# FROM ARISTOTELE TO EINSTEIN
## THE LONG JOURNEY OF PHYSICS
## FROM GEOCENTRIC SYSTEM TO RELATIVITY

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A quick journey through the history of Physics, from Aristotle to Copernicus, Galileo, and Newton, continuing to the modern physics of Lorentz and Einstein; which brings us from the absolute motion of the geocentric system to the relative motion of Galileo, to continue to the phenomena that occur when the speed of objects approaches that of light, described by the modern theory of relativity.



-- This work may contain grammatical errors. We apologize to our readers. --

Modern physics begins its history in the last years of the sixteenth century with studies, experiments and written works of Galileo.
In the following three centuries science finally had a great development discovering innumerable laws, considered, then, perfect and immutable. But between the end of the nineteenth century and the early years of twentieth century, with the studies of Fitzgerald, Lorentz, Poincaré, Einstein and others, it turned out that the laws of classical physics are not applicable to systems including speeds that are not negligible compared to the speed of light . In 1905 Einstein exposed the theory of Special Relativity which deals with inertial reference systems, i.e. in uniform rectilinear motion. A further step forward came in 1916, again thanks to Einstein, with the theory of General Relativity which also includes accelerated reference systems and the curvature of space due to the masses of the bodies.
Before seeing these themes, it is necessary to consider, even in a very concise manner, the historical evolution of the concepts of physics before Galileo.

Aristotle (384-322 BC), still popular in the Middle Ages and defined by Dante - master of those who know - claimed that in order to obtain uniform rectilinear motion it was necessary to apply a constant force to an object (of course, we know this is wrong) . Since the state of quiet exists only without external forces, for the Aristotelians there was this important difference between state of quiet and uniform rectilinear motion.

Moreover the motion was essentially absolute. In fact, it was supposed that the Earth, motionless, was precisely the center of the universe and all the motions had to be referred to it. This description of the universe is called geocentric and is consistent with the Bible.
Aristarchus of Samos (310 - 230 BC) proposed the heliocentric system, with the Sun in the center and all the planets, including Earth, revolving around it, which, however, was immediately rejected by the powerful of the time precisely because it denied the centrality of the Earth.
Ptolemy (100 - 175 AD) in the second century AC completed the description of the geocentric system. His work came to Europe through the Arabic translation under the name of Almagest and remained in use up to four centuries ago.
From the time of Aristotle, in fact, about 19 centuries took humanity to get out of these misunderstandings, drawn from philosophical deductions, supported by religious power as dogmas and based only on the appearance of events.
In the 1530 Copernicus wrote the - Comentariolus - a short work in which he again exposed the heliocentric system, supported by new astronomical observations and mathematical calculations.
The reaction to his work did not wait because it contradicted the Holy Scriptures, and Martin Luther's lightning arrived immediately; while the Catholics did not oppose it at the time. And Copernicus, who was a Polish Catholic ecclesiastical, was able to continue his research in his astronomical observatory. In 1543, a few days before his death, he agreed to print his book "De revolutionibus orbium coelestium" , in which he described the heliocentric system more widely.
Giordano Bruno supported the Copernican system and deduced that the universe is infinite and there is no center in it. He also added that there are infinite worlds populated and animated by the infinite love of God. He was condemned to the stake in 1600.
In the previous dark centuries even other people, remained unknown, very likely tried to propose the heliocentric system of Aristarchus, but they were not listened to, or they too were "reduced to silence".
Against the geocentric system, in addition to the apparent motion of the Sun around the Earth, there was also the question of - stellar parallax - that is, the variation of the angle of observation of a star after a time of six months, when the Earth occupies on its orbit a position diametrically opposed to the previous one. At the time of Copernicus and Galileo it was not yet known that the distance between the Earth and the stars, even the nearest ones, is very great compared to the diameter of the Earth's orbit, and the parallax of the nearest star, the Proxima Centauri, is only 0.75 seconds of arc, an angle so small that it was absolutely impossible to evaluate with the instruments of those times. Only in the nineteenth century it was possible to measure it for the first time.
However the supporters of the heliocentric system went on their way and in 1609 Kepler, studying the data of the observations of Tico Brahe, succeeded in establishing that the orbits of the planets are slightly elliptical, and not perfectly circular, as was believed before then.

Previously, in 1593, Galileo finally succeeded in correcting the error of Aristotle and exposing the law of inertia, which states: an object moves with uniform rectilinear motion when no external forces act upon it, or when their sum is equal to zero.
This, actually, is the very clear and concise expression written by Newton more than half a century later. However, this fundamental principle was discovered by Galileo and a few years later it was exposed, with a longer version, also by Descartes, and later by Newton.
Galileo also discovered that the uniform rectilinear motion of a system of objects, or of a laboratory, has no effect on the mechanical processes that take place in it. Now we know that it does have effects on all the other processes: chemical, optical, electromagnetic, thermal, etc. For this aspect all the reference systems in a still state or in uniform rectilinear motion are equivalent. These systems are called inertial or Galilean, precisely in honor of their discoverer.

In addition to this, Galileo's overall work is very important: he invented and disseminated the method of rational scientific reasoning, bringing science to a completely new approach to nature, based on the results of experiments and observations, and completed with mathematical applications. Whereas before, science, which was substantially that of Aristotle, was set on philosophical deductions and attributed to objects and substances strange qualities, including those of nobility. For example, before Galileo's intervention, Copernicus writes that the Sun is at the center because it is a resplendent gentleman. While Newton, after Galileo, writes that the Sun is at the center because it has a mass much greater than the planets. It must also be said that at the time of Galileo, instruments for measuring lengths, weights and time were already available, which there were not, especially the clocks, in previous centuries. Galileo was also the first to use the telescope in astronomy. With the improvements that himself made he managed to make the first discoveries, like the four main satellites of Jupiter, and other important observations. He was also a great popularizer and wrote many works, including one of the most famous scientific masterpieces of all time, the - Dialogue above the two greatest systems of the world - with which he forever demolished the theories of Aristotle and Ptolemy and contributed to the affirmation of the Copernican system.
For this reason in 1633 he was tried in Rome by the Holy Office and was forced to solemnly abjure the heliocentric theory. So he managed to avoid the stake and was sentenced "only" to life imprisonment. The sentence was immediately commuted into perpetual isolation, first in Rome, then in Siena, and finally in his house in Arcetri, where he died in 1642.
But his thought was already widespread in Europe and with the new method of study and the principle of inertia, classical mechanics was born.
The new road opened by Galileo was soon followed by other great ones, Newton first of all. The new method was also extended to other fields of science and began an incessant series of discoveries in all scientific disciplines.

We return briefly to Aristotle and to the incorrect concept of uniform rectilinear motion obtained by an external force. It is evident that the error is particularly ingenuous because it was enough to consider an arrow thrown from a bow to immediately understand that an external force, in reality, accelerates the object. Newton, in fact, exposed the famous equation $\mathbf{F = m{\cdot}a}$
which clearly expresses this property of the forces.

He also discovered the law of gravity : $\mathbf{F = GM'M"/ R^2}$

This equation is very important and very useful because it allows us to interpret the motion of the planets around the Sun and to perform other astronomical calculations. But it must be emphasized that it is not the physical explanation of the force of gravity; because the equation expresses only what happens, and not why it happens. Newton, in fact, at first told: - I do not pretend hypothesis on the physical nature of force -. He also wrote in the Mathematical Principles that it is absolutely wrong to attribute to the masses the property of exerting forces at a distance on other masses, without any medium interposed, as some philosophers of the time claimed.
And some time later, in the Quaestiones of Optics (Query 21) he argued that the different density of the medium (ether) surrounding the masses is the physical cause of gravity.

With the fall of the hypothesis of immobility and centrality of the Earth, the absolute or privileged reference system bound to it was missing, and the problem of the multiplicity of the velocities and the trajectories of the same body, relative to several references, was posed. For example, the motion of the Moon with respect to the Earth has a velocity and a trajectory, and with respect to the Sun another velocity and another trajectory, which are also true.
So it result the relative quality of the velocities and, directly, also the physical relativity of kinetic energy, since it is a function of the squared speed, according to the known formula :

$\mathbf{E = \frac{1}{2} mv^2}$ and therefore it depends on the observer.

Indeed it was already clear, even before Galileo, that a carriage running has a completely different energy effect if the observer is a passenger traveling above it, or if he is on the road.
Therefore every speed, trajectory and kinetic energy must not be imagined in an absolute sense, but only in a sense relative to the observer.
For the study of the motion of an object it is necessary to know the space-temporal relations between the object and that of reference, or between the object and the observer, also an abstract purely conceptual observer, however meaning that he is imaginatively equipped with all the necessary instruments to determine the position of the object.

For this purpose also a reference coordinate system is defined which is bound with the observer, and the position of the moving object is defined by three spatial coordinates. Then it is necessary to have a clock to connect the variation of position of the object with the passing of time and, at this point, the motion is completely determined in the space and time and it is possible to write its mathematical expression.

No longer having a central body considered firm, to define an absolute reference system then remained only the possibility of binding it to the universal ether, the motionless medium that was supposed to fill the whole space, and which in various forms was accepted by the major physicists of history: Newton, Faraday, Maxwell, Lorentz and Michelson included. However, despite many experiments, the main one was that of Michelson-Morley, we have not yet managed to define "the motion relative to the ether" or, simply, relative to the space, observing only what happens inside the laboratory.

The concept of space is very important and has been studied throughout all the history of human thought. But in the first decades of the twentieth century the space was identified, very hastily, with – nothingness – of vacuum. Later, however, it emerged that the space is a participant in physical events, and it is not a simple passive scenario. Therefore the argument is taken up later, when we will have exposed new elements, such as the gamma factor and the curvature of space.

Also about the Michelson-Morley experiment is written later, but it is good to anticipate that it is done by performing measurements only on what happens inside the laboratory, without looking outside, (as for the Galileo's conceptual experiments inside the famous ship's hold).

Since no effect of the speed of the Earth on those measurements was observed, it was established that, from this point of view, all the reference systems in uniform rectilinear motion are equivalent, precisely because the observer can perform all the possible experiments inside his own laboratory that he will not notice any effect of its speed.

Instead, if the observer also looks outside, and if he points his telescope on "fixed stars" or on the far away galaxies, then he can evaluate his state of motion according to two physical phenomena which are: the Doppler effect and the aberration of the light of the stars. In fact Lorentz continued to believe in the existence of an absolute reference system bound with space, established with external observations.

Recently also the observation of the background radiation highlights the observer's motion with respect to space, and reveals to us that the Earth moves at about 400 km per second. Which agrees with the estimated speed with the two previous phenomena.

For this reason, in our days it can be argued that the reference system with respect to which the background radiation is isotropic can be considered privileged above all others.

In this way all the paradoxes, or misunderstandings, including that of twins, are eliminated.

Also Feynman in Six Not-So-Easy Pieces specifies well that it is impossible to define the observer state of motion, just on the condition that he makes measurements only on what happens inside the laboratory, and not outside it.
In fact, due to the Doppler effect, the light of the stars is received with a frequency that depends precisely on the speed of the observer.
While the aberration of light affects the orientation angle of the telescope used to observe a star (not lying on the Earth's velocity direction) as a function of the speed of the Earth's observer.
And repeating the measures after six months, when the speed of the Earth relative to the Sun has reversed, the effects of the change in speed are immediately evident because the measured values are different from the previous ones.

It should be noted that all the movements considered straight and uniform that we consider, in reality, are only approximations of curved trajectories, albeit with a very large radius.
It is not difficult to see that a reference system bound to the Earth is not inertial. In fact, the Earth moves relative to the Sun according to an ellipse with small eccentricity, and it also has a rotation motion around its own axis.
However, for most physics problems, our natural reference system can be considered inertial with sufficient degree of precision. In fact, the annual rotation around the Sun takes place on a curve with an average radius of about 150 million kilometers and for short time intervals the translation can be approximated with a straight line.
And the rotation around the polar axis has a small angular velocity, about a round angle in the 24 hours.
This last movement is perceptible only for few phenomena: the Foucault pendulum, the deviation of atmospheric perturbations and sea currents, the prevailing erosion of one of the two banks of the rivers that move in a North-South direction.
While the revolution around the Sun highlights the non-inertial of Earth when we must study the motion of the other planets. For this purpose the Gea reference system is not suitable; the motion of the planets must be refer to the Helios reference system. In other words, it is evident that Copernicus is right and that Ptolemy is wrong.

Regarding the gravitational force acting on the celestial bodies, classical mechanics takes the hypothesis of the instantaneousness of gravitational actions, even if it is not expressly declared. But no action can be achieved without matter, or substance of a medium, or interaction of particles; therefore it can’t be instantaneous.
For modern physics the reciprocal action between distant objects, gravitational or electromagnetic, is schematized (but not explained) with a vector field and is transmitted from point to point with finite speed: the speed of light.
The concept of the field was introduced in the nineteenth century by Faraday with his research on electromagnetic forces, then it was extended to gravitational ones, and to electromagnetic waves by Maxwell and Hertz.
At that time the fields and the waves were intended as physical states of the ether,

then considered as a substance contained within space. But this concept of ether was wrong and led to evident contradictions, so it was abandoned. And as we have already said, twentieth-century physics has identified space with - nothingness of vacuum-.
But in this nothingness fields and waves were left, so they became abstract concepts devoid of any physical support, pure graphic-mathematical formalisms.
Many people are convinced that to explain the force of gravity it is sufficient to exclaim: - With the field! - And then draw two vectors on a piece of paper.
But it is not so, because must be defined what physically is the field in space, and how it physically interacts with matter.
But since space is still identified with nothingness of the vacuum, as in the twentieth century, then it is impossible to find answers in the nothingness. Therefore, in order to really explain the physical reasons of gravity, the current concept of space must be reviewed.
In this direction, an important step forward was made by Einstein in 1916, proposing the curvature of space with the theory of General Relativity, as we will see later.

Regarding the time we have to consider if the observer receives instantly the information of an event, or with a certain distance-dependent delay. That is to say if we can evaluate the speed of light as - tending to infinity - or not.
Galileo tried to measure the speed of light, but not being equipped with adequate means, he concluded that his speed is infinite, or very big, meaning that it is millions of times greater than the speed of the bodies studied. With these hypotheses, the time that takes the image of an event to reach the observer is absolutely negligible (in mathematics we say: a $\Delta t$ tending to zero), if the distance between event and observer is not immense. As a result, two observers placed at different points will receive the image of the same event at the same time (almost). Then we can think of an absolute time, equal for all the points of the space in question and for all observers.
The speed of light is indicated by the letter c, initial of - celeritas - (speed in Latin), and we know that it is not infinite, but it is about 300000 km per second. And if we are studying motions with non-negligible velocities with respect to c, or with very large distances, then we can no longer use absolute time.
Let's think, for example, of an object that travels with a speed equal to 1/10 of c and an observer; when the object passes by a point P, which we place a kilometer away from the observer, he receive the information that it is at that point with a delay of 1/300000 of a second, during which the object has already traveled another hundred meters. So, at the moment that the observer believes that the object is in correspondence with point P, in reality it is already a hundred meters ahead.
If another observer is present in the system, with a distance different from the point P, he will receive the information that the object passes by the point P in an instant different from the previous one.
A similar fact occurs when the distances are very large. For example, if we look at the star Sirius, about eight light years away from Earth, we can think at this moment it is right where we see it, but it actually occupied that position eight years ago and

now it is a bit off. The same thing happens for other stars even more distant. Some of these have already collapsed and they no longer exist, but we continue to see them as they were alive, and the images of their collapse will come to Earth in many years. Therefore, if the distances or speeds are very big, then absolute time must be renounced.
It is also important to define what happens in the transition from one reference system to another. In mathematical terms this problem is called: coordinates transformation. We have to find the equations that bind the coordinates of a point in a reference system to the coordinates of the same point with respect to another reference system.
For objects that have a speed much lower than c and with not immense distances, Galileo's transformations are used, and this is the field of classical mechanics. Whereas Lorentz transformations must be used for objects that have not a negligible speed with respect to c; this is instead the field of modern theory of relativity.

**Galilean Inertial Systems**

As we have just said, they are the inertial reference systems where speeds are much smaller than the speed of light.
For example, we can establish that it must be $v < 0.001c$, or $v < 0.0001c$, or even smaller values. It depends on the degree of precision required for the phenomenon studied, because with the v/c ratio the - gamma factor - varies, which we'll see in the next paragraph; and in the conditions written above we can assume it is equal to unity.

Given two observers in constant reciprocal motion, we define two coordinate systems K and K ', consisting of two tern of orthogonal axes, bound with the two observers. For more clarity, let us further assume that the two axes x and x 'are oriented along the direction of the relative motion of the system K' with respect to the system K, which occurs with velocity v. The same point P, in the system K' has the coordinates (x', y ', z') ; and in the system K has coordinates (x, y, z). Let's say t = 0 the instant in which the two tern coincide.
The equations of transformation of the coordinates between the two systems are called Galileo transforms:

$$x' = x - v \cdot t\,, \qquad y' = y, \qquad z' = z\,.$$

For Galilean systems, time is identical in all reference systems, in other words the rhythm of clocks does not depend on their speed. Moreover, events are perceived instantaneously in all points of the space examined by both observers, therefore the existence of an absolute time **t = t'** is admitted.
Another fundamental hypothesis is that the length of the unit of measurement, that is the rule with which all lengths are measured, does not vary with the state of motion, i.e. : **L = L'** (we will see later that these last hypotheses are not always true, even

though it may seem unintuitive).
As we have already said, it results that the velocities of the bodies, their trajectories and the kinetic energies are relative to the chosen reference system. However, in Galilean systems other quantity do not change: masses, forces, accelerations, potential energy, are absolutely identical in all inertial reference systems. They are called invariants with respect to the transformation of Galileo, and very important, even the laws of physics do not depend on the choice of the reference system.

**Inertial Systems with non-negligible velocity compared to c, Lorentz transformations**

We have just seen that when the speed of the objects is negligible compared to c, it is assumed that the mass, lengths and rhythm of the clocks do not change with the speed. With the rhythm of the clocks we mean any periodic movement that can be used to measure time, from the pendulum to the oscillations of the atoms.
These hypotheses were considered evident and true until the end of the nineteenth century, and many people are convinced that they are still valid today, but they represent only the appearance of physical reality.
After the Michelson-Morley experiment, it was suggested for the first time that the lengths do not remain unchanged when the speeds are not too small compared to c. Later it was shown that with these conditions the following phenomena happens:

a) the clock in motion with speed v has a slower rhythm than the clock in stillness:

(1) $\mathbf{\Delta t' = \Delta t / \sqrt{1 - \beta^2}}$ with $\mathbf{\beta = v / c}$

This fact is called dilatation of time.

b) the length of a segment parallel to the direction of motion is contracted:

(2) $\mathbf{L = L_o \cdot \sqrt{1 - \beta^2}}$ with **Lo** length of the segment at low speed or stationary.

This phenomenon is called: contraction of the moving rules.

c) the mass of a moving body increases with the speed:

(3) $\mathbf{m = m_0 / \sqrt{1 - \beta^2}}$

here m is called relativistic mass, and $m_0$ is the mass at rest, that is, the mass of the stationary object with respect to the observer.
Instead, the electric charge remains constant and independent from v.

In the three equations we immediately notice the presence of the same square root.

Then we define: $\gamma = 1 / \sqrt{1 - \beta^2}$ , this term is called **gamma factor**, or Lorentz factor, and it is indicated with the Greek letter gamma ɣ, and it is of fundamental importance for the Theory of Relativity, so much so that we will meet it several times in every texts of Relativity.
Equation (3) is often expressed with the gamma factor in this way:

(3bis) $\mathbf{m = \gamma \cdot mo}$

Equations 1, 2, 3 are called Lorentz, although the second is of the Irish Fitzgerald. From the three formulas, and more evident from (3), it turns out that particles can't reach the speed of light, because the root in the denominator would tend to zero and the mass m to infinity.
With regard to equations (3) and (3bis) must be said that some texts don't use them from several years. But they use the following:

for the momentum: (4) $\mathbf{q = \gamma mv}$ and for the energy: (5) $\mathbf{E = \gamma mc^2}$

in which the product **ɣm** always appears, as in (3bis).
In the equations 4 and 5 with m the resting mass is indicated.
For these systems the gamma factor becomes greater than 1 and it can also reach very high values. Therefore it is necessarily to renounce the transformations of Galileo and to use the **Lorentz Transformations**:

**(6)** $x' = (x - v \cdot t) \cdot \gamma$; **(7)** $y' = y$; **(8)** $z' = z$; **(9)** $t' = (t - v \cdot x / c^2) \cdot \gamma$

The last equation (9) shows that the time t ', assigned to an event by the observer O', depends on the time t and on the coordinate x measured by the observer O.
So, when speed is not negligible with respect to c, space and time are no longer separate concepts, but are closely interconnected to each other, so we must use the word space-time.
While for the Galilean systems, with $v \ll c$, we have t '= t, both independent of the spatial coordinates. Then we can still use the word space.

In the early twentieth century many physicists remained skeptical in front of the three Lorentz equations and, for a long time, the world of science split between those who believed in them and those who judged these facts as apparent or wrong. This until their experimental verification.
The first experimental confirmations arrived with particle accelerators in the first decade of the twentieth century for the formula (3) and later also the first two were confirmed, so that since many years these events are recognized as real by all the

physicists of world.  For example, time dilation is verified with clocks located on GPS satellites.
So the observer in motion with velocity v not negligible compared to c, towards the observer in stillness, has a clock with a slower rhythm, a greater mass and a meter that is contracted if it is oriented in the direction of motion, while the its length remains unchanged if it is arranged perpendicular to the speed.
The determination of the speeds can be made with respect to the fixed stars, or to the other galaxies, with the already said methods of the Doppler effect and of the aberration of the light of the stars, or with respect to the background radiation. Or, more simply, we can choose a reference system bound to the Earth.
Of course these variations are appreciable only for very high speeds, because the gamma factor contained in the formulas becomes significantly different from the unit only for values of v of the order of hundreds or thousands of kilometers per second, and certainly not for the speeds that we reach with the our means of transport, including airplanes.
Of the three phenomena, what seems most "inexplicable" is certainly the increase in mass with speed, which is expressed by the product **$\gamma \cdot m_o$** in equations 3) and 3bis), or by da **$\gamma \cdot m$** in equations 4) and 5) of texts that do not use relativistic mass. But it is necessary to acknowledge that it has been confirmed by more than a century of tests in all the particle accelerators of the world, therefore it is indisputable.
And it's easy to check for circular accelerators, like the LHC in Geneva.
It is sufficient to calculate, starting from equation 4), the centripetal force that must act on the particle to force it into uniform circular motion, which obviously is proportional to its mass.

We have **$F = dq/dt$** with **$q = \gamma mv$** and the result is : **$F = \gamma mv^2 / R$**

The last equation clearly indicates that the particle in motion with velocity v has the mass equal to **$\gamma m$**. While its mass at rest, or at low speeds, is **m**.

In addition to this, the increase in mass with speed is also confirmed by the examination of collisions of protons, both elastic and inelastic. So whether we like it, or not, we have to realize that the mass increase really happens.
But it can’t be interpreted with the current concepts of space and particle, because a particle that moves in the space considered empty, with nothingness around, it can’t increase the mass.
Then, as with gravity, we have a further proof that we need to review these two concepts: space and particle; just as Einstein tried to do after General Relativity, and as it is written on page 14.

Although all these facts may seem unintuitive, it is only from the point of view of the prejudices in considering as absolute truth the representations of classical physics, arising from our human perception limited to very small speeds. And we have already seen that we must not trust appearances. Indeed, the Earth was considered stationary until the intervention of Copernicus and Galileo, while in reality it travels, with all of us above, at 30 km per second around the Sun, and at about 100 km /s compared to the "fixed stars" together to the whole solar system which, in turn, follows the rotation and translation of the Milky Way. And the overall speed of the Earth, resulting from all these motions, is about 400 km /s.

**Short description of the Michelson-Morley experiment**

The experiment was carried out in 1887, and was conducted by the famous scientist Michelson with the technical help of Morley. Then space was still identified with ether by most scientists, Michelson included, and the aim was to highlight the effects of Earth's motion through the ether. But the outcome was negative.
A careful examination of the experiment allowed the Irishman Fitzgerald to propose equation 2), concerning the contraction of lengths with speed, to explain its failure. Immediately after the Dutchman Lorentz, in an independent way, presented that equation supporting it also with a precise physical explanation. But then, last years of the nineteenth century, it was considered a hypothesis of convenience, not credible. And the speculation about the negative outcome of the experiment continued without taking it into account. And this was the main reason that caused the identification of space with nothingness of vacuum, which occurred in the first decades of the twentieth century.
Very briefly, the experiment consisted of measurements of interference between two rays of light performed with an interferometer composed of two orthogonal arms, which was oriented in various ways on a horizontal plane.

And equation (2) : $L = Lo \sqrt{(1 - \beta^2)}$ clearly indicates that the length of the interferometer arm parallel to the speed of the Earth (which is not completely negligible with respect to c) undergoes a contraction, while for the other arm , which is orthogonal to speed, this does not happen.
And it is for this reason that the outcome of the experiment was negative, in the sense that the figures of interference of the two rays did not change by varying the orientation of the interferometer. But at that time, as we have said, the contraction of Fitzgerald - Lorentz was not accepted because these phenomena had not verified yet.
Over the years, many other scientists have re-proposed this explanation, including Eddington. Even Feynman in Six Not-So-Easy Pieces exposes a very clear description of the experiment in which he considers this contraction, which is currently accepted by all the physicists of the world. In fact, equation (2) has been present for many years on all physics texts.
Therefore, in the following decades, when it became evident that the contraction is absolutely true and real, it would have been necessary to completely reconsider the conclusions that followed the experiment. But this has not been done, except in a marginal way and only in recent times.

**From classical Physics to modern Physics**

The three phenomena expressed by the equations 1), 2), 3) of Lorentz, together with Planck's quantum hypothesis, have determined a real revolution in the science, which took place at the beginning of twentieth century. So that Physics made a real transition from classical physics to that modern.
Moreover, in the following years it was found that each particle has both corpuscular and undulatory properties, whereas before it was considered a simple corpuscle.
If we also consider the law of mutual connection between energy and mass, expressed by the famous equation **$E = m \cdot c^2$**, and the link between the particle and the field that surrounds it, then we must conclude that the very nature of the particles, of the field, matter and energy, in reality they belong to an immensely larger picture of the reductive and simplistic representation linked to our current knowledge that identify the space with the nothingness of the vacuum and the particles as foreign bodies in it.
And even the smallest particles: electrons, quarks, neutrinos, etc., with all their different physical properties, they prove to be complex and inexhaustible objects.
So we have not reasons to be incredulous in front of the three Lorentz formulas.
And we have already witnessed the Copernican revolution and that of Galileo, which caused the definitive abandonment of the physical theories of Aristotle and opened the way for Newton and the other great ones.
It remains clear that, unlike the systems of Ptolemy and Aristotle, classical Physics has not set. It remains valid for systems in which the speed of objects is much smaller than c; in fact, under these conditions in the Lorentz equations the gamma factor tends to one, and we return to have:

**$t' = t$ $\quad$ $L = L$ $\quad$ $m = mo$**

that is, absolute time, constant lengths and mass, as for Newton's Physics.

And finally we get to the intervention of Einstein.

**Theory of Special Relativity**

In 1905 Einstein expounded the theory of Special Relativity that studies inertial reference systems, in uniform rectilinear motion, within which, however, accelerated motions of objects can occur.
A fundamental contribution to this work, even if not officially recognized, came from his first wife, Mileva Maric, a very good mathematics, who in return was mistreated and marginalized by her husband.
At the basis of the theory there are two principles:
a) all the laws of physics are identical in all inertial reference systems.
b) the speed of light is independent of the source and observer motion.

The first principle is an extension of what Galileo said in the seventeenth century, and means that the constant speed of the system, in which the tests are carried out, has no effect on the performance of any test and on any measure made on what happens inside the system (without looking outside the system) as already written.

The second principle derives directly from the dilatation of time and from the contraction of the moving rules, expressed by the equations 1) and 2) of Lorentz, and had already been proposed by Poincaré.

On some popular books, and in some television broadcasts, the theory of relativity is often presented without mentioning the gamma factor and Lorentz equations. While they are indispensable for a valid understanding.
In fact, it is evident that they are at the base of this theory, both from the physical point of view and from the mathematical one. On the other hand, the theory itself in its entirety is a further confirmation of their validity, which is added to the experimental verifications.
It must also be clear that the representations of the theory of relativity are not an absolute truth. They, like classical mechanics, express an approximate truth, but with a degree of approximation better than that expressed by classical mechanics.

Einstein, with the help of his wife Mileva Maric, starting from the Lorentz formulas exposed the transformations of the velocities for the systems that have v not negligible compared to c, and the famous formula $\mathbf{E = m \cdot c^2}$ which states that energy corresponds to mass and, reciprocally, mass corresponds to energy; and it is fundamental for nuclear reactions. (In this last equation with m we indicate the relativistic mass, expressed by equation n°3).

## Theory of General Relativity

The theory of General Relativity (GR) deals with non-inertial, i.e. accelerated, reference system, and gravitation. It was presented by Einstein in November 1915 and was published a few months later.
Gravitation is proposed as a physical property of space: due to the presence of a very large mass, for example a planet or a star, space curves in a very perceptible way, and this have effects on other objects. Even objects with a small mass produce a small curvature of space, but usually their reciprocal effects are negligible.

As we have already written, with this theory space proves to have physical properties that make it also capable of interacting with matter, and which can’t be attributed to vacuum understood as nothingness. Because "nothingness of vacuum" (but it does not exist at all) can’t be inflected, or more generally, it can’t change state. In fact we can’t have nothingness that change with time. And nothingness of vacuum

can’t interact with matter.
Einstein, then, proposed to return to the ether, which he abandoned, but not completely rejected, in 1905. And after 1916 he presented a new model of ether which identify it with - physical space and its physical properties - as already proposed by P. Drude and M. Abraham towards the end of the nineteenth century.

Einstein added the important idea that particles are effects of energy in physical space, and no longer foreign objects. And this new concept is of fundamental importance, because it allows us to explain the movement of particles and objects in the space without the obstacle of the "wind of ether", but also to interpret the increase in mass with the speed expressed by equations 3) and 4).
This is well documented, with the acts of the same Einstein, in the book - Einstein and the ether - author L. Kostro. And from other quotations of Einstein, contained in the file: - The New Ether of Einstein - which can be found with Google. Because of this he was accused by some colleagues of constantly contradicting himself.
But the fact of questioning his own opinions of previous years and of admitting own mistakes (on such difficult subjects) can be understood, instead, as an act of coherence with the search of truth and of great intellectual honesty.

The physical space with its physical properties should have replaced the space as the nothingness of the vacuum, giving again a physical sense to the fields and to the waves, but it was not welcome by science and was soon forgotten, or even - tacitly censored -, so much so that even today it is not presented in university texts, and few people know this subject. On the contrary, Einstein is described as the main "breaker" of the ether. But in reality he was only opposed to the old models of ether understood as a substance contained within space, and not to physical space with physical properties.
It should be noted that, also before 1905, it was sufficient to consider Maxwell's equations of electromagnetic fields, to immediately see that they also attribute to the "empty" space physical properties, such as the presence of the electromagnetic fields **H** and **E**, the inductions **B** and **D**, the displacement current and the constants $\mu_o$ and $\varepsilon_o$.
Also the speed of light is clearly a physical property of space, being:

$$c = 1 / \sqrt{\mu_o \cdot \varepsilon_o}$$ in the SI (International System)

Maxwell, in fact, was a very strong proponent of the ether, even though he lived in an era in which the supporters of the nothingness were already active.
Einstein, of course, knew the Maxwell equations, but he did not accept the ether model as a substance distinct from space and contained within space, as was the Luminiferous Ether of Maxwell and all previous models.
Moreover, it is also useful to add that modern theories of the Standard Model and of the Higgs field are oriented towards a model of space, or space-time, which has

physical properties, and no longer towards space understood as nothingness of vacuum.

With regard to accelerated reference systems, Einstein postulated the following **- Principle of Equivalence -** (PE) which states: in a closed laboratory the effects of an external gravitational field are equivalent to the effects due to an acceleration of the laboratory.
To explain this principle the example of the missile in space is exposed, very far from any star or planet, which is accelerated by rocket thrust. A person inside, feels a force exerted by the floor on his feet, just as happens when his body is subject to gravity due to the proximity of a planet.
Obviously, if the observer can look outside the laboratory, he immediately can see if there is, or there is not, the near planet that causes gravitational force; and he can also evaluate his own motion. Therefore also the PE is valid only for internal observations.
But the equivalence between gravitation and force due to the acceleration impressed on the laboratory, can already be obtained by reasoning of Classical Physics. So the innovative part of the GR is undoubtedly the curvature of space.
Its main confirmations came from the study of the advancement of the perihelion of Mercury and the curvature of the light rays coming from the stars due to the gravity of the Sun. And recently also from the observation of the effects of gravitational waves, which are oscillations of the curvature of the space that propagate at the speed of light.

Many people are surprised that Einstein did not receive the Nobel Prize for relativity theory, but only a few years later for demonstrating the existence of "quanta of light", later called photons. Although it is known that Newton already supported the corpuscular aspect of light, but with the means of his time he couldn’t prove its existence.
But we know that the original contributions of the relativity of motions are from Galileo regarding classical relativity, and for the modern part, of Fitzgerald, Lorentz, Poincaré and Mileva Maric.
Einstein has completed this theory, and has integrated it with General Relativity.
He also have proposed the most fantastic and most famous equation in the history of science: $\mathbf{E = m \cdot c^2}$ (with relativistic mass m).
At least Einstein is credited with having demonstrated and disseminated it in 1905, because, even in this case, it seems that it is not really his paternity, but of someone else, and precisely the Italian Olindo De Pretto who presented an article containing the equation to the Royal Veneto Institute of Sciences, Letters and Arts of Schio on November 1903, and which was published on February 2, 1904.
It must be added, unfortunately, that equation also indicated the way for the construction of the terrifying atomic bombs launched on the cities of Hiroshima and Nagasaki, by the Americans.

And to recommend the construction of those bombs, with a famous letter to the president of the United States, was also Einstein himself.

**Many Thanks for the reading.**

Main authors of reference:
A. Deana, Cavedon, Feynman, Kostro, G.I. Naan, N.F. Ovcinnikov.