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PROPER TIME PHYSICS

J. M. C. Montanus
Bunuellaan 16, 1325 PL Almere
The Netherlands
hans.montanus@wxs.nl

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Abstract

It will be argued that Minkowski's implementation of distances is not unique. An alternative implementation will be proposed. If Einstein's prescription for light speed measurements is applied to the new implementation, the special theory of relativity is recovered. Yet, the present model is based on a spacetime with a preferred frame of reference. A clock at rest with respect to the preferred frame is used for the parametrisation of events. The proper time of an object is taken as its fourth coordinate. Distances will be measured according to the Euclidean metric. In the present approach mass is a constant of motion. A mass will be ascribed to photons and neutrinos. Mechanics, gravitational dynamics and electrodynamics will be reformulated in close correspondence with classical physics. The new gravitational dynamics leads to the correct predictions for the deflection of light and the precession of perihelia, while it is based on a flat spacetime. A new conservation law emerges from the new mechanics: the conservation of proper time momentum. It allows for a mechanical explanation for Compton scattering and pair annihilation. In the new electrodynamics the electric field will be proportional to the proper time velocity. Intriguing consequences will be discussed. The equation of motion for the proper time momentum turns out to be very powerful. In the classical limit it reduces to the classical law for the conservation of energy. The Bohr model for the atom will be given a new explanation. As will be discussed briefly, the present approach gives a new notion to matters as energy, the structure of spacetime, antiparticles and the arrow of time. In fact, the contents of the present paper will have extreme implications for the foundations of physics in general.

1. Introduction

"*Was Einstein Right?*" is one of the numerous books which puts the theory of relativity (TR) to the test [1]. The answer always turns out to be confirmative. Yet, Minkowski's implementation of distances is not completely satisfactory for a lot of physicists, including the present author. For instance, it can be argued that the time parameter, the fourth coordinate and the Minkowski distance are not defined in a canonical way [2,3]. It also has been demonstrated that the concept of a curved spacetime is inconsistent [4]. If one sets up a parametrised spacetime in a canonical way, one inevitably arrives at an absolute Euclidean spacetime (AEST). With 'absolute' is meant that there is a preferred frame of reference. Distances are measured according to the Euclidean metric, even in the presence of a gravitational field. So, the AEST is flat everywhere. According to the AEST theory the proper-time of an object is taken as the fourth coordinate of that object. In practise this means that the TR and the AEST convert into each other by rearranging equations such that the time parameter serves as the proper-time and vice versa: $t \leftrightarrow \tau$. As a consequence, the proper-time velocity $u_4 := c d\tau / dt$ will appear in the dynamical equations in a very pronounced way. Gill et al have the subsequent electrodynamics appropriately denoted as *proper-time classical electrodynamics* [5]. This notation will be followed throughout the paper. In this paper also gravitational dynamics will be reformulated. For obvious reasons it will be denoted as *proper-time gravitational dynamics*. The new mechanics will be denoted as *proper-time mechanics*. The reformulation will be in close correspondence with classical physics. Since electromagnetic interactions can also be decribed by quantum electrodynamics, it can be expected that quantum field theory and thus also quantum mechanics should be reformulated according to the new concept of time. This opinion is shared with Gill et al [6]. It is the personal belief of the author that in the future a completely new description of physics will emerge. The latter can adequately be denoted as *proper-time physics*.

The plan of the paper is as follows. In Section 2 an argument will be given against Minkowski's implementation of distances as well as against the related Minkowski's metric. To be specific, a 'relativistic' football match will be considered in order to show as simple as possible the inconsistency in Minkowski's definition of four-dimensional distances. An alternative will be proposed. In the alternative model, distances are measured according to

Euclid's definition. It will be argued that the proper-time of an object should be taken as the fourth coordinate of that object, while the proper-time of the clock (of the observer) at rest in the frame of reference should be taken as the time parameter. It will also be argued that spacetime is absolute in the sense that there is a preferred frame of reference.
In Section 3 the AEST will be set up on the basis of an obvious postulate and some first principles. Also, the correspondence with the theory of relativity will be illuminated. It will, for instance, be shown that the special theory of relativity (STR) can be completely recovered if measurements are conducted as prescribed by Einstein.
Section 4 is about proper-time mechanics. That is, we will consider collisions between particles. Some illuminating examples will be given.
In section 5 proper-time gravitational dynamics will be considered in a flat AEST. Although it seems quite opposite to the general theory of relativity, it leads to the same predictions. By means of the result of Section 2 a decisive argument will be given against the concept of spacetime 'curvature'.
In Section 6 proper-time electrodynamics will be considered in an AEST. As a striking example, Bohr's model for the atom will be reconsidered.
In Section 7 we will discuss the consequences of the sign of proper-time.
In Section 8 some words will be spent on the direction of further research.

2. A 'relativistic' football match

In this section a football match will be considered from the AEST point of view and the TR point of view respectively. In the case of the latter a major flaw will be exposed.

Let us imagine a football stadium. The stadium is filled with spectators and a football match is about to begin. Let the stadium clock be situated at the center C. The stadium clock will be used to keep track of the order of the successive events. For obvious reasons it will be referred to as the time parameter t. Coincidently, it also represents the proper-time of the audience (the observers): $t = \tau_C$. Furthermore, identical clocks will be mounted on player A and the ball B. They represent the proper-time of the player, τ_A, and the proper-time of the ball, τ_B, respectively. The match starts at, say, three p.m. At that instant of time all the three clocks read 15.00. Since the AEST

description of the match diverges from the TR description, the match has to be described separately. We will start with the AEST description.
As soon as the referee has blown the whistle, player A starts to run. For the infinitesimal interval of player A we have according to the AEST theory

$$ds_A^2 = dx_A^2 + dy_A^2 + c^2 d\tau_A^2 \ . \tag{1}$$

Note that $dz_A = 0$ for a horizontal football court. For the infinitesimal interval of the stadium clock we have

$$ds_C^2 = c^2 d\tau_C^2 \equiv c^2 dt^2 \ . \tag{2}$$

Note that for the stadium clock also $dx_C = dy_C = 0$, since the stadium clock is at rest. That is, we conveniently regard it as the preferred frame of reference. According to the AEST theory every object moves with a four-dimensional velocity equal to the speed of light. Hence,

$$ds_A^2 = ds_C^2 \tag{3}$$

or

$$c^2 dt^2 = dx_A^2 + dy_A^2 + c^2 d\tau_A^2 \ . \tag{4}$$

From the latter we obtain the following expression for the time dilation of player A:

$$d\tau_A = \sqrt{1 - v^2 / c^2}\, dt \ , \tag{5}$$

where v is the spatial velocity of player A. Suppose that after half an hour player A hits the ball. At that very instant of time the stadium clock reads 15.30, while the clock of player A reads, say, 15.25. Since the mean velocity of the ball has exceeded the mean velocity of player A, its time dilation will be larger. So, the clock of the ball will read, say, 15.20. The time dilations are exaggerated just for convenience. According to the AEST theory the coordinate difference between two objects is given by

$$\Delta x^\mu = x_A^\mu - x_B^\mu \ , \tag{6}$$

where μ runs from 1 through 4. For the sake of clarity the reader should recall that the proper-time of the object is taken as the fourth coordinate: $x^4 = c\tau$. When player A hits the ball we have $\Delta x = x_A - x_B = 0$ and $\Delta y = y_A - y_B = 0$. So, at t = 15.30 the spatial distance between the player and the ball is zero (as required for a player hitting the ball). However, the four-dimensional Euclidean distance between them will not be zero:

$$\Delta s_{A\leftrightarrow B}^2 = \Delta x^2 + \Delta y^2 + c^2 \Delta\tau^2 = c^2(\tau_A - \tau_B)^2 \tag{7}$$

or $\Delta s_{A\leftrightarrow B} = 300c$ meters. For the Euclidean distance between two events and the infinitesimal displacement we have $\Delta s^2 = \Delta x^2 + \Delta y^2 + c^2 \Delta\tau^2$ and $ds^2 = c^2 dt^2$,respectively. The latter might suggest that $\Delta s^2 = c^2 \Delta t^2$ is a possible definition for the distance between two objects. However, it is not. If it were, we would find for the four-dimensional distance between the player and the ball at the moment the player hits the ball the following: $\Delta s = \Delta t = 15.30 - 15.30 = 0$. The latter is in disagreement with expression (7). Therefore, four-dimensional distances in an AEST will always be defined as follows:

$$\Delta s^2 = \Delta x_\mu \Delta x^\mu \ , \tag{8}$$

where $\Delta x_\mu = \delta_{\mu\nu} \Delta x^\nu$ with δ the Euclidean metric δ =diag. (1, 1, 1, 1). This is the canonical definition for four-dimansional distances in an AEST. It is valid in general for any kind of distance whether it is a four-dimensional distance between two objects:

$$\Delta s^2 = \Delta x^2 + \Delta y^2 + \Delta z^2 + c^2 \Delta\tau^2 \tag{9}$$

or an infinitesimal displacement of a single object:

$$ds^2 = dx^2 + dy^2 + dz^2 + c^2 d\tau^2 \ . \tag{10}$$

In summary, the improper definition $ds^2 = c^2 dt^2$ holds for infinitesimal intervals of a single object, but not for distances between two objects: $\Delta s^2 \neq c^2 \Delta t^2$. The canonical definition $ds^2 = dx_\mu dx^\mu$ holds for infinitesimal intervals of a single object, see equation (10), as well as for distances between two objects, see equation (9).

I will show that a similar situation is also present in the TR. To this end we will consider the TR description of the football match. According to Minkowski's definition for distances [7], the infinitesimal interval of player A is given by

$$ds_A^2 = dx_A^2 + dy_A^2 - c^2 dt^2 \ . \tag{11}$$

For the infinitesimal interval of the stadium clock this is

$$ds_C^2 = -c^2 dt^2 \ . \tag{12}$$

As is known, in the TR the length of intervals are taken equal to c times the proper-time lapse. For player A this is

$$-c^2 d\tau_A^2 = dx_A^2 + dy_A^2 - c^2 dt^2 \tag{13}$$

and for the stadium clock this is

$$-c^2 d\tau_C^2 = -c^2 dt^2 \ . \tag{14}$$

Since $t \equiv \tau_C$, that is, since the proper-time of the observer is taken as the fourth coordinate for the object, expression (14) is a trivial identity. The relation (13) is mathematically identical to the AEST relation (4). However, conceptually they are completely different. In the AEST theory the proper-time of player A is taken as the fourth coordinate, while the proper-time of the observer (the stadium clock) is taken as the time parameter. In the TR the proper-time of the observer (the stadium clock) is taken as the fourth coordinate , while the proper-time of player A is taken as the time parameter. As a consequence, in the TR the proper-time of the observer (the stadium clock) serves simultaneously as the fourth coordinate for all the different objects, while there are as many parameters as objects. As is known, it leads to problems for the parametrisation of relativistic multibody dynamics as well as relativistic quantum theories. For this reason Fock, Tetrode and others tried to construct single parameter theories. Usually one proposes an additional evolution parameter independent of the proper-time. For instance, Horwitz and Piron [8] proposed to use the proper-time of the barycenter of a two body system as the evolution parameter. A historical review on this matter has been given by Fanchi [9]. The necessity of an absolute evolution parameter for the formulation of quantum gravity has been exposed by Gaioli and Garcia-Alvarez [10]. It can therefore be seen as an advantage of the AEST approach that all the objects have distinct values for their fourth coordinate, while they are parametrised by a single evolution parameter.

Let us proceed with the description of the football match according to the TR. When the player hits the ball, the spatial distance between them is zero. At this point the TR is, of course, identical to the AEST. The difference comes into play when the four-dimensional distance is considered at the very moment of player A hitting ball B. According to the TR it is given by

$$\Delta s_{A\leftrightarrow B}^2 = \Delta x^2 + \Delta y^2 - c^2 \Delta t^2 = 0 + 0 - 0 = 0 \ . \tag{15}$$

The TR relation for the infinitesimal displacement of a single object: $ds^2 = -c^2 d\tau^2$, suggests for distances between two objects the following

relation: $\Delta s^2 = -c^2 \Delta\tau^2$. However, for player A hitting the ball B the latter would yield: $\Delta s_{A\leftrightarrow B} = ic(\tau_A - \tau_B) = 300c$ (imaginary) meters, in disagreement with expression (15). The inconsistency can be avoided by defining the four-dimensional distances in the TR as

$$\Delta s^2 := \Delta x^2 + \Delta y^2 + \Delta z^2 - c^2 \Delta t^2 \tag{16}$$

and certainly not as $\Delta s^2 = -c^2 \Delta\tau^2$. As we will see in section 6, this will completely destroy the concept of a curved spacetime and therefore the validity of the GTR.

In summary, the improper definition $ds^2 = -c^2 d\tau^2$ is valid (within the concept of the TR) for infinitesimal displacements of a single object, but not for distances between objects: $\Delta s^2 \neq -c^2 \Delta\tau^2$. The alternative definition $ds^2 = dx^2 + dy^2 + dz^2 - c^2 dt^2$ is valid (if we take the Minkowski metric for granted for a moment) for infinitesimal intervals of a single object as well as for distances between two objects, see equation (16).

The inconsistency in the TR because of its improper definition for distances is not new. Phipps already clarified it by explicitly distinguishing between differential quantities referring to two worldlines and those referring to one [11]. The present line of arguments is a popularised version of it. As we saw, the argument helped us avoiding a similar kind of improper definition for distances in the AEST.

Opponents to the AEST theory might reply with the following criticism: "For the determination of the time coordinate of an event an observer will use his clock in the same way as he uses his yardstick for the determination of the spatial coordinates of the same event. So, it is quite natural to take the clock of the observer as the fourth coordinate of the observed event (or object)". Well, it might seem natural but it is not. It is hard to leave this idea since we are more or less grown up with it. For the time coordinates of events we always read off the watch in our hands. Suppose an object is at position x_1 according to our yardstick while our watch reads t_1. Also suppose that the object is at position x_2 according to our yardstick, while our watch reads t_2. Indeed we feel inclined to say that the object has moved a distance $x_2 - x_1$ in space, while it has moved a 'distance' $c(t_2 - t_1)$ in time. However, this is not the case. To this end we note that the clock of the observer represents the proper-time of the observer. Thus the 'distance' $c(t_2 - t_1)$ is our proper-time lapse. What we measure with our watch is just our own fourth coordinate. Therefore it cannot also be used as a fourth coordinate for the observed objects (as unfortunately is the situation in the TR). So, when an object is at position x_1 when our watch reads t_1 and at x_2 when our watch reads t_2, we should say that the object has moved a distance $x_2 - x_1$ in space, while we (the observers) have moved a 'distance' $c(t_2 - t_1)$ in time.The misconception would probably not have occured if the proper-time of the object would have been apparent to us from the very beginning. In order to see this, consider the mouse of your personal computer. As soon as you move the mouse, its new position (x, y) is immediately displayed on the screen of your computer. It is not hard to imagine a three dimensional mouse. As soon as you moves such a mouse in space, its new position (x, y, z) will then be displayed on your screen. The final thing to do, is to imagine a four-dimensional mouse. To this end we mount a clock on the mouse of the computer. In this way the proper-time of your mouse can be read off electronically and displayed on your screen. As soon as you move the mouse (very quickly) you will observe that its clock will run slower: time-dilation. So, now there are four coordinates on your screen: x, y, z, τ . In case we had played with such a toy on high school, we probably would have considered it as natural to take the proper-time of an object as its fourth coordinate. The internal clock of your computer (displayed separate from the proper-time of the mouse) is not redundant. It will serve as a parameter in order to keep track of the successive events.

The objections outlined in this section are not the only ones that can be raised against Minkowski's implementation. Additional arguments can be found in my previous papers [2,3]. Some of them will be present in the following sections. To avoid length, I will not recall all the arguments in the present paper. Instead I prefer to set up the AEST and look for its consequences.

3. The AEST and its correspondence with the TR.

In this section a four-dimensional AEST will be constructed. A comparison will be made with the TR. As argued before, the proper-time of the object is taken as the fourth coordinate of that object. Observed distances will be measured according to the Euclidean metric:

$$ds^2 = \delta_{\mu\nu} dx^\mu dx^\nu \ , \qquad (17)$$

where the summation is understood over repeated indices. The indices run from 1 through 4, where the fourth coordinate is c times the proper-time of the observed object. An advantage of the AEST theory is that there will be no difference between covariant and contravariant tensors: $A_\mu = A^\mu$, $F^{\mu\nu} = F^\mu{}_\nu = F_{\mu\nu}$ and so on. So, in the sequel of the paper the Euclidean distance will be expressed as

$$ds^2 = dx_\mu dx^\mu \ , \qquad (18)$$

where the summation is understood over repeated indices in the Euclidean sense.

Now, for a Euclidean spacetime there are a priori two possibilities: either it is relative (absence of a preferred frame of reference) or it is absolute (presence of a preferred frame). It can be shown that a relative Euclidean spacetime bears nonsensical properties, while an absolute Euclidean spacetime does not [2]. Next to this, there is some experimental evidence for a preferred frame of reference [12]. Also a consistent description of stellar aberration requires absolute motions [13,14]. We therefore will restrict ourselves to an absolute Euclidean spacetime (AEST). The adverb 'absolute' should not be seen in the historical meaning of a spacetime where all the clocks run equally fast. Instead, with 'absolute' is ment that there is a preferred frame of reference. In the spirit of Mach the preferred frame is thought to be such that the sum of all the momenta of all the objects in the universe vanishes. A clock at rest with respect to this absolute rest frame will run fastest. Its time will be referred to as absolute time and used as the time parameter. A clock moving with respect to this absolute frame runs slower. Its time will be denoted as τ and it will be used as the fourth coordinate: $x_4 = c\tau$. Because of the relation (4), which is valid in the AEST as well as in the TR, we postulate the following: In the absence of gravitation all objects move with a four-dimensional Euclidean velocity equal to the speed of light in a vacuum. This postulate can be expressed as follows

$$u_\mu u^\mu = c^2 \ . \qquad (19)$$

Again, the (Euclidean) summation is understood over repeated indices. Explicitely it reads

$$c^2 = \dot{x}^2 + \dot{y}^2 + \dot{z}^2 + c^2\dot{\tau}^2 \ . \qquad (20)$$

The dot stands for the derivative with respect to the parameter t. For instance, $u_4 = c\dot{\tau} = cd\tau / dt$ is the proper-time velocity. The consequence of the equation (19) is that objects moving off from the absolute origin with a constant velocity, all will reach a three sphere with radius $c\Delta t$ during a lapse of absolute time Δt. For a clock at rest with respect to the absolute rest frame, we have $\tau_{clock} = \tau_{absolute} \equiv t$. It will be used as the time parameter.

In order to draw the trajectories of the objects in a four-dimensional AEST, we clearly need a fifth axis; a parameter axis. This does not mean that the AEST is five dimensional. It just is a four-dimensional spacetime extended with a parameter axis. Since a four-dimensional spacetime is difficult to represent on a plane sheet of paper, we will restrict ourselves to a two dimensional hyperplane. That is, we will restrict ourselves to the x_1, x_4-plane. The situation is drawn in Figure 1.

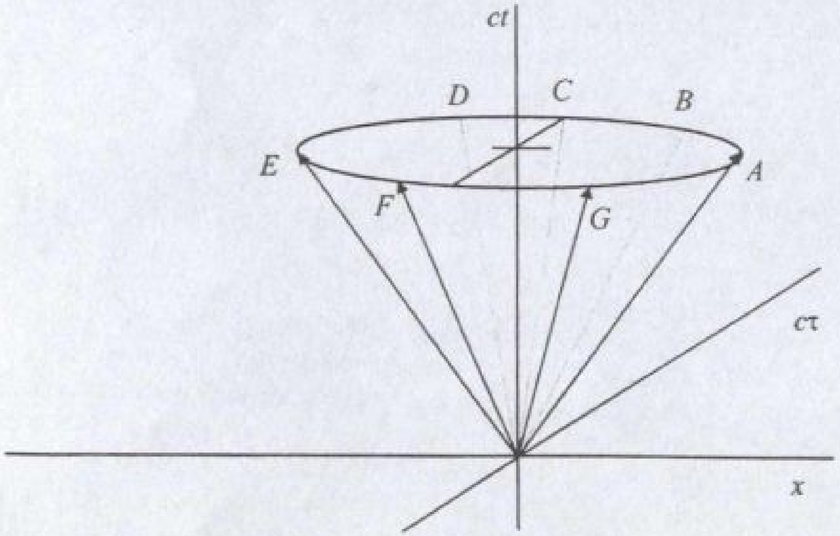


Figure 1. Various objects, A through G, moving in a two dimensional hyperplane for increasing parametervalue.

The parameter axis ct is drawn perpendicular to the x_1, x_4-plane. After a simultaneous start in the origin, the simultaneous positions of the objects constitute a circle, whose radius increases as much as the time parameter. The result is a cone in a three dimensional diagram. Again, we emphasize that this

diagram being three dimensional, does not mean that the hyperplane under consideration is three dimensional. Instead, the diagram represents a two dimensional hyperplane extended with a parameter axis. If we suppress the parameter axis, that is, if we take a top view of Figure 1, we obtain the corresponding AEST diagram, see Figure 2. The AEST diagram shows some resemblance with the so called space-proper-time representation of Newburgh and Phipps [15]. In the AEST diagram, objects starting simultaneously in the origin, all will reach a circle with radius cdt during a lapse of parameter time dt. They should since they obey the equation (20). So, the paths in the AEST diagram always reflects the fundamental relation

$$dt^2 = dx^2 + dy^2 + dz^2 + c^2 d\tau^2 \ . \tag{21}$$

The circle in the AEST diagram in Figure 2 is a line of simultaneous endpoints of the infinitesimal trajectories of particles who moved off simultaneously (at $t = 0$, say) from the origin. As a consequence, the relation between spatial velocity and proper-time velocity will be of goniometrical nature. As we will see, the latter allows for a simple calculation of the 'relativistic' factor.

The calculation of the velocities in the AEST is a matter of projecting the four-dimensional velocities on the space axes and the proper-time axis. For the object B we have for its spatial velocity $v_B = c\cos\varphi$ and for its proper-time velocity $cd\tau_B / dt = c\sin\varphi$. It immediately follows that $d\tau_B / dt = \sqrt{1-\cos^2\varphi}$. Inserting $\cos\varphi = v_B / c$, we obtain

$$d\tau_B = dt / \gamma_B \ , \tag{22}$$

where $\gamma_B = (1 - v_B^2 / c^2)^{-1/2}$. This result is well-known from the theory of relativity. The goniometrical nature of the factor γ becomes very transparent in the present approach. The object C is an object at rest in the origin of the absolute rest frame. For it we have $v_C = 0$ and $d\tau_C = dt$. The object D moves in the negative x-direction, while its proper-time runs forward: $v_D < 0$, $d\tau_D = dt / \gamma_D$. The object E is a photon moving in the negative x-direction: $v_E = -c$, $d\tau_E = 0$. The particle G is moving in the negative proper-time direction: $d\tau_G = -dt / \gamma_G$. If one likes, the reversed proper-time can be conceived as if the hands of the 'internal clock' of particle G are rotating counterclockwise. According to the AEST theory a backwards running proper-time means that the particle behaves in an opposite way. Alternatively, if particle B and particle G have opposite properties, then particle G can be regarded as an antiparticle. Particle F moves in the negative x-direction and in the negative proper-time direction. So, it also is an antiparticle. The object A, finally, is a photon moving in the positive x-direction. Although it makes less sense, one can also suppress the proper-time axis instead of the parameter axis.

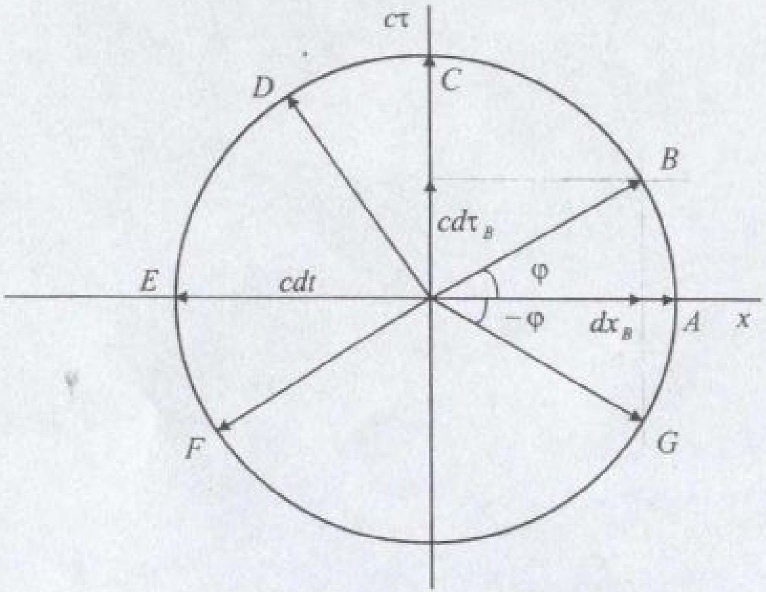


Figure 2. The AEST diagram for the objects A through G.

Suppressing the proper-time axis, that is, taking a front view of Figure 1, we obtain the Minkowski diagram, see Figure 3. We see that the Minkowski diagram actually is a space diagram extended with a parameter axis. If one regards (erroneously) the time parameter as the simultaneous fourth coordinate for all the objects, the Minkowski diagram can easily be taken for a space-time diagram. Unfortunately, this is exactly what has happened in the TR. The present approach makes clear that the Minkowski diagram actually is a space diagram extended with the parameter axis. The projection of the full diagram in Figure 1 to the diagram in Figure 3 illuminates why there is a lightcone in the Minkowski diagram and a gap outside the lightcone. It also illuminates that the trajectories of objects moving in the AEST at an angle φ and $-\varphi$ respectively, are mapped on the same trajectory in the Minkowski diagram. The points of the circle in the AEST diagram all have the same value

for the time parameter. Since the value of the time parameter is mistaken as the simultaneous value of the fourth coordinate of the objects, these points lie on a horizontal line in the Minkowski diagram.

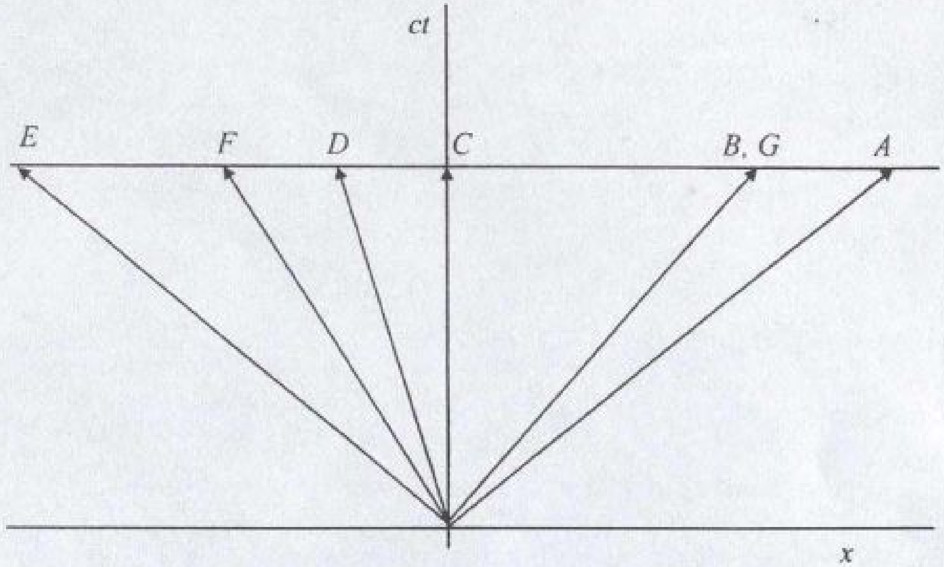


Figure 3. The Minkowski diagram for the objects A through G.

As a consequence, in the TR the four-dimensional distances always are purely spatial. At first instance this might seem natural. However, it is not. Giving it a little thought it is in fact quite odd. Simultaneity is indissolubly connected with the time ordering of events. It is the time parameter which should determine simultaneity and not the fourth coordinate. Imagine, for instance, two four-dimensional mice electronically connected to a computer screen. If we move the mice with differents speeds, we will not be surprised if different values for the time coordinates simultaneously appear on the screen of our computer. Moreover, it even is required by a realistic time dilation.

In summary, for a canonical spacetime model with four coordinates and one parameter, one should expect the values for all the four coordinates to differ from one object and another, not just for the three spatial coordinates as in the TR. One also should expect that the motion of all the objects can be parametrised by one single parameter, not by infinitely many parameters as in the TR. The AEST theory does satisfy these logical requirements, while the TR clearly does not.

So far, we have just considered velocities with respect to the absolute rest frame. Now we will briefly consider velocities with respect to a moving observer. Without loss of generality we let the observer move with a constant speed v_O in the positive x-direction. The Michelson and Morley experiment [16] can be explained in an AEST if one assumes a physical length contraction, as shown by Lorentz [17]. At this point the AEST is similar to the TR, except that there is no doubt about the physical reality of the length contraction [2]. Because of this length contraction the yardstick of the moving observer O will shrink with a factor $\gamma_O = (1 - v_O^2 / c^2)^{-1/2}$. As a consequence the infinitesimal change of a measured distance looks larger by the same factor than its Galilean value $dx_A - dx_O$. Thus

$$dx_{meas} = \gamma_O (dx_A - dx_O) \, , \tag{23}$$

where the subscripts A and O identify the object A and the observer O respectively.

Since the clock of the moving observer runs slower than a clock at rest, we have for the proper-time $t_O \equiv \tau$ of the observer: $dt_O = dt / \gamma_O$. Now, the Einstein synchronization procedure [18] for to-and-fro light speed experiments hinges on a circular reasoning. To be specific, the synchronization of clocks is based on the assumption of the invariance of the speed of light, while the invariance of the speed of light hinges on the synchronization of the clocks. If one applies the Einstein synchronization procedure to the AEST, that is, if one lets the observer synchronize his clocks such that he obtains in a to-and-fro experiment the same value for the speed of light, then the moving observer will measure a slightly different value for an infinitesimal time lapse [2] :

$$dt_{meas} = dt - \gamma_O (dx_A - dx_O) v_O / c^2 \, . \tag{24}$$

The expressions (23) and (24) can be elaborated to

$$dx_{meas} = \gamma \left(dx_A - \frac{v_O}{c} cdt \right) \tag{25}$$

and

$$cdt_{meas} = \gamma \left(cdt - \frac{v_O}{c} dx_A \right), \tag{26}$$

respectively. We recognize them as the Lorentz transformation. However, the AEST approach makes clear that the transformation (26) actually is a

parameter transformation and not a coordinate transformation. The transformation of the fourth coordinate of object A is

$$d\tau_{meas} = d\tau_A \, . \tag{27}$$

That is, the proper-time of an object is invariant; it is the same for every observer. Since the application of the Einstein synchronisation procedure leads to the Lorentz transformation, it also leads to Einstein's addition theorem for velocities. In fact, the STR is completely recovered in this way [2]. It should be emphasized that this does not mean that spacetime is relative after all. The seeming relativity is not a consequence of the structure of spacetime as it is believed to be in the TR. On the contrary, it is an artificial consequence of the way we conduct measurements. Without the synchronization, it would be obvious that spacetime is absolute and Euclidean. Since physics will not reckon with the artificial way we conduct measurements, one expects that the predictions following from the AEST theory will diverge from the predictions following from the TR. Remarkably enough this does not happen to be the case. It turns out that the two distinct theories lead to predictions which are similar to a high extent. Examples of such similarities will be given in the next sections.

4. Proper-time mechanics

In this section a semi-classical explanation will be given for Compton scattering and pair annihilation. Before we start the analysis it has to be mentioned that in the AEST theory mass is taken to be independent of velocity. It has been shown that in the AEST theory the concept of a velocity-independent mass does not run into conflict with accelerator experiments [19]. As also stressed by Strel'tsov [20], the TR is ambiguous at this point: scalars should be invariant, while mass is an exception to this rule. For the same reason the presence of mass in the Lagrangians is troublesome in the TR. As will be shown in this section, a fully consistent mechanics can be based on invariant masses. For a start we will consider the AEST Lagrangian for a free object:

$$L = m u_\mu u^\mu \, . \tag{28}$$

In the AEST the Euler-Lagrange equations of motion read [21]

$$\partial L / \partial x^{\mu} = d / dt\, \partial L / \partial u^{\mu} \quad . \tag{29}$$

The total energy of the object follows from

$$E = u^{\mu} \partial L / \partial u^{\mu} - L \equiv m u^{\mu} u_{\mu} \, , \tag{30}$$

and is a constant of motion: $\dot{E} = 0$. By means of the AEST postulate (19), the total energy is also given by

$$E = mc^2 \; . \tag{31}$$

Since mass is a constant of motion in the AEST theory, the value we take for m is the same as what is called rest mass in the TR. In the AEST theory it does not make sense to speak about a rest mass since mass is independent of velocity. Applying the Euler-Lagrange equations to the free Lagrangian, we obtain

$$m u_{\mu} = p_{\mu} \; , \tag{32}$$

where each momentum p_{μ} is a constant of motion: $\dot{p}_{\mu} = 0$. In the sequel of the paper a profound role will be played by the proper-time momentum p_4.

Since this section is about collisions, we have to consider more than one object. In order to distinguish the different objects we clearly need an identifier. Therefore, the momentum of an object will be denoted as $p_{i,\mu}$, where the i identifies the object. For instance, the momentum $p_{7,3}$ is the momentum in the z-direction of the seventh particle. If there are initially n particles, the total momentum before the collision amounts to $\sum_{i=1}^{n} p_{i,\mu}$. If there are N particles after the collision, the final total momentum amounts to $\sum_{i=1}^{N} P_{i,\mu}$. The quantities after the collision will be written as capitals just in order to avoid the use of primes. As in classical mechanics, we require that the total momentum in each direction has to be conserved:

$$\sum_{i=1}^{n} p_{i,\mu} = \sum_{i=1}^{N} P_{i,\mu} \; . \tag{33}$$

Also, the total energy has to be conserved:

$$\sum_{i=1}^{n} m_i c^2 = \sum_{i=1}^{N} M_i c^2 \; . \tag{34}$$

Dividing both sides by the square of the speed of light, we can also refer to it as the conservation of total mass:

$$\sum_{i=1}^{n} m_i = \sum_{i=1}^{N} M_i \; . \tag{35}$$

During the collision process we will allow a change of the number of particles as well as of the mass of each particle as long as the total mass is conserved. Of special interest will be the conservation of proper-time momentum:

$$\sum_{i=1}^{n} m_i \sqrt{c^2 - v_i^2} = \sum_{i=1}^{N} M_i \sqrt{c^2 - V_i^2} \; . \tag{36}$$

For a classical collision the number of particles and the mass of each particle will not change during the collision process. The velocities of the objects will be small compared to the speed of light. With the substitution of $n = N$, $m_i = M_i$, $v_i << c$ and $V_i << c$, equation (36) reduces to second order in

$$\sum_{i=1}^{n} m_i c (1 - \tfrac{1}{2} v_i^2 / c^2) = \sum_{i=1}^{n} m_i c (1 - \tfrac{1}{2} V_i^2 / c^2) \tag{37}$$

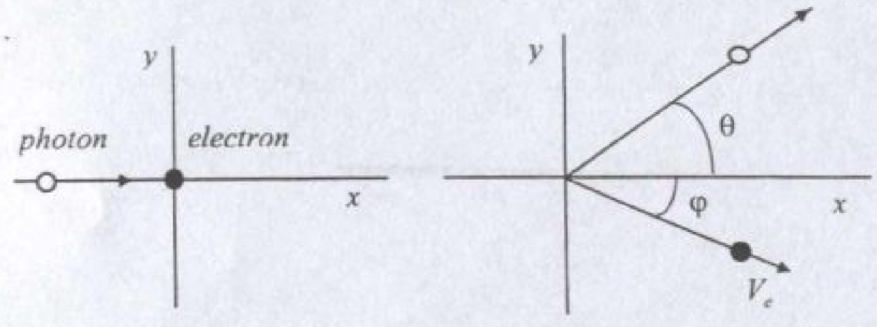
or simply

$$\sum_{i=1}^{n} \tfrac{1}{2} m_i v_i^2 = \sum_{i=1}^{n} \tfrac{1}{2} m_i V_i^2 \; . \tag{38}$$

We conclude that in the classical limit the conservation of proper-time momentum reduces to the conservation of kinetic energy. From the AEST point of view it is better to speak of conservation of proper-time momentum. By means of the system of equations (33) and (35) an AEST analysis of a classical collision between , say, two billiard balls can be performed [22]. The results are in agreement with classical kinematics. In the next subsections we will consider collisions between elementary particles.

4.1 Compton scattering

As mentioned before, for nonclassical collision the number of particles and the mass of each particle may change during the collision process. For nonclassical collisions the AEST concept of mass invariance allows to ascribe a mass to a neutrino and a photon as follows: $m = hf / c^2$, where f is the frequency of oscillation in an internal dimension. The internal frequency can change during a collision. For instance, when a photon is scattered against a free electron its frequency will decrease. This is known as the Compton effect. From the AEST point of view this means that the mass of the photon has decreased. Since the total mass has to be conserved this implies that the mass of the electron has increased during the collision. With these considerations in mind a semiclassical explanation can be given for the Compton effect. The experiment is as follows. A photon with frequency f is incident on a free electron at rest, see Figure 4. On collision the photon is scattered at an angle θ, while the electron moves off at an angle φ with velocity V_e.



Before collision ***After collision***

Figure 4. Compton scattering. After the collision the electron moves off with a speed V_e at an angle φ. The photon moves off at an angle θ.

According to the equations (33) the conservation of momentum in the x, y and τ -direction read for this collision

$$m_\gamma c = M_\gamma c\cos\theta + M_e V_e \cos\varphi \ , \tag{39}$$

$$0 = M_\gamma c\sin\theta - M_e V_e \sin\varphi \ , \tag{40}$$

and

$$m_e c = M_e\sqrt{c^2 - V_e^2} \ , \tag{41}$$

respectively. For the conservation of mass we have

$$m_\gamma + m_e = M_\gamma + M_e \ . \tag{42}$$

The subscripts γ and e identify the photon and the electron respectively. Eliminating the final mass of the electron, we obtain

$$m_\gamma M_\gamma (1-\cos\theta) = m_e(m_\gamma - M_\gamma) \ . \tag{43}$$

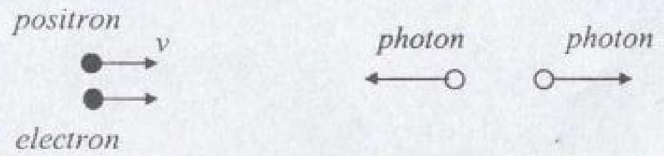
Substituting $m_\gamma = h / c\lambda$ and $M_\gamma = h / c\lambda'$, we obtain for the Compton shift:

$$\lambda' - \lambda = \lambda_{c,e}(1-\cos\theta) \ , \tag{44}$$

where $\lambda_{c,e} = h / cm_e$ is the Compton wavelength for the electron. We see that the AEST prediction and the TR prediction for the Compton shift are identical [23]. This is a remarkable result since the conservation laws read entirely different in the TR. Such a remarkable agreement also occurs for the annihilation of an electron-positron pair. As we will see in the next subsection, the AEST explanation of pair annihilation is far more close to our notion of reality.

4.2 Pair annihilation

When an electron and a positron annihilate, two photons emerge. In case the electron and the positron are moving at the moment of annihilation, the wavelengths of the emerging photons will be shifted. By means of the system of equations (33) and (35) we will offer the AEST explanation for it. To this end we consider an electron and a positron both moving with a velocity v in the x-direction. After the annihilation two photons will move off in opposite directions, see Figure 5.



Before annihilation ***After annihilation***

Figure 5. The annihilation of an electron and a positron. After the annihilation two photons emerge in opposite directions.

The conservation of momentum in the x- and τ -direction read

$$m_e v + m_p v = M_{\vec{\gamma}} c - M_{\overleftarrow{\gamma}} c \qquad (45)$$

and

$$m_e \sqrt{c^2 - v^2} - m_p \sqrt{c^2 - v^2} = 0 \; , \qquad (46)$$

respectively. The conservation of mass reads

$$m_e + m_p = M_{\vec{\gamma}} + M_{\overleftarrow{\gamma}} \; . \qquad (47)$$

In these equations e and p identify the electron and the positron. The subscript $\vec{\gamma}$ ($\overleftarrow{\gamma}$) identifies the photon which moves off to the right (left). A negative sign is taken for the proper-time of the positron. This is legitimate since $u_4 = -\sqrt{c^2 - v^2}$ also is a solution of equation (19). The minus sign just means that the proper-time of the positron is running backwards. As mentioned before, it is the opposite sign of proper-time which makes the behaviour of the positron opposite to the behaviour of the electron. So, in fact the negative sign is required since it means that the positron is an anti-electron. From equation (46) it follows that the mass of the electron is equal to the mass of the positron. The other two equations then lead to [22]:

$$M_{\vec{\gamma}} = m_e (1 + v/c) \qquad (48)$$

and

$$M_{\overleftarrow{\gamma}} = m_e (1 - v/c) \, . \qquad (49)$$

By means of the relations $\vec{\lambda} = h/cM_{\vec{\gamma}}$ and $\overleftarrow{\lambda} = h/cM_{\overleftarrow{\gamma}}$ the latter equations can also be written as

$$\vec{\lambda} = \lambda_{c,e} / (1 + v/c) \qquad (50)$$

and

$$\overleftarrow{\lambda} = \lambda_{c,e} / (1 - v/c) \; , \qquad (51)$$

respectively, where $\lambda_{c,e} = h/cm_e$ is the Compton wavelength for the electron. In case the velocity of the electron-positron pair is equal to zero, the wavelength of the emerging photons will both be equal to the Compton wavelength for electron. For the nonzero velocity of the pair, the wavelengths clearly are shifted. The expressions (50) and (51) are identical to the ones found with the TR [24]. For the ratio of the wavelengths we find

$$\vec{\lambda} / \overleftarrow{\lambda} = (c - v)/(c + v) \; . \qquad (52)$$

We see that the ratio of the wavelengths only depends on the velocity of the pair. This expression for the ratio of the wavelengths holds for any particle-antiparticle annihilation. In order to give a clear exposition of the conceptual difference between the AEST theory and the TR, we will consider the following cases: 1) both the observer and the pair are at rest with respect to the absolute rest frame, 2) the observer is at rest with respect to the absolute rest frame while the pair is moving with a velocity v in the right (this is just the situation considered above), 3) the pair and the observer both are moving with velocity v to the right (that is, the observer is co-moving with the pair) and 4) the pair is at rest with respect ot the absolute rest frame while the observer is moving to the left.

Case 1. According to both the AEST theory and the TR there will be no shift: $\vec{\lambda} / \overleftarrow{\lambda} = 1$.

Case 2. According to both the AEST theory and the TR the wavelengths will be shifted as given by the expression (52).

Case 3. In the TR this case is identical to case 1. So, according to the TR the wavelengths will not be shifted. According to the AEST theory the wavelengths will be shifted as given by the expression (52). That is, they really are shifted in the sense that there are two different frequencies generated. We will refer to it as the 'real' shift. However, the measured values for the wavelengths will also be Doppler shifted for an observer which is moving with respect to the absolute rest frame:

$$\left(\frac{\vec{\lambda}}{\overleftarrow{\lambda}}\right)_{meas} = \left(\frac{c+v}{c-v}\right)\left(\frac{\vec{\lambda}}{\overleftarrow{\lambda}}\right)_{real} \; . \qquad (53)$$

For the derivation of the Doppler shift for a moving observer in an AEST we start considering the 'Galilean' expressions for the shift: $\vec{\lambda} = (1 + v/c)\vec{\lambda}_{real}$ and $\overleftarrow{\lambda} = (1 - v/c)\overleftarrow{\lambda}_{real}$, where v is the velocity of the observer (towards the right). The latter expressions are too naive since the length contraction of the yardstick of the observer will make that the observed wavelength looks larger with a factor $\gamma = (1 - v^2/c^2)^{-1/2}$. As a consequence the expression for the observed wavelengths become

$$\vec{\lambda}_{meas} = \frac{(1 - v/c)}{\sqrt{1 - v^2/c^2}} \vec{\lambda}_{real} \equiv \sqrt{\frac{c-v}{c+v}} \, \vec{\lambda}_{real} \qquad (54)$$

and

$$\bar{\lambda}_{meas} = \frac{(1+v/c)}{\sqrt{1-v^2/c^2}}\bar{\lambda}_{real} \equiv \sqrt{\frac{c+v}{c-v}}\,\bar{\lambda}_{real} \;. \qquad (55)$$

From these expressions one immediately obtains the expression (53). Substitution of the expression (52) for the ratio of the real shift in the expression (53) leads to $(\bar{\lambda}/\bar{\lambda})_{meas} = 1$. Obviously, the Doppler shift precisely compensates the real shift. Therefore we do not measure a shift for the wavelengths. So, both the AEST theory and the TR predict the same result in this case.

Case 4. According to the TR there is no difference with case 2. Therefore the shift will be given by the expression (52) in the TR. According to the AEST theory the wavelengths will not be shifted since the pair is at rest in the absolute rest frame. That is, there is no 'real' shift: $(\bar{\lambda}/\bar{\lambda})_{real} = 1$. However, the measured values for the wavelengths will be Doppler shifted for the moving observer. Therefore the measured value for the ratio of the wavelengths will be

$$\left(\frac{\bar{\lambda}}{\bar{\lambda}}\right)_{meas} = \left(\frac{c-v}{c+v}\right)\left(\frac{\bar{\lambda}}{\bar{\lambda}}\right)_{real} \equiv \frac{c-v}{c+v} \;. \qquad (56)$$

The latter is identical to the TR prediction (52). So, in all cases both theories predict the same result. The conceptual differences become very transparent. In the AEST theory it always is clear whether the shift is a real shift (due to the motion of the pair with respect to the absolute rest frame) or whether the shift is a Doppler shift (due to the Doppler effect for the moving observer). In the TR the shift is a real shift if the inertial frame of the observer is taken as the frame of reference, while the shift is a Doppler shift when the inertial frame of the pair is taken as the frame of reference. In the TR the shift partly is a real shift and partly a Doppler shift for every other frame of reference. Elementary logic prescribes that an annihilating pair can generate just one single value for the real shift. The AEST theory therefore is in agreement with our inner sense of logic. According to the TR the pair has to be able to adjust simultaneously the amount of real shift to all the different observers. The TR therefore runs into conflict with our inner sense of logic. Alternatively, at this point the TR is paradoxal, while the AEST theory clearly is not.

5. Proper-time gravitational dynamics

In this section we will present a new model for gravitation in a flat AEST. Before we investigate the consequences of the new gravitational dynamics, we first will offer two decisive arguments against the GTR. To this end we start considering the Schwarzschild solution as it is found in the GTR:

$$c^2 d\tau^2 = (1-2\mu/r)c^2 dt^2 - (1-2\mu/r)^{-1}dr^2 - r^2 d\varphi^2 - r^2\sin^2\varphi\, d\theta^2 \qquad (57)$$

Firstly, as we saw in Section 2, Minkowski's definition for distances is inconsistent. So, it is not allowed to substitute $ds^2 = -c^2 d\tau^2$ in the expression above. As a consequence the coefficients $(1-2\mu/r)$ and $(1-2\mu/r)^{-1}$ cannot be interpreted as the components of a metrical tensor. Since Einstein's derivation of the Schwarzschild solution is entirely based on the concept of a curved spacetime, we have to draw the conclusion that the GTR is ill-founded. Secondly, it is easy to show that expression (57) is already inconsistent itself [4]. Let us start by assuming that the coefficients are additive (we prefer to speak of coefficients rather than metrical components since we want to show that spacetime is flat) . Since the Schwarzschild solution holds for every spherically symmetric source mass, it also should hold for every spherical part of it. For convenience we will denote a small spherical part as an 'atom'. Adding the potentials of all the atoms which constitute the bigger sphere, we arrive at the correct expression for the coefficient guiding the dt^2:

$$g_{tt} = 1 - 2\sum_{i=1}^{N}\mu_i / r_i = 1 - 2\mu/r \;, \qquad (58)$$

where N is the number of 'atoms', r_i is the distance between the i-th atom and the object, and $\mu_i = Gm_i/c^2$, with m_i the mass of the i-th atom [4]. However, the addition of potentials does not lead to the correct expression for the coefficient guiding the dr^2 since each atom also will partly contribute to the coefficient guiding the $r^2 d\varphi^2$. As a consequence, the addition leads to $g_{rr} < (1-2\mu/r)^{-1}$ and $g_{\varphi\varphi} > 0$ for the bigger sphere. The latter clearly is wrong. Because of the deviation one may feel inclined to reject the procedure of the addition of potentials. Also, the nonlinearity of the Einstein equations suggests the addition of potentials to be invalid. However, if it is not allowed to add potentials then either the coefficient $g_{tt} = 1 - 2\mu_i/r_i$ for the spherical atom or the coefficient $g_{tt} = 1 - 2\mu/r$ for the bigger sphere has to be wrong. But that also is not possible: neither of them is allowed to differ from the

Schwarzschild solution since both represent the g_{ij} for a spherical source. Clearly a 'reductio ad absurdum' is established. This completes the proof of the other flaw in the GTR.

In the foregoing analysis the inconsistency of the GTR is shown in two ways. For a consistent AEST alternative of the Schwarzschild solution it follows from some first principles that the coefficients have to be diagonal, isotropic and exponential [4]. In spherical coordinates it reads

$$c^2 dt^2 = e^{2\mu/r} c^2 d\tau^2 + e^{4\mu/r}(dr^2 + r^2 d\varphi^2 + r^2 \sin^2\varphi \, d\theta^2) . \tag{59}$$

The corresponding Lagrangian for gravitational dynamics in an AEST is given by

$$L = m\left[e^{2\mu/r}(u_4)^2 + e^{4\mu/r}(\dot{r}^2 + r^2\omega^2 + r^2 \sin^2\varphi \, \Omega^2)\right] , \tag{60}$$

where $\omega = \dot{\varphi}$ and $\Omega = \dot{\theta}$. Indeed, the application of equation (30) to this Lagrangian immediately gives equation (59). The Euler-Lagrange equations (29) lead, after transformation to polar coordinates, of course, to

$$r^2 \ddot{r} = r^3\omega^2 + 2\mu(k^2 - r^2\omega^2) - \mu \, e^{-2\mu/r}(u_4)^2 , \tag{61}$$

$$e^{4\mu/r} m r^2 \omega = A \tag{62}$$

and

$$e^{2\mu/r} m u_4 = B , \tag{63}$$

respectively, where A and B are constants of motion: $\dot{A} = 0$, $\dot{B} = 0$. In the remainder of this section we will restrict ourselves to motions in the $\theta = 0$ plane. For such motions equation (59) can be written as

$$e^{-2\mu/r}(u_4)^2 = e^{-4\mu/r}c^2 - k^2 - r^2\omega^2 . \tag{64}$$

The set of equations (61) through (63) completely determine the evolution of the three coordinates r, φ and τ . Equation (64) is not independent; it can be derived from the other three equations of motion. Usually, one frequently uses equation (64) for practical purposes. Explicit calculations show that the above set of equations do lead to the correct predictions for the deflection of light and the precession of the perihelia of planets [4]. Also, the gravitational time dilation and the gravitational red shift are the same as in the GTR.

In the weak field ($\mu \ll r$) and low velocity ($v \ll c$) approximations, equation (61) reduces to Newton's law:

$$r^2 \ddot{r} = r^3\omega^2 - GM . \tag{65}$$

To zero order equation (62) reduces to Kepler's law: $m r^2 \omega \doteq$ constant. From the full equation (62) we see that the angular momentum will, in general, not be conserved. For strong gravitational fields the conservation of angular momentum might even be heavily violated. In general, the angular momentum will be reduced by a local gravitational factor. We will therefore refer to equation (62) as the conservation of the 'locally reduced' angular momentum. Of special interest is the conservation law (63). Taking its square and substituting equation (64), we obtain

$$e^{2\mu/r}c^2 - e^{6\mu/r}(k^2 + r^2\omega^2) = B^2 / m^2 . \tag{66}$$

In the weak field and low velocity approximations it reduces to

$$2mc^2 \mu / r - mv^2 = B^2 / m - mc^2 , \tag{67}$$

where $v := k^2 + r^2\omega^2$. Since B, c and m are constants, equation (67) can also be written as

$$½mv^2 - GMm / r = \Sigma , \tag{68}$$

where Σ is a constant of motion. We will write the classical total energy as Σ in order to avoid confusion with the AEST total energy E as in equation (30). Equation (68) is commonly known as the conservation of the sum of the kinetical and potential energy. From the AEST point of view it is better to regard equation (63) as the conservation of the 'locally reduced' proper-time momentum.

The weak field and high velocity approximation leads to the correct parabolic and hyperbolic trajectories [25]. Also, for the limit $v = c$ one arrives at the correct prediction for the trajectory of a (massive) photon.

The gravitational dynamics for a nonsingular Schwarzschild solution also has been investigated by Jeffries [26]. On the basis of the natural requirement of nonzero densities Jeffries proposes the following:

$$c^2 d\tau^2 = e^{-2\mu/r}c^2 dt^2 - e^{2\mu/r}(dr^2 + r^2 d\varphi^2 + r^2 \sin^2\varphi \, d\theta^2) . \tag{69}$$

The latter expression is independently proposed by Huang [27]. The latter can simply be rearranged to the AEST equation (59). So, they are mathematical equivalent, and they will therefore lead to the same predictions. Conceptually there is an enormous difference since coefficients in the AEST equation (59) will not be interpreted as metrical components. That is, we will not make use of the inconsistent definition $ds^2 = c^2 dt^2$. If we did, we would introduce the same kind of error as in the GTR. Instead, we will make use of the consistent definition for distances

$$ds^2 = c^2 d\tau^2 + dr^2 + r^2 d\varphi^2 + r^2 \sin^2 \varphi \, d\theta^2 \ . \tag{70}$$

For the sake of clarity we consider the following two cases.
Case 1. An object at rest in the vicinity of a source mass. For this object equation (59) reduces to $d\tau = e^{-\mu/r} dt$, while equation (70) reduces to $ds = c d\tau$. This can be interpreted as follows. Due to the presence of a gravitational field, the clock of the object runs slower than the clock of an observer (which can be thought to be far away from the gravitational field) at rest with respect to the absolute rest frame. The four-dimensional distance the object has travelled during the time lapse dt amounts to $ds = e^{-\mu/r} c dt$. Alternatively, the four-dimensional AEST velocity for an object in the vicinity of a source mass is given by $\dot{s} = c / e^{\mu/r}$. This is precisely what one expects from a gravitational field.
Case 2. A photon in the vicinity of a source mass. As in free space, the clock of the photon will not run (zero proper-time). So, equations (59) and (70) reduce to $v = c / e^{2\mu/r}$ and $\dot{s} = v$ respectively. Clearly, the photon moves slower than a photon in free space. This also is precisely what one expects from a gravitational field. There is nothing more to it. A curvature is not at all needed. Another advantage of the present model is that the velocity of the photon can be written as $v = c / n_s$, where $n_s = e^{2\mu/r}$ is the gravitational index of refraction. In this way the deflection of light can also be calculated by means of Snell's law [28]. Snell's law is based on Fermat's principle which states that the path of a photon minimizes the action $S \propto \int dt$. The latter only makes sense if t is taken as the parameter precisely as in the AEST theory. It does not make sense if the proper-time of the photon (which is zero anyway) is taken as the parameter. At this point the TR runs into conflict with the principle of Fermat, while the AEST theory does not.

For the strong field situation one has to consider the full equations (61) through (63). By means of equation (64), equation (61) can be elaborated to

$$r^2 \ddot{r} = (r - \mu) r^2 \omega^2 + 3\mu k^2 - e^{-4\mu/r} GM \ . \tag{71}$$

The derivative of equation (62) with respect to the time parameter t gives

$$(2r - 4\mu) \dot{r} \omega + r^2 \dot{\omega} = 0 \ . \tag{72}$$

Next to the radial velocity $k = \dot{r}$ it is convenient to define the rotational velocity as follows: $w := r\omega$. Then, the complete set of equations becomes

$$\begin{aligned} w &= r\dot{\varphi} \ , \\ \dot{w} &= -(r - 4\mu) w k / r^2 \ , \\ k &= \dot{r} \ , \\ \dot{k} &= \left[3\mu k^2 + (r - \mu) w^2 - e^{-4\mu/r} GM \right] / r^2 \ . \end{aligned} \tag{73}$$

Together with the initial conditions $\varphi(0) = \varphi_0$ and $r(0) = r_0$, the autonomous system (73) completely determines the evolution of the polar coordinates r and φ of an object.
For circular orbits it follows that $k = 0$, $\dot{k} = 0$, $\dot{w} = 0$, while

$$w = e^{-2\mu/r} \sqrt{GM / (r - \mu)} \ . \tag{74}$$

The minimum value for the radius of a pure circular orbit is found by substituting the maximum rotational velocity. The maximum rotational velocity is the rotational velocity of a photon in a circular orbit. From equation (64) it follows that the maximum rotational velocity is given by $w_{\max} = e^{-2\mu/r} c$. The minimum value for the radius of the circular orbit is then easily found to be $r_{\min} = 2\mu$. For large radii, that is, in the weak field approximation, equation
(74) reduces to the classical result $w = \sqrt{GM / r}$.
For pure radial trajectories it follows that $w = 0$, $\dot{w} = 0$ and

$$\dot{k} = (3\mu k^2 - e^{-4\mu/r} GM) / r^2 \ . \tag{75}$$

For a photon radially falling towards the center of the source mass we obtain from equation (64): $k_{photon} = e^{-2\mu/r} c$. The substitution of the latter in equation (75) leads to

$$\dot{k}_{photon} = 2 e^{-4\mu/r} GM / r^2 \ . \tag{76}$$

In the weak field region this would have been $\dot{k}_{photon} = 2GM / r^2$. Clearly the photon decelerates when it falls down to the center of gravitation. In fact, the deceleration is required since the speed of a radially falling photon continuously reduces because of the gravitational index of refraction. Indeed, the derivative of the radial photon velocity $k_{photon} = e^{-2\mu/r}c$ with respect to t also leads to the deceleration (76).

For a radially falling low-speed object, the equation (75) reduces to $\dot{k} = -e^{-4\mu/r}GM/r^2$. In the weak field approximation this is equal to the classical result $\dot{k} = -GM/r^2$. In summary, low-speed objects are attracted to the center while high-speed objects are repelled. The turning point is found by imposing the condition $\dot{k} = 0$ to the equation (75). The result is

$$k = -e^{-2\mu/r}c/\sqrt{3}\ . \qquad (77)$$

In the weak field region the turning point is at $k = c/\sqrt{3}$. So, in the weak field region objects moving with a radial velocity about $0.58c$ will feel the least from the gravitational field. However, a situation with $\dot{k} = 0$ will not last, since the derivative of equation (77) with respect to t leads to $\dot{k} < 0$. Alternatively, the radial motion causes the object to enter a region of stronger gravitation. As a consequence the object will decelerate.

In general, the system (73) will lead to various interesting kinds of motion, especially in the strong field region. Further investigations of the consequences of the dynamical system (73) is beyond the scope of the present paper. We will end this section with some concluding remarks.

First of all, gravitational dynamics, ranging from the precession of the perihelia of planets to the trajectories of photons, can be given a consistent explanation in a flat AEST. It also leads to the correct value for the gravitational time dilation and the gravitational red-shift. The AEST model has a lot of advantages:

- the gravitational dynamics is understood in a flat spacetime, no curvature is needed.
- gravitational potentials are additive. For instance, for N source masses the coefficients in the Lagrangian (60) will be $\exp\left(\alpha \sum_{i=1}^{N} \frac{\mu_i}{r_i}\right)$, where $\mu_i = GM_i/c^2$ and where r_i is the distance between the source M_i and the object. The numerical constant α is equal to 2 and 4 for the time and space coefficients respectively. For each kind of source mass the corresponding Lagrangian can therefore easily be determined. In the GTR the Lagrangians corresponding to arbitrary configuration of gravitational sources are, in general, hard to determine (if not impossible).
- the velocity-independent mass is present in the Lagrangian without any trouble. In the GTR one is forced to leave the velocity dependent mass out of the Lagrangian. In the GTR the equation for the total energy has to be multiplied afterwards with the mass in order to obtain the correct dimension for the energy. However, for relativistic electrodynamics the velocity dependent mass cannot be left out of the Lagrangian. As we will see in the next section, it will completely destroy the validity of relativistic electrodynamics.
- a mass can be ascribed to the photon and the neutrino since mass is velocity-independent in the AEST theory. In the TR this is impossible since it would lead to infinite masses for objects moving with the speed of light.
- the path of a photon is in agreement with the principle of Fermat.
- the path of a photon is the same as in the GTR. So, phenomena like gravitational lensing is also present in the AEST theory.
- since the AEST is free of singularities, it excludes the existence of black holes, Einstein-Rosen bridges, wormholes, Hawking radiation and so on. Nevertheless, dark massive regions still can exist in the AEST. For this it is sufficient to note that the velocity of a photon is extremely reduced when radiated from a heavy source. As a consequence, these photons still might have not reached the earth. Photons radiated from less heavy neighbour sources might already have reached us. The latter ones may show high red-shifts indicating the presence of an 'invisible' heavy source mass. If we could bring ourselves to be patient, we will experience that the 'invisible' source sooner or later starts to shine.

The most fundamental conclusion is that the nature of the metric cannot be a consequence of the Lagrangian, not even if it is of the type $L = g_{\mu\nu}u^\mu u^\nu$. The subsequent equations of motion say nothing about the metric. They are just equations of motion. The Lagrangian is invented as a mathematical technique in order to determine the evolution of the coordinates of the objects. In order to know what these coordinates represent, the metric has to be defined before the Lagrangian is constructed. Shortly, the metric cannot be an a posteriori result of the Lagrangian. The metric has to be defined a priori in a canonical and consistent way, precisely as we did in the AEST theory. In the GTR it is the use of an inconsistent definition for distances which has led to the misconception of a curved spacetime.

6. Proper-time electrodynamics

In analogy with classical dynamics the four-acceleration and the four-force in an AEST will be defined as

$$a^{\mu} := \dot{u}^{\mu} \equiv \ddot{x}^{\mu} \tag{78}$$

and

$$K^{\mu} := \dot{p}^{\mu} \equiv m a^{\mu} \ , \tag{79}$$

respectively. Remember, the dot stands for the derivative with respect to the time parameter. In the TR the dynamics is covered by the Lorentz group. The AEST, however, is covered by the much more simple group SO(4) [19]. The elements $(M_{\mu\nu})_{\rho\sigma}$, or simply $M_{\mu\nu\rho\sigma}$, of the infinitesimal generators $M_{\mu\nu}$ of the group SO(4) are given by

$$M_{\mu\nu\rho\sigma} = \delta_{\mu\sigma}\delta_{\nu\rho} - \delta_{\mu\rho}\delta_{\nu\sigma} \ , \tag{80}$$

where $\delta_{\mu\sigma} = 1$ if $\mu = \sigma$ and zero otherwise. From the latter expression one can easily derive the identities

$$M_{\mu\nu\rho\sigma} = -M_{\nu\mu\rho\sigma} \ , \quad M_{\mu\nu\rho\sigma} = -M_{\mu\nu\sigma\rho} \ , \quad M_{\mu\nu\rho\sigma} = M_{\rho\sigma\mu\nu} \tag{81}$$

as well as the AEST analogue of the Lorentz algebra

$$\left[M_{\mu\nu}, M_{\kappa\lambda}\right] = \delta_{\mu\kappa} M_{\nu\lambda} - \delta_{\mu\lambda} M_{\nu\kappa} - \delta_{\nu\kappa} M_{\mu\lambda} + \delta_{\nu\lambda} M_{\mu\kappa} \ . \tag{82}$$

As known, the elements of the Lie group SO(4) can be written in an exponential form. A change in the four-velocity can therefore be written as

$$a_{\mu} = \tfrac{1}{2}\omega^{\rho\sigma} M_{\rho\sigma\mu\nu} u^{\nu} \equiv u^{\nu}\omega_{\nu\mu} \ . \tag{83}$$

For the four-force we then obtain

$$K_{\mu} = m u^{\nu} \omega_{\nu\mu} \ . \tag{84}$$

The AEST Lagrangian for elecrodynamics reads

$$L = m u_{\mu} u^{\mu} + 2q A_{\mu} u^{\mu} \ , \tag{85}$$

where q is the electromagnetic charge of the object and where A_{μ} is the electromagnetic potential field as felt by the object. Note that the mass m can be present in the Lagrangian without any trouble. In the TR this is not possible since the Euler-lagrange equations of motion would lead to disturbing terms containing the derivative of m with respect to the velocity v of the object. In the AEST theory mass is independent of velocity. So, disturbing derivatives of the mass do not occur. The Lagrangian (85) is such that equation (31) automatically is preserved. Indeed, for the Lagrangian (85) equation (30) gives

$$E = m u_{\mu} u^{\mu} \equiv mc^2 \ . \tag{86}$$

Equation (29) leads to the following Euler-Lagrange equations of motion:

$$K_{\mu} = q u^{\nu} (\partial_{\mu} A_{\nu} - \partial_{\nu} A_{\mu}) \ . \tag{87}$$

The partial derivatives are with respect to the coordinates of the object. Thus, $\partial_i = \partial / \partial x^i$ and $\partial_4 = c^{-1}\partial / \partial\tau = (u_4)^{-1}\partial / \partial t$. In analogy to what is done in relativistic electrodynamics [29], an antisymmetrical tensor F will be defined as follows:

$$F_{\nu\mu} = \partial_{\mu} A_{\nu} - \partial_{\nu} A_{\mu} \ . \tag{88}$$

The four-force then reads

$$K_{\mu} = q u^{\nu} F_{\nu\mu} \ . \tag{89}$$

Comparison with equation (84) tells that the angular velocities $\omega_{\mu\nu}$ of the object are caused by the tensor field $F_{\mu\nu}$ as they are felt by the object. With the additional definitions

$$E_i := -cF_{i4} \leftrightarrow F_{i4} = -E_i / c \tag{90}$$

for the electrical field, and

$$B_k := -\tfrac{1}{2}\varepsilon_{klm} F^{lm} \leftrightarrow F_{ij} = -\varepsilon_{ijk} B^k \ . \tag{91}$$

for the magnetic field, the four-force takes the form

$$K_4 = -q u^j E_j / c \ , \tag{92}$$

$$K_j = q(u_4 E_j / c + \varepsilon_{jkl} u^k B^l) \ , \tag{93}$$

where ε is the Levi-Civita tensor. The role of the proper-time velocity clearly comes into play. In vector notation the latter equation reads

$$\vec{K} = q(\vec{E}/\gamma + \vec{v} \times \vec{B}) . \tag{94}$$

It differs in a subtle way from the conventional Lorentz force. The reason for this is obvious. In the TR the time parameter is taken as the fourth coordinate of the object. Therefore the 'velocity of time' will always be equal to c in the TR. In the AEST theory the proper-time of the object is taken as the fourth coordinate. Therefore the proper-time velocity will be equal to c/γ . The consequences will be substantial. In order to illuminate these, we consider a charged particle subject to a linear acceleration in an electric field. The AEST analogue of the Lorentz force then reduces to $m\vec{a} = q\vec{E}/\gamma$. According to the TR we would have $m_0\gamma\,\vec{a} = q\vec{E}$. Mathematically the two expressions are identical. The acceleration decreases for increasing velocity at the same rate for both theories. Conceptually, however, they are completely different. According to the TR the decrease of acceleration is due to the increase of the mass. In the AEST mass is, as any other scalar, a constant of motion. In the AEST the decrease of the acceleration is due to a decrease of the sensitivity of the object to the electric field. The sensitivity is proportional to the proper-time velocity. In particular, a particle with reversed proper-time velocity will respond oppositely; as an antiparticle. The proper-time velocity might also have consequences for Coulomb's law. In classical dynamics Coulomb's law reads

$$K = \frac{Qq}{4\pi\varepsilon_0 r^2} , \tag{95}$$

where r is the distance between the charges Q and q. According to the AEST theory the sensitivity of charge q to fields will be proportional to its proper-time velocity u_4 . It can be argued that the intensity of the field caused by the charge Q also is proportional to its proper-time velocity U_4 [19]. Capitals are used in order to avoid the use of identifiers for the different objects. So, according to the AEST theory the electric force between two charges would rather be given by

$$K = \frac{QqU_4u_4}{4\pi\varepsilon_0 r^2 c^2} . \tag{96}$$

The fact that both the proper-time velocities should be present in the expression above, can also be seen on the basis of symmetry. That is, if one of the proper-time velocities is left, Newton's action-equals-reaction principle

would not be satisfied. The presence of the proper-time velocities might modify Coulomb's law. As a consequence, the subsequent dynamics might differ from the classical one if the velocities of the charges approach the speed of light. Unfortunately, for two-body motions it is hard to make a reliable comparison with the relativistic electrodynamics because of the retardation effect. The description of retardation leads to an implicit equation. As a consequence, the Liénard-Wiechert type of potentials lead to infinite series of corrections. The retardation corrections become significant when the velocities approach the speed of light, and that is precisely in the region where differences between the present theory and the relativistic electrodynamics can be expected. In order to avoid the problem of retardation we restrict ourselves to the case of the motion of an electron in the vicinity of a heavy electrical source. We take a heavy source mass since we want it to be at rest. For convenience we let the source generate a static electric field. That is, we discard magnetic fields due to the spin of the source. For this case it is sufficient to consider the fourth component of the potential field. Then the Lagrangian for the motion of the electron reads

$$L = mu_\mu u^\mu + 2qA_4u_4 , \tag{97}$$

where $A_4 = \dfrac{-QU_4}{4\pi\varepsilon_0 rc^2}$ and $q = -e$. Anticipating the Bohr model for the atom, we take $Q = Ze$ for the charge of the nucleus (the source). Furthermore, for the proper-time velocity of a nucleus at rest, we have $U_4 = c$. If we also restrict ourselves to motion in the $\theta = 0$ plane and change to polar coordinates, the Lagrangian reads

$$L = m(k^2 + r^2\omega^2) + mu_4^2 + \frac{2Ze^2u_4}{4\pi\varepsilon_0 rc} . \tag{98}$$

For this Lagrangian the Euler-Lagrange equations of motion read

$$m\ddot{r} = mr\omega^2 - \frac{Ze^2u_4}{4\pi\varepsilon_0 r^2 c} , \tag{99}$$

$$mr^2\omega = L \tag{100}$$

and

$$mu_4 + \frac{Ze^2}{4\pi\varepsilon_0 rc} = B , \tag{101}$$

where L and B are constants of motion. Of course, L is the angular momentum of the electron. Equation (101) for the proper-time momentum will be of special interest. By means of equation (86) it can also be written as

$$m\sqrt{c^2 - v^2} + \frac{Ze^2}{4\pi\varepsilon_0 rc} = B \ , \tag{102}$$

where v is the velocity of the electron. In general, $v^2 = k^2 + r^2\omega^2 \equiv k^2 + w^2$. For circular motions, as in Bohr's model, we will use v for the rotational velocity. The use of v instead of w makes the subsequent equations look more familiar to us. For low velocities, as actually is the case in the Bohr atom, the latter equation reduces, to first order, to

$$\frac{1}{2}mv^2 - \frac{Ze^2}{4\pi\varepsilon_0 r} = mc^2 - Bc \ . \tag{103}$$

Since m, c and B are constants of motion, the latter equation can also be written as

$$\frac{1}{2}mv^2 - \frac{Ze^2}{4\pi\varepsilon_0 r} = \Sigma \ , \tag{104}$$

where Σ is a constant of motion. The latter equation is usually regarded as the conservation of the sum of the kinetic and potential energy. Now we know it is just a consequence of the Euler-Lagrange equation of motion for the proper-time momentum. In general, B and thus also Σ will depend on the initial position and the initial velocity of the electron. As can be inferred from equation (99), for a slow circular motion the value for Σ is $-Ze^2/8\pi\varepsilon_0 r$. For more general motions of the electron we should set $u_4 = \sqrt{c^2 - k^2 - r^2\omega^2}$ in equation (99). With the notation w for the rotational velocity, the complete set of equations becomes

$$\begin{aligned} w &= r\dot{\varphi} \\ \dot{w} &= -wk \\ k &= \dot{r} \\ \dot{k} &= \frac{w^2}{r} - \frac{Ze^2\sqrt{c^2 - k^2 - w^2}}{4\pi\varepsilon_0 r^2 mc} \end{aligned} \tag{105}$$

This autonomous system completely determines the evolution of the polar coordinates r and φ of the electron. For pure radial motions, for instance, we have $w = 0$, $\dot{w} = 0$ and

$$m\gamma\,\ddot{r} = \frac{-Ze^2}{4\pi\varepsilon_0 r^2} \ , \tag{106}$$

precisely as in relativistic electrodynamics. Remember, the mass m in the AEST theory is the same as what is regarded as the rest mass in the TR. For pure circular motions, we have

$$m\gamma\,\frac{v^2}{r} = \frac{Ze^2}{4\pi\varepsilon_0 r^2} \tag{107}$$

and

$$mvr = L \ . \tag{108}$$

Equation (107) is mathematically identical to the one used in Sommerfeld's model for the atom. The factor γ, responsible for the fine-structure splitting, is not due to an increase of mass. Instead it is due to a decrease of sensitivity of the electron. Equation (108) slightly differs from the relativistic expression:

$$m\gamma\, vr = L \ . \tag{109}$$

Remember the m stands for what is regarded to be the rest mass in the TR. As we will see in the discussion of the Bohr atom, the difference turns out to be in favor of the AEST theory.

6.1 The Bohr atom reconsidered

Equations (99), (100) and (104) are similar to the classical equations. We could therefore proceed in the same manner. As can easily be checked by the reader, it leads to the same prediction for the frequency of the absorbed or emitted photon. Yet, there is a substantial conceptual difference. In Bohr's model the electron absorbs the 'energy' of the photon in order to make a transition to a state of higher 'energy'. In the AEST theory, however, an energy difference between states can only be accomplished if the mass of the electron is different for each state. Also, the conservation of mass is only satisfied if the electron absorbs or emits the mass of the photon. Remember, in the AEST theory photons have mass. Because of the conceptual differences, an explanation for the Bohr atom will be offered on the basis of the present theory. To this end, the AEST conservation laws will be applied to the process of absorption or emission of a massive photon. The initial state of the electron will be given an index n, the final state an index N. The conservation of mass for the emission of a photon reads

$$m_n - m_\gamma = m_N \quad (110)$$

A plus sign would correspond to the absorption of a photon. In case the initial state and final state consists of free particles, the conservation of proper-time momentum would read

$$m_n\sqrt{c^2 - v_n^2} = m_N\sqrt{c^2 - v_N^2} \quad (111)$$

As we saw, this conservation law leads to an entirely new description of Compton scattering and pair annihilation. However, for the transition between bound states it will be too naive. Consider, for instance, a particle captured in a bound state which becomes free after a collision.When leaving the potential well, its spatial velocity as well as its proper-time velocity will change. The change of the potential should therefore be taken into consideration as well. Since the constant B is the sum of the proper-time velocity and the proper-time potential $Z\alpha\hbar/r$, it is reasonable to assume that it is the quantity B in the equation (101) which has to be conserved:

$$B_n = B_N \quad (112)$$

By means of this conservation law I will offer an alternative description of the Bohr atom. For circular orbits equation (99) can be written as $mv^2 r = Z\alpha\,\hbar u_4$. With α the fine-structure constant, the square reads $m^2v^4r^2 = Z^2\alpha^2\hbar^2(c^2 - v^2)$. Taking the square of equation (100) and applying the quantisation condition, we obtain $m^2v^2r^2 = n^2\hbar^2$. From the latter two equations we can either eliminate mr:

$$v^2 = \frac{Z^2\alpha^2c^2}{n^2 + Z^2\alpha^2}, \quad (113)$$

or eliminate v:

$$m^2r^2 = \frac{n^2\hbar^2(n^2 + Z^2\alpha^2)}{Z^2\alpha^2c^2}. \quad (114)$$

Similar expressions hold for the state N. Equation (101) can be elaborated to

$$B_n r = \frac{(n^2 + Z^2\alpha^2)\hbar}{Z\alpha}. \quad (115)$$

From the latter two equations , in turn, one finds

$$B_n = mc\sqrt{1 + Z^2\alpha^2/n^2}. \quad (116)$$

Substitution of this expression in the conservation law (113) then gives

$$\frac{m_n^2}{m_N^2} = \frac{1 + Z^2\alpha^2/N^2}{1 + Z^2\alpha^2/n^2}. \quad (117)$$

For a free electron, $n = \infty$, the mass of the electron will be denoted as m_e. Its value is the same as what is called the rest mass of the electron in the TR. With $m_e = m_\infty$ it follows that the mass of the electron in the n state is given by

$$m_n = \frac{m_e}{\sqrt{1 + Z^2\alpha^2/n^2}}. \quad (118)$$

A similar expression holds for the electron in the N state. It follows that $m_N < m_n$ if $N < n$, in correspondence with the classical picture of the emission of a photon when the electron makes a transition to a lower state. Substituting the expressions for the electron masses in the different states into equation (110) and using the frequency-momentum relation, $m_\gamma c = hf/c$, for the photon, we obtain for the frequency of the emitted photon

$$f = \frac{m_e c^2}{h}\left(\frac{1}{\sqrt{1 + Z^2\alpha^2/n^2}} - \frac{1}{\sqrt{1 + Z^2\alpha^2/N^2}}\right). \quad (119)$$

With good approximation, that is, for small Z, it can be written as

$$f = \frac{m_e Z^2\alpha^2c^2}{2h}\left(\frac{1}{N^2} - \frac{1}{n^2}\right). \quad (120)$$

This is precisely Bohr's classical result [30].
From equations (114) and (118) we obtain for the radius of the circular orbit of the electron in the n state:

$$r_n = \frac{(n^2 + Z^2\alpha^2)\hbar}{Z\alpha\, cm_e}. \quad (121)$$

For small Z it reduces to the classical value $r_n = n^2\hbar/Z\alpha\, cm_e$. Similarly, for small Z expression (113) reduces to

$$v_n = Z\alpha\, c/n. \quad (122)$$

The latter is equal to the classical result. As can be inferred from equations (107) and (109), the latter also holds in the TR. That is, it also holds for large velocities. The implication of the TR relation (122) is that an ionized atom with $Z > 137$ cannot have an electron in the $n = 1$ state since the velocity of the electron would exceed the speed of light. The AEST expression (113) does not bear this shortcoming. For every Z the velocity of the electron is smaller than the speed of light. The classical equation (104) is only approximately valid for low velocities of the electron. At this point the present theory is in favor. The important thing is that a consistent model for the Bohr atom can be given which is entirely based on the concepts of an AEST and of an invariant mass. As we saw, it leads to order $Z^2\alpha^2$ to the correct prediction for the separation of the spectral lines of hydrogenic atoms. The next step, of course, is to analyze the situation for elliptical orbits to order $Z^4\alpha^4$ to see if the present model also leads to Sommerfeld's prediction for the fine structure separation. Although highly interesting, it is beyond the scope of this paper.

6.2 About the Maxwell equations

As might be obvious from the similarity with relativistic electrodynamics, the Maxwell equations can also be derived in an AEST [19]. With respect to an observer at rest in the absolute rest frame, the Maxwell equations are identical to the ones in the TR. Also, for moving frames of reference the proper-time approach can be applied. The proper-time of an object moving with respect to the new, moving frame still has to be taken as the fourth coordinate. Actually, everybody will agree about its value since proper-time is invariant with respect to the observer. The difference is laid in the parametrisation. In the same way as the (global) clock at rest with respect to the absolute rest frame parametrises the events, the (local) clock at rest with respect to the moving frame will then be used for the parametrisation. In short, a moving observer will use his proper-time for parametrisation. On the basis of this concept, Gill et al succeeded in generalising the proper-time electrodynamics with respect to moving observers. The resulting Maxwell equations, for instance, contain a damping term and explains radiation reaction as inertial reaction to acceleration [6].

It would take too much space to discuss all the (new) kinds of electrodynamical motions. This section will therefore be ended with the conclusion that the present theory offers good possibilities for the construction of a consistent and satisfying electrodynamics in an AEST. On one hand, the new electrodynamics is close to the classical electrodynamics. On the other hand, it deviates from classical electrodynamics in a subtle way because of the presence of the proper-time velocity.The most important consequence, for the moment, is that electric fields effectively are proportional to the proper-time

of the source, in the same way as the magnetic fields are proportional to the spatial velocity of the source. As we will see in the next section, it can have intriguing implications.

7. The sign of proper-time

In the discussion of pair annihilation we already explicitly made use of the phenomenon of reversed proper-time. In this section we will consider some further consequences of proper-time reversal.

7.1 Pion decay

We consider a pion at rest decaying into a muon and a neutrino. Without loss of generality, the x-direction can be taken as the direction the muon moves off. The conservation of momentum in the x-direction, proper-time momentum and mass, are adequately described as follows [22] :

$$0 = -M_\nu c + M_\mu V_\mu \ , \tag{123}$$

$$\sigma_u m_u \sqrt{c^2 - v_u^2} + \sigma_d m_d \sqrt{c^2 - v_d^2} = \sigma_\mu M_\mu \sqrt{c^2 - V_\mu^2} \ , \tag{124}$$

and

$$m_\pi = M_\nu + M_\mu \ . \tag{125}$$

The subscripts identify the particles in obvious notation. The capitals correspond to the situation after the decay. The left-hand side of the equation (124) corresponds to a model where the quarks move in rotational orbits around a common barycenter. The mass of the pion equals the sum of the masses of the quarks: $m_\pi = m_u + m_d$. The σ 's are the signs of the proper-time velocities of the particles under concern. It either is +1 or -1. Since explicit use is made of the mass of the neutrino, the present theory is supported by the recent observations with the SuperKamiokande neutrino detector [31]. From equations (123) and (125) it follows that

$$V_\mu / c = (m_\pi - M_\mu) / M_\mu \ ; \tag{126}$$

Putting in the actual masses, we get $V_\mu = 0.32c$. This result differs somewhat from the value $0.27c$ as predicted by the TR [32]. Substitution of the latter into equation (124) leads to

$$\sigma_u m_u\sqrt{c^2-v_u^2}+\sigma_d m_d\sqrt{c^2-v_d^2}=\sigma_\mu c\sqrt{2m_\pi M_\mu - m_\pi^2}\ . \qquad \textbf{(127)}$$

The right-hand side makes sense if the mass of the muon is larger than half the mass of the pion. So, the conservation of proper-time momentum leads to the following limits for the muon mass: $\tfrac{1}{2}m_\pi \le M_\mu \le m_\pi$. For a pion at rest the velocities of the quarks will be given by $m_u v_u = -m_d v_d$, because of conservation of momentum. If we also put in the actual value of the muon mass, $M_\mu \cong \tfrac{3}{4}m_\pi$, equation (127) becomes

$$\sigma_u m_u\sqrt{c^2-v_u^2}+\sigma_d\sqrt{m_d^2c^2-m_u^2v_u^2}\cong\sigma_\mu c m_\pi/\sqrt{2}\ . \qquad \textbf{(128)}$$

Taking the square, we obtain

$$2\sigma_u\sigma_d\sqrt{c^2-v_u^2}\sqrt{\kappa^2c^2-v_u^2}\cong 2v_u^2-c^2(1-\kappa)^2/2\ , \qquad \textbf{(129)}$$

where the ratio of the quark masses is defined as $\kappa = m_d / m_u$. Taking the square once more, we arrive at

$$v_u^2/c^2 \cong -(\kappa^2-6\kappa+1)/8\ . \qquad \textbf{(130)}$$

For the other quark we find

$$v_d^2/c^2 \cong -(\kappa^{-2}-6\kappa^{-1}+1)/8\ . \qquad \textbf{(131)}$$

These expressions only make sense if the right-hand sides are nonnegative. So, the conservation of proper-time momentum leads to the following limits for the ratio of the quark masses:
$3-2\sqrt{2} < \kappa < 3+2\sqrt{2}$. The proper-time velocities of the quarks read $\dot{\tau}_u \cong \sigma_\mu(3-\kappa)/2\sqrt{2}$ and $\dot{\tau}_d \cong \sigma_\mu(3-\kappa^{-1})/2\sqrt{2}$. It follows that the velocity for the up quark would be equal to the speed of light if $\kappa = 3$. Larger values for κ correspond to the situation with reversed proper-time for the up quark. Similarly, the velocity of the down quark would be equal to the speed of light if $\kappa = 1/3$. Smaller values for κ correspond to the situation with reversed proper-time for the down quark. For illustrative purposes the spatial velocities and the proper-time velocities of the quarks are plotted in Figure 6.
Now, let us take a positive proper-time for the electron. We could take a negative proper-time for the electron as well, it is just a matter of convention. With this convention negative charges correspond to positive proper-times

and positive charges to negative proper-times. The advantage of this convention is that the positron will have a negative proper-time velocity and is therefore the antiparticle of the electron (remember, in the present model it is the reversal of proper-time which changes a particle into its antiparticle). Clearly, it would have been more convenient if the charge of the electron was defined as positive. Since history cannot be changed, it has to be done this way. With this convention, the sign of the proper-time of the quarks have to be equal to each other as well as to the sign of the proper-time of the muon. The situation $\sigma_\mu = \sigma_d = \sigma_u = +1$ corresponds to the decay of the negative pion: $\pi^- \equiv d\bar{u} \to \mu^- + \nu$. Similarly, the situation $\sigma_\mu = \sigma_d = \sigma_u = -1$ corresponds to the decay of the positive pion: $\pi^+ \equiv \bar{d}u \to \mu^+ + \bar{\nu}$. In either case we arrive at the following limits for the ratio of the quark masses: $3^{-1} < \kappa < 3$. This, in turn, leads to the following range for the mass of the up quark: $\tfrac{1}{4}m_\pi < m_u < \tfrac{3}{4}m_\pi$. A similar range holds for the down quark.

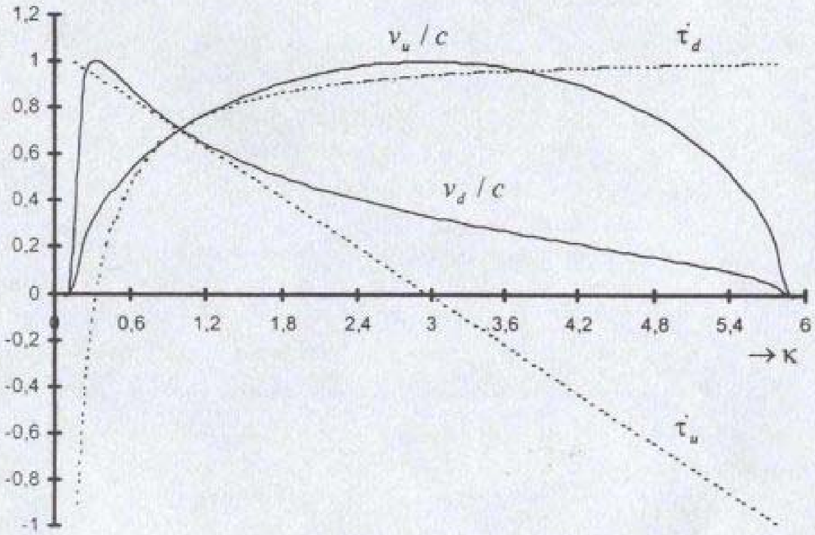


Figure 6. The rotational velocities and proper-time velocities of the quarks inside the pion plotted against the ratio of their masses.

Also, the decay of the neutral pion can be given a comprehensible explanation. Consider a quark-antiquark pair, $u\bar{u}$ for instance. Since the quark and the antiquark will have equal mass, they will orbit around their common barycenter with equal velocity. As a consequence, the magnitude of their proper-times will also be equal. However, being an antiparticle the antiquark will have reversed proper-time. The two proper-time momenta will therefore cancel each other. Similarly, the total proper-time momentum of the $d\bar{d}$ pair will aslo be zero. Since $\pi^0 = (u\bar{u} - d\bar{d})/\sqrt{2}$, the total proper-time momentum of the neutral pion will be zero. Such particles will be referred to as zero proper-time particles. The photon and the neutrino also are zero proper-time particles. The conservation of proper-time momentum requires the total proper-time of the decay products also to be zero. This can be satisfied in two ways. Either the decay product is a zero proper-time particle, like the η and ω meson, or the decay is a $\gamma\gamma$ pair. Since there are no zero proper-time mesons with a mass smaller than the neutral pion, the neutral pion can only decay in a pair of photons. The conservation of momenta requires the photons to move off in opposite directions. The conservation of mass leads to the expression

$f = m_\pi c^2 / 2h$ for the frequency of the photons. Again, the AEST prediction is identical to the TR prediction. Of course, particle physics offers a more detailed understanding for particle decay. However, the possibility should not be excluded that the conservation of proper-time momentum will lead to additional restrictions for decay processes. It should also be noted that the present analysis of pion decay is not complete. When the pions decay, a transition is made from a bound state (two bound quarks) to a free state (a free muon and a free neutrino). So, the left-hand side of equation (124) should also contain the proper-time potentials of the quarks. For this reason the present analysis is of limited value. It should rather be seen as a qualitative analysis in order to show some of the consequences of the sign of proper-time. Further research clearly is desired.

7.2 CPT and the arrow of time

As we saw in the previous section, the intensity of the electric field generated by a charged elementary particle is proportional to its proper-time velocity, while the generated magnetical field is proportional to its spatial velocity. It therefore makes sense to distinguish the electric charge from the magnetic

charge. The effective electric and magnetic charges can be written as QU_4 and QV, respectively. So, for each velocity of the source the 'state' of its effective charges can be written as follows: $Q[U_4, V]$. For our purposes it is convenient to separate the sign of the proper-time velocity from its magnitude. Thus $Q[\sigma_E |U_4|, V]$. As mentioned before, an antiparticle is regarded as a particle with reversed proper-time. Since both the electric and magnetic fields can change sign, a sign should also be present in the effective magnetic charge. Thus $Q[\sigma_E |U_4|, \sigma_B V]$. For the electric field it is clear that it is related to the sign of proper-time. For the magnetic field it is not. In fact, the sign of the magnetic field can be related to the helicity of an internal kind of motion (not to be confused with spin). This idea originates from the following considerations. Firstly, the sign of spin magnetism is determined by the sign of the spin. It can therefore be imagined that the sign of the classical (spinless) magnetism is related to some other kind of internal rotation. Secondly, for an electron in a bound orbit, the quantisation of the angular momentum, $mvr = n\hbar$, and the concept of the de Broglie wavelength, $2\pi r = n\lambda$, lead to the relation $mv = hf / c$. That is, the frequency is proportional to velocity. Something which has also been advocated by Smit on the basis of the triangular relationship between the spatial, proper-time and total velocity [33]. As follows from the Biot-Savart law for point particles, the magnetic field generated by the (spinless) electron also is proportional to its velocity. For a charged particle moving at the speed of light (taking the possibility for granted), the generated magnetic field is proportional to the speed of light. Also, now the frequency is proportional to the speed of light, as can be seen from the relation $mc = hf / c$. The notation is chosen on purpose in order to show that frequency is related to momentum, and not to energy as the usual notation, $mc^2 = hf$, suggests. In case the velocity is equal to the speed of light, there is no mathematical difference. If in both examples the magnetic field as well as the frequency are proportional to the velocity of the charge, then it is reasonable to assume a connection between the magnetic field and the frequency of the internal oscillation. Since this part of the paper contains an element of speculation, it is worthwhile to mention that also soliton-like models for the photon suggest a relationship between the electromagnetic amplitude and frequency [34]. If the idea is correct, then the 'state' of a moving charge can be written as $Q[\sigma_E |U_4|, \sigma_B V]$, where the first sign is the sign of proper-time and the second sign is the helicity of the rotation in an internal dimension. The helicity is +1 for a righthanded rotation and -1 for a lefthanded rotation. Now we can define the following operators for changing a state.

$$C: \quad C\left[\pm|U_4|, \sigma_B V\right] = \left[\mp|U_4|, \sigma_B V\right]. \qquad (132)$$

It reverses proper-time and therefore the sign of electric field.

$$P: \quad P\left[\sigma_E|U_4|, \pm V\right] = \left[\sigma_E|U_4|, \mp V\right]. \qquad (133)$$

It reverses the helicity and therefore the sign of the magnetic field.

$$T: \quad T\left[\pm|U_4|, \pm V\right] = \left[\mp|U_4|, \mp V\right]. \qquad (134)$$

It reverses both the proper-time and the helicity and therefore both the electric and magnetic field. It is the latter operation which changes a particle into its antiparticle and vice versa.

These operators have the following properties: $C^2 = 1$, $P^2 = 1$, $T^2 = 1$ and $CP = T = -1$.

In electromagnetism there exists no particle which respond to an electric field as an electron and to a magnetic field as a positron. So, in electromagnetic interactions C and P cannot occur on itself. Alternatively, the reversal of proper-time is always accompagnied by the reversal of helicity, CP (or T) cannot be violated. For instance, in most decay processes, such as the decay of the negative pion in a negative muon and a neutrino, also the conjugated decay takes place (the decay of the positive pion into a positive muon and an antineutrino). Since C must be accompanied by P, the handedness of the neutrino will also be reversed. As known, it explains why it takes CP to conjugate the decay and why the handedness of the antineutrino is opposite to the handedness of the neutrino. It should be noted, however, that our definitions for the operators differ from the usual ones. Usually C stands for the conjugation of total charge (both electric and magnetic), thus similar to our T. Usually P stands for the parity of spin, while our P has nothing to do with spin. On the contrary, it is related to some other kind of internal rotation. To be specific, it is related to the phase factor (governed by the U(1) group) of the quantum mechanical wavefunction for electromagnetism. A conceptual difference also occurs for the operator T. If we run the movie of a moving electron backwards, the helicity of the internal rotation will be reversed. Also, the hands of a comoving clock will run counterclockwize: proper-time reversal. The operator T usually is regarded as the reversal of universal time (the evolution parameter). Our T changes a particle into its antiparticle. That

is, it reverses proper-time and not the evolution parameter. As can be seen in Figures 1 and 2, an antiparticle runs backwards in proper-time, while parameter time still is running forward. That is, in the AEST the motion of an antiparticle is preciseley as causal as the motion of a particle. Our T does not reverse the time-ordering of events. Clearly, the present theory will have consequences for the discussion of the arrow of time.

Obviously, the present theory does not solve matters as the parity violation in weak interactions. However, a generalisation of the present theory to the situation for the weak interaction might do. It cannot hurt to look at things from a different angle. I therefore considered it worthwhile to be mentioned.

7.3 Zero proper-time electrons

When an electron is subject to a linear acceleration its sensitivity to the electric field will decrease at the same rate its proper-time velocity decreases (giving rise to the misconception of increasing mass). Approaching the speed of light the sensitivity becomes extremely low. It therefore never can reach the speed of light. However, once it moves with the speed of light a very interesting phenomenon occurs. Next to being insensitive for electric fields, it also does not generate an electric field. What remains is a sort of magnetic monopole. Not in the sense that $\partial_i B^i \neq 0$ as for the conventional monopole. This 'monopole' generates a rotational magnetic field. Still it is a sort of monopole since it generates solely a magnetic field and no electric field. In analogy with the word *electron* it could be called a *magnetron*, but that word already is used for the cooking device. The 'state' of this monopole can be written as $-e\left[0, \sigma_B c\right]$. That is, it is electrically neutral. The state of this monopole is stable. Its path may be deviated by a magnetic field, but its velocity cannot be decelerated by an electric field. Let us also consider a positron moving at the speed of light. What we then have is an 'anti-monopole'. As we saw, changing from the electron to the positron goes with the CP operation. As a consequence, the handedness of the antimonopole will be opposite to the handedness of the monopole. The accompanied conjugation of electric charge is, although present, invisible since it is effectively zero. Because of this there cannot be two kinds of monopoles with opposite handedness. If the monopole is righthanded, the antimonopole is lefthanded. This reminds us to the parity rule for neutrinos. Since neutrinos also move at the speed of light, I suggest to denote the new monopole as a 'magnetrino'. I neither know if the magnetrino will ever be found, nor if it even exists. Yet, it seemed worthwhile to be mentioned.

8. Scope for the future

At the end of a paper one usually summarizes the results and discusses the consequences. As an example, a consequence of the present single parameter model is that it solves the simultaneity problem in the 'equal-time canonical commutation rules' for quantum operators. Also, for multibody interactions and the evolution of the quantum wave function, a single evolution parameter is required or at least highly desired. The present theory meets this requirement. As another example, the present theory solves the problem of the missing equation. Drawing the analogy with fluid dynamics, as argued by Jeffries, one expects five equations in the TR [26]. The latter clearly is governed by four equations: three for the momenta and one for the energy. Fluid dynamics is governed by five equations: three for the momenta, one for density and one for pressure. The present model also is governed by five equations: three for the momenta, one for mass (corresponding with the density equation in fluid dynamics) and one for the proper-time momenta (corresponding with classical energy or pressure in the case of fluid dynamics).

I can easily fill pages with advantages of the new model, but I will not. This time it might be better to let the readers draw their own conclusions. Instead, I want to spend some words on the direction of further investigations.

So far, the reformulation of mechanics, gravitational dynamics, and classical electrodynamics was quite successful, or at least promising. In my opinion, the incorporation of spin magnetism will not meet serious problems. In fact, a proper-time formulation of the Dirac theory recently appeared [35]. The next step would be to see whether flavor and chromodynamics can be reformulated within the concepts of the AEST theory. On one hand one can expect the underlying group structure for the internal symmetries not to be different. On the other hand, substantial differences can be expected for quantum field theory since the Feynman calculus is highly based on the theory of relativity. Inevitably it will also have implications for the foundations of quantum mechanics, probably even on a conceptual level. Once the reformulation has been successful a new description of physics will emerge. The sign, velocity,

and momentum of proper-time will be emphatically present in the new physics. The latter can therefore be appropriately denoted as *proper-time physics*.

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References

[1] C.M. Will, *Was Einstein Right?*, Basic Books Inc. Publ., 1986.

[2] H. Montanus, Phys. Essays **4**, 350 (1991).

[3] H. Montanus, Phys. Essays **6**, 540 (1993).

[4] H. Montanus, Phys. Essays **10**, 666 (1997).

[5] T.L. Gill, W.W. Zachary and J. Lindesay, Found. Phys. Lett. **10**, 547 1997).

[6] T.L. Gill, W.W. Zachary and J. Lindesay, Int. Journ. Theor. Phys. **37**, 2573 (1998).

[7] H. Minkowski, Phys. Z. **20**, 104 (1908). Reprinted in *The Principle of Relativity* (Dover, NY, 1923).

[8] L.P. Horwitz and C. Piron, Helv. Phys. Acta **46**, 316 (1973).

[9] J.R. Fanchi, Found. Phys. **23**, 487 (1993).

[10] F.H. Gaioli and E.T. Garcia-Alvarez, Gen. Rel. & Grav. **26**, 1267 (1994).

[11] T.E. Phipps, Jr., *Heretical Verities*, Non-fiction Library, Urbana, 1986, page 37.

[12] B. Nodland and J.P. Ralston, Phys. Rev. Lett. **78**, no. 16, 3043 (1997).

[13] P. Marmet, Phys. Essays **9**, 96 (1996).

[14] D.E. Spencer and U.Y. Shama, Phys. Essays **9**, 476 (1996).

[15] R.G. Newburgh and T.E. Phipps, Jr., Nuovo Cim. X, **67B**, 84 (1970).

[16] A.A. Michelson and E.W. Morley, Am. J. Sci. **34**, 333 (1892).

[17] H.A. Lorentz, Kon. Akad. Wetensch. Amsterdam **1**, 74 (1892). English version: *Collected Papers* (Nijhoff, Den Haag, 1934 - 39), Vol. 4, p. 219.

[18] A. Einstein, *The Meaning of Relativity*, Princeton Science Library edition, 1988, page 27.

[19] H. Montanus, Phys. Essays **10**, 116 (1997).

[20] V. N. Strel'tsov, JINR Commun. D2-96-427, Dubna (1996).

[21] H. Montanus, Phys. Essays **8**, 594 (1995).

[22] H. Montanus, Phys. Essays **11**, 280 (1998).

[23] R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles*, John Wiley & Sons, 1974, page 42.

[24] R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles*, John Wiley & Sons, 1974, page 51.

[25] H. Montanus, Phys. Essays **11**, 563 (1998).

[26] C. Jeffries, Phys. Essays **8**, 168 (1995).

[27] Y.S. Huang, Phys. Essays **4**, 532 (1991).

[28] H. Montanus, Phys. Essays **11**, 395 (1998).

[29] A.O. Barut, *Electrodynamics and Classical Theory of Fields and Particles* (Dover, NY, 1980).

[30] R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles*, John Wiley & Sons, 1974, page 112.

[31] SuperKamiokande Collaboration, Y. Fukuda et al., Phys. Rev. Lett. **81**, no.8, 1562 (1998).

[32] D. Griffiths, *Introduction to Elementary Particles*, John Wiley & Sons, 1987, page 95.

[33] J. Smit, Phys. Essays **6**, 21 (1993).

[34] P. Kamenov and B.Slavov, Found. Phys. Lett. **11**, 325 (1998).

[35] T.L. Gill, Found. Phys. **28**, 1561 (1998).