the interferometer is at rest $v = 0$; $\beta = 0$; $g = 1$

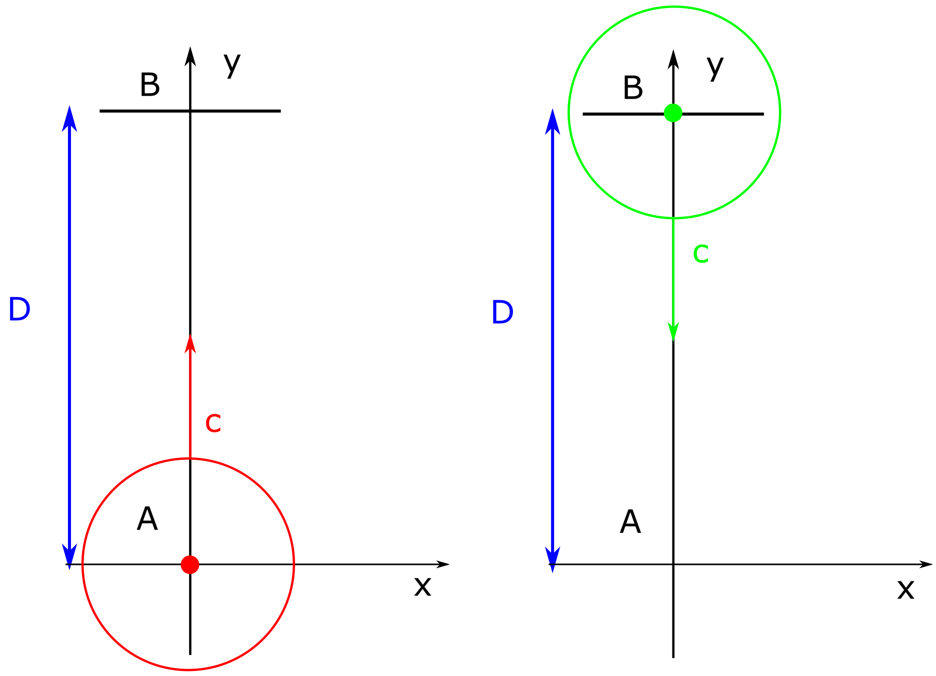

Figure 1.14: Step 1 and 2 for an optical signal to move away and go back to A

Time needed for an optical signal to go from A to B:

$$t_1 = D$$

Time needed for an optical signal to go back to A:

$$t_2 = D$$

Time needed for an optical signal to go and back to A:

$$t = t_1 + t_2 = 2D$$

Note: The lengths and distances are expressed in light-seconds

1.4.2 Transversal path when the interferometer is moving at the speed of $\beta = v/c$

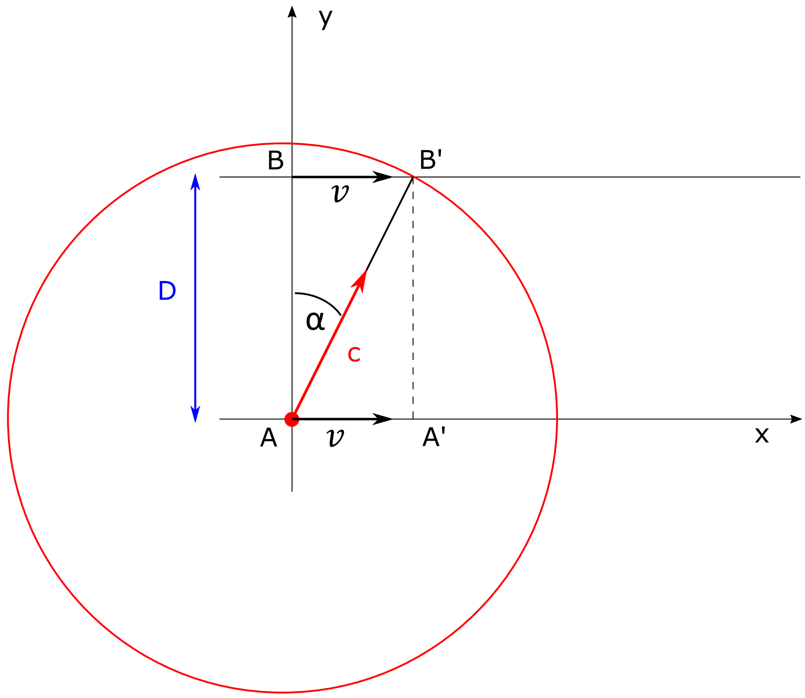

Figure 1.15: Step 1

Considering the trignometric situation:

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

$$\cos\alpha = \sqrt{1 - \sin\alpha^2} = \sqrt{1 - \beta^2} = g$$

$$\cos\alpha = \frac{c.D}{c.t_1}$$

$$\cos\alpha = \frac{D}{t_1}$$

$$t_1 = \frac{D}{\cos\alpha}$$

$$t_1 = \frac{D}{g}$$

Time needed, and expressed in the reference frame associated with the moving interferometer, for a signal emitted from A to reach B′. B′ is the position of B having moved during one period of the signal.

$$t_1' = g.t_1$$

$$t_1' = D$$

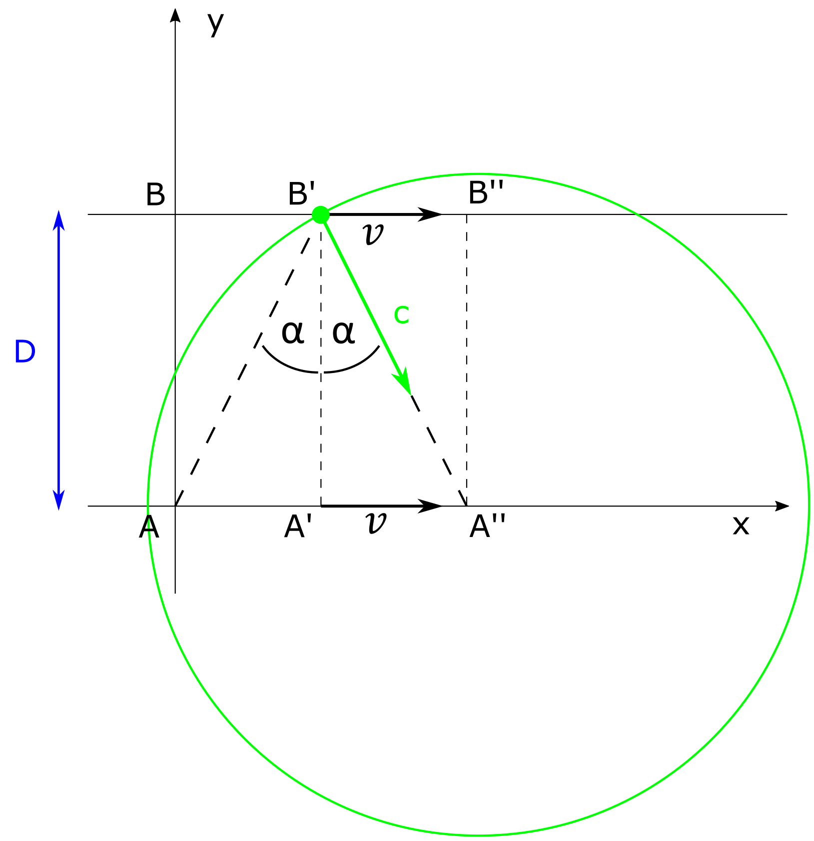

Figure 1.16: Step 2

Time needed for the signal emitted from B′ to reach A″:

A″ is the position of A′ having moved during another period of the signal. It is basically the same time than the one for B to reach B′ in the step before.

$$t_2 = \frac{D}{g}$$

Time needed, and expressed in the reference frame associated with the moving interferometer, for a signal emitted from B′ to reach A″

$$t'_2 = g.t_2$$

$$t'_2 = D$$

$$t'_1 + t'_2 = 2D$$

<u>Notes:</u>

- As the initial coordinate of A is zero in the resting interferometer, the value of x for A is zero. The following expression: $t' = g.t - \beta.x$ simplifies in this particular case to: $t' = g.t$
- If λ is the wavelength when the emitter is at rest, then the emitted frequency when the emitter moves is given by: λ/g

1.4.3 Conclusion for the transversal path

The times estimated by a resting observer are the same than the ones estimated by a moving observer associated with the moving interferometer. From the observers' point of views:

- A moving object keeps its height unchanged to the following value : D

- For a moving observer, the height of the moving object stays also unchanged to the following value : D

More over:

- A moving object actually keeps its height unchanged to the following value : D

=> This is just the particular case where the observations and measurements match with the phenomenon.

We can repeat our demonstration with the interferometer moving at the speed of $\beta_1 = v_1/c$ in a first time, and in a second time moving at the speed of $\beta_2 = v_2/c$. The measurements of the lengths along the transversal path of the moving interferometer will then be equal in both cases to: D

1.4.4 Longitudinal path for the resting interferometer: $v = 0$; $\beta = 0$; $g = 1$

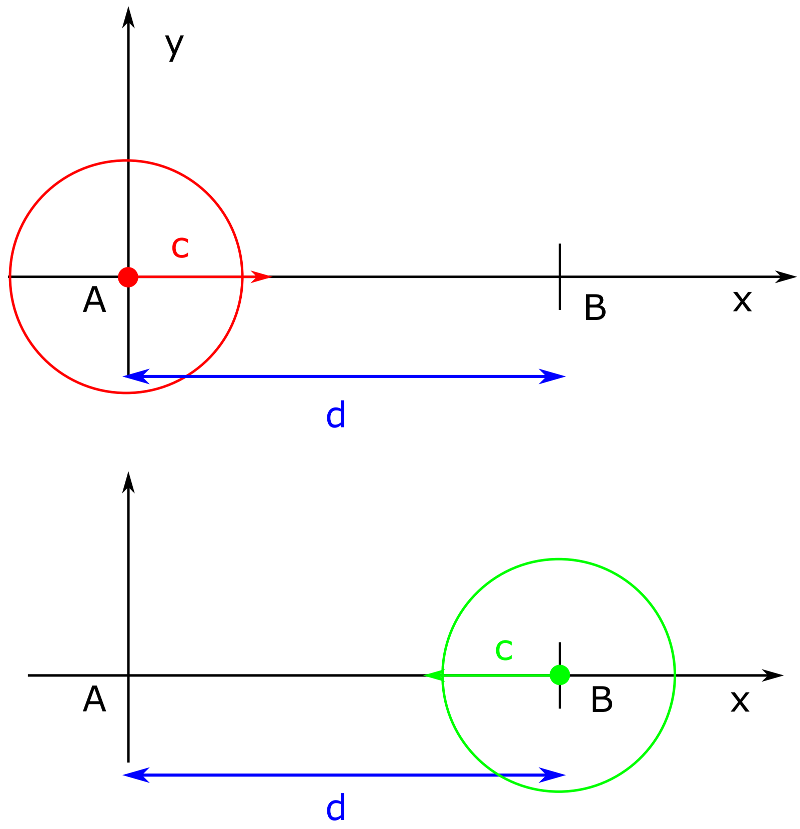

Figure 1.17: Step 1 and 2

Time needed for an optical signal to go from A to B:

$$t_1 = d$$

Time needed for an optical signal to go back to A:

$$t_2 = d$$

Time needed for an optical signal to move away and go back to A:

$$t = t_1 + t_2 = 2d$$

<u>Note:</u> The lengths and distances are expressed in light-seconds

1.4.5 Longitudinal path for the moving interferometer: $\beta = v/c$

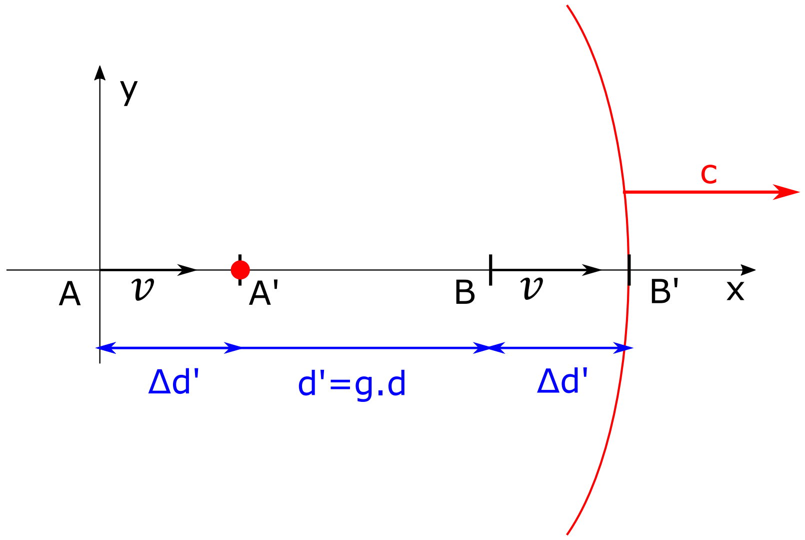

Figure 1.18: Step 1

The moving arm is contracting, according to the Lorentz transformations to the length: $d' = g.d$

As B is moving at the speed of v and the optical signal is moving at the speed of light c, the former emitted from A would need the same time to reach B′ as it would be needed to reach B at the normalized speed of $(1 - \beta)$:

$$t_1 = \frac{g.d}{1 - \beta}$$

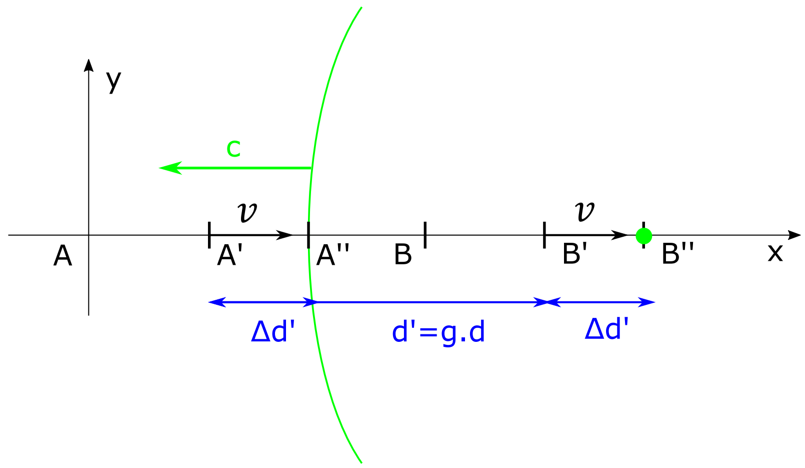

Figure 1.19: Step 2

The moving arm is contracting, according to the Lorentz transformations to the length: $d' = g.d$

As A′ is moving at the speed of v and the optical signal is moving at the speed of light c, the former emitted from B′ would need the same time to reach A″ as it would be needed to reach A′ at the normaized speed of $(1 + \beta)$:

$$t_2 = \frac{g.d}{1+\beta}$$

This leads to the following time values for t1 and t2:

$$t_1 + t_2 = \frac{g.d}{1-\beta} + \frac{g.d}{1+\beta}$$
$$t_1 + t_2 = g.d.\frac{1+\beta+1-\beta}{(1+\beta).(1-\beta)}$$
$$t_1 + t_2 = \frac{2g.d}{g^2} = \frac{2d}{g}$$

The global time needed and expressed in the reference frame associated with the moving interferometer, for a signal emitted from A to reach A" is then:

$$t'_1 + t'_2 = g.(t_1 + t_2) = g.\frac{2d}{g}$$
$$t'_1 + t'_2 = 2d$$

Notes:

- As the initial coordinate of A is zero in the resting interferometer, the value of x for A is zero. The following expression: $t' = g.t - \beta.x$ simplifies in this particular case to: $t' = g.t$
- If λ is the wavelength when the emitter is at rest, then the emitted frequency when the emitter moves is given by: λ/g

1.4.6 Conclusion for the longitudinal path

The estimated times for a resting observer are the same than the ones for a moving observer. From the observers' point of views:

- A moving object contracts from d to $g.d$ from a resting observer's point of view, $g.d$ being its real length according to our assumption.

- A moving object, though being contracted from d to $g.d$, will be seen with a length of d by the moving observer. The former is allowed, in the name of the relativity principle, to say that he is at rest while the object is movig away from him.

More over:

- A moving object actually contracts from d to $g.d$
=> Beyond the equivalence of the two different observers' point of views, the reality of the phenomenon is not the same.

We can repeat our demonstration with the interferometer moving at the speed of $\beta_1 = v_1/c$ in a first time, and in a second time moving at the speed of $\beta_2 = v_2/c$. The measurements of the lengths, made by a co moving observer along the longitudinal path, will then be equal in both cases to: d

In conclusion, the Michelson and Morley experiment made of two arms, one transversal, the other one longitudinal to its movement, wont' give any time difference, whatever its speed. Once the two optical signals have been put in phase, no phase difference will occur. At the speed of v_1 like at the speed of v_2, a co moving observer will find a time value equal to:

$2d$; d being the length of the considered arm, expressed in light-seconds

1.4.7 Summary tables

Longitudinal Lengths - Table 2

Longitudinal lengths	estimated length in the resting reference frame (real length)	estimated length in the moving reference frame R'1	esttimated length in the moving reference frame R'2
Object at rest	d	$g_1.d$	$g_2.d$
β_1 moving object	$d'_1 = g_1.d$	d	$(g_1.g_2 + \beta_1.\beta_2).d$
β_2 moving object	$d'_2 = g_2.d$	$(g_1.g_2 + \beta_1.\beta_2).d$	d

Transversal Lengths - Table 3

Transversal lengths	estimated length in the resting reference frame (real length)	estimated length in the moving reference frame R'1	esttimated length in the moving reference frame R'2
Object at rest			
β_1 moving object		D	
β_2 moving object			

Longitudinal speeds - Table 4

Longitudinal speeds	estimated speed in the resting reference frame (absolute speed)	estimated speed in the moving reference frame R'1	esttimated speed in the moving reference frame R'2
Object at rest	0	β_1	β_2
β_1 moving object	β_1	0	$v'_{r1} = \frac{v'_{r2}+(\beta_1.g_2-\beta_2.g_1)}{1+(\beta_1.g_2-\beta_2.g_1).v'_{r2}}$
β_2 moving object	β_2	$v'_{r2} = \frac{v'_{r1}-(\beta_1.g_2-\beta_2.g_1)}{1-(\beta_1.g_2-\beta_2.g_1).v'_{r1}}$	0

Transversal speeds - Table 5

Transversal speeds	estimated speed in the resting reference frame (absolute speed)	estimated speed in the moving reference frame R'1	esttimated speed in the moving reference frame R'2
Object at rest			
β_1 moving object		0	
β_2 moving object			

1.4.8 Discussion on the special relativity paradoxes

The mirror paradox

The mirror paradox consists in putting a moving mirror in front of a moving observer tending together to the speed of light. According to the classic rules of speed composition in a Galilean reference frame, the reflection of the observer in the mirror may disappear as the relative speed $(c - v)$ of the incoming shape of the observer to the mirror would tend to zero.

To treat this case, Albert Einstein will use the special relativity theory postulating the invariance of the speed of light and its consequence: a contraction of space and a dilatation of time.

We rather consider that we are in the same situation as the moving interferometer like exposed before.

$$t'_1 = g.t_1 = \frac{g^2.d}{1-\beta} = d.(1+\beta)$$
$$t'_2 = g.t_2 = \frac{g^2.d}{1+\beta} = d.(1-\beta)$$
$$t'_1 + t'_2 = 2.d$$

The time for the shape of the observer to make the round trip between the mirror and himself is then constant, whatever the speed of the mirror and the observer. Then the image reflected by the mirror will never disappear.

The twin paradox

The twin paradox consists in making travelling in space one of the twin while the second one is staying on earth. The question is then: if the travelling twin reached the speed of light, would he be younger than the one stayed on earth when he came back? As time is supposed to contract for the travelling twin, it is supposed to be the case.
According to our new understanding of the relativity, there is neither contraction nor dilatation of time, but more basically a slowdown of the mechanisms within any matter, then for the travelling twin. That's why time will seem to go slower for him.

We are tempted to conclude that the travelling twin will come back younger than his twin stayed on earth, as his biological rhythms have slowed down. For the same reason, any moving clock will count the time a slower way. The two following situations: the acceleration phase of the twin to move away and his deceleration phase to come back and meet again his twin are falsely symmetrical in terms of counting time. Time accumulation is a one way phenomenon. There won't be any compensation of the accumulated time in the first phase of the travel by the second phase of it. Time just accumulates, though this accumulation is accelerating in the first phase of the travel, unlike it is decelerating in the second phase of the travel.

If we consider furthermore that not only mechanisms slow down, but also lengths contract in the way of the movement, the situation is more ambiguous. What about becoming older a faster way if biological rhythms slow down whereas the dimensions of the twin's body contract at the same time? Let us point out that the slowdown phenomenon of the biological rhythms is isotropic, unlike the twin's body's contraction which occurs only in the way of his movement. If the twin's body contracted in his whole dimensions, we could assume that the travel wouldn't have any effect on him. Without any contraction, we could assume that the travelling twin would come back younger for sure. We are here in an ambiguous situation since the slowdown of time is isotropic, unlike the contraction of the dimensions. As the situation is ambiguous, we will conclude that the travelling twin will come back younger still.

Chapter 2

The Doppler Effect

2.1 Review of the classical Doppler Effect

The Doppler Effect is a physical phenomenon which makes a signal frequency being modified when the emitting source is moving (the absolute Doppler Effect), or from the point of view of a receiver when the former or the latter are moving (the relative Doppler Effect).
In a first step, we will focus on the classical Doppler Effect, that is the one concerning accoustic waves or any non-electromagnetic wave. We will then use our first study to focus on the relativistic Doppler Effect according to our new understanding of the Lorentz equations and their consequences on the frequency of a moving emitter or receiver.

Let us use the following notations for the chapter:

* λ : The wavelength when the emitter is at rest

* λ_{av} : The length of the front wave of the emitter

* λ_{ar} : The length of the backward wave of the emitter

* λ_r : The wavelength like is is perceived by the receiver

2.1.1 The emitter and the receiver are at rest

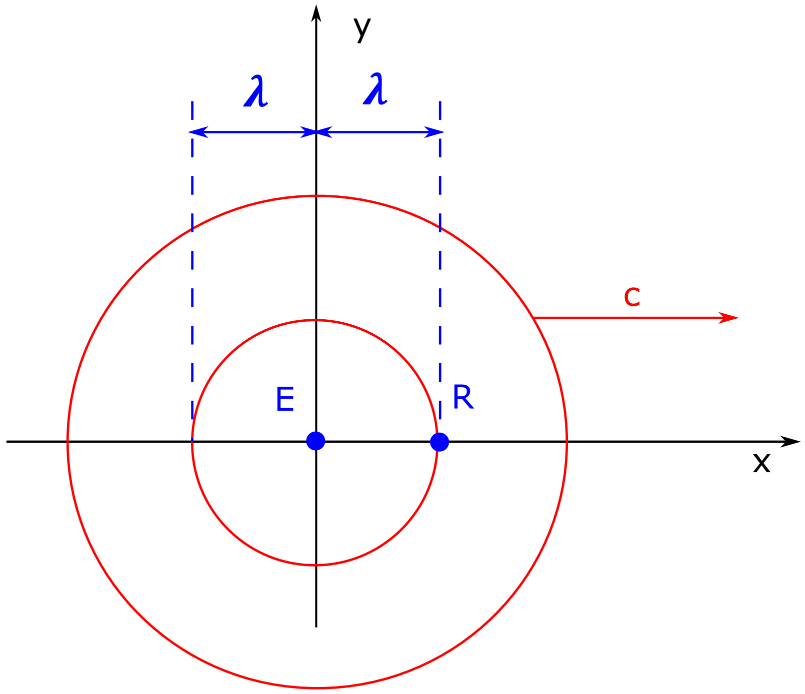

Figure 1.23: The emitter and the receiver are at rest

The periodic signal, having for frequency f and also for wavelength c/f, needs $2.c/f$ of time to reach the receiver. The next front has the speed of c (like every front), and covers a distance of c/f. Then we basically have:

$$f_{rec} = f_{em} = \frac{c}{\lambda}$$

$$\lambda_{av} = \lambda_{ar} = \lambda$$

$$\lambda_r = \lambda$$

2.1.2 The emitter is moving away or is coming to the resting receiver

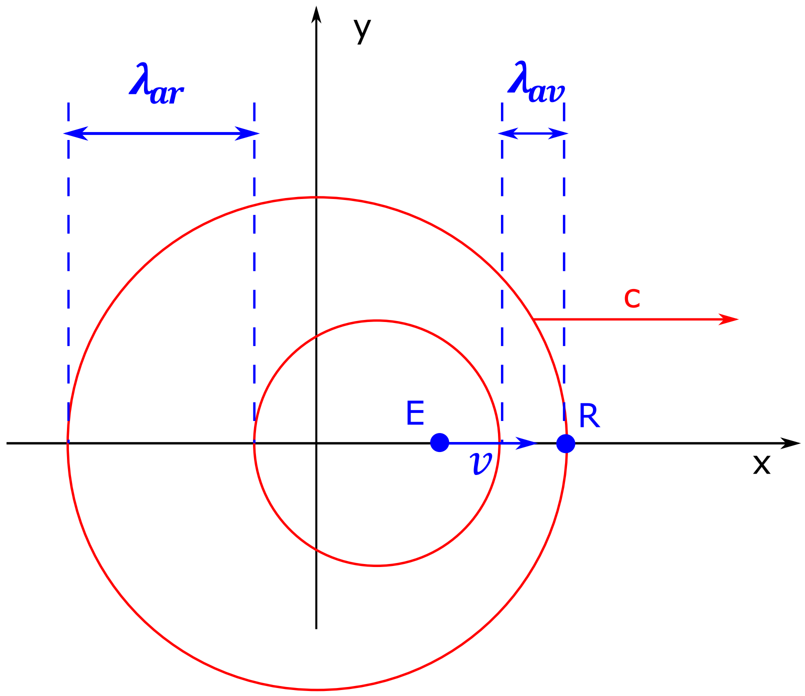

Figure 1.24: The emitter is moving away or is coming to the resting receiver

The periodic signal, having for frequency f that is for wavelength c/f, needs $2.c/f$ of time to reach the receiver. The next front has the speed of c, and covers a distance of $(c+v)/f$ (approaching case). This leads to:

$$\lambda_{av} = \frac{2.c}{f_{em}} - \frac{c+v}{f_{em}} = \frac{c-v}{f_{em}}$$

More over:

$$f_{em} = \frac{c}{\lambda}$$

This leads to:

$$\lambda_{av} = \lambda.(1-\beta)$$
$$\lambda_r = \lambda_{av}$$

For the same reason, we will obtain in the case of a moving away emitter:

$$\lambda_{ar} = \lambda.(1+\beta)$$
$$\lambda_r = \lambda_{ar}$$

2.1.3 The emitter is moving, the receiver is moving the same and is located on the transversal axis of the movement

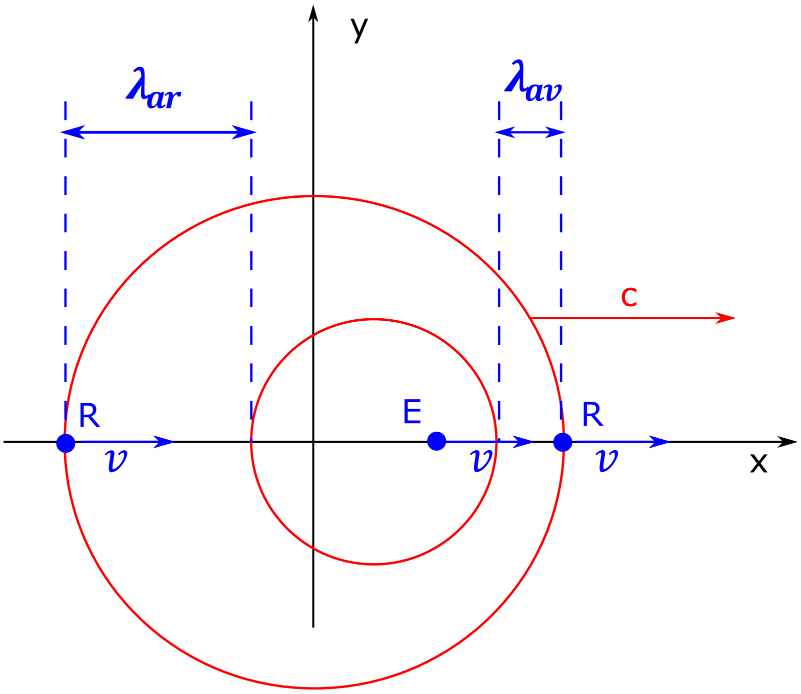

Figure 1.25:
The emitter is moving, the receiver is moving the same and is located on the transversal axis of the movement

If we focus on the received frequency of the signal to the receiver, then the Doppler Effect due to the emitter's movement is compensated by the receiver's movement. The relative Doppler Effect perceived by the receiver is nil.

$$\lambda_r = \lambda$$

The receiver won't be able to perceive any changing, though the emitter's frequency and wavelength have been actually modified by the Doppler Effect:

$$\lambda_{av} = \lambda.(1 - \beta)$$
$$\lambda_{ar} = \lambda.(1 + \beta)$$

2.1.4 The emitter is at rest, the receiver is moving away

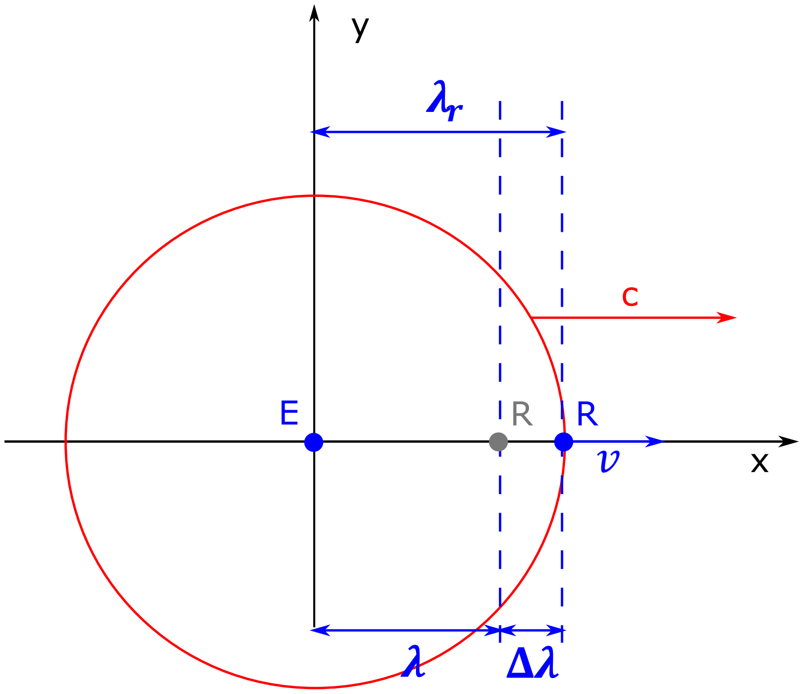

Figure 1.26: The emitter is at rest, the receiver is moving away

The receiver moving at the speed of v covers a $\Delta\lambda$ distance during the time of one signal period, while the front of the wave is running at the speed of c during the same time.

The time needed to cover the $\Delta\lambda$ distance is the same than the one needed to cover the λ distance at the speed of $(c - v)$

$$\Delta.t = \frac{\lambda}{c - v}$$

This leads for $\Delta\lambda$ to:

$$\Delta\lambda = v.\Delta.t = \lambda.\frac{v}{c - v}$$

The relative wavelength for the moving away receiver is then given by:

$$\lambda_r = \lambda + \Delta\lambda = \lambda(\frac{c - v + v}{c - v}) = \lambda.\frac{c}{c - v}$$

$$\lambda_r = \frac{\lambda}{1 - \beta}$$

The emitter being at rest leads also to:

$$\lambda_{av} = \lambda_{ar} = \lambda$$

2.1.5 The emitter is at rest, the receiver is coming to the emitter

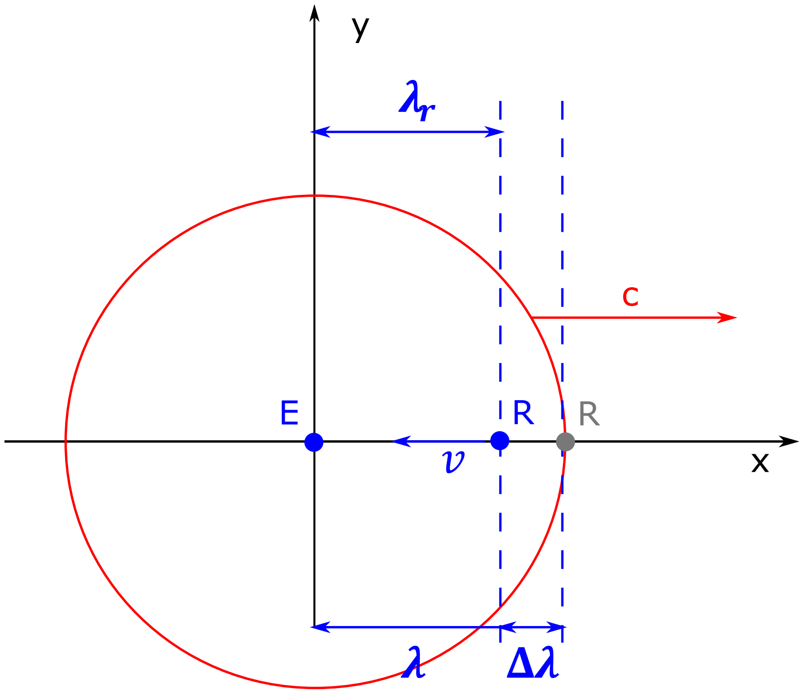

Figure 1.27: The emitter is at rest, the receiver is coming to the emitter

The receiver moving at the speed of v covers a $\Delta\lambda$ distance during the time of one signal period, while the front of the wave is running at the speed of c during the same time.

The time needed to cover the $\Delta\lambda$ distance is the same than the one needed to cover the λ distance at the speed of $(c + v)$

$$\Delta\lambda = \frac{\lambda}{c + v}$$

This leads for $\Delta\lambda$ to:

$$\Delta\lambda = v.\Delta.t = \lambda.\frac{v}{c + v}$$

The relative wavelength for the approaching receiver will be then:

$$\lambda_r = \lambda - \Delta\lambda = \lambda(\frac{c + v - v}{c + v}) = \lambda.\frac{c}{c + v}$$

$$\lambda_r = \frac{\lambda}{1 + \beta}$$

The emitter being at rest leads also to:

$$\lambda_{av} = \lambda_{ar} = \lambda$$

2.1.6 The emitter and the receiver are moving at different speeds, the receiver is located on the transversal axis of the movement

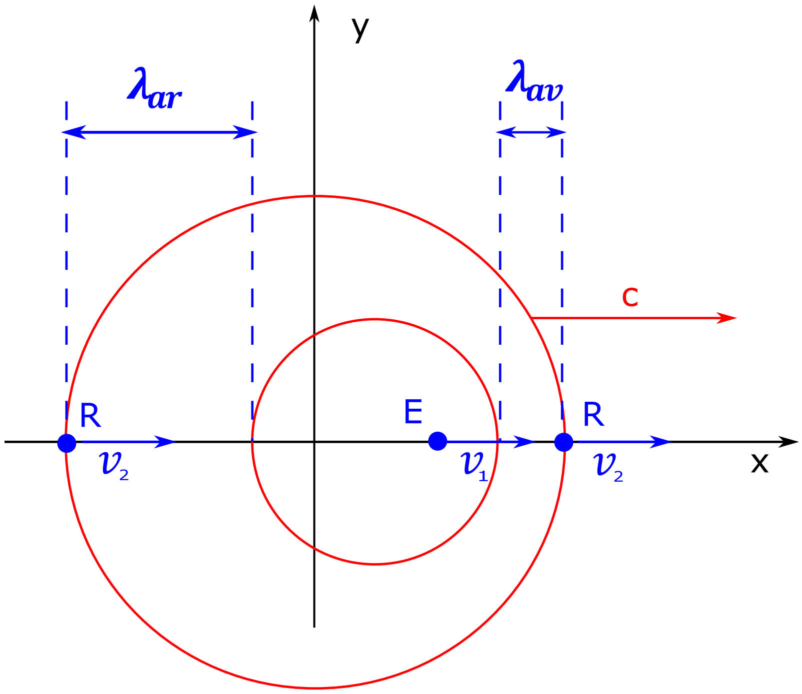

Figure 1.27 bis: The emitter and the receiver are moving at differents seeds, the receiver is located on the transversal axis of the movement

We have to combine the absolute Doppler Effect due to the emitter's movement, and the relative Doppler Effect to the receiver

According to the absolute Doppler Effect, the wavelength for the backward wave of the emitter is given by:

$$\lambda_{ar} = \lambda.(1 + \beta_1)$$

According to the relative Doppler Effect, the perceived wavelength for the receiver approaching from behind is then given by:

$$\lambda_r = \lambda.\frac{1 + \beta_1}{1 + \beta_2}$$

According to the absolute Doppler Effect, the wavelength for the front wave of the emitter is given by:

$$\lambda_{av} = \lambda.(1 - \beta_1)$$

According to the relative Doppler Effect, the perceived wavelength for the ahead receiver moving away is then given by:

$$\lambda_r = \lambda.\frac{1 - \beta_1}{1 - \beta_2}$$

Note: If the emitter and the receiver have the same speed, that is $\beta_1 = \beta_2$, then we are in the case where: $\lambda_r = \lambda$

2.1.7 The emitter is moving, the receiver is moving the same and is located on the longitudinal axis passing through the emitter

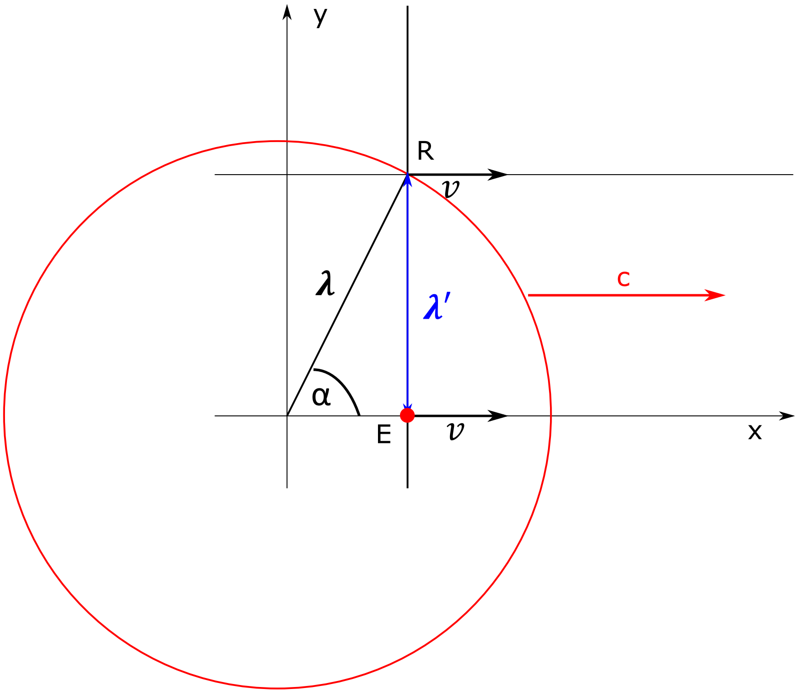

Figure 1.28: The emitter and the receiver are moving the same

At the second emitting period of time, the trigonometric situation leads to:

$$\sin\alpha = \frac{\lambda'}{\lambda}$$

More over:

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

$$\sin\alpha = \sqrt{1-\cos^2\alpha} = \sqrt{1-\beta^2} = g$$

This leads to:

$$\lambda' = g.\lambda$$

For the received frequency of the signal to the receiver, then the Doppler Effect due to the emitter's movement is compensated by the receiver's movement: $\lambda_r = \lambda$

Nevertheless, the emitter's frequency and wavelength have been actually modified by the Doppler Effect. The wavelength of the signal on the axis is given by: $\lambda' = g.\lambda$

2.2 The relativistic Doppler Effect

By considering that mechanisms within matter slowdown according to our new understanding of the Lorentz equations, we will now focus on the relativistic Doppler Effect.

2.2.1 The emitter is moving and the receiver is at rest

Let us assume that a moving emitter, having f for frequency of its periodic signal, willl emit on the following frequency when it is moving at the speed of β:

$$f' = g.f$$

This means that the wavelengths for the resting and moving emitter are related by the equation:

$$\lambda' = \frac{\lambda}{g}$$

The equations for the classical Doppler Effect have then to be modified to take into account the wavelength correction by the Lorentz factor g due to movement. Once this is done, we will be able to use again these equations in the relativistic context.

For the backward wave:

$$f_{ar} = \frac{g.f}{1+\beta} = f.\frac{\sqrt{(1-\beta).(1+\beta)}}{\sqrt{(1+\beta)^2}} = f.\sqrt{\frac{1-\beta}{1+\beta}}$$

$$\lambda_{ar} = \frac{\lambda}{g}.(1+\beta) = \lambda.\sqrt{\frac{1+\beta}{1-\beta}}$$

For a receiver being at rest and located behind the emitter, the perceived wavelength equals to the wavelength of the emitter:

$$\lambda_r = \lambda_{ar}$$

$$\lambda_r = \lambda.\sqrt{\frac{1+\beta}{1-\beta}}$$

For the front wave:

$$f_{av} = \frac{g.f}{1-\beta} = f.\frac{\sqrt{(1-\beta).(1+\beta)}}{\sqrt{(1-\beta)^2}} = f.\sqrt{\frac{1+\beta}{1-\beta}}$$

$$\lambda_{av} = \frac{\lambda}{g}.(1-\beta) = \lambda.\sqrt{\frac{1-\beta}{1+\beta}}$$

For a receiver being at rest and located in front of the emitter, the perceived wavelength equals to the wavelength of the emitter:

$$\lambda_r = \lambda_{av}$$

$$\lambda_r = \lambda.\sqrt{\frac{1-\beta}{1+\beta}}$$

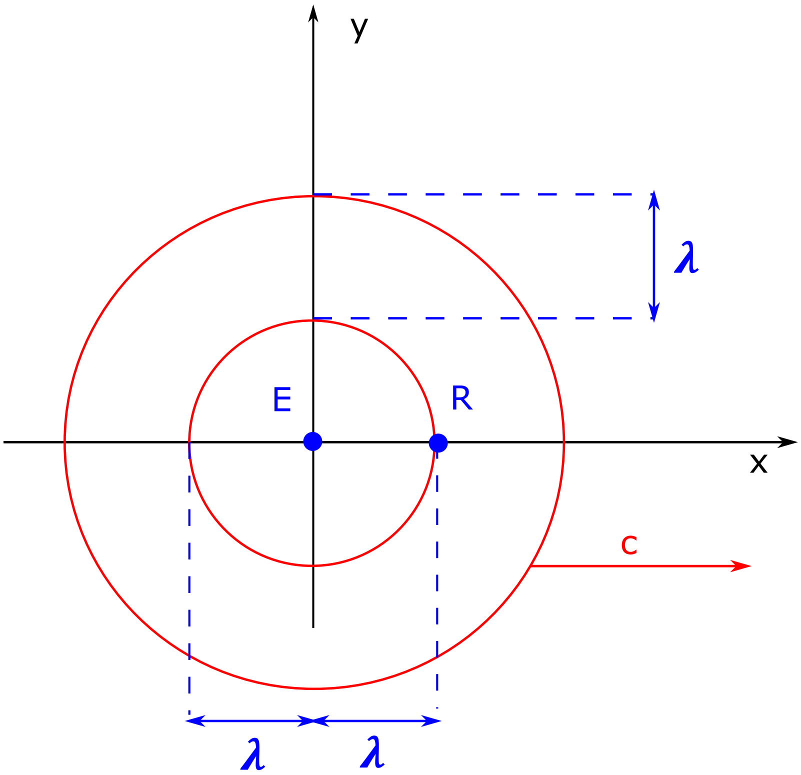

Figure 1.29: At rest emitter

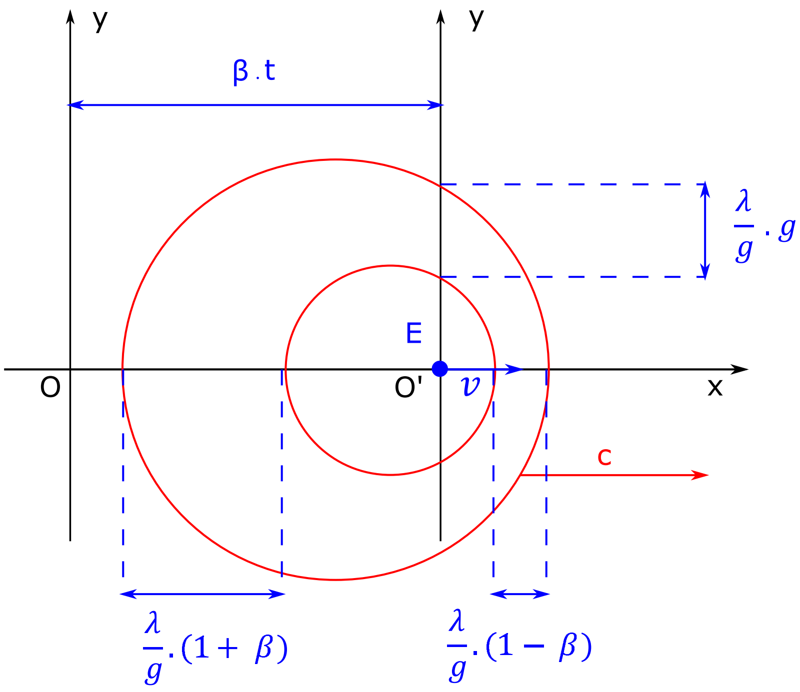

Figure 1.30: Moving emitter

Note:

- The second Lorentz equation expressing time transformation highlights a phase shift phenomenon for two different clocks on the axis of the movement. For two clocks located one at the begin of an object having d for length, another at its end, there should be a phase difference like follows:

$$\phi = -\beta.d$$

The ahead emitter should emit later than the one located behind, though they both stayed on the same modified frequency as they are comoving.

- Surprisingly but according to the combination of the classical Doppler Effect and the relativistic one, the Doppler relativistic effect implies the following wavelength for the signal on the longitudinal axis passing through the emitter:

$$\frac{\lambda}{g}.g = \lambda$$

- We should distinguish two aspects which may look similar : the relativistic effect and the relative one. The relativistic effect is connected with electromagnetic waves, and expresses the influence of the emitter's speed on the wavelength and the frequency of the emitted signal. The relative effect is about how is received a signal from the receiver's point of view. If the emitter is at rest and the receiver is moving, for example, then the real frequency of the signal doesn't change, whereas its measurement by the moving receiver does. If the emitter and the receiver are moving the same, then the receiver won't perceive any changing, though the frequency of the emitter actually changed. These are a typical examples of relative effects.

2.2.2 The emitter is at rest and the receiver is moving

When the receiver is moving while the emitter is staying at rest, it is the turn of the former to have its mechanisms being slowed down. We postulate that everything goes as if the receiver behaved with a $g.f$ received frequency while being at rest. We have then to use again the formula of the classical Doppler Effect and combine it with the relativistic effect on frequency:

For the receiver moving away from to the emitter:

$$g.f_r = f.(1-\beta)$$

$$f_r = f.\frac{\sqrt{(1-\beta)^2}}{\sqrt{(1-\beta).(1+\beta)}}$$

By definition: $\lambda = c/f$ and $\lambda_r = c/f_r$

$$\lambda_r = \lambda.\sqrt{\frac{1+\beta}{1-\beta}}$$

For the receiver coming to the emitter:

$$g.f_r = f.(1+\beta)$$

$$f_r = f.\frac{\sqrt{(1+\beta)^2}}{\sqrt{(1-\beta).(1+\beta)}}$$

By definition: $\lambda = c/f$ and $\lambda_r = c/f_r$

$$\lambda_r = \lambda.\sqrt{\frac{1-\beta}{1+\beta}}$$

Note: The emitter being at rest, its wavelength stays unchanged to the value λ

2.2.3 Physical interpretation of the relativistic Doppler Effect

On the one hand: The estimated wavelength from the moving receiver's point of view - while the emitter is at rest - is equal to the estimated wavelength from the resting receiver's point of view while the emitter is approaching

On the other hand: The estimated wavelength from the moving away receiver's point of view - while the emitter is at rest - is equal to the estimated wavelength from the resting receiver's point of view while the emitter is moving away.

=> There is a strict equivalence of the observations and the measurements, whatever the observer is moving and the source is staying at rest, or the former is staying at rest and the latter is moving.

=> Nevertheless, there is no equivalence of the effects. When the emitter is moving, its frequency is actually modified according to the Lorentz factor g. When the emitter is at rest while the receiver is moving, the frequency of the emitter stays the same. It would also be possible to guess which of the two ones is moving and which one is at rest, by using a second receiver and putting it at a different position. If the estimated frequency changed for him too, we could guess that the emitter is moving but the receiver doesn't, unless we would assume that the two receivers have the same relative movement compared to the emitter. This could be the case in some precise circumstances.

For the same reason, the properties of a resting receiver would stay the same when the relative movement was due to the movement of the emitter. Using a second emitter would be helpful to guess who is moving, who is staying at rest. The equivalence of the frequencies measurements hides the hiatus between the reality of the phenomena and their observations.

2.2.4 Discussion

The special relativity of Albert Einstein leads to the same arithmetical results as our new approach. There is here a common conclusion concerning the relative aspect of the observer's point of view.
Nevertheless, a "time dilatation" is convoked in the special relativity theory. We rather consider that "time dilatation" doesn't occur, but rather and more basically a slowdown of the mechanisms within matter. Among these mechanisms, we want to point out the electron's frequency. We postulate then that the electron's frequency is modified by its movement according to the Lorentz factor g.

Let us be given, for example, a radio emitter of 10 Ghz when it is at rest. Let us now speed up the radio emitter until it's reaching 30 km/s, that is a c normalized speed of $\beta = 10^{-4}$.

The emitted frequency is shifting from f to f' according to:

$$f' = g.f$$
$$f' = g.f = \sqrt{1-(10^{-4})^2}.10^{10}$$

$f - f' \approx 50$ Hz

When the emitter is moving away from the receiver, we have the following equation for the perceived frequency:

$$f_r = f_{ar} = \lambda.\sqrt{\frac{1-\beta}{1+\beta}}$$

$$f_r = f_{ar} = 10^{10}.\sqrt{\frac{1-10^{-4}}{1+10^{-4}}}$$

$f_r \approx 9.998000250$ GHz

When the emitter is approaching to the receiver, we have the following equation for the perceived frequency:

$$f_r = f_{av} = \lambda.\sqrt{\frac{1+\beta}{1-\beta}}$$

$$f_r = f_{ar} = 10^{10}.\sqrt{\frac{1+10^{-4}}{1-10^{-4}}}$$

$f_r \approx 10.002000250$ GHz

It would be also possible to build the same experiment with the emitter staying at rest and the receiver moving. The measurement would give the same shift of frequency.

Of course we have to point out that a resting position is uncertain as far as everything is in movement in the universe. We should then consider this resting situation as relative for any experiment. We would better say that an object which has been moved away may be in a different situation - in regard of the Wave middleware - than the one which has not been speeded up to be moved away. The perfect resting situation among the Wave middleware is, let us remind it, impossible to reach for any observer. Making the study of the relativistic Doppler Effect by taking into account the movement of the emitter and the receiver would deserve another full part development, partly unitiated in the annex **The relativistic Doppler Effect with a moving emitter and receiver**

2.3 Revisiting the Michelson and Morley experiment

2.3.1 The longitudinal arm is at rest

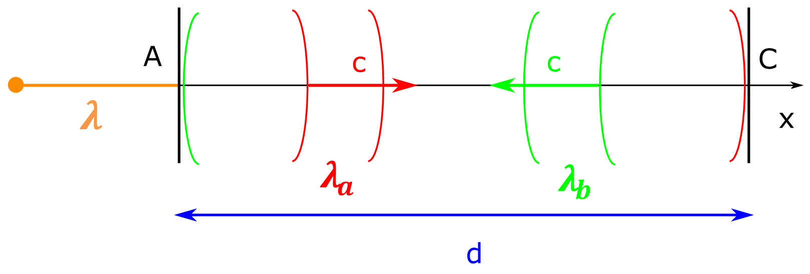

Figure 1.31: Round trip of the signals when the interferometer is at rest

For the front wave within the interferometer, we have:

$$\lambda_a = \lambda$$

For the backward wave within the interferometer, we have:

$$\lambda_b = \lambda$$

2.3.2 The longitudinal arm is moving at the speed of $\beta = v/c$

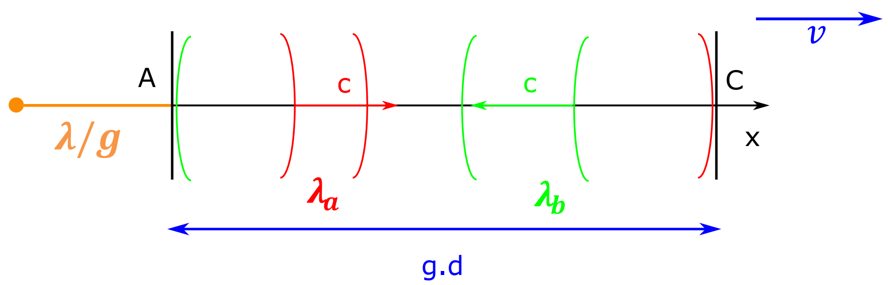

Figure 1.32: Round trip of the signals when the interferometer is moving

The emitter and the interferometer are moving at the speed of β. The wavelength of the front wave is then influenced by the Lorentz factor g and the Doppler Effect:

$$\lambda_a = \frac{\lambda}{g}.(1 - \beta)$$

The mirror located at C is behaving like a secondary source, moving at the same speed as the primary one, that is emitting on the same frequency. As there is a Doppler Effect for the returning wave too, the wavelength for it is given by:

$$\lambda_b = \frac{\lambda}{g}.(1 + \beta)$$

2.3.3 The transversal arm is at rest

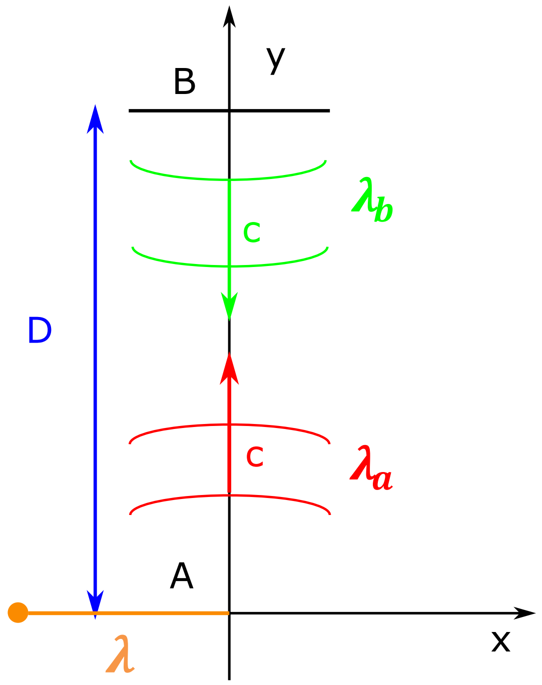

Figure 1.33: Round trip of the signals when the interferometer is at rest

For the front wave within the interferometer, we have:

$$\lambda_a = \lambda$$

For the backward wave within the interferometer, we have:

$$\lambda_b = \lambda$$

2.3.4 The transversal arm is moving at the speed of $\beta = v/c$

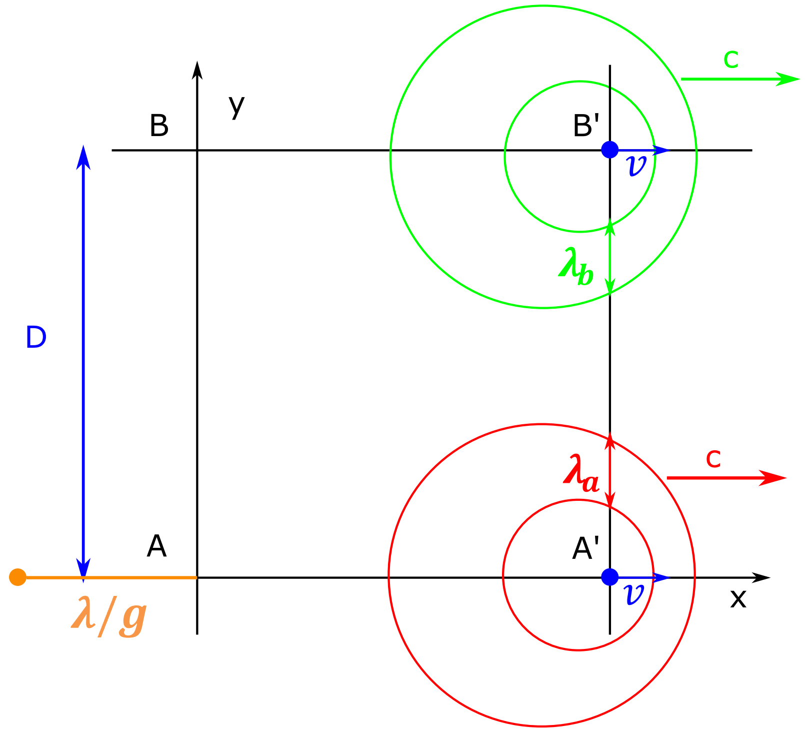

Figure 1.34: Round trip of the signals when the interferometer is at rest

The emitter and the interferometer are moving at the speed of β, then we have for the front wave the following wavelength:

$$\lambda_a = \frac{\lambda}{g}.g$$
$$\lambda_a = \lambda$$

The mirror located at B is behaving like a secondary source, moving at the same speed as the primary one, that is emitting on the same frequency. As there is a Doppler Effect for the returning wave too, the wavelength for it is given by:

$$\lambda_b = \frac{\lambda}{g}.g$$
$$\lambda_b = \lambda$$

2.3.5 Conclusion

- We have already exposed in the first chapter that the time needed for the waves to move away and come back stayed unchanged for the longitudinal arm, whether the interferometer is at rest or is moving. Idem for the transversal arm.

- We have also exposed the existence of a net of waves within the two arms of the interferometer

- In the next chapter, based on a simplified model for matter, we will assume and expose the existence of a net of standing waves emerging whithin matter and its net of atoms, like it does occur for the lights signals within the Michelson and Morley interferometer.

Chapter 3

Structure of matter

3.1 Assumption about the structure of matter

We will now shortly present an assumption for the structure of matter, mostly based on the ideas of some independent researchers like Gabriel Lafrénière or Youri Ivanov [9] , whose works can be regarded as a new wave mechanics theory.

Our model for matter will be as simple as possible, for pedagogical purpose. We will assume that every atom behaves like an oscillator, emitting waves in its environment. The covalent bonds between the atoms will be considered as the stationary waves emerging between each other, and resulting from the combination of the atoms emitted waves. The atoms would tend to locate at the nodes of this net, the distance between the atoms would then depend on how waves contract, dilate and also combine to each other when they move.

We will postulate that the wavelength of the resulting standing wave equals to the harmonic average of the two wavelengths of the front wave and the backward wave. The harmonic, geometric and arithmetic averages are also given by the following relations:

$$M_g = \sqrt{\lambda_{av}.\lambda_{ar}}$$
$$M_a = \frac{1}{2}.(\lambda_{av} + \lambda_{ar})$$

By definition of the harmonic average:

$$M_h = \frac{{M_g}^2}{M_a}$$

[9] http://mirit.ru/rd_2007en.htm

3.2 Standing waves formed within a net of stationary atoms at rest

3.2.1 Schematic representation

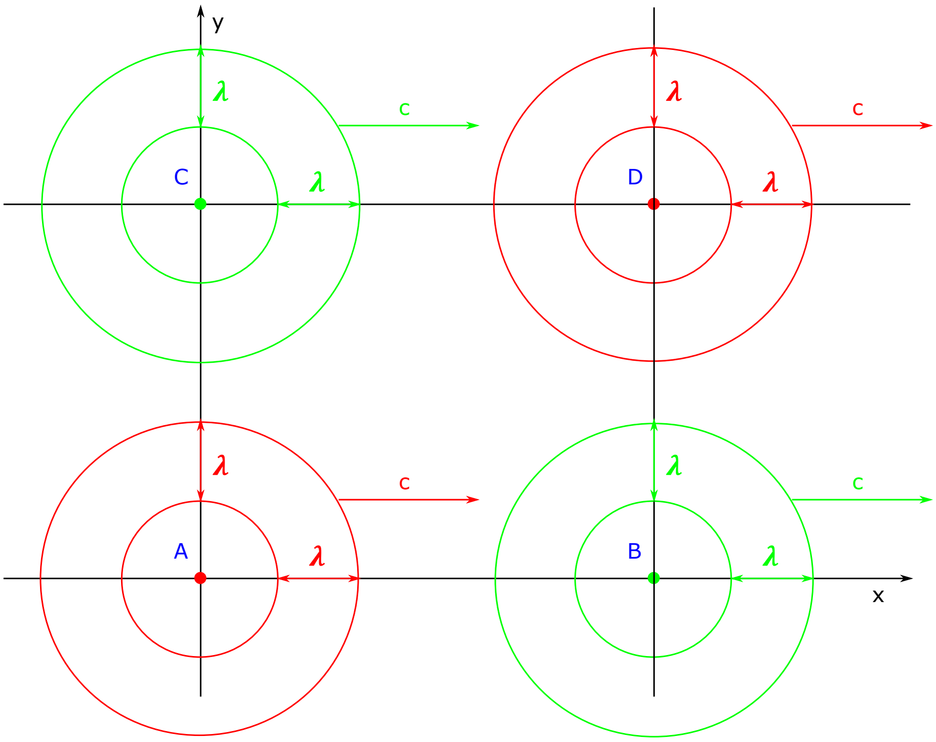

Figure 1.35: Stationary structure of atoms at rest

3.2.2 Wavelength of the transversal standing wave when the net of atoms is at rest

$$\lambda_{av} = \lambda$$
$$\lambda_{ar} = \lambda$$

This leads to:

$$M_g^2 = \lambda^2$$
$$M_a = \frac{1}{2}.(\lambda + \lambda) = \lambda$$
$$M_h = \lambda$$

3.2.3 Wavelength of the longitudinal standing wave when the net of atoms is at rest

$$\lambda_{av} = \lambda$$
$$\lambda_{ar} = \lambda$$

This leads to:

$$M_g^2 = \lambda^2$$
$$M_a = \frac{1}{2}.(\lambda + \lambda) = \lambda$$
$$M_h = \lambda$$

3.3 Standing waves formed within a net of moving atoms

3.3.1 Schematic representation

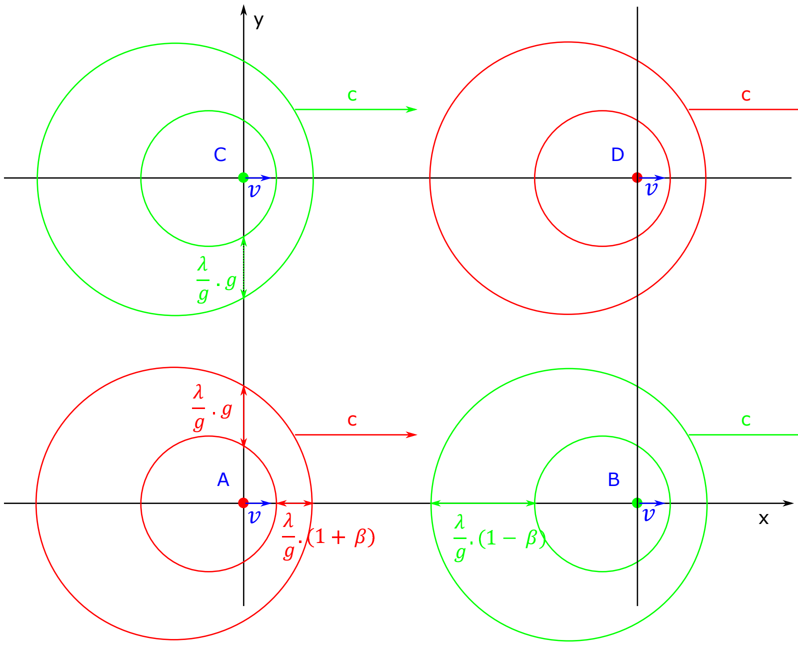

Figure 1.36: Moving structure of atoms

3.3.2 Wavelength of the transversal standing wave when the net of atoms is moving

$$\lambda_{av} = g.\frac{\lambda}{g}$$
$$\lambda_{ar} = g.\frac{\lambda}{g}$$

This leads to :

$$M_g^2 = \lambda^2$$
$$M_a = \frac{1}{2}.(\lambda + \lambda) = \lambda$$
$$M_h = \lambda$$

3.3.3 Wavelength of the longitudinal standing wave when the net of atoms is moving

$$\lambda_{av} = \frac{\lambda}{g}.(1-\beta)$$

$$\lambda_{ar} = \frac{\lambda}{g}.(1+\beta)$$

This leads to:

$$M_g = \sqrt{\frac{\lambda}{g}.(1-\beta).\frac{\lambda}{g}.(1+\beta)} = \lambda$$

That is:

$$M_g^2 = \lambda^2$$

$$M_a = \frac{1}{2}.(\frac{\lambda}{g}.(1-\beta) + \frac{\lambda}{g}.(1+\beta)) = \frac{2.\lambda}{2.g} = \frac{\lambda}{g}$$

$$M_h = g.\lambda$$

3.4 Consequences on the matter's dimensions

The atoms are at rest, they locate at the nodes of the resulting net of standing waves whose harmonic average is equal to λ.

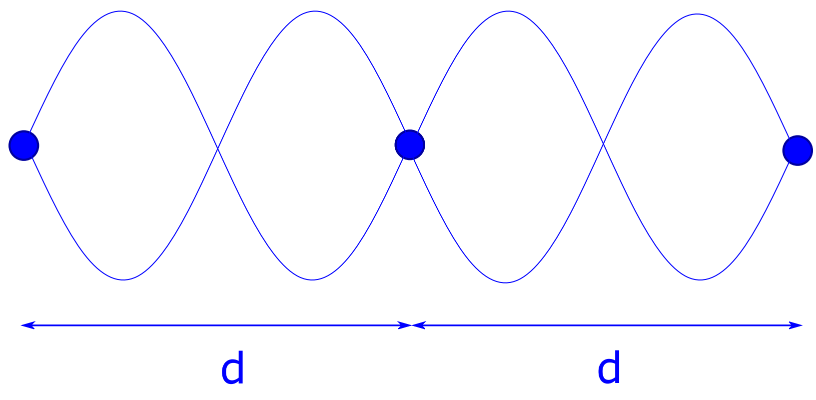

Figure 1.37: A net of stationary atoms at rest

The atoms are moving at speed of $\beta = v/c$, they locate at the nodes of the resulting standing waves formed by a contracted front wave of one atom and a dilated backward wave of the other one.

If λ is the signal's wavelength emitted by the equivalent oscillator, then the wavelength of the resulting standing wave will be given by: $g.\lambda$.

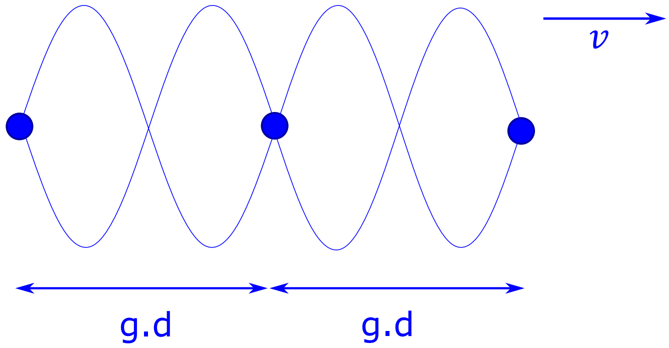

Figure 1.38: A net of moving atoms

If the distance between the atoms is given by d when they are at rest, then their distance when they move is given by $g.d$. That's why matter contracts according to the Lorentz factor g in the way of its movement

Notes:

- The harmonic average is equal to λ for the resulting standing waves on the transversal axis, whether the net of atoms is at rest or is moving. This basically means that the transversal dimensions of matter stay unchanged according to its longitudinal movement.

- The optical signals within the Michelson and Morley interferometer are influenced the same way as the arms themselves of the interferometer. That's why, according to our model, the interferometer is unable to show any influence of the movement on light.

- The net of standing waves is stationary for the net of atoms or for a moving observer associated to it, nevertheless it is actually in movement with the moving net of atoms. That's why the russian researcher Youri Ivanov uses the subtle expression *Lively standing waves* [10] to name it.

- By considering that matter and light are influenced the same way by movement, we strengthen the idea of a wave nature for matter, leading to the notion of waves of matter

- While the waves of matter always run at the absolute speed of light c, their combination moves at the same speed as matter does. This reminds us the wave speed group associated with the waves packet as foreseen by the French researcher Louis de Broglie around the 1920 years [11]

3.5 Discussion

We started our presentation by exposing the relation between the Lorentz transformations on one hand, and on the other hand the contraction of matter and also the slowdown of the mechanisms within matter due to its movement.

[10]Youri Ivanov - *op. cit.*
[11]Louis de Broglie - *op. cit.*

We are now allowed to express the things a more subtle way. **The Lorentz transformations are in the first instance the mathematical expression of the influence of movement on waves** and their properties: speed, frequency, magnitude and phase though we didn't focus on the two last points. It is in the first instance an expression of the influence of the Doppler Effect on waves and their properties.

The variables x and x' on the one hand, t and t' on the other hand, express in the first instance the length of the waves and the period of the waves. As matter is made of waves, we can then use the same variables and the same Lorentz equations to measure a distance or a time, and to relate them for an object alternatively being at rest and moving. As the net of the standing waves of matter contracts, the length of matter contracts too. As the mechanisms of matter slow down, the process to make a time measurement will slow down too, making the illusion of a contraction of time itself. A moving clock won't show the same time than a resting one, two clocks moving a different way won't also give the same time.

Chapter 4

Final conclusion

This publication was mostly inspired by the work of Gabriel Lafrénière (1942-2012), with the hope that it is faithful with his ideas. The kernel of it is a new interpretation of the Lorentz transformations.

We shouldn't consider space-time as a geometric locus, but rather space as a physical middleware and time as a variable representing the activity in the universe.

The Wave middleware has intrinsic properties: the constant speed of light or of any electromagnetic wave is one of them. Let us mention some other ones like the Planck constant or the vacuum permittivity that we would rather call the middleware permittivity.

When matter moves, it does contract in the way of its movement, its mechanisms also slow down. The seeming symmetry and the relativity of the observer's point of view hide the reality of the phenomena. We should at least not consider the point of view of an observer as a criterion of reality, but rather as the only way to make any measures in our environment to quantify it. This is whatever the only way to make some physical measurements as far as the still and resting position in the Wave middleware is impossible to reach for any observer.

There is no contraction of space, nor dilatation of time, but rather and more basically a contraction of matter and a slowdown of its mechanisms. A material object behaves like a net of standing waves connecting atoms to each other, and also emerging from the waves of matter made by the atoms themselves. The length and period of the waves are influenced by their movement, like is matter.

This new approach to relativity, to the Lorentz transformations, to matter and waves aims at opening a new way to model mechanics and electromagnetism. It would allow us to build some kind of neo-Newtonian approach of mechanics. Classical mechanics could be renewed by our approach and related again with the great discoveries made in the 20th century by Albert Einstein, his contemporaries and his successors (see also the annex **Doppler Mechanics** for further explanations). Our hope is to take part of the research and physics discussions, to open some new research prospects as fundamental physics faces problems to unify its two main branches built around relativistic mechanics and quantum mechanics, and to participate in a better understanding of physics.

Appendix A

Doppler Mechanics

In this annex, we will propose some new approach to wave mechanics, by highlighting the relations between waves, mass and inertia. We will use the notion of **waves of matter**.

A.1 Active and reactive mass

Let us distinguish the waves of matter located behind the associated mass, and the ones located in front of it.

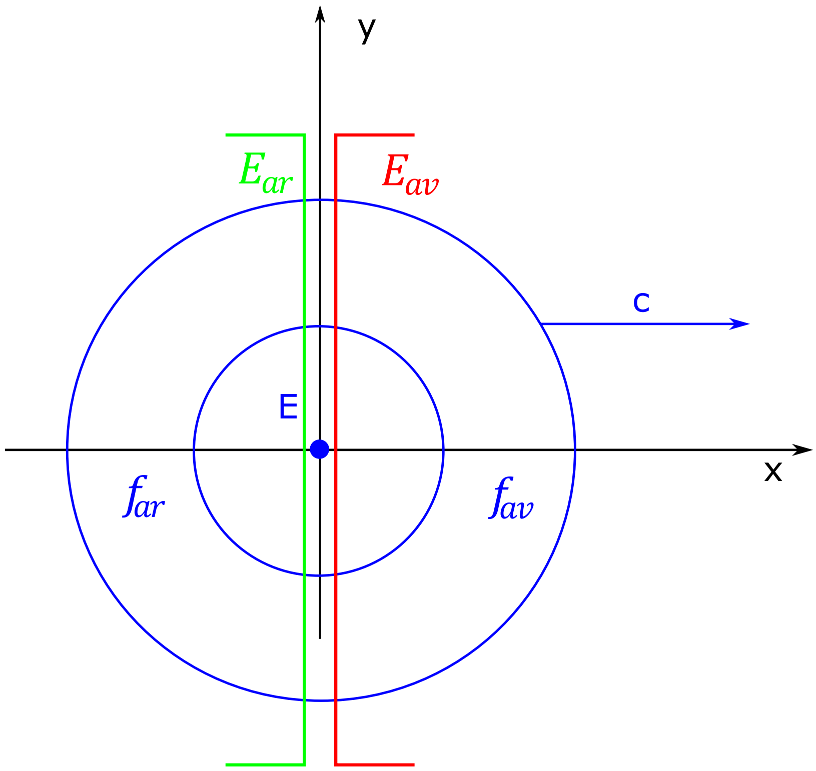

Figure 1.39: At rest mass and its associated waves

For a resting object:

$$E = E_{av} + E_{ar} = m.c^2$$

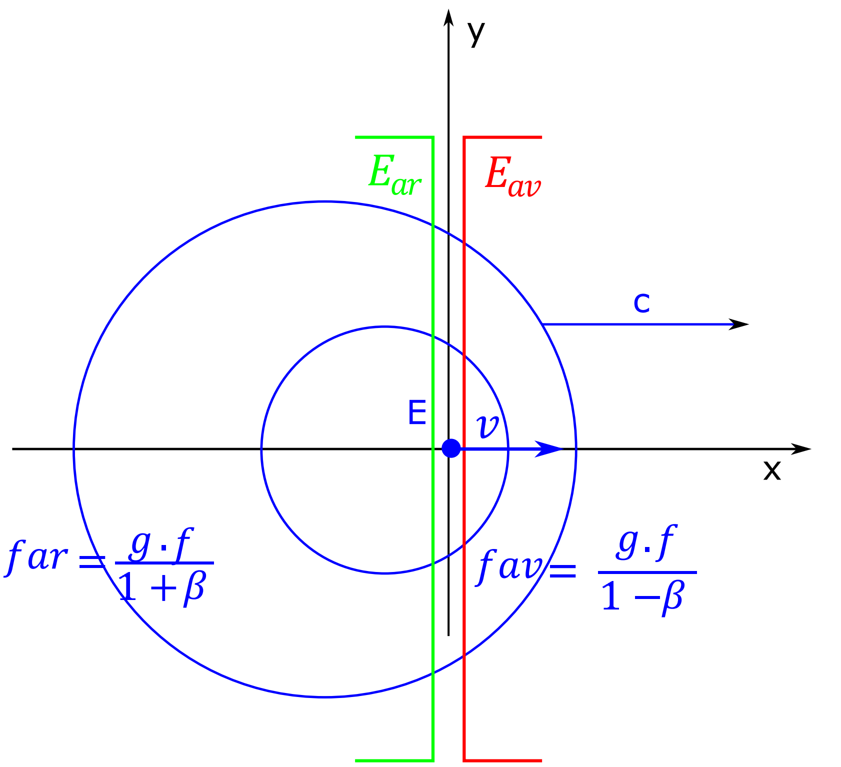

Figure 1.40: Moving mass and its associated waves

For a moving object:

$$E = E_{av} + E_{ar} = \frac{m.c^2}{g}$$

$$\beta = v/c$$

$$g = \sqrt{1-\beta^2}$$

A.1.1 Energetic balance for an object at rest

The energy contained in an object at rest is given by the Einstein's formula giving the equivalence between energy and mass:

$$E = m.c^2$$

Let us now make the difference between active mass and reactive mass; as well as between the energy we can associate with them. The former corresponds to the energy contained in the front wave, the latter in the backward wave. They are equal for an object at rest.

When a mass is at rest, we have basically:

$$E_{av} = E_{ar}$$

$$E_{av} + E_{ar} = m.c^2$$

This leads to:

$$E_{av} = \frac{m.c^2}{2}$$

$$E_{ar} = \frac{m.c^2}{2}$$

Assuming that the energy of a signal is proportional with its frequency leads us to:

$$E_{av} = \frac{m.c^2}{2} = A.f$$

$$E_{ar} = \frac{m.c^2}{2} = B.f$$

Where: A=B for symmetric reason.

A.1.2 Energetic balance for a moving object

The energy contained in a moving object is given by the following relativistic formula:

$$E = \frac{m.c^2}{g}$$

Assuming that the energy of a signal is proportional with its frequency leads us to:

$$E_{av} = C.\frac{g.f}{1-\beta}$$

$$E_{ar} = D.\frac{g.f}{1+\beta}$$

<u>Conservation of energy</u>

Let us use the principle of energy conservation to write an equation where the ratio of the front and backward energies for an object at rest equals to the ratio of the front and backward energies for a moving object:

$$\frac{E_{av_{mvt}}}{E_{av_r}} + \frac{E_{ar_{mvt}}}{E_{ar_r}} = \frac{E_{mvt}}{E_r} = \frac{\frac{m.c^2}{g}}{m.c^2} = \frac{1}{g}$$

This leads to:

$$\frac{C}{A}.\frac{\frac{g.f}{1-\beta}}{f} + \frac{D}{B}.\frac{\frac{g.f}{1+\beta}}{f} = \frac{1}{g}$$

$$\frac{C}{A}.\frac{g}{1-\beta} + \frac{D}{B}.\frac{g}{1+\beta} = \frac{1}{g}$$

$$\frac{C}{A}.(1+\beta) + \frac{D}{B}.(1-\beta) = 1$$

Let us note one particular and trivial solution for this equation:

$$\frac{C}{A} = \frac{D}{B} = \frac{1}{2}$$

This leads to:

$$E = \frac{m.c^2}{g} = (\frac{1}{2}.\frac{g}{1-\beta} + \frac{1}{2}.\frac{g}{1+\beta}).m.c^2 = (m_a + m_r).m.c^2$$

For a moving object having m for mass, its energy split into a front and backward wave due to the Doppler Effect like follows:

$$E = E_{av} + E_{ar} = m_a.c^2 + m_r.c^2$$

$m_a = \frac{1}{2}.\frac{g}{1-\beta}.m$ is the active mass

$m_r = \frac{1}{2}.\frac{g}{1+\beta}.m$ is the reactive mass

This leads to the following equation:

$$\frac{E_{av}}{E_{ar}} = \frac{f_{av}}{f_{ar}} = \frac{1+\beta}{1-\beta}$$

A.1.3 Active and reactive mass in the case of an elastic collision

Classical representation

Before the collision:

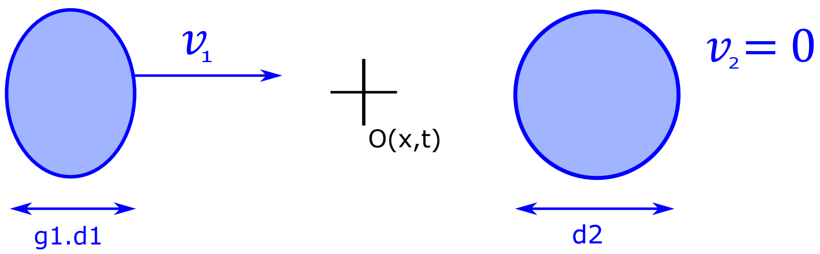

Figure 1.41:
The object M1 having for mass m_1 is moving to M2

$$E_{m1} = \frac{m_1.c^2}{g_1} = \frac{1}{2}.\frac{g_1}{1-\beta_1}.m_1.c^2 + \frac{1}{2}.\frac{g_1}{1+\beta_1}.m_1.c^2$$

$$E_{m2} = m_2.c^2 = \frac{m_2.c^2}{2} + \frac{m_2.c^2}{2}$$

After the collision:

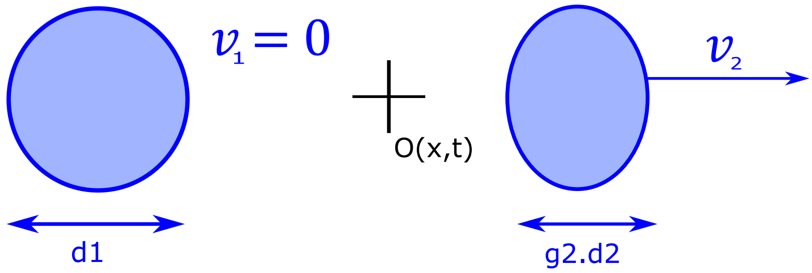

Figure 1.42:
The object M1 has been stopped by the collision with M2 while the latter has been put in movement

$$E_{m1} = m_1.c^2 = \frac{m_1.c^2}{2} + \frac{m_1.c^2}{2}$$

$$E_{m2} = \frac{m_2.c^2}{g_2} = \frac{1}{2}.\frac{g_2}{1-\beta_2}.m_2.c^2 + \frac{1}{2}.\frac{g_2}{1+\beta_2}.m_2.c^2$$

Energy balance for an elastic collision:

$$\frac{m_1.c^2}{g_1} + m_2.c^2 = m_1.c^2 + \frac{m_2.c^2}{g_2}$$

Momentum balance for an elastic collision:

$$\frac{m_1.v_1}{g_1} + \frac{m_2 * 0}{g_2} = \frac{m_1 * 0}{g_1} + \frac{m_2.v_2}{g_2}$$

$$\frac{m_1.v_1}{g_1} = \frac{m_2.v_2}{g_2}$$

Considering forces, we will use the classical expression:

$$F = \frac{dp}{dt} = \frac{d}{dt}(\frac{m.v}{\sqrt{1-(\frac{v}{c})^2}})$$

With:

$$v = \frac{dx}{dt}$$

If we consider the two dynamic masses given by $\frac{m_1}{g_1}$ and $\frac{m_2}{g_2}$, and also their reference frame having for center their mobile center of gravity, we will then be allowed to write the following equation in this reference frame:

$$F_{12} = F_{21}$$

$$\frac{dp_1}{dt} = \frac{dp_2}{dt}$$

$$\frac{d}{dt}\left(\frac{m_1.v_1}{\sqrt{1-(\frac{v_1}{c})^2}}\right)=\frac{d}{dt}\left(\frac{m_2.v_2}{\sqrt{1-(\frac{v_2}{c})^2}}\right)$$

Representation with the waves of matter

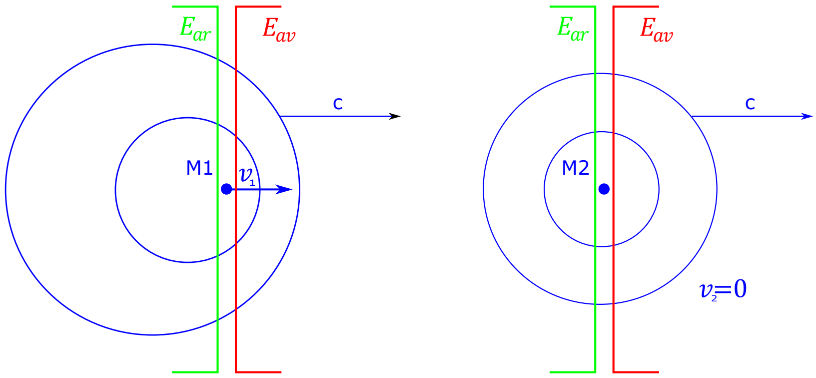

Figure 1.43: Before the collision

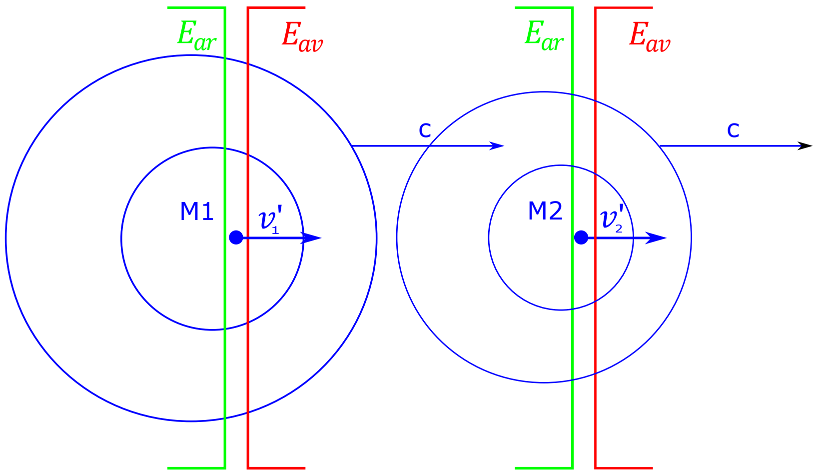

Figure 1.44: During the collision

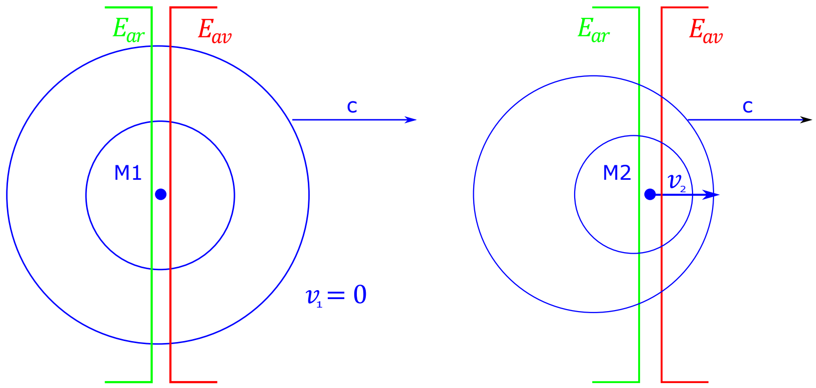

Figure 1.45: After the collision

A.2 Discussion

From our point of view, there is an equivalence between an energy transfer and a dynamic mass transfer during an elastic collision. The mass can be split into an active and a reactive one, which are increased by the momentum acquired during the collision. According to the momentum balance equation, it is possible to relate the four variables β_2, β_1, m_1 and m_2 and therefore calculate one mass according to the other one and their respective speeds before and after the collision, for example.

These equations are similar with the ones used in classical special relativity, nevertheless our physical interpretation of the phenomenon is different. We consider that the dynamic mass can be split into two masses, one active and another one reactive, like we can split the global energy of the waves into the fraction contained in the front waves and the fraction contained in the backward waves.

Moreover, let us point out the existence of an electrodynamics field between the two coexisting waves of matter, being the locus where the energy transfer is made possible. This electrodynamics field would not only be dynamic, but would also typically evolve with the reverse squared distance between the two centers of the both emitting and receiving waves of matter.

The energy transfer is not instantaneous, but rather depends on the waves of matter running at the speed of light's absolute value. The idea of an instantaneous collision of classical mechanics has to be renewed for the idea of a dynamic mass and energy transfer at the speed of light, which can be qualified as a quasi-instantaneous collision.

Let us finally notice that we have considered the periodic waves of matter, their phase and frequency, but we haven't made any assumption on their magnitude. If their magnitude quickly decreased with the distance of their emitting point, then the energy transfer would not only proceed at the speed of light, but would also proceed over very short distances, typically over interatomic distances where valence bonds occur.

A.3 Kinetic energy

We will now expose a new formula for kinetic energy, according to the energy balance in a relativistic context. The global energy for a mass m moving at the speed of β is given by:

$$E_{tot} = E_{repos} + E_c$$

This leads to:

$$\frac{m.c^2}{g} = m.c^2 + E_c$$

$$E_c = \frac{m.c^2}{g}.(1 - g)$$

For relativistic speeds, we have $\frac{v}{c} \to 1$, that is: $g \to 0$, this leads to:

$$\lim_{v \to c} E_c = \lim_{g \to 0} E_c = \lim_{g \to 0} \frac{m.c^2}{g}.(1-g)$$
$$\lim_{g \to 0} E_c = \lim_{g \to 0} \frac{m.c^2}{g}$$

Let us introduce the Lorentz factor g within the classical formula of kinetic energy for a mass m moving at the speed of β. This leads to:

$$E_c = \frac{1}{2}.\frac{m}{g}.v^2$$

More over:

$$g = \sqrt{1-(\frac{v}{c})^2}$$
$$v^2 = c^2.(1-g^2)$$

Equivalent to:

$$E_c = \frac{1}{2}.\frac{m.c^2}{g}.(1-g^2)$$

This leads when $g \to 0$ to:

$$\lim_{v \to c} E_c = \lim_{g \to 0} E_c = \lim_{g \to 0} \frac{1}{2}.\frac{m.c^2}{g}.(1-g^2)$$
$$\lim_{g \to 0} E_c = \lim_{g \to 0} \frac{m.c^2}{2.g}$$

For relativisitc speeds, we can point out a difference of the kinetic formula between the classical but revisited expression and the one in a relativistic context. This difference turns around a factor of: $\frac{1}{2}$

For non-relativistic speeds, that is when $\frac{v}{c} \to 0$ and $g \to 1$, we have:

According to the relativistic expression:

$$\lim_{v \to 0} E_c = \lim_{g \to 1} E_c = \lim_{g \to 1} \frac{m.c^2}{g}.(1-g)$$
$$\lim_{v \to 0} E_c = 0$$

According to the classical expression:

$$\lim_{v \to 0} E_c = \lim_{v \to 0} \frac{1}{2}.m.v^2$$
$$\lim_{v \to 0} E_c = 0$$

Proposition of Gabriel Lafrénière

In a surge of intuition, Gabriel Lafrénière proposes a renewed version for the kinetic energy formula, by integrating the speed of a moving mass a more subtle way.

The idea is to notice that the Lorentz factor ranges from 0 to 1. It is then possible to relate the factor of $\frac{1}{2}$ with the Lorentz factor by using the following expression:

$$E_c = \frac{m.v^2}{g}.\frac{1}{1+g}$$

Considering this new kinetic formula, we can accommodate the classical and the relativistic expression of it. Indeed:

$$\lim_{v \to c} E_c = \lim_{g \to 0} \frac{m.v^2}{g}.\frac{1}{1+g}$$

$$\lim_{g \to 0} E_c = \lim_{g \to 0} \frac{m.c^2}{g}$$

For relativistic speeds, the global energy of a moving mass is mostly its kinetic energy. The classical but revisited formula for kinetic energy is then in concordance with the relativistic expression of it.

Note: For an elastic collision we can then establish the following equivalence between:

$$\frac{m_1.c^2}{g_1} + m_2.c^2 = m_1.c^2 + \frac{m_2.c^2}{g_2}$$

And:

$$\frac{m_1.v_1^2}{g_1.(1+g_1)} + m_1.c^2 + m_2.c^2 = m_1.c^2 + \frac{m_2.v_2^2}{g_2.(1+g_2)} + m_2.c^2$$

That is:

$$\frac{m_1.v_1^2}{g_1.(1+g_1)} = \frac{m_2.v_2^2}{g_2.(1+g_2)}$$

For non-relativistic speeds, our new expression of kinetic energy allows us to retrieve the classical one. Indeed:

$$\lim_{v \to 0} E_c = \lim_{g \to 1} \frac{m.v^2}{g}.\frac{1}{1+g}$$

$$\lim_{v \to 0} E_c = \frac{1}{2}.m.v^2$$

The expression of the kinetic energy in classical mechanics may be considered as a simplified expression when the relativistic effects can be neglected.

Appendix B

The relativistic Doppler Effect with a moving emitter and receiver

In this annex, we will make a short study of the relativistic Doppler Effect when the emitter is moving away and the receiver is moving in the same direction than the emitter. This example brings us closer to the experimental conditions for a study of the cosmic Redshift.

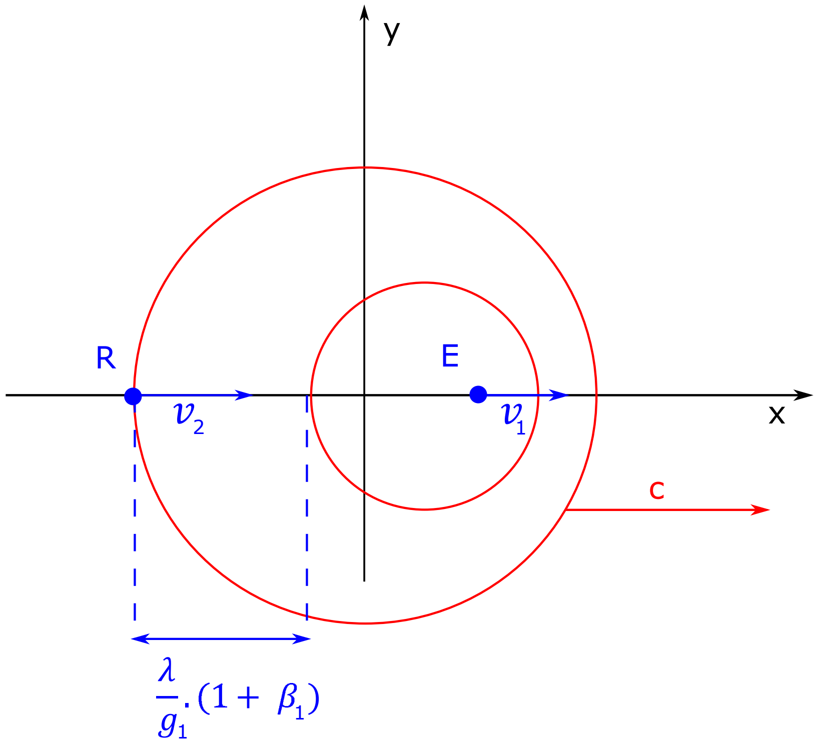

Figure 1.46: The emitter and the receiver are moving, the emitted wave is light or any electromagnetic wave

Let us call β_1 the speed ratio of the emitter, β_2 the speed ratio of the receiver, λ the wavelength of the emitter

If we consider the absolute Doppler Effect for the emitter, its movement at the speed of β_1 implies a backward wave with the following wavelength:

$$\lambda_{ar} = \frac{\lambda}{g_1}.(1+\beta_1)$$

If we consider the relative Doppler Effect for the receiver, we have to take into account the two following aspects linked with its speed:

- The speed β_2 of the receiver
- The modification of its equivalent receiving frequency from f_r to $g_2.f_r$ for any frequency, in other words for its equivalent receiving wavelength from λ_r to λ_r/g_2

This leads to the following equation for the wavelength like it is perceived by the receiver:

$$\frac{\lambda_r}{g_2} = \frac{\lambda}{g_1}.\frac{1+\beta_1}{1+\beta_2}$$

$$\lambda_r = \frac{g_2}{g_1}.\lambda.\frac{1+\beta_1}{1+\beta_2}$$

$$\lambda_r = \lambda.\frac{\sqrt{(1-\beta_2).(1+\beta_2)}}{\sqrt{(1-\beta_1).(1+\beta_1)}}.\frac{\sqrt{(1+\beta_1)^2}}{\sqrt{(1+\beta_2)^2}}$$

$$\lambda_r = \lambda.\sqrt{\frac{(1-\beta_2).(1+\beta_1)}{(1-\beta_1).(1+\beta_2)}}$$

By using the same method, we will establish that :

- When the emitter is moving away and the receiver is moving in the opposite direction (mutual distancing):

$$\lambda_r = \lambda.\sqrt{\frac{(1+\beta_2).(1+\beta_1)}{(1-\beta_1).(1-\beta_2)}}$$

- When the emitter is approaching and the receiver is moving in the same direction:

$$\lambda_r = \lambda.\sqrt{\frac{(1+\beta_2).(1-\beta_1)}{(1+\beta_1).(1-\beta_2)}}$$

- When the emitter is approaching and the receiver is moving in the opposite direction (mutual approaching):

$$\lambda_r = \lambda.\sqrt{\frac{(1-\beta_2).(1-\beta_1)}{(1+\beta_1).(1+\beta_2)}}$$

Appendix C

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Appendix D

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