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Conjecture on the True Cause and Meaning of Time Dilation

Abstract

The fundamental forces of nature are mediated by the exchange of particles; photons mediate the electromagnetic force, gluons the strong force, W and Z particles the weak force. It is shown that the duration of the exchange of a force or messenger particle between two interacting particles is a function of the velocity through space of the two interacting particles and is also a function of the orientation of the two particles relative to their common velocity. The greater the velocity of the two particles the longer it takes for the particle exchange between them. The interaction between two particles is thus slowed by their motion through space. This slowing with velocity of the interaction between particles underlies the fundamental process occurring in any physical entity (proton, nucleus, atom, or macro object). ***It is the essence of time dilation.*** The dependence of time dilation on the orientation of two interacting particles relative to their common velocity is an important finding of this study and may appear to contradict the 'known' singular dependence of time dilation on velocity. The dependence of time dilation on the orientation of the interacting particles is overcome when a large number of particles are aggregated and their orientations relative to the velocity of the aggregate body or entity are randomized. Alternatively, the rapidly changing orientation of two particles in the turbulence of space will itself randomize the orientation of the particles and cause the value of time dilation of the particles to 'average out'. We can look at time dilation in two ways; 1) time actually slows for the fast moving entity or 2) the basic process that governs the entity takes longer as the entity moves through space, but time itself does not slow down. This may be more a philosophical question than a scientific one. The momentum of current thought is clearly with time slowing down for the moving entity. The conclusion of this paper is that time dilation is a slowing of the fundamental process of an entity when the entity is moving through space, not a slowing of time itself.

Time and the Mediation of Forces

We couldn't articulate it more clearly than Professor Hawley [1]: '...it is clear that at a very basic level, time is tied into measurements of space.' And again: '...we define our concepts of space and time intervals in comparison with standard physical processes.'

'The rate at which physical processes occur gives us our measure of time, and if all those rates changed together, an observer could not notice it. Try to imagine measuring time that does not involve some periodic physical process!'

'Modern physics has shown that physical processes depend on the interaction of fundamental forces at a very basic level.' And lastly, 'For physical processes, the exchange of the particles that produce forces has ultimate importance. Moreover, the crucial distinguishing factor of special relativity is not so much the speed of light, as it is the existence of a finite speed of propagation of forces.'

The particle exchanges that underlie all processes, atomic, chemical and biological, determine the measures of time taken by such processes. It will be shown in this paper that these exchanges take longer when the entity encompassing the exchange is moving. Accordingly, processes moving relative to space take longer than do stationary processes, but as said above, not because time itself is slowed down.

Time Dilation, An Interpretation

Determine How the Transit Time of a Force Particle from One 'Primary' Particle to Another Depends on the Orientation of the Primary Particles Relative to Their Common Velocity Vector

The objective of this exercise is to compare the transit time of a force or messenger particle moving between two primary particles A and B that themselves are moving with the transit time of the force particle moving between A and B when the two primary particles are stationary. In addition, it is intended to show the dependence of this transit time on the orientation of the two primary particles, and thus the trajectory of the force particle, relative to the common velocity of particles A and B.

Does space provide a metric by which motion through it can be reckoned? We think it's simpler than that. [2] Imagine a set of Cartesian coordinates x, y as shown in Figure 1. Designate the origin of the coordinates as point A. Say that point A represents the location of some particle and point B represents the instantaneous location of another particle which is to be the recipient of a force or messenger particle emanating from the first particle. Let Point B be a distance R from point A, but in any arbitrary direction from point A. Consider the force particle to be the means to carry a unit of force between one particle and another, or it can represent any mediating interaction between two particles. It is the purpose of this example to show that as our system of particles (such as an atom) moves through space, the process of exchanging a force or messenger particle between one primary particle and another takes longer when the system of particles is moving through space than when the system is stationary with respect to space. A key point here is that the initial location of point B is at a distance R from A, but can be in any arbitrary direction relative to the velocity of the pair of interacting particles. Thus, in our example, a circle of radius R represents the locus of points on which point B can be located. One of the objects of this inquiry is to determine the dependence of the transit time from A to B of the force or messenger particle on the orientation of particles A and B relative to their common velocity.

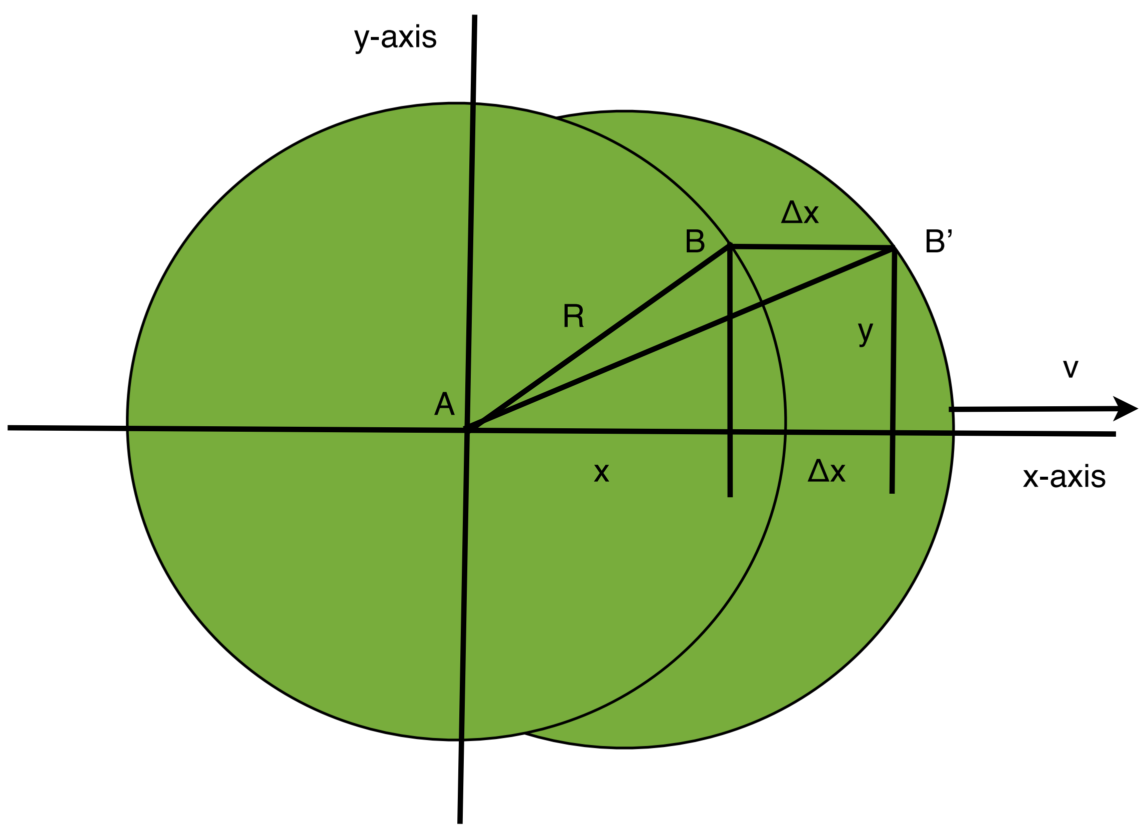

Figure 1. A Force or Messenger Particle Moves from A to B' as Both Particles (and the Circle) Move to the Right at the Velocity v. (The Circle Represents the Locus of Particle B That Can Be At Any Point on the Circle.)

Let x, y represent the coordinates of point B. The distance of point B from the origin is given by

$$R = (x^2 + y)^{1/2} \tag{1}$$

When the system of particles is not moving with respect to space, then point B is some point on the edge of a stationary circle of radius R that is centered at point A. Under this condition, our force or messenger particle, call it a photon, moving from point A to point B would take time

$$t_s = (x^2 + y^2)^{1/2} / c \tag{2}$$

where

t_s is the time of travel for the photon when the circle is stationary

c is the velocity of light

Let t_m represent the transit time for a photon moving from A to B' when the system of particles (i.e. the circle) is moving with respect to space. The location of point B moves to point B' during the time that the photon travels from A to B'.

In the time t_m the circle will move an amount $\Delta x = v\, t_m$. Recognize that t_m is a variable that depends on the distance between A and B', the velocity of the particles A and B, the transit velocity c of the force particle and the direction from A to B.

Throughout this paper, the orientation angle θ of the interacting particles is defined to be the angle from the x-axis to the line from A to B. The line from A to B is the line between the ***initial positions*** of the interacting particles.

Our objective, again, is to determine how the transit time of the force particle varies with the velocity v of the primary particles A and B and their orientation angle θ relative to the velocity v. Here v is the direction of the positive x-axis.

After time t_m Point B has moved to point B' and is located at x + Δx, y. The distance of point B' from the origin is

$$((x + \Delta x)^2 + y^2)^{1/2} = (x^2 + 2\,(x\,\Delta x) + \Delta x^2 + y^2)^{1/2} \tag{3}$$

The transit time t_m of the photon moving from A to B' on the circle is given by the distance traveled divided by its velocity:

$$t_m = (x^2 + 2\,(x\,\Delta x) + \Delta x^2) + y^2)^{1/2} / c \tag{4}$$

Rewrite Eq (4) as

$$t_m = (x^2 + y^2 + 2\,(x\,\Delta x) + \Delta x^2)^{1/2} / c \tag{5}$$

Square both sides of Eq (5)

$$t_m^2 = (x^2 + y^2 + 2\,(x\,\Delta x) + \Delta x^2) / c^2 \tag{6}$$

Square both sides of Eq (2):

$$t_s^2 = (x^2 + y^2) / c^2 \tag{7}$$

Substitute Eq (7) into Eq (6).

$$t_m^2 = t_s^2 + \left(2\,(x\,\Delta x) + \Delta x^2\right) / c^2 \tag{8}$$

Now, recall that $\Delta x = v\,t_m$. Substitute this relation into Eq (8).

$$t_m^2 = t_s^2 + 2\,(x\,v\,t_m) + v^2\,t_m^2) / c^2 \tag{9}$$

In our system or coordinates,

$$x = R \cos\theta \tag{10}$$

where

θ is the angle from the x-axis to the line R from the origin to point B (not B').

Substitute Eq (10) into Eq (9).

$$t_m^2 = t_s^2 + (2\,R\cos\theta \cdot v\,t_m + v^2\,t_m^2) / c^2 \tag{11}$$

Now, let $K = v / c$, so that

$$v = K\,c \tag{12}$$

Substitute Eq (12) into Eq (11).

$$t_m^2 = t_s^2 + (2\,R\cos\theta \cdot K\,c\,t_m + K^2\,c^2\,t_m^2) / c^2 \tag{13}$$

Rearrange Eq (13).

$$t_m^2\,(1 - K^2) = t_s^2 + (2\,R\cos\theta \cdot K\,c\,t_m) / c^2 \tag{14}$$

Also, from Eqs (1) and (2), the transit time of the force or messenger particle moving from A to B when the particles are stationary is just the radius R of the circle divided by the velocity c of the force particle.

$$t_s = R / c \qquad (15)$$

Substitute Eq (15) into Eq (14) to yield

$$t_m^2 (1 - K^2) = t_s^2 + (2 K t_s \; t_m \cos\theta) \qquad (16)$$

Divide both sides of Eq (16) by t_s^2.

$$t_m^2 (1 - K^2) / \; t_s^2 = 1 + (2 K \; \cos\theta \cdot t_m / t_s) \qquad (17)$$

Rearrange Eq (17).

$$t_m^2 (1 - K^2) / \; t_s^2 - (2 K \; \cos\theta \cdot t_m / t_s) - 1 = 0 \qquad (18)$$

This quadratic formula can be solved for the ratio of t_m / t_s, the time dilation of the two particles A and B moving at velocity v with an orientation of θ relative to their velocity vector v. Inserting the terms of Eq (18) into the familiar quadratic Eq (19) yields the formula for t_m / t_s shown in Eq (20).

The solution for the quadratic formula of the form $ax^2 + bx + c = 0$ is

$$x = (- b \pm (b^2 - 4ac)^{1/2}) / 2a \qquad (19)$$

$$t_m / t_s = \left(K \cos\theta \; \pm (K^2 \cos^2\theta + (1 - K^2))^{1/2}\right) / (1 - K^2) \qquad (20)$$

Equation (20) can be simplified further. Combine terms inside the square root and use the familiar trigonometric identity $\cos^2\theta + \sin^2\theta = 1$.

$$t_m / t_s = \left(K \cos\theta \pm (1 - K^2 \sin^2\theta)^{1/2}\right) / (1 - K^2) \qquad (21)$$

Equation (21) is graphed in Figure 2 for the range of orientation angle θ of 0 to 180 deg. Though not shown, the curve is symmetrical about the 180 deg line, but not over the range shown. The caption of Figure 2 identifies the curve as the ***Uncorrected*** Time Dilation... Uncorrected for what? We know that the time dilation for a macro object (an object composed of a very large number of particles) is given by

$$tm / ts = 1 / (1 - v^2 / c^2)^{1/2}$$

This value is yielded by Eq (21) only for orientation angles θ of 90 deg and 270 deg. The average of the curve over all orientation angles from 0 to 360 deg is clearly not that for 90 deg. So what is the cause of the asymmetry in the values of time dilation over the entire range of orientation angle? The assertion is that we have not accounted for length contraction in the frame of the interacting particles. We will address the correction for this phenomenon in the section *'Change Perspective to the Frame of the Moving Ship'.*

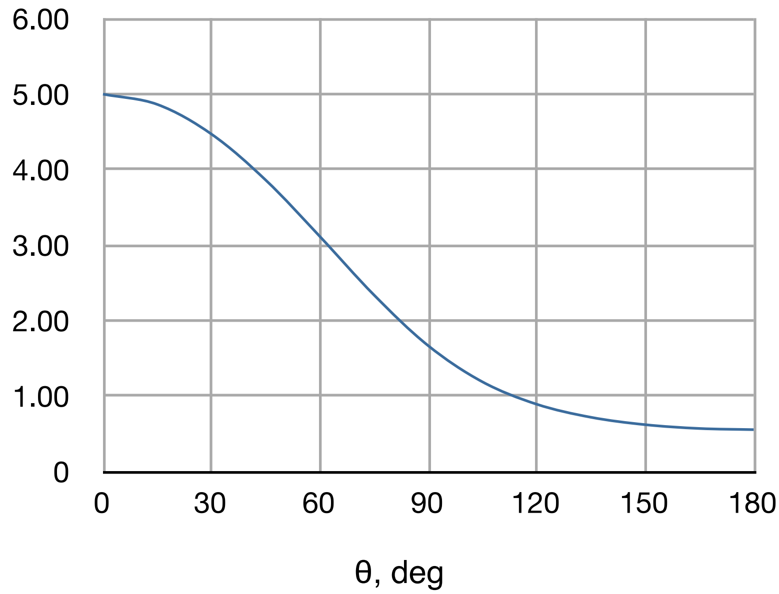

Figure 2. Uncorrected Time Dilation, (tm / ts in Eq (21) for K = v/c = 0.8 as a Function of Orientation Angle of a Single Pair of Interacting Particles Relative to Their Common Velocity Vector

Determine the Time Dilation for a Two-Way Interaction Between Particles

Equation (21) expresses the time dilation for a one-way transit of a force particle between two interacting particles. If we want to construct a clock using this mechanism we need to evaluate the transit time of a two-way communication between the two interacting particles. To do this we can sum the transit times of the force particle when it moves back and forth between the two interacting particles. We do this by summing the transit time for the initial orientation angle θ of an interacting pair of particles with the transit time for the opposite angle $\theta + \pi$.

The first term in the numerator of Eq (21) becomes

$$K\,(\cos\theta + \cos(\theta + \pi)) = 0 \qquad (22)$$

The first term thus goes away because $\cos\theta$ and $\cos(\theta + \pi)$ are of equal value, but opposite sign.

Inside the square root, $\sin^2\theta = \sin^2(\theta + \pi)$, so this term does not change. Keep in mind that t_s doubles when we figure the two-way transit between the interacting particles. The final result for the time dilation for a two-way transit between interacting particles is

$$t_m / t_s = (1 - K^2 \sin^2 \theta)^{1/2} / (1 - K^2) \tag{23}$$

Remembering that $K = v / c$, the time dilation of the moving particles is a function of their velocity and their orientation relative to their common velocity vector. A graph of Equation (23) is portrayed in Figure 3.

The orientation angle θ in Eq (23) and Figure 3 may be interpreted as the orientation angle between two mirrors of a photon clock relative to the direction of travel of the clock. When the mirrors are in line with the direction of travel of the clock, θ is 0 deg or 180 deg. Recall that the calculation of t_m / t_s is made for the two-way transit of a force or messenger particle; in one direction and its opposite. When the orientation of the mirrors is perpendicular to the direction of motion of the clock, θ is 90 deg or 270 deg (not shown).

If we expect the photon clock to measure the passage of time correctly (in its own frame of motion) the measurement should be independent of the orientation of its mirrors. Clearly our calculation of the time dilation of Eq (23) must be corrected to yield the known [2] [3], and experimentally verified, value of the time dilation of a moving object. Enter the phenomenon of length contraction.

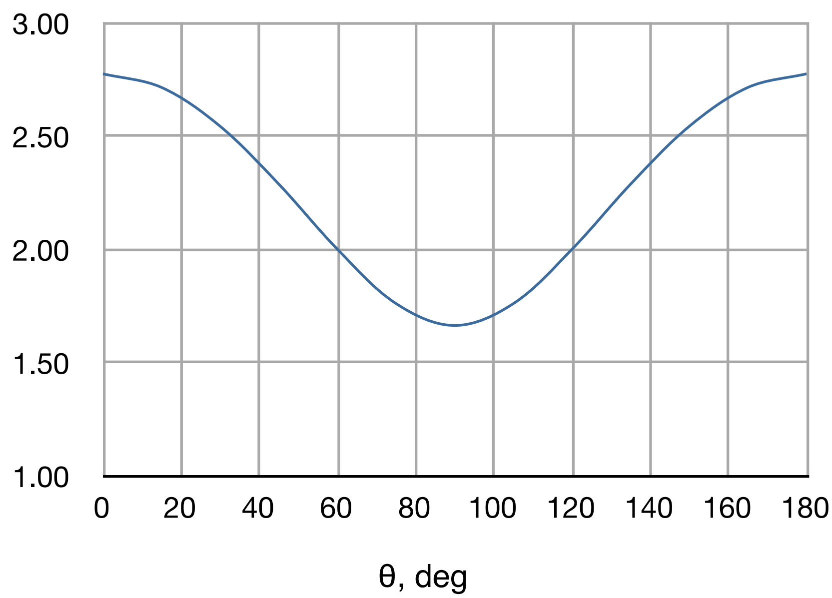

Figure 3. The Uncorrected Ratio t_m / t_s of the Period of a Photon Clock Moving at $K = v/c = 0.8$ as a Function of the Orientation Angle θ of Two Interacting Particles Relative to the Velocity Vector of the Clock

Change Perspective to the Frame of the Moving Ship

Determine the Length Contraction Factor

The value given in Equation (23) for the time dilation of a moving photon clock holds for the perspective or frame of a stationary observer. What about the behavior of the clock from the frame of the moving ship? We would expect that all clocks would be slowed by the same amount, an amount that is dependent only on the velocity of the ship relative to space, not the orientation of the clock's mirrors relative to the clock's velocity vector. The factor that will equate the rates at which all clocks run is the contraction of length in the direction of motion of the ship. [3] Rather than make an explicit calculation of the effect of length contraction on the transit time of the force or messenger particle in mediating the interaction of two particles, a more facile determination of the contraction factor can be made if we start with the known value of time dilation and calculate the adjustment needed to the equation of time dilation given in Eq (23). This contraction factor will be seen to be a function of both the orientation angle of the two interacting particles and their common velocity vector.

To determine the value of the contraction factor F:

$$t_m / t_s = (1 - K^2 \sin^2 \theta)^{1/2} / (1 - K^2) \cdot F = 1 / (1 - K^2)^{1/2} \qquad (24)$$

Solve Eq (24) for the contraction factor F.

$$F = \left((1 - K^2) / (1 - K^2 \sin^2 \theta)\right)^{1/2} \qquad (25)$$

We've asserted that Eq (25) is the length contraction factor, but what functions must it serve? These functions determine the form that the contraction factor must take.

1. The length contraction takes place only in the direction of the velocity vector of the interacting particles.
2. The length contraction factor should be a function of the orientation angle of the interacting particles relative to their common velocity vector.
3. For a particle orientation of 0 or 180 deg the length contraction factor should be $1 / \gamma$, where γ is the Lorentz factor $1 / (1 - K^2)^{1/2}$. In these cases the particle orientation is completely in line with their common velocity vector.
4. For a particle orientation of 90 or 270 deg the length contraction factor should be 1.0 (no contraction), because the particle orientation is perpendicular to their common velocity vector and no component of their orientation is in the direction of their velocity.
5. When multiplied by the uncorrected value of time dilation for the two-way interaction between two particles the contraction factor must yield the Lorentz factor γ, a value that is independent of the orientation angle between the

interacting particles. These functions are assured, given the derivation of the factor.

6. When multiplied by the uncorrected value of time dilation for the one-way interaction between two particles, the contraction factor must yield an average value of time dilation equal to the value of the Lorentz factor γ for the entire range of orientation angles from 0 to 360 deg.

Table 1 shows the contraction factor F of Eq (25) for the four cardinal points of the orientation angle of two interacting particles. The table shows that the contraction factor of Eq (25) serves the functions listed above in items 3 and 4 for the four orientation angles given. Is there another form that would meet these two requirements? Yes, there is: $(1 - K^2 \cos^2 \theta)^{1/2}$. However, calculations determine that this form fails the requirements of items 5 and 6 in the list above.

Table 1. Contraction Factor for the Four Cardinal Points of the Orientation Angle of Two Interacting Particles

θ, deg	**$\sin^2 \theta$**	**$1 - K^2 \sin^2 \theta$**	**$(1-K^2)^{1/2}$ / $(1 - K^2 \sin^2 \theta)^{1/2}$**	**Contraction Factor**
0 or 180	0	1	$(1 - K^2)^{1/2}$	$1 / \gamma$
90 or 270	1	$1 - K^2$	1	1

Figure 4 is a graph of Eq (25) and shows the dependence of the contraction factor F on the orientation angle θ of the interacting particles relative to their common velocity vector v. The range of orientation angle from 180 to 360 deg duplicates the values over the range of 0 to 180 deg. The value of K of 0.8 yields values of the contraction factor of 0.6 at orientation angles of 0 and 180 deg and a value of 1.0 (no contraction) at an orientation angle of 90 deg. These values are in agreement with the functional requirements of items 3 and 4 in our list. It will be shown in the two sections *'Apply the Length Contraction Factor to the Two-Way Particle Interaction'* and '*Apply the Length Contraction Factor to the One-Way Particle Interaction'* that the functional requirements of items 5 and 6 are met by the contraction factor F of Eq (25).

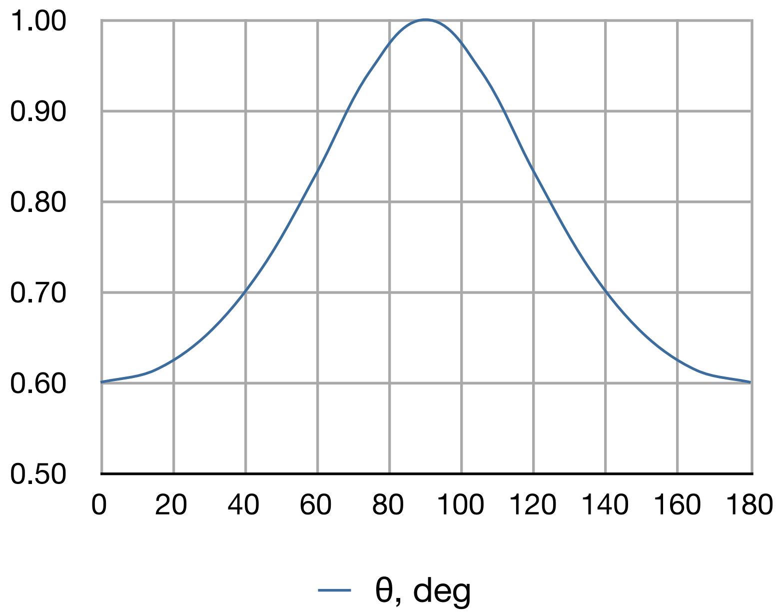

Figure 4. Contraction Factor F as a Function of Orientation Angle θ of the Interacting Particles Relative to Their Common Velocity Vector v (K = v/c = 0.8) (From Eq (25))

Apply the Length Contraction Factor to the Two-Way Particle Interaction

Naturally, when we apply the contraction factor F to the uncorrected value of time dilation of Eq (24), e.g., multiply Eq (24) by Eq (25), we get the value we chose to get.

$$t_m / t_s = 1 / (1 - K^2)^{1/2} \tag{26}$$

Equation (26) expresses the time dilation for the two-way transit of a force or messenger particle between two interacting particles. The two transits are 180 deg out of phase relative to each other, but the orientation of the pair of interacting particles relative to their common velocity vector can have any value. Equation (26) is also valid for our photon clocks for any angle of orientation of the mirrors relative to the velocity vector of the ship.

Apply the Length Contraction Factor to the One-Way Particle Interaction

We may now apply the contraction factor to the equation, Eq (21), for the time dilation for the one-way interaction between a single pair of particles. Multiplying Eq (21) by the expression for the contraction factor F of Eq (25) yields the corrected expression for the time dilation of two interacting particles as a function of their velocity and their orientation relative to their common velocity vector.

$$F \cdot (t_m / t_s) = [\ 1 + K \cos \theta / (1 - K^2 \sin^2 \theta)^{1/2}\ ] / (1 - K^2)^{1/2}) \tag{27}$$

The graph in Figure 4 of this equation shows the dependence of time dilation between two particles on their orientation θ relative to their common velocity vector. Unlike the graph of the uncorrected time dilation of the two-particle interaction of Figure 2 the graph of time dilation for two interacting particles corrected for length contraction is symmetrical about the 90 deg point. In Figure 4 values of time dilation are shown for orientation angles from 0 to 180 deg. The average value of time dilation of this curve over the range from 0 to 180 deg is the value of time dilation for an orientation angle θ of 90 deg. ***The value of time dilation for an aggregate of a very large number of interacting particles that would comprise a macro object would be this average value.*** This value is obtained by letting θ = 90 deg and solving Eq (27).

For V = 90 deg, cos θ = 0 and sin θ = 1. Inserting these values into Eq (27) yields:

$$F \cdot (t_m / t_s) = [\, 1 + K \cdot 0 / (1 - K^2 \cdot 1)^{1/2} \,] / (1 - K^2)^{1/2} \tag{28}$$

which reduces to

$$F \cdot (t_m / t_s) = 1 / (1 - K^2)^{1/2} \tag{29}$$

Recalling that $K = (1 - v^2 / c^2)$, Eq (29) becomes the familiar time dilation equation for a moving object.

$$F \cdot (t_m / t_s) = 1 / (1 - v^2 / c^2)^{1/2} \tag{30}$$

The time dilation experienced by two interacting particles should also be expressed by Eq (30) based on the assumption that the orientation of two such particles will change violently in the froth of space. Accordingly their time dilation would be the average time dilation for all angles of orientation relative to their common velocity vector. That average value for all orientations is the same as that for an orientation angle of 90 deg and is given in Eq (30).

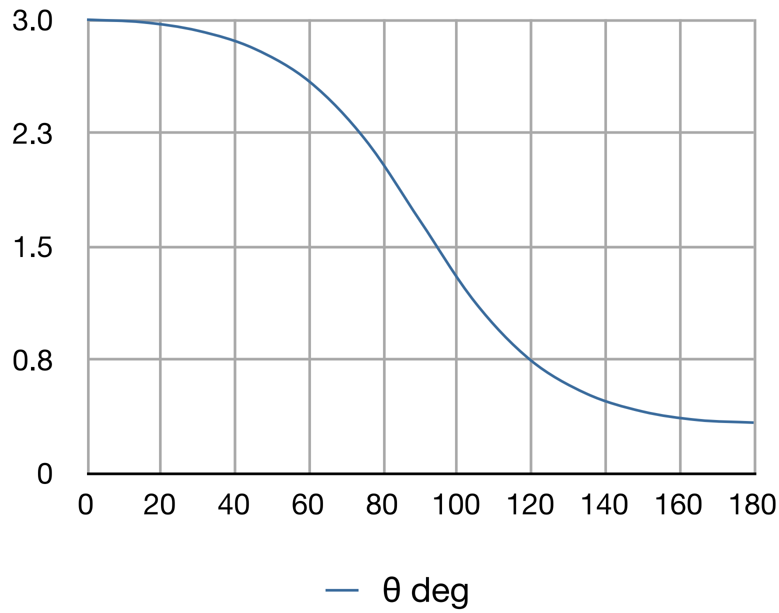

Figure 4. Time Dilation of the Interaction of Two Particles Corrected for Length Contraction (K = v/c = 0.8, from Eq (27))

The Analysis of Time Dilation in Two Dimensions is Valid for Three

Review Figure 1 showing the interaction of two particles that exchange a force or messenger particle that moves between particle A, initially at point A and particle B, initially at point B. The circle defines the locus of points on which point B can be located. As particles A and B (and the circle) move in the direction of the positive x-axis, point B moves to point B’ in the time it takes for the force particle to transit the distance between the two interacting particles. The two-dimensional analysis proceeds accordingly.

Imagine now that the plane of the circle can assume any angle about the x-axis. The orientation of the line from A to B’ will change relative to space, but the distance between A and B’ will not be altered and our analysis of the time of transit of the force particle from A to B’ will be unaffected.

The locus of points on which the particle at point B can reside is now a sphere of radius R instead of a circle of radius R and our two-dimensional analysis is valid for three dimensions.

Summary of Controlling Equations

1. The contraction factor F to be multiplied by the uncorrected value for time dilation for either a two-way particle interaction or a one-way particle interaction is given by:

   $F = \big((1 - K^2) / (1 - K^2 \sin^2 \theta)\big)^{1/2}$ (25)
   where $K = v/c$

2. The value of the time dilation of a one-way interaction between two particles corrected for length contraction is given by:

   $(t_m / t_s)_{(corrected)} = [\, K \cos \theta / (1 - K^2 \sin^2 \theta)^{1/2} + 1 \,] / (1 - K^2)^{1/2}$ (27)

3. The value of the time dilation for an aggregate of a large number of particles or a macro object is the average of the aggregate time dilations of the constituent particles. This value is given by:

   $(t_m / t_s)_{(corrected)} = 1 / (1 - v^2 / c^2)^{1/2}$ (30)

4. The value of the time dilation of a two-way interaction between two particles corrected for length contraction is given by:

   $(t_m / t_s)_{(corrected)} = 1 / (1 - v^2 / c^2)^{1/2}$ (30)

Conclusions

1. The duration of the exchange of a force or messenger particle between two interacting particles is a function of their common velocity through space and is also a function of the orientation of the two particles relative to their common velocity vector.
2. The slowing with velocity of the interaction between particles underlies the fundamental process occurring in any physical entity (proton, nucleus, atom, or macro object). ***It is the essence of time dilation.***
3. The dependence of time dilation on the orientation of the interacting particles is overcome when a large number of particles are aggregated and their orientations relative to the velocity of the aggregate body or entity are averaged.
4. When a large number of particles are aggregated as in Item 3, the time dilation of the aggregate entity in response to its motion through space is the average of the time dilations of the constituent particles.
5. The rapidly changing orientation of two particles in the turbulence of space will itself randomize the orientation of the particles and cause the value of time dilation of the particles to ‘average out’.
6. The conclusion of this paper is that time dilation is a slowing of the fundamental process of an entity when the entity is moving through space, not a slowing of time itself.

7. Length contraction along the direction of motion of an interacting pair of particles must be considered in determining the time dilation of the particles in response to their motion through space.
8. The length contraction factor is a function of both the orientation angle of the interacting particles relative to their common velocity vector and the value of that velocity.
9. The two-dimensional analysis of this paper is valid for three dimensions.
10. Time dilation of moving, interacting particles or an object composed of particles is dependent only on motion relative to space and is intrinsic, absolute and not dependent on the observation of an outside observer.
11. The clock in our discussion is generic for any process that is a function of time; a chemical reaction, the half-life of an unstable particle or the frequency of light emitted by an energized atom to name a few. All such processes are slowed by motion through space.
12. Time dilation is not caused by acceleration.

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