Physics of Aberration rather than Special Relativity

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Abstract  A phenomenological explanation is presented for the physics of aberration, which is in contrast with special relativity physics. The effect of relativity is identified with an effect due to the velocity of observation being affected by the velocity of a moving particle. In contrast with the currently accepted view, it is demonstrated that the classical concepts of time and simultaneity are natural for describing relativistic phenomena.

Keywords  Ether drift, Twin paradox, Time dilation, Superluminal motion, Aberration of starlight, Aberration of field, Liénard-Wiechert potential, Magnetic frequency.

1 Introduction

Einstein’s theory of special relativity has become a commonplace in modern physics, as taken for granted as Newton’s law of classical mechanics or the Maxwell equations of electromagnetism. However, it was resisted for many years because of the second postulate on which the theory is based. The second postulate, which states that the speed of light is independent of the motion of its source, destroys the concept of time as a universal variable independent of the spatial coordinates. It forces on us a radical rethinking of our ideas about time and space. Many attempts were made to invent theories that would explain all the observed facts without this assumption. Our changed concept of time is the result of its gradual establishment through experiments in violent controversy.

This work is another such attempt. In contrast with previous works, I tried to pick out an essential physical point in the relativistic formalism. Attention was focused on the Lorentz condition which led to the formulation of special relativity. In this attempt, I have come to see a physics behind the aberration of starlight. In this paper, I present a phenomenological explanation for the physics of aberration. This is in contrast with the relativistic explanation of special relativity physics. It begins by reasoning a physical origin of relativistic phenomena, leading to the relativistic form of equations on the basis of classical physics. There is no need to make an assumption.

We need to rethink some of the established thought and review the understanding of special relativity physics.

2 Ether drift

The Michelson-Morley experiment was undertaken to investigate the possible existence of an ether drift [1]. In principle, it consisted merely of observing whether there was any shift of the fringes in the Michelson interferometer when the instrument was turned through an angle of 90°. Observations showed that the shift is at most but a small fraction of the predicted value. The negative result was explained as demonstrating the absence of the ether drift. However, it could have been due to the experiment itself being incapable of demonstrating the ether drift.

Fizeau performed an experiment to determine whether the speed of light in a material medium is affected by motion of the medium relative to the source and observer. The experiment is much in the same way as the Rayleigh refractometer except the tubes containing water flowing rapidly between the source and observer. An alteration of the speed of light was observed in the Fizeau experiment, which was in reasonable agreement with the value given by Fresnel’s dragging formula. In the Michelson-Morley experiment, it is assumed that the ether is in uniform motion through the source and observer. As viewed from the Fizeau experiment, the ether drift cannot be assumed in this arrangement. The circumstances are the same as for the Earth, whose motion cannot be defined without an extraterrestrial reference. Even if the Michelson-Morley experiment is performed in water flowing rapidly in one direction, the null result is expected since the velocity of the water flow cannot be defined in this arrangement.

This is in contrast with the relativistic formalism which led to the formulation of special relativity. In this attempt, I have come to see a physics behind the aberration of starlight. In this paper, I present a phenomenological explanation for the physics of aberration. This is in contrast with the relativistic explanation of special relativity physics. It begins by reasoning a physical origin of relativistic phenomena, leading to the relativistic form of equations on the basis of classical physics. There is no need to make an assumption.

In the case of sound under the same circumstances, no change of pitch is to be expected as remarked by Rayleigh about Doppler’s principle [2].

We should mention the Michelson-Morley experiment performed with an extraterrestrial light source. Apparently, the motion of the light source relative to the half-silvered mirror is ineffective in changing the interference pattern. As shown in the Michelson interferometer, only the motion of the half-silvered mirror relative to one of the other two mirrors can give rise to an effect on the
interference fringes. It is clear that the point of splitting into two beams plays the role of an effective source in that interferometer. The experiment using sunlight differs from the original only by taste rather than coverage.

3 Twin paradox

Lorentz obtained transformation equations by using a covariant condition which preserves the speed of light in all uniformly moving systems. Einstein showed that the transformation equations with the covariant condition require revision of the usual concepts of time and simultaneity, leading to the result that a moving clock runs more slowly than a stationary clock. Such a concept of time gives rise to the twin paradox, however. In mechanics, it is impossible by means of any physical measurements to label a coordinate system as intrinsically “stationary” or “uniformly moving”; one can only infer that the two systems are moving relative to each other. According to this fundamental postulate, like velocity and distance, time must also be symmetric with respect to the two systems. This is what the twin paradox points out.

We consider the experiments performed to verify the phenomenon of time dilation. The mean lifetime of \( \pi \)-mesons was determined using the decay of \( \pi \)-mesons at rest in a scintillator [3]. In this method, the mean lifetime of \( \pi \)-mesons was determined by a direct measurement of the time required to decay. In order to investigate the phenomenon of time dilation, an attempt to measure the mean lifetime of a rapidly moving \( \pi \)-meson beam was undertaken [4]. An experiment of this nature was arranged to measure the attenuation in flight of a \( \pi \)-meson beam of known lifetime using a scintillation counter telescope of a variable length. The measured mean free path was divided by the mean velocity to get the mean lifetime. The mean lifetime thus obtained, when the Lorentz time dilation was taken into account, was in fair agreement with the data measured in the rest system of \( \pi \)-mesons. It is generally recognized that these experiments have verified the phenomenon of time dilation.

However, those experiments have an ambiguous bearing on the phenomenon of time dilation. In the latter experiment, the relativistic correction was made directly in the mean lifetime, keeping the particle velocity intact. This is otherwise without example in high-energy physics, where the relativistic correction has been made in the form of four-vector velocity.

The four-vector velocity is conceived in the context of time and space, leading to the formulation of special relativity. The space components are defined as the rate of change of the path of a particle with respect to its proper time, the time component being defined as that of a light. Such a definition is a result of confusion, however, unless by intention. The four-vector velocity cannot be defined by the Lorentz time dilation; they are alternative conceptually. In fact, in that definition has the path dilation been disregarded. The mean free path measured in the experiment is not the distance of its proper lifetime but that multiplied by the \( \gamma \) factor. Once the Lorentz time dilation is taken into account, there is no room for the four-vector velocity formulation. This is what we observe. Either the time dilation or the four-velocity can be consistent with the experimental result. From the experiment it is evident that the time dilation and the four-velocity are alternative. To see the definite result, the mean lifetime of a rapidly moving \( \pi \)-meson beam must be determined by direct measurement in experiment. The mean lifetime thus obtained will be the same as the data measured in the rest system of \( \pi \)-mesons if the twin paradox is the correct argument. Such an experiment has never been done in the past. Nevertheless, we can infer the result from a comparison with astronomical observations.

A series of observations by a new technique between 1968 and 1970 indicated that the components making up the nucleus of radio source 3C279 were in motion [5]. The activity, which occurs on a scale of milliseconds of arc, could not have been detected with the techniques available before the early 1970s. Surprisingly, the speed of the components was estimated to be about ten times the speed of light. The mysterious phenomenon received scientific attention, immediately. Some other quasars such as 3C273 also turned out to be superluminal sources. From direct observations of the distances travelled and the times required it is reported that their nuclei contain components apparently flying apart at speeds exceeding the speed of light. The concept of the speed of light as a limiting speed of material particles, which has been confirmed in physics, has been questioned in astronomy.

It seems that the \( \pi \)-meson experiment and the observation of superluminal motion are equivalent. The only difference would be in their explanations. In physical meaning, the observation of superluminal motion is equivalent to an experiment that has measured directly the mean lifetime of a rapidly moving \( \pi \)-meson beam. It is certain therefore without requiring an explicit experiment that the mean lifetime of a rapidly moving \( \pi \)-meson beam obtained by direct measurement is equivalent to the mean lifetime in the \( \pi \)-rest system. Their equivalence leads us to the conclusion that a particle velocity itself appears dilated to the observer, keeping time intact. It is then only natural to predict an equal ageing of twins in relative motion, by which the twin paradox is resolved naturally. The Lorentz time dilation is nothing more than a merely mathematical relation. The phenomenon of time dilation is nothing but a physical misconception of it. As pointed out by the twin paradox, the concept of time dilation violates the relativity of uniformly moving systems.
4 Aberration of light

The Bradley observation of the aberration of starlight seems to be even more important to modern physics than previously thought. This is because the aberration effect can physically be interpreted as expressing an equation which is in contrast with the Lorentz condition leading to the formulation of special relativity. I would like to show a physics behind the aberration which is in contrast with special relativity physics.

In 1727, Bradley discovered an apparent motion of star which he explained as due to the motion of the Earth in its orbit. This effect, known as aberration, is quite distinct from the well-known displacements of the nearer stars known as parallax. Bradley’s explanation of this effect was that the apparent direction of the light reaching the Earth from a star is altered by the motion of the Earth during propagation. The reason for this is much the same as that involved when a little girl walking in the rain must tilt her umbrella forward to keep the rain off her feet.

Let the vector \( \mathbf{v} \) represent the velocity of the Earth relative to a system of coordinates fixed in the solar system, and \( \mathbf{c} \) that of the light relative to the solar system. Then the velocity of the light relative to the Earth has the direction of \( \mathbf{c'} \), which is the vector difference between \( \mathbf{c} \) and \( \mathbf{v} \). This is the direction in which the telescope must be pointed to observe the star image on the axis of the instrument. When the Earth’s motion is perpendicular to the direction of the star, the relation \( c^2 - v^2 = c^2 \) follows from the vector difference. If we set \( c' = kc \), we see that the observation is performed at speed \( c' \) greater than when the Earth is at rest. Keeping in mind that the speed of light can be measured of speed, the altered speed of observation may give rise to the same effect as would be the case if the velocity scale were altered at the moment of observation. Accordingly, the velocity of the Earth is supposed to be \( v' = kv \) in relation to the observation. Taking this velocity of the Earth, the “Bradley” relation becomes \( c^2 - v'^2 = c^2 \). The velocity scale can then be written in the closed form \( k = 1/(1 - v^2/c^2)^{1/2} \). This is just the \( \gamma \) factor in special relativity. As a result, the angle of aberration \( \alpha \) is given by

\[
\sin \alpha = \beta, \quad \cos \alpha = 1/\gamma, \quad \text{and} \quad \tan \alpha = \gamma \beta, \tag{1}
\]

where \( \beta = v/c \). The appearance as the velocity scale shows that the \( \gamma \) factor is of an optic nature at the speed of observation. This means that the relativistic effect is in nature an optical phenomenon.

After this consideration, mention may be made of the difference between the present interpretation and the relativistic explanation. In the present interpretation, the velocity of the Earth and the velocity of light relative to it are respectively assumed to be \( \gamma v \) and \( \gamma c \), while the velocity of light relative to the solar system at rest is \( c \). If the distance to the solar system is \( R \), the distance to the Earth is \( \gamma R \). Regardless of whether the Earth is at rest or in motion, consequently, the time required for light to reach the Earth is \( R/c \). In the relativistic explanation, the velocity of the Earth and the velocity of light relative to it are respectively \( v \) and \( c \), whereas the velocity of light relative to the solar system at rest is assumed to be \( c/\gamma \) in the Earth’s frame [6]. The time required to reach the Earth is here \( \gamma R/c \). Although explanations are different, the same relations are given for the angle of aberration. For the Michelson-Morley experiment, however, they are different. In contrast to the relativistic explanation, the null result is expected from the present interpretation.

Having revealed the hidden nature of the aberration of starlight, we are going to examine its effect on the equations of motion in Newtonian mechanics. From the vector difference between \( \mathbf{c'} \) and \( \mathbf{v'} \) for the velocity of light, a derivative with respect to time gives the equation of corresponding accelerations

\[
\frac{dc'}{dt} - \frac{dv'}{dt} = \frac{dc}{dt} = 0. \tag{2}
\]

The scalar product of the accelerations in this equation with the corresponding velocity vectors is written

\[
c' \frac{dc'}{dt} - v' \frac{dv'}{dt} = 0, \quad \text{so} \quad c \frac{d(c)}{dt} - v \frac{d(v)}{dt} = 0. \tag{3}
\]

Equation (3) can also be obtained by differentiating the Bradley relation \( c^2 - v'^2 = c^2 \) with respect to time. The kinetic energy \( T \) is defined in general to be such that the scalar product of the force and the velocity is the time rate of change of \( T \). In comparing (3) with the definition of \( T \), the relativistic expression for kinetic energy is seen to be \( T = \gamma mc^2 \) [7]. In the present discussion, the mass has been treated as a constant [8]. The Bradley relation \( c^2 - v'^2 = c^2 \) can then be expressed in terms of kinetic energy and momentum, which is the covariant energy-momentum equation with \( T^2/c^2 - p^2 = m^2c^2 \). There is no difficulty in obtaining the relativistic form of energy and momentum equations along the physical line of thought in the framework of classical mechanics.

Because the aberration effect is ascribed to a change in the velocity of observation due to the motion of an observer, it is thought that relativistic phenomena would appear due to the measurement velocity being affected by a particle velocity. It is just like a vector difference between velocities. This illustrates why relativistic phenomena appear more pronounced as the velocity of particles approaches the velocity of light. The idea becomes clear. Is the effect of relativity just an effect due to the velocity of measurement being affected by the velocity of a particle? Understood as such, special relativity physics is identified itself as denoting the branch of physics which takes into consideration even the measurement velocity.

3
as affected by the particle velocity. This makes clear why the velocity of light appears in the equations of motion of a material particle. In this regard, a particle speed as fast as or faster than light, apart from the possibility of a material particle. In this regard, a particle speed beyond the limit of observation.

We suppose that the Earth is uniformly moving with velocity $\mathbf{v}$ with respect to the solar system. For simplicity, let the origins of the coordinates of the Earth and the solar system be coincident at time $t = 0$, at which time the star emits a pulse of light. If this pulse of light reaches the solar system at a time $t$, the propagation paths of the light to the solar system and the Earth are respectively given by $R = ct$ and $R' = c't$. Let $x$ and $x'$ be the respective projections of $R$ and $R'$ along the direction of $\mathbf{v}$. By the Pythagoras theorem, then, the geometric figure of aberration gives us the expression

$$c^2t^2 - x^2 = c'^2t'^2 - x'^2. \quad (4)$$

The general form of expression for aberration stands in contrast with the Lorentz condition which led to the transformation equations. It suggests taking $c't$ in place of $ct'$ as used in the Lorentz condition. They can be illustrated by the geometry of the Pythagoras theorem. In form, they correspond to an orthogonal transformation in a four-dimensional space consisting of the path of propagation of light and the three coordinates of space. It is important to notice their difference.

The aberration of starlight shows the simultaneous arrival of light signals starting from the star at the two points $x$ and $x'$ in relative motion. The effect gives a physical interpretation for the four-dimensional space, which includes the observation in the description of motion. The Lorentz condition finds its explanation in a spreading spherical wave with time, which starts from the star and reaches the point $x$ at time $t$ and the point $x'$ at time $t'$.

In the covariant form this gives the fourth coordinate as time. But it is given for the length of the path of propagation of light in terms of time. The Lorentz condition is a geometric relation. It has no physical bearing on a relative motion of the two points. With this very reason, the Lorentz transformation equations turn out to be the result of an ill-conceived marriage.

Seeing the Doppler effect, there is no doubt that the velocity of light is not independent of the motion of its source. The invariance of the velocity of light in all uniformly moving systems, which plays so decisive a role in the Lorentz transformation, has an ambiguous bearing on the experimental facts. To be consistent with observation for the aberration of starlight, the Doppler shift, and the Michelson-Morley experiment, the second postulate should be replaced by the restricted, but more accurate, postulate that the velocity of light appears the same in all uniformly moving systems if and only if the source and the observer are both in a given system.

While a pulse of light propagates to the Earth, the motion of the Earth displaces its position: $x' = x - ct$. In the same manner as derived the Lorentz transformation equations we can obtain an expression for the propagation path of starlight to the Earth. The aberration of starlight expressed in (4) can equally be solved to give

$$c't = \gamma(ct - vx/c) \quad \text{or} \quad c' = \gamma c (1 - \beta \cos \theta). \quad (5)$$

Since the ratio between $x$ and $ct$ is the direction cosine of the propagation path of starlight with respect to $\mathbf{v}$, it can be expressed in the more familiar form of the Doppler shift formula. It is of interest to see that the aberration of starlight gives a general derivation of the relativistic formula for the Doppler shift. This leads us ultimately to consider the transverse Doppler shift as due to the aberration effect and thus as observed in the direction inclined at the angle of aberration toward the direction of motion of a moving source.

We can give a general derivation of the expression for the angle of aberration. As shown in the geometric figure, the ratio between the propagation path of starlight and the path of the Earth is a direction cosine. We obtain

$$\cos \theta' = \frac{\cos \theta - \beta}{1 - \beta \cos \theta} \quad \text{from} \quad \frac{x'}{c't} = \frac{\gamma(x - vt)}{\gamma(ct - vx/c)}. \quad (6)$$

This is the same expression as given by considering the transformation of the phase of light wave, by Einstein [9].

It has been shown algebraically that two successive transformations with velocity parameters $\beta_1$ and $\beta_2$ are equivalent to a single Lorentz transformation of parameter $\beta = (\beta_1 + \beta_2)/(1 + \beta_1\beta_2)$. This also follows from the ratio in (6), in consequence of the interpretation of $x'/ct$ as the velocity parameter of a particle in the rest system and $x'/c't$ as the velocity parameter of observer...
in the laboratory. The formula for the addition of velocities comes from the inverse transformation equations. The inverse equations differ only by a change in the sign of $v$. Note that the $\gamma$ factor is symmetric with respect to two systems in relative motion, the physics of relativity. It is misleading to introduce the relation $\Delta x'/\gamma = \Delta x$ as a basis for the Lorentz-FitzGerald contraction hypothesis from $\Delta x' = \gamma \Delta x$ given as a consequence of the Lorentz transformation equations.

5 Aberration of fields

Newton’s gravitational force is a static force. There is no notion of propagation, an action at a distance. In modern physics, it is required that a force be transmitted with a velocity. If the gravitational field propagates with the velocity of light instead of instantaneously; the gravitational field must suffer aberration, just as light does. It is then realized that the aberration of starlight expresses the aberration of the gravitational field of star.

Let $R$ be the radius vector from a star to the retarded position of the Earth. If the star is in a direction perpendicular to the motion of the Earth, the path of propagation of starlight to the Earth is given by $R/c$. The gravitational potential of the star can then be written as

$$\left[ \frac{GM}{R} \right]_{t-R/c} \quad \text{and} \quad \left[ \frac{GM}{\gamma R} \right]_t.$$ (7)

We may infer this form of gravitational potential from the aberration of starlight. It shows that the gravitational potential at the point of observation at time $t$ is determined by the state of motion of the Earth at the retarded time $t - R/c$, for which the time of propagation of light from the star to the observation point just coincides with $R/c$.

We can extend this to the case where the star is not in a direction perpendicular to the motion of the Earth. The propagation path of starlight to the Earth is then given by $R' = \gamma R(1 - \beta \cdot n)$, where $n$ is a unit vector in the direction of $R$. The gravitational potential can thus be written in the general form

$$\frac{GM}{\gamma R(1 - \beta \cdot n)}.$$ (8)

If we define the gravitational field by the gradient of potential, then we obtain from the gravitational potential the expression

$$\frac{GM}{\gamma^2 R^2(1 - \beta \cdot n)^2} (n - \beta),$$ (9)

where we have used $\nabla R(1 - \beta \cdot n) = n - \beta$ [10].

It is thought possible to express in a covariant form the aberration effect on the gravitational field. The gravitational field acting on the Earth is different in direction and magnitude from that when the Earth is at rest. In the geometric figure the difference is shown to be an acceleration that the moving Earth has during the propagation. The spatial variation in propagation of the gravitational field may be expressed in the form

$$\left[ \frac{GM}{R^2} \right]_{t-R/c} \Rightarrow \left[ \frac{GM}{\gamma^2 R^2(1 - \beta \cdot n)^2} (n - \beta) + \frac{d(\gamma v)}{dt} \right]_t.$$ (10)

This equation shows that the gravitational field acting on a moving system must be balanced by an acceleration the system would have during propagation. Total gravitational effects observed at a moving system will thus be the same, regardless of how fast it moves. This makes the gravitational field invariant in the covariant form.

Following the same line of reasoning, the Coulomb field produced by a moving electron can be expressed in the form of (8) by replacing the gravitational charge $GM$ by the electronic charge $e$. The Coulomb field thus obtained is in formal agreement with the electric field of an electron in uniform motion in electrodynamics. We can make a comparison with the Liénard-Wiechert potential in terms of the retarded and present times:

$$\left[ \frac{e}{R(1 - \beta \cdot n)} \right]_{t-R/c}, \quad \left[ \frac{e}{\gamma R(1 - \beta \cdot n)} \right]_t.$$ (11)

Since the relation of the retarded position to the present position of a moving electron is not, in general, known, the Liénard-Wiechert potential ordinarily permits only the evaluation of the field in terms of retarded position and velocity of the electron. In the present approach, the unknown effect occurring during the propagation is assumed to be an aberration effect on the field attributed to its finite propagation velocity. As applied to a moving source of light, the aberration effect on the propagation of light to the observer yields an expression equal to the relativistic formula for the Doppler shift. This furnishes support for that assumption. The unknown effect occurring during the propagation would be the aberration of the Coulomb field produced by a moving electron.

The electric field of a moving electron divides itself into a velocity field and an acceleration field [11]. In the present approach, the Coulomb potential alone induces the velocity field. Thus to make this approach agree with the electric field of a moving electron, the vector potential should be deduced solely from the acceleration field. On the assumption that the $\gamma$ factor is cancelled out by the relativistic correction to velocity, this deductive reasoning leads to the following expressions for the vector potential:

$$\left[ \frac{\mathbf{v}}{R(1 - \beta \cdot n)} \right]_{t-R/c}, \quad \left[ \frac{\mathbf{v} - (\mathbf{v} \cdot n)n}{\gamma R(1 - \beta \cdot n)} \right]_t.$$ (12)

This shows that the vector potential is evaluated by the component of velocity perpendicular to $n$. When we view
the vector potential in this way, we realize that the component of velocity parallel to \( n \) has been incorporated in the velocity of field propagation. This makes it reasonable to expect the form of (12). Actually, it is true that the velocity of source appears as perpendicular to \( n \) by the velocity of propagation relative to the velocity of source.

The Liénard-Wiechert potentials are to be evaluated at the retarded time. For derivatives, thus, we make use of transformations obtained by differentiating \( R = c(t - t_0) \):

\[
\frac{\partial}{\partial t} = \frac{1}{1 - \beta \cdot n} \frac{\partial}{\partial t_0}, \quad \nabla = \nabla_R - \frac{\mathbf{n}}{c(1 - \beta \cdot n)} \frac{\partial}{\partial t_0}. \tag{13}
\]

When viewed from the present point, however, the aberration effect should be taken into consideration. In passing, we remark that the effect requires the vector potential to be transverse, satisfying the radiation gauge. In addition, the effect requires to evaluate the vector potential with respect to the path of propagation, \( c/\partial t \) in place of \( c dt \).

In the retardation gauge, then, the electric field is given by

\[
\mathbf{E} = -\frac{1}{c} \frac{\partial \mathbf{A}}{\partial t} = \frac{e}{c} \frac{\mathbf{n} \times (\mathbf{v} \times \mathbf{n})}{c^2 R^2 (1 - \beta \cdot n)^2} + \frac{e}{c^2} \frac{\mathbf{n} \times \{ (\mathbf{n} - \mathbf{v}) \times \dot{\mathbf{v}} \}}{\gamma R (1 - \beta \cdot n)^3}. \tag{14}
\]

The first term is a result of differentiating \( R \) by noting here \( R = ct \). The second term is in agreement with the acceleration field except the \( \gamma \) factor. As shown by (14), in form, the time derivative is equivalent to the differential operator. In the intuitive form, therefore, the magnetic induction may be evaluated in terms of the electric field:

\[
\mathbf{B} = \nabla \times \mathbf{A} = -\frac{n}{c} \frac{\partial}{\partial t} \times \mathbf{A} = \mathbf{n} \times \mathbf{E}. \tag{15}
\]

The aberration effect on the potential fields lends itself to incorporation in the classical theory of radiation.

We now consider the motion of an electron in a uniform magnetic field \( \mathbf{H} \). If the electron has no velocity component along the field, it moves along a circle in the plane perpendicular to the field. The electron moving in the field satisfies the equation

\[
mv^2 r/r^2 = e\mathbf{v} \times \mathbf{H}. \tag{16}
\]

There would be an aberration of uniform magnetic field because of its finite propagation velocity. The physics of the situation is reminiscent of the aberration of starlight, where the field replaces starlight and the electron replaces the Earth in its orbit. The angle between \( \mathbf{v} \) and \( \mathbf{H} \) must be \( \pi/2 - \alpha \), instead of being \( \pi/2 \). The equation is written

\[
mv^2/r = (eH/c) \sin(\pi/2 - \alpha). \tag{17}
\]

From the relation in (1), we find the magnetic frequency to be \( eH/\gamma mc \). We can find a complete derivation of the relation for the magnetic frequency from the point of view of aberration. The \( \gamma \) factor must be the aberration effect.

Insight into the relativistic velocity of an electron can be provided by considering the mechanism by which the velocity of an electron is determined. An electrostatic spectrograph to determine the velocity of an electron consists in balancing the magnetic and electric deflections against each other [12]. The electron moving in a uniform magnetic field \( \mathbf{H} \), perpendicularly to \( \mathbf{H} \), describes a circular path of radius \( R_H \):

\[
mv^2 R_H/R_H^2 = ev/c \times \mathbf{H}. \tag{18}
\]

If this electron moves in a radial electric field \( \mathbf{E} \), it can describe a circular path of radius \( R_E \) given by

\[
mv^2 R_E/R_E^2 = e\mathbf{E}. \tag{19}
\]

The equation of motion for the electron moving in the fields \( \mathbf{H} \) and \( \mathbf{E} \) applied simultaneously is then given by balancing the centrifugal force arising from the magnetic deflection against the centrifugal force due to the electric deflection, by

\[
e\mathbf{E}R_E = ev/c \times HR_H. \tag{20}
\]

Taking into account the aberration occurring in the form of the vector difference between \( \mathbf{v} \) and \( \mathbf{H} \), the angle between \( \mathbf{v} \) and \( \mathbf{H} \) is tilted at an angle of aberration toward the direction of motion of the moving electron. Thus,

\[
e\mathbf{E}R_E = vHR_H \sin(\pi/2 - \alpha). \tag{21}
\]

The velocity of the electron is found to be \( \gamma e\mathbf{E}R_E/HR_H \), where \( \beta = E_R/H \). In this regard, \( e\mathbf{E}R_E/HR_H \) is seen to be the intrinsic velocity the electron would have if the velocity of propagation of the fields were infinite, thereby not suffering aberration. This elucidates why a particle velocity itself appears dilated to the observer. The speed of high-energy particles of \( \gamma v \) can easily be superluminal phenomenologically. It should be noted that the apparent speed of high-energy particles is ascribed to the aberration of uniform magnetic field. The relativistic velocity is identified with the apparent velocity of which the \( \gamma \) factor arises out of the effect of aberration.

6 Covariant Maxwell equations

We consider the electromagnetic fields seen by an observer in the system \( S \) when a point charge \( q \) moves by in a straightline path along the \( x \) direction with a velocity \( \mathbf{v} \). Let \( S' \) be the moving coordinate system of \( q \). The charge is at rest in this system. But when viewed from the system \( S \), the charge represents a current \( \mathbf{J} = q\mathbf{v} \) in the \( x \) direction. The electromagnetic fields are then related through Ampère’s law:

\[
\nabla \times \mathbf{B} = \frac{4\pi}{c} \mathbf{J} + \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t}, \quad \nabla \times \mathbf{B} = \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t}. \tag{22}
\]
Ampère’s law keeps its form invariant with respect to the two systems in relative motion. They are related at the same time, and so are the equations: \( t = t' \).

In the covariant form, nonetheless, it is instructive to write the equations of transformation between \( S \) and \( S' \) in terms of \( t \) and \( t' \). For that purpose, instead of using \( ct \) and \( c't \), we use here the Lorentz transformation equations.

Let us apply to the equation the Lorentz transformation of coordinates with \( \gamma (ct - \beta x), \gamma (x - vt), y, z \) \( \gamma = [ct, x, y, z]_{S'} \). The \( y \) and \( z \) components are homogeneous equations. The transformation of these components is straightforward. The \( x \) component is an inhomogeneous equation. Its transformation does not seem to be so.

By Coulomb’s law \( \nabla \cdot \mathbf{E} = 4\pi q \), the equation can be written as

\[
\frac{\partial B_y}{\partial y} - \frac{\partial B_z}{\partial z} = \frac{v}{c} (\nabla \cdot \mathbf{E}) + \frac{1}{c} \frac{\partial E_x}{\partial t}.
\]  
(23)

If we multiply the \( \gamma \) factor and use the inverse equations, we can transform the equation into the form

\[
\frac{\partial}{\partial y} \left\{ \gamma \left( B_y - \frac{v}{c} E_y \right) \right\} - \frac{\partial}{\partial z} \left\{ \gamma \left( B_z + \frac{v}{c} E_z \right) \right\} = \frac{1}{c} \frac{\partial E_x}{\partial t}.
\]  
(24)

We may start with Faraday’s law. In exactly the same manner, we use the relation \( \nabla \cdot \mathbf{B} = 0 \) to obtain the equations of transformation. This completes the transformation of electromagnetic fields from the Maxwell equations.

7 Concluding remarks

We are taught special relativity in such a way that the phenomenon of time dilation is daily verified in high-energy physics laboratories. But the verification is not so explicit; one can only infer the lifetime dilation from the mean free path for the \( \pi \)-meson decay measured in the experiment. Nor are we unanimous in accepting or interpreting the concept of time dilation. The superluminal motion is by no means mysterious. The astronomical observation has shown us that a particle velocity itself appears dilated to the observer phenomenologically. Had the time been measured directly, the \( \pi \)-meson experiment would have shown essentially the same. Not only the experiment but the theory is incomplete. The aberration of uniform magnetic field has been overlooked in physics. The effect of aberration gives rise to the \( \gamma \) factor of velocity, which disproves the phenomenon of time dilation. For the relativistic mass, likewise, the aberration effect disproves the experimental result. The effect of relativity is due to the \( \gamma \) factor of velocity arising out of aberration.

From special relativity we learn that the equations of motion should be covariant in the mathematical structure of time and space. By identical treatment of time and space, as Minkowski addressed [13], the forms in which the equations of motion are displayed gain in covariance. The Lorentz transformation equations were obtained by applying a covariant condition to two systems in relative motion. In the relative motion of two systems, however, it is assumed that time is the same in both systems. Two systems in relative motion cannot be covariant in time and space. The covariant condition can be satisfied by an equation for motion of a system or relative motion of two systems, providing a geometry in time and space for motion. But two systems in relative motion must not be confused with a relative motion of two systems. As noted by Sommerfeld [14], the fourth coordinate is not \( t \) but \( ct \). In the case of a moving source of light, furthermore, it is the velocity of light that appears dilated to the observer.

We can find in the effect of aberration a phenomenological explanation of special relativity physics. This reflects that the physical origin of relativistic phenomena lies in the aberration of starlight. The emphasis should be on the physics of special relativity can be replaced in form and content by the physics of aberration. In contrast with special relativity, this leads us to an understanding of relativistic phenomena using a physical reasoning. It is demonstrated that the usual concepts of time and simultaneity are natural for describing relativistic phenomena. Einstein’s argument is in essence a mathematical explanation based on the transformation equations. The resulting equations of Einstein’s theory had been proved to be correct, contributing greatly to modern physics. However, the correct result does not always warrant the correctness of assumption. In the past controversy, the incorrect argument is not in opponents’ minds but in Einstein’s theory assuming the dilation of time scales. The concept of time dilation makes no sense physically; time is an independent variable and motion is relative to each other.

Appendix: Remark on the superluminal motion

There has been a precision measurement of the neutrino velocity at 17 GeV with the OPERA detector at the underground Gran Sasso Laboratory [15]. The neutrino speed is measured by passing through about 730 km of the Earth’s crust from the CERN, showing values equivalent to the light speed within experimental errors. Intense debate on the experiment increases our interest in the OPERA result [16]. At much higher energy, the amazing result is compatible with earlier measurement of the neutrino velocity at 3 GeV from the Fermilab NuMI beam with the MINOS detector [17].

In the early 1970s, we were aware of a superluminal motion from the observation of radio source 3C279. Most astronomers could not believe the motion to be the case because the superluminal velocity cannot be accepted by
the theory of special relativity. The current explanation
given in astronomy must be reasonable, but it cannot be
a physical explanation for the superluminal motion.

From a phenomenological point of view it is evident
that a particle velocity itself appears dilated to the ob-
server by the $\gamma$ factor. The superluminal motion of jet in
quasars must be such an apparent velocity. In fact, the
intrinsic speed of the jet has been calculated by using the
$\gamma$ factor required for the apparent velocity measured in
the jet of 3C279 [18]. The derivation of apparent velocity
is detailed in astronomy. But it is the aberration effect.
It is due to the vector difference between the velocities of
jet and light. A pulse of light emitted by the jet is prop-
agated to us in the apparent direction. Like the velocity,
we may deduce the intrinsic direction from the jet image.

The neutrino velocity does not seem to be of the same
character. The neutrino velocity has been determined
with high accuracy through the measurement of the time
of flight and the distance between the source of the neu-
trino beam at CERN and the OPERA detector at Gran
Sasso Laboratory. The neutrino velocity cannot be an
apparent velocity; the neutrino itself must be moving at
such speed. Notice no effect of relativity in such mea-
surement. Then the motion of neutrino is unobservable
because the observation cannot catch up in speed with the
neutrino. We can only observe the track of neutrino. This
suggests their speed for why neutrinos could not be de-
tected directly. Their negligible mass and neutral charge
are technical reasons. In principle, we cannot apply the
energy-momentum equation to the motion of neutrinos.
This is because the four-momentum equation is given for
the motion of a particle which is observable at the speed
of light. Neutrino physics is a new physics beyond the
observation and description of motion.

References

[1] F. T. Jenkins and H. E. White, Fundamentals of Opt-
tics (McGraw-Hill, 1976) 4th ed., p. 416
[2] J. W. S. Rayleigh, The Theory of Sound (Dover, 1945)
vol. 2, p. 155
[3] M. Jakobson, A. Shulz, and J. Steinberger, Phys. Rev.
81 (1951) 894; C. E. Wiegand, Phys. Rev. 83 (1951) 1085
[4] R. P. Durbin, H. H. Loar, and W. W. Havens Jr, Phys.
Rev. 88 (1952) 179
[5] Review article, “Quasar’s Jet; Faster Than Light?”
Science in Korea (1982) 24
[6] W. K. H. Panofsky and M. Phillips, Classical Elec-
tricity and Magnetism (Addison-Wesley, 1962) 2nd ed.,
p. 303
[7] H. Goldstein, Classical Mechanics (Addison-Wesley,
1950), p. 202
[8] C. G. Adler, Am. J. Phys. 55 (1987) 739; L. B. Okun,
Phys. Today (June 1989) 31
[9] H. A. Lorentz, A. Einstein, H. Minkowski, and H.
Weyl, The Principle of Relativity (Dover, 1952), p. 56
[10] Reference 6, p. 356
[11] J. D. Jackson, Classical Electrodynamics (John Wiley
& Sons, 1975) 2nd ed., p. 657
[12] M. M. Rogers, A. W. McReynolds, and F. T. Rogers
Jr, Phys. Rev. 57 (1940) 379
[13] Reference 9, p. 75
[14] Reference 9, p. 92
[15] OPERA Collaboration, arXiv:1109.4897 (2011)
[16] A. G. Cohen and S. L. Glashow, arXiv:1109.6562
(2011); ICARUS Collaboration, arXiv:1110.3763 (2011)
[17] MINOS Collaboration, arXiv:0706.0437 (2007)
[18] B. G. Piner et al., arXiv:astro-ph/0301333 (2003)