On the Nature of Relativistic Phenomena

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Based upon the Bradley observation of the aberration of starlight, an attempt is made to explain the experimental facts of importance concerning the special theory of relativity. It is demonstrated that the Galilean concept of time, in contrast to the currently accepted view, is even more natural for describing the physics of relativistic phenomena.

1. Introduction

The special theory of relativity is now believed to apply to all forms of interactions except large-scale gravitational phenomena. Daily it is employed by scientists in their consideration of precise atomic phenomena, in nuclear physics, and above all in high-energy physics. It serves as a touchstone in modern physics for the possible forms of interaction between fundamental particles. 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. Because this was a revolutionary and unpalatable idea, many attempts were made to invent theories that would explain all the observed facts without this assumption.

This work is another such attempt. The argument begins by pointing out that the physics of relativistic phenomena can be looked upon as having its origins in the aberration of starlight, leading to a phenomenological derivation of the relativistic equations of motion. The interpretation proposed in this paper eliminates the second postulate, thus denying the current concepts of time and the speed of light generally accepted in modern physics. It will be discussed that this alternative point of view is even more natural for describing the physics of relativistic phenomena. It should be noted that the proposed interpretation is based upon the Galilean concept of time and is consistent with all the observed facts of importance related to the special theory of relativity. This paper will show how the interpretation can be fitted into the framework of modern physics. However, it is not intended to be a discussion concerning the general theory of relativity.

2. Ether Drift

We consider the well-known experiments related to the speed of propagation of light in a moving medium [1]. The Michelson-Morley experiment was undertaken to investigate the possible existence of the ether drift. 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°. The negative result of the Michelson-Morley experiment shows that it is impossible to demonstrate the existence of the ether drift. This result was interpreted 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 important 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. In the Fizeau experiment, an alteration of the speed of light was observed, which was in reasonable agreement with the value given by Fresnel's dragging formula. From a comparison of the Fizeau experiment with the Michelson-Morley experiment, we realize that the arrangement of the Michelson-Morley experiment makes it impossible to detect the ether drift. In the Michelson-Morley experiment, both the source and the observer are at rest while the ether is in uniform motion through the arrangement. As viewed from the Fizeau experiment, the ether drift cannot be defined 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, for example, 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. In the case of sound under the same circumstances, indeed, no change of pitch was observed, as it should be [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, if any, in the domain of taste rather than coverage.

3. Twin Paradox

In 1905, Einstein[3] showed that the Lorentz transformation which preserves the speed of light in all uniformly moving systems requires revision of the usual concepts of time and simultaneity. He was thus led to the result that a moving clock runs more slowly than a stationary clock. However, such a concept of time gives rise to the twin paradox. 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 π-mesons was determined using the decay of π-mesons at rest in a scintillator [4]. In this method, the mean lifetime of the π-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 π-meson beam was undertaken [5]. An experiment of this nature was arranged to measure the attenuation in flight of a π-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 π-mesons. It is generally recognized that these experiments have verified the phenomenon of time dilation.

However, the latter experiment seems to have an ambiguous bearing on the phenomenon of time dilation. In that experiment, the relativistic correction was made directly in the mean lifetime, keeping the particle velocity intact. This is in contrast with high-energy scattering theory, where the relativistic correction is made in the particle velocity.

The four-velocity is defined as the rate of change of the path of a particle with respect to its proper time. Based upon this definition, one can say that the four-velocity results from the Lorentz time dilation, and hence they are compatible. However, it is evident that the current definition disregarding the dilation of its proper path is inconsistent with experimental fact. Observation of the dilated mean free path of π-meson beam with respect to its proper lifetime points out that once the Lorentz time dilation is taken into account, there is no room for the four-velocity formulation. Either the time dilation or the four-velocity, not both of them, can be consistent with experimental observation. This means that the time dilation and the four-velocity are alternatives, so that the four-velocity cannot result from the Lorentz time dilation. In this regard, the question arises: In time and velocity, which component would appear phenomenologically dilated to the observer? To see the truth, the mean lifetime of a rapidly moving π-meson beam must be determined by direct measurement. The mean lifetime so obtained will be the same as the data measured in the rest system of π-mesons if what the twin paradox points out is correct. Although such an experiment is probably undertaken, there does not seem to be a publication that describes the experiment of this kind. In spite of this, we can infer the result from a comparison with astronomical observation.

In 1971, Shapiro observed that the components making up the nucleus of radio source 3C279 were in motion. Surprisingly, the speed of the components was estimated to be about ten times the speed of light [6]. The activity, which occurs on a scale of milliseconds of arc, could not have been detected with the techniques available before the early 1970s. Special attention was immediately given to observation of the mysterious phenomenon, from which some other quasars such as 3C273 also turned out to be superluminal sources. From direct observations of the distances traveled 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 astrophysics.

It seems that the π-meson experiment and the observation of superluminal motion are physically equivalent. The only difference would be their stages and their interpretations therein. On the comparison of the experiment with the observation, we come to see that, phenomenologically, the velocity component itself would appear dilated to the observer, keeping the time intact. It is certain therefore without requiring explicit experiment that the mean lifetime of a rapidly moving π-meson beam obtained by direct measurement is equivalent to the mean lifetime in the π-rest system. This constitutes a verification of the prediction of equal ageing of the twins in relative motion and thus resolves the twin paradox. It confirms fully that the phenomenon of time dilation is nothing else but illusion existing only in mathematical formalism. From a logical point of view, one cannot attach any absolute reference of the phenomenon to one system in preference to the other system as long as it depends only on the relative velocity between them. Ironically, the relativistic explanation violates the relativity of uniformly moving systems and artificially obscures the physics of the situation they reveal.

4. Aberration of Starlight

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 of starlight can be interpreted as expressing the covariant equations of motion leading to the physics of special relativity. The phenomenological point of view that the origins of relativistic phenomena lie in the physics of aberration of starlight is discussed in this section.

In 1727, Bradley discovered an apparent motion of the 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. The effect of parallax is to cause the stars which are observed in a direction perpendicular to the plane of the Earth's orbit to move in small circles, and from their angular diameters the distances of the stars are computed. Aberration, which depends on the Earth's velocity, also causes the stars observed in this direction to appear to move in circles. Here, however, the circles are the same for all stars, whether near or distant. 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 in its orbit. The observer and his or her telescope are being carried along with the Earth at a velocity of about 29.6 km/s, and if this motion is perpendicular to the direction of the star, the telescope must be tilted slightly toward the direction of motion from the position it would have if the Earth were at rest. 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 **v** represent the velocity of the Earth relative to a system of coordinates fixed in the solar system, and **c** that of the light relative to the solar system. Then the velocity of the light relative to the Earth has the direction of **c'**, which is the vector difference between **c** and **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 velocity difference. This shows how the velocity of observation is altered by the motion of the Earth. Assuming $c' = \gamma c$, this means 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 also be a measure of speed, the altered measurement speed is conjectured to give rise to the same effect as would be the case if the velocity scale were correspondingly altered at the moment of measurement. Accordingly, the velocity of the Earth is considered to be $v' = \gamma v$ in relation to the observation. Taking this velocity of the Earth, the Bradley relation becomes $c'^2 - v'^2 = c^2$, from which the velocity scale is given in a closed form by $\gamma = 1\big/\left(1 - v^2/c^2\right)^{1/2}$. The velocity scale appears due to the observation velocity being affected by the velocity of the Earth during observation. The appearance of the γ-factor as the velocity scale has nothing to do with relativity but rather—and this seems to be particularly important—is of a purely observational nature. As a consequence of this consideration, the relations for the angle of aberration α can be written as

$$\sin\alpha = \beta, \qquad \cos\alpha = (1-\beta^2)^{1/2}, \qquad \tan\alpha = \beta/(1-\beta^2)^{1/2} \tag{1}$$

where $\beta = v/c$.

At this point it may be of some interest to check the difference between the present interpretation and the relativistic explanation of the aberration of starlight. In the present interpretation, the velocity of the Earth and the velocity of light relative to it are respectively assumed to be γv and γc, while the velocity of light relative to the solar system at rest is c. If the distance from the star to the solar system is R, the distance to the Earth is given by $R/\cos\alpha = \gamma R$, where α is the angle of aberration.

Thus the time required to reach the Earth becomes R/c. These assumptions are in contrast with those in the relativistic explanation. 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/γ in the Earth's frame [7]. Thus, in this explanation, the time required to reach the Earth is given by $\gamma R/c$. Note that both the Bradley observation of the aberration of starlight and the propagation path perpendicular to the ether drift in the Michelson-Morley experiment can be represented by the same geometric figure. As viewed from the present interpretation, the result of the Michelson-Morley experiment depends solely on whether or not the speed of light is affected while traveling the path parallel to the ether drift. This is why we have compared the Michelson-Morley experiment with the Fizeau experiment in Section 2. Note that in spite of their difference, both of those interpretations give the same relations for the angle of aberration.

Having revealed the hidden nature of the Bradley observation, we can now proceed to the second stage and investigate its effect on the equation of motion. From the vector difference between **c'** and **v'** for the velocity of light, a derivative with respect to time gives the covariant equation of accelerations

$$\frac{\mathrm{d}\mathbf{c}'}{\mathrm{d}t} - \frac{\mathrm{d}\mathbf{v}'}{\mathrm{d}t} = \frac{\mathrm{d}\mathbf{c}}{\mathrm{d}t} = 0. \tag{2}$$

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

$$c'\frac{\mathrm{d}c'}{\mathrm{d}t} - v'\frac{\mathrm{d}v'}{\mathrm{d}t} = 0, \quad \text{that is,} \quad c\frac{\mathrm{d}(\gamma c)}{\mathrm{d}t} - v\frac{\mathrm{d}(\gamma v)}{\mathrm{d}t} = 0. \tag{3}$$

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 Equation (3) with the definition of T, the relativistic expression of kinetic energy appears as $T = mc^2 \big/ \left(1-\beta^2\right)^{1/2}$ [8]. In the present discussion, the mass has been treated as a constant.[9] The Bradley relation $c'^2 - v'^2 = c^2$ can therefore be expressed in terms of the kinetic energy and momentum, which is seen to be the covariant energy-momentum equation with $T^2/c^2 - p^2 = m^2c^2$. This shows how the relativistic equations of motion can be derived on Newtonian mechanical grounds.

Since the aberration effect is attributed to the finite velocity of observation which is affected by motion of the Earth, it is thought that relativistic phenomena would appear due to the measurement velocity being affected by velocity of a moving body, like a vector difference between velocities. This explains why relativistic phenomena appear more pronounced as the velocities of particle approach the velocity of light and why the velocity of light appears in the equations of motion of material particles. The conjecture naturally arises: Is then the relativity effect just an effect due to the measurement velocity being affected by velocity of a moving body? Understood as such, relativistic physics is identified itself as denoting the branch of physics which takes into consideration even the measurement velocity relative to the particle velocity for a moving particle with velocity not small compared with the velocity of light. In this regard, a particle speed as fast as or faster than light, apart from the possibility of existence, is unobservable in a direct way because such a particle goes beyond the observation speed.

In order to obtain the covariant equation of coordinates, we suppose that the Earth is uniformly moving with velocity 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 v. Then the geometric figure of the aberration of starlight draws

$$c^2t^2 - x^2 = c'^2 t^2 - x'^2 . \tag{4}$$

It is straightforward to generalize this discussion to the two inertial reference frames S and S' with a relative velocity v between them, instead of the solar system and the Earth. The Bradley observation of the aberration of starlight suggests taking $c't$ as a fourth coordinate in place of ct' as used in the Lorentz relation. The fact that the geometric figure of the aberration of starlight draws the covariant equation of coordinates seems to me to form the physical background for the point of view that the physics of special relativity has its origin in the aberration effect.

The Bradley relation in equation (4) stands in contrast to the Lorentz relation leading to the Lorentz transformation with respect to the concepts of time and the speed of light. In these relations, which relation is consistent with the experimental facts? The Bradley relation describes the simultaneous arrival of light signals starting from the star at the two points x and x' in relative motion. In contrast, the Lorentz relation finds a complete interpretation in a spreading spherical wave which starts from the star and reaches the point x at time t and the point x' at time t' sequentially. Figure 1 shows the difference between the Bradley relation and the Lorentz relation. Recalling 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 current explanation should be replaced by the restricted, but more accurate, explanation that the velocity of light is the same in all uniformly moving systems if and only if the source and the observer are both in a given system. It is then apparent that the Lorentz relation has no bearing on the two systems in relative motion. In this regard, the Lorentz transformation turns out to be a result of an ill-conceived marriage.

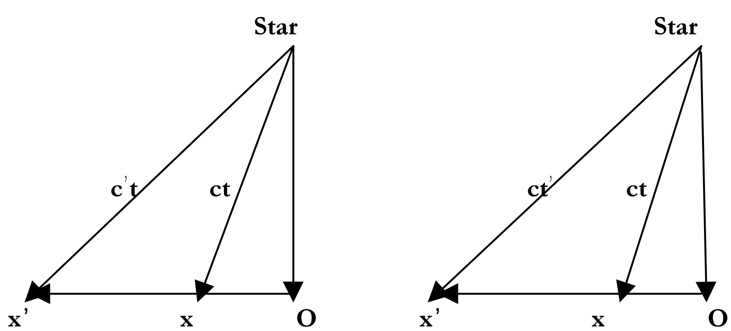

Figure 1. Illustration of the Bradley relation from aberration of starlight and the Lorentz relation from spreading spherical wave.

The fourth component of the Lorentz transformation is worthy of mention. The four coordinates in the Earth can be related to those in the solar system by the Lorentz transformation using equation (4) instead of the Lorentz relation. The fourth component of this transformation becomes

$$c't = \frac{ct - vx/c}{(1-\beta^2)^{1/2}} \qquad \text{or} \qquad c' = \frac{c(1-\beta\cdot\mathbf{n})}{(1-\beta^2)^{1/2}}, \tag{5}$$

where **n** is a unit vector in the direction of **R**. Since the ratio between x and ct is the direction cosine of the propagation path of the light with respect to v, it can be expressed in the more familiar form of the Doppler shift formula. It is of particular interest to note that the fourth component of this Lorentz transformation gives a more general derivation of the relativistic formula for the Doppler shift. This leads us to consider the transverse Doppler shift as due to the aberration effect and as observed in the direction inclined at an angle of aberration toward the direction of motion of a moving source.

We can also give a more general derivation of the expression for the angle of aberration. The ratio between the x component and the fourth component of this transformation can be written using the direction cosines so defined as

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

which is the same expression as obtained in its most general form by Einstein. It has been shown algebraically that two successive Lorentz transformations with velocity parameters $\cdot_1$ and $\cdot_2$ are equivalent to a single Lorentz transformation of parameter . $\beta = (\beta_1 + \beta_2)/(1+\beta_1\beta_2)$, , by multiplying the matrices of the two separate transformations. But the ratio between the components can also be used to obtain the law for addition of velocities. As it stands, the structure of (6) makes it obvious that the formula for the addition of velocities is straightforwardly given by simply rewriting ratios of coordinates to time in uniform velocity terms.

5. Aberration of Fields

We now turn our attention to the gravitational field of the star. We begin by noting that there would be an aberration of the gravitational field because of its finite propagation velocity. If we assume that the gravitational field propagates with the velocity of light, the gravitational field must suffer aberration, just as light does. It is then found that the aberration of the starlight expresses the aberration of the gravitational field of the star.

Let **R** be the radius vector from the star to the solar system. The length of the path along which the light propagates to the Earth is given by $R/\cos\alpha = R/(1-\beta^2)^{1/2}$, where α is the angle of aberration. The gravitational field of the star can therefore be written in terms of the retarded and present positions of the moving Earth as

$$\left[\frac{GM}{R^2}\right]_{t-R/c}, \quad \left[\frac{GM(1-\beta^2)}{R^2}\right]_t. \tag{7}$$

where G is the gravitational constant and M the mass of the star. In the above equation, the subscript means that the quantity in the bracket is to be evaluated at that time. The gravitational field 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 the light from the star to the field point just coincides with R/c. Equation (7) describes the aberration of the gravitational field occurring during the propagation. The alterations in the direction and the magnitude of the gravitational field are attributed to the propagation velocity of the field as affected by the motion of the Earth during its propagation. 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 the light to the Earth is then given by $R' = R(1-\beta\cdot\mathbf{n})/(1-\beta^2)^{1/2}$, where **n** is a unit vector in the direction of **R**. The aberration of the gravitational field can therefore be expressed in the general form

$$\frac{GM(1-\beta^2)}{R^2(1-\beta\cdot\mathbf{n})^2}. \tag{8}$$

If we take the path of integration to be *R'*, the distance from the star to the field point at which we determine the potential, we obtain for the gravitational potential at the point of observation

$$\frac{GM(1-\beta^2)^{1/2}}{R(1-\beta\cdot\mathbf{n})}. \tag{9}$$

Since the alteration of the gravitational field of the star is attributed to the motion of the Earth during its propagation, one may picture that the gravitational field acting on the Earth differs from that when the Earth is at rest by the acceleration which the moving Earth has during the propagation of the field. The aberration of the gravitational field then draws the covariant equation of fields

$$\frac{GM}{R^3}\mathbf{R} = \frac{GM}{R'^3}\mathbf{R}' + \frac{d\mathbf{v}'}{dt}. \tag{10}$$

The explicit form of potential energy in Eq. (9) is furnished by the scalar product of the gravitational fields in Eq. (10) with the corresponding radius vectors. It should be noted that the derivation of potential energy is performed in exactly the same manner as in the covariant equation of accelerations for kinetic energy. Equations (2) and (10) can thus be considered as covariant formulations of Newton's equations of motion for describing relativistic mechanics.

Following the same line of reasoning, the aberration of the Coulomb field produced by a moving electron can be expressed in the form of Eq. (8) by replacing the gravitational charge *GM* by the electronic charge *e*. The electric field thus obtained is similar to the Coulomb field of an electron in uniform motion in electrodynamics. We now compare the Lienard-Wiechert potential with the potential given in this approach:

$$\left[\frac{e}{R(1-\beta\cdot\mathbf{n})}\right]_{t-R/c}, \quad \left[\frac{e(1-\beta^2)^{1/2}}{R(1-\beta\cdot\mathbf{n})}\right]_t. \tag{11}$$

Since the relation of the retarded position to the present position of a moving electron is not, in general, known, the Lienard-Wiechert potential ordinarily permits only the evaluation of the field in terms of the retarded position and velocity of the electron. In the present approach, the unknown effect occurring during the propagation is assumed to be the aberration of the field attributed to its finite propagation velocity, which is affected by the motion of the electron. As applied to a moving source of light, the propagation path of light to the observer, when it is written in terms of frequency, yields an expression equal to the relativistic formula for the Doppler shift. This favors the assumption that the unknown effect occurring during the propagation is the aberration of the Coulomb field produced by a moving electron.

In electrodynamics, the electric field of a moving electron divides itself into "a velocity field," which is independent of acceleration, and "an acceleration field," which depends linearly upon acceleration. The velocity field is essentially static field, whereas the acceleration field is typical radiation field. 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 in electrodynamics, the vector potential should be deduced solely from the radiation field. On the assumption that the relativistic correction to the velocity component of vector potential involves the cancellation of the factor $(1-\beta^2)^{1/2}$ arising from the propagation path, this deductive reasoning leads to the following forms of expression for the vector potential:

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

It suggests that the component of the velocity perpendicular to **n** plays the role of an effective velocity in the evaluation of the vector potential. When we view it in this way, we realize that the component of the velocity parallel to **n** has been incorporated in the propagation path of the fields. Taking into account this geometrical image of the velocity, it seems sensible to expect that the vector potential of Eq. (12) expresses an effect occurring during its propagation. Moreover, the vector potential describes the transverse field in the intuitive forms

$$[\mathbf{n}\cdot\mathbf{A}]_t = 0, \quad \mathbf{E}_{rad} = -\frac{1}{c}\left[\frac{\partial\mathbf{A}}{\partial t}\right]_t = \frac{e}{c^2}\left[\frac{\mathbf{n}\times\{(\mathbf{n}-\mathbf{v})\times\mathbf{a}\}}{R(1-\beta\cdot\mathbf{n})^2}\right]_t. \tag{13}$$

When this is compared to the familiar result in electrodynamics, a factor of $(1-\beta\cdot\mathbf{n})$ is smaller than that. However, the general form of the power is given by the time integral of radiation emitted by the charge at the retarded time and, in the time integration, the relation between the retarded and present times $\mathrm{d}t_{ret} = \mathrm{d}t(1-\beta\cdot\mathbf{n})$ has been used [10]. Therefore, the electric field of Eq. (13) leads to the same form as the general expression for the energy detected at an observation point. As a result, it is seen that this deductive scheme for the vector potential lends itself to incorporation in the classical theory of radiation.

So far the aberration of radial fields has been discussed, nothing has been said about the physical significance of the aberration of uniform fields. We now consider the motion of an electron perpendicular to a uniform magnetic field **H**. Because the motion of the electron influences the velocity of propagation of the field, the apparent direction of the field acting on the electron will be tilted at an angle of aberration toward the direction of motion of the moving electron. Thus the angle at the field point between the field and the velocity of the electron would be $\pi/2-\alpha$, instead of being $\pi/2$, where α is the angle of aberration. By using the relation in Eq. (1), we can obtain the well-known expression for the cyclotron frequency $(eH/mc)(1-\beta^2)^{1/2}$, showing a new way of deriving and understanding the cyclotron frequency.

Insight into the apparent velocity of charged particle can now be provided by considering the mechanism by which the velocity of the particle is determined. An electrostatic spectrograph to determine the velocity of an electron consists in balancing the magnetic and electric deflections against each other [11]. The electron moving in a uniform magnetic field **H**, perpendicularly to **H**, describes a circular path of radius R_H. If this electron moves in a radial electric field **E**, it can describe a circular path of radius R_E. The equation of motion for the electron moving in the fields **H** and **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 $\mathbf{E}R_E = e\mathbf{v}/c\times\mathbf{H}R_H\,(=mv^2)$.. Taking into account the aberration occurring in the form of the vector difference between **v** and **H**, the angle at the field point between **v** and **H** would be $\pi/2-\alpha$, instead of being $\pi/2$, where α is the angle of aberration. Thus, the equation of motion becomes $cER_E = vHR_H\sin(\pi/2-\alpha)$, from which the apparent velocity of the electron is found to be $cER_E/HR_H(1-\beta^2)^{1/2}$, instead of being cER_E/HR_H, where $\beta = ER_E/HR_H$.. In this regard,

$cER_E\,/\,HR_H$, generally recognized as the velocity of the electron, is seen to be the velocity the electron would have if the velocity of propagation of the fields were infinite, thereby not suffering aberration. In fact, the speeds of high-energy particles of γv are frequently superluminal phenomenologically. It should be emphasized that these particles' speeds are attributed not to the phenomena of time dilation but to the apparent velocities of the fields as affected by the motions of particles. This consideration once again leads us to the conclusion that, phenomenologically, the particle velocity itself would appear dilated to the observer, keeping its time intact. The aberration of the uniform magnetic field furnishes physical support for that conclusion. It is then only natural that the concept of time is to be recovered.

6. Covariant Equations of Motion

One may ask whether there is a change in form of the equations of motion due to the velocity of propagation of fields. In passing we remark the covariant formulation of field equation resulting from the finite velocity of propagation of field. We are now going to examine the essential changes in physical outlook due to the velocity of propagation of fields.

Let us consider two moving systems, S and S' with a relative velocity between them. From (10) we find that the gravitational fields acting on the respective systems can be related to each other by equating the fields on the left:

$$\left[\frac{GM}{R^3}\mathbf{R}+\frac{d\mathbf{v}}{dt}\right]_S=\left[\frac{GM}{R^3}\mathbf{R}+\frac{d\mathbf{v}}{dt}\right]_{S'}. \tag{14}$$

Similarly, for the electromagnetic fields,

$$\left[e\mathbf{E}+\frac{e\mathbf{v}}{c}\times\mathbf{B}-\mathbf{F}\right]_S=\left[e\mathbf{E}+\frac{e\mathbf{v}}{c}\times\mathbf{B}-\mathbf{F}\right]_{S'}. \tag{15}$$

The formulations suggest an obvious generalization of the equations of motion when the velocity of propagation of fields is taken into account. Together with the covariant energy-momentum equation $[T^2/c^2-p^2]_{S\cdot}[T^2/c^2-p^2]_{S'}$, they show how physical phenomena appear the same in uniformly moving systems. Considering only the motion of S' relative to S, Eq. (14) goes over into the form of (10).

In mechanics, the Lagrange equation is derived from D'Alembert's principle. But one may also approach the Lagrangian formulation by way of Hamilton's principle and attempt simply to find a function L for which the Euler-Lagrange equations, as obtained from the variational principle, agree with the known relativistic equations of motion. It is usually not difficult to find a function satisfying these requirements. However, the present approach requires in addition that the Lagrange equation should be written in such a way as to conform to the form of (10) or (14). A covariant formulation of the Lagrange equation should therefore have the form.

$$\left[\frac{\partial L}{\partial r}-\frac{d}{dt}\left(\frac{\partial L}{\partial v}\right)\right]_S=\left[\frac{\partial L}{\partial r}-\frac{d}{dt}\left(\frac{\partial L}{\partial v}\right)\right]_{S'}. \tag{16}$$

Accordingly, Hamilton's principle is written covariantly as

$$\left[\delta\int L\,dt\right]_S=\left[\delta\int L\,dt\right]_{S'}. \tag{17}$$

If we further ask for the covariant formulation for the canonical equations of Hamilton, we can predict in the same manner

$$\left[\frac{\mathrm{d}r}{\mathrm{d}t}-\frac{\partial H}{\partial p}\right]_S = \left[\frac{\mathrm{d}r}{\mathrm{d}t}-\frac{\partial H}{\partial p}\right]_{S'}, \left[\frac{\partial H}{\partial r}+\frac{\mathrm{d}p}{\mathrm{d}t}\right]_S = \left[\frac{\partial H}{\partial r}+\frac{\mathrm{d}p}{\mathrm{d}t}\right]_{S'}. \tag{18}$$

The first half of Hamilton's equations seems to represent the covariant formulation of the vector difference between **c** and **v** for the velocity of light.

Continuing along these lines, in the Maxwell equations, we come to the transformation equations of electromagnetic fields. As an example, we consider the 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 **v**. Let S' be the moving coordinate system of q. The charge is at rest in this system. But when viewed from the laboratory, the charge represents a current $\mathbf{J}=q\mathbf{v}$ in the x direction. Ampere's law can then be written in the covariant form

$$\left[\nabla\times\mathbf{B}=\frac{4\pi}{c}\mathbf{J}+\frac{1}{c}\frac{\partial\mathbf{E}}{\partial t}\right]_S = \left[\nabla\times\mathbf{B}=\frac{1}{c}\frac{\partial\mathbf{E}}{\partial t}\right]_{S'}. \tag{19}$$

The y and z components of (19) are homogeneous equations. If we apply to these homogeneous equations the Lorentz transformation equations of coordinates with $[(ct..x),.(x.vt), y, z]_S[ct, x, y, z]_{S'}$, we obtain in the system S the equations

$$\frac{\partial B_x}{\partial z'}-\frac{\partial}{\partial x'}\left\{\gamma\left(B_z-\frac{v}{c}E_y\right)\right\}=\frac{1}{c}\frac{\partial}{\partial t'}\left\{\gamma\left(E_y-\frac{v}{c}B_z\right)\right\}, \tag{20}$$

$$\frac{\partial}{\partial x'}\left\{\gamma\left(B_y+\frac{v}{c}E_z\right)\right\}-\frac{\partial B_x}{\partial y'}=\frac{1}{c}\frac{\partial}{\partial t'}\left\{\gamma\left(E_z+\frac{v}{c}B_y\right)\right\}. \tag{21}$$

Here the time derivatives should be understood as the formal notation representing the system to which they refer while keeping simultaneity of the two systems in relative motion.

The covariance of these components of fields under the Lorentz transformation was explicitly shown by Lorentz and Einstein [12]. But it would seem that the covariance of the x component was assumed implicitly. The explicit transformation of that component can proceed as follows: We may write the x component of (19), using Coulomb's law $\nabla\cdot\mathbf{E}=4\pi q$, as

$$\frac{\partial B_z}{\partial y}-\frac{\partial B_y}{\partial z}=\frac{v}{c}(\nabla\cdot\mathbf{E})+\frac{1}{c}\frac{\partial E_x}{\partial t}. \tag{22}$$

By multiplying this equation with γ, we are led to

$$\frac{\partial}{\partial y'}\left\{\gamma\left(B_z-\frac{v}{c}E_y\right)\right\}-\frac{\partial}{\partial z'}\left\{\gamma\left(B_y+\frac{v}{c}E_z\right)\right\}=\frac{1}{c}\frac{\partial E_x}{\partial t'} \tag{23}$$

when we take into account the inverse Lorentz transformation of coordinates. The inverse equations differ from the Lorentz transformation equations only by a change in the sign of **v**, in which γ-factor is symmetric with respect to the two systems in relative motion. In the above equation, the inverse transformation equations have been used merely as another mathematical connection between the two sets of coordinates.

Faraday's law and $\nabla\cdot\mathbf{B}=0$ can be used equivalently to obtain the transformation equations. Consequently, the explicit equations of transformation of electromagnetic fields are

$$\begin{aligned} E_{x'} &= E_x, & B_{x'} &= B_x, \\ E_{y'} &= \gamma(E_y-\beta B_z), & B_{y'} &= \gamma(B_y+\beta E_z), \\ E_{z'} &= \gamma(E_z+\beta B_y), & B_{z'} &= \gamma(B_z-\beta E_y). \end{aligned} \tag{23}$$

This completes the demonstration of the covariance of electrodynamics. It should be emphasized that the transformation equations of electromagnetic fields can also be obtained in an explicitly covariant form directly from the Maxwell equations themselves without using the transformation properties of the field-strength tensor of rank two.

It is remarkable that Eq. (15) is in agreement with the relation between fields which was found when formulated Faraday's law of induction. In putting Faraday's law of induction in differential form, we have found that the electric field **E'** in a coordinate frame moving with a velocity v relative to the laboratory is $\mathbf{E}' = \mathbf{E} + \mathbf{v}/c \times \mathbf{B},$ where **E** and **B** are the fields in the laboratory. This is exactly in agreement with what Eq. (15) describes in manifestly covariant form between fields in the laboratory and the moving coordinate system of circuit.

7. Conclusion

The discussion in this paper shows that the aberration of starlight is interpreted as expressing the covariant equations of motion leading to the physics of relativistic phenomena. This suggests that the origins of relativistic phenomena lie in the physics of the aberration of starlight, in which the Galilean concepts of time and the speed of light are natural for describing the phenomena. The present interpretation stands in contrast with the relativistic explanation with regard to the concepts of time and the speed of light. While the relativistic explanation is deduced from mathematical formalism, the present interpretation is induced by physical phenomenon. The present interpretation leads us naturally to an understanding of relativistic phenomena using a unified concept. This is obviously in contrast with the current explanation that has given rise to much controversy. In controversy, the incorrect argument is in Einstein's theory of relativity, which is founded upon the, albeit mathematically consistent, physically inconsistent concepts of time and the speed of light, not in opponents' minds pointing them out. Paradoxically, the correct results of the theory aggravated the situation, since they led contrary to accept the physically inconsistent concepts therein as the most consistent together with the correct mathematical results. The theory of special relativity is a result of confusion coming from mixing up the notions, consistent and inconsistent.

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