Uniting Einstein's Relativity with Measurement Technology

Repairing Special Relativity for Noether's conservation laws

Introduction and relevance

The formulas of Einstein's theory of Relativity are mathematical by nature. Eddington described Einstein's theory as: "The Mathematical Theory of Relativity". For example, Einstein's theory of Special Relativity, based on the Lorentz transformation, describes "length contraction", but no width or height contraction. To *measurement physicists* however, length, width, and height depend on the unit meter. In fact, Einstein *originally* did *not* talk about "length contraction" but about "*measuring stick contraction*", see paragraph 12 of his book "My Theory". So the relevant question is: are we talking about contraction of the *amount* of meters and/or contraction of the *meter itself*?

The authors of this article, three academic engineers specialized both in Einstein's Relativity and in measurement technology, have found the answers, which they have published in three books. It is about the repair of Einstein's Relativity in accordance with Noether's laws on energy and momentum conservation and with measurement technology. This article confines itself to the question above, one aspect of the book "Repairing Special Relativity", by differentiating between mathematical and physical formulas.

The importance of this new analysis is evident to physicists. It has consequences in explaining the specific effects of high-speed particle measurements of the protons within the Large Hadron Collider (LHC), as fully described in our book "Repairing Special Relativity". This article will demonstrate that the protons within the LHC *do not deform*, whatever the speed of these protons is within the LHC. Consistently worked out, the repair leads to an elegant resolution of the Ehrenfest paradox and the twin paradox of Special Relativity.

An even bigger impact results from applying the same approach to General Relativity in our second book: "Repairing Schwarzschild's Solution", which takes the mathematical "singularity" out of the Schwarzschild solution. This book *simplifies* the Schwarzschild solution and *predicts* the temperature of the core of massive spheres like the earth (more than 5,380 Kelvin) and the sun (more than 15.5 million Kelvin). The third book "Repairing Robertson-Walker's Solution" results in a cosmological model without the need for "dark energy".

Starting principle and methodology

In *measurement technology*, length, width, and height depend on the unit, the "measuring stick". Let us begin with the use of the unit foot as measuring stick. When we use a larger measuring stick (for example a one meter measuring stick) you measure a shorter *coordinate* of length. Consequently a larger unit meter (a larger measuring stick) would give you a *shorter coordinate of length, width, and height*. For example, the author's length is *both* 5.9 foot *and* 1.80 meter. In other words, the *multiplication* of a *coordinate* of length and the used *unit* of length remains independent of the chosen measuring stick.

The authors have named this the "*principle of uniform measurements*"; anyone's measured *uniform* length is independent of the unit chosen. The basic connotation is that the uniform measurement of an object is independent of the observer or its units.

Let us begin to look at the unit second since it is our primary unit, of which we can derive the units meter and kilogram. The unit second is defined as 9,192,631,770 cycles on a cesium clock. We know, proven by the Hafele-Keating experiment, that cesium clocks tick slower at high speed. Therefore, the proper unit second of a proper observer at speed must be longer than the SI unit second on the surface of the earth according to the principle of uniform measurements:

$[s_0] = \gamma.[s]$ proper *unit* second $[s_0]$ *dilation* (1)

$\gamma = (1 - v^2 / c^2)^{-½}$ [ ] boost-factor "γ" of Special Relativity (2)

The boost-factor "γ" ranges from 1.0 at zero speed "v" to infinity at the speed of light "c". The proper unit second is thus longer than the SI unit second of an observer at rest relative to the reference frame of the earth. Explanation: The reference frame of the measurements in SI units could be the reference frame of the Large Hadron Collider (LHC) at CERN. The proper measurements are done by a *hypothetical* observer (the "proper" observer) travelling along a proton that circles the LHC. In other words, the clock of the proper observer on a proton in the LHC ticks slower than the clocks of the LHC observers and thus *measures* less time between two events:

$dt_0 = dt / \gamma$ $[s_0]$ proper *coordinate* "dt_0" time *contraction* (3)

So, the *uniform* time difference "dt_u" between two events is measured the same by the proper observer as by the LHC observers, irrespective of their difference in units:

$dt_u = dt_0.[s_0] = dt.[s]$ *uniform* time difference "dt_u" (4)

The *uniform time difference* "dt_u" between any two events inside or outside the LHC is measured the same! So, what changes at high speed are the units and coordinates, but the uniform time difference, uniform space, uniform mass, and uniform charge remain the same!

Uniform space and Noether frames

The dilation of the measuring stick means *coordinate contraction* of not just length, but *also of width, and of height*, according to the principle of uniform measurements. Here is a contradiction with the Lorentz transformation when it comes to the effects of high speed on width and height staying the same; a problem first pointed out by Ehrenfest, the so-called "Ehrenfest paradox".

The Ehrenfest paradox explains the problem in physics of Special Relativity. Ehrenfest pointed out that a solid disk at a high rotational speed would deform according to Special Relativity. It would result in a smaller circumference, but an invariant radius.
This is a contradiction between Einstein's theory of Special Relativity (based on the Lorentz transformation) and measurement technology. This is solved by the authors with the help of a less famous but brilliant mathematician: Emmy Noether.
Emmy Noether deduced the conditions under which energy and momentum conservation can be proven within a reference frame.

The authors have named a reference frame that adheres to energy and momentum conservation, a "Noether frame". *Within a Noether frame the constants of nature are invariant to location and time*. The invariance of the speed of light "c" and the Newton constant "G" results in the dilation of the unit meter and kilogram since these units are interrelated with the unit second. The reintroduction of units in the formulas of physics will demonstrate the *relativity of both the units and the coordinates*. *The end result is a repaired theory of Special Relativity, which is free of paradoxes and is united with Noether's laws of energy-momentum conservation and measurement technology*.

Formulas and units in Special Relativity

The measured variables in the laws of physics have *normally* the *same* basic units on both sides of the "=" sign as measured by the *same* observer. For example:

$F = m.a$ $[kg.m.s^{-2}]$ Newton's second law (5)

In this equation, "F" is the measured force in $[kg.m.s^{-2}]$, "m" the measured mass in [kg] and "a" the measured acceleration of the mass-particle in $[m.s^{-2}]$. All variables are measured by the same observer in the same basic SI units (second, meter, and kilogram). The units of "F" are a straight multiplication of the units of "m" and "a". In *most* branches of physics, the observers and its units of the measured variables on both sides of the "=" sign are the same. However, the formulas of Special Relativity are in breach of this principle of measurement technology:

$E = m.c^2 = \gamma.m_0.c^2$ [J] Energy of mass-particle (*coordinate-only formula*) (6)

In this formula, is "*E*" the measured energy in Joules [J], "γ" the boost-factor, and "*m*" the measured mass in kilograms. Both "*E*" and "*m*" are measured by the observers of the Noether frame (LHC observers) in the units of the Noether frame. However, "m_0" is the *proper* mass as measured by the *proper observer* in *proper kilograms* in the LHC. Mathematically, we may conclude from (6) that:

$m = \gamma.m_0$ [kg] Mass of a proton (*coordinate-only formula*) (7)

It tells us that the mass "*m*" of the particle within the LHC in SI kilograms as measured by the LHC observers is the boost-factor "γ" larger than the mass "m_0" proper observers measure in proper kilograms. This can only mean one thing according to the principle of uniform measurements: the proper kilogram $[kg_0]$ of the proper observer is much larger than the SI unit of the LHC observers:

$[kg_0] = \gamma.[kg]$ Proper unit kilogram dilation (*unit-only formula*) (8)

Note: The units of measurement (SI or otherwise) are put in square brackets to clearly distinguish these from the coordinates ("*m*" and "m_0"). Furthermore, the variables depending on the boost-factor "γ" are printed italic, while the invariant variables are printed normal. High speed results in a larger proper unit kilogram $[kg_0]$ as used by the proper observer, relative to the unit [kg] of the LHC observers; the higher the speed, the higher the boost-factor "γ", the larger this proper unit kilogram $[kg_0]$ gets.

The same will follow later for the length: a longer proper measuring stick, the proper unit meter [m_0], at high speed results in a shorter measured coordinate length "l_0". Note: do not confuse the proper *unit* meter [m_0] with the proper *coordinate* mass "m_0".

The question reformulated

Now reconsider Einstein's Relativity. In formula (7), the mass "m" is measured in [kg], while the mass "m_0" is measured in *proper* kilograms [kg_0]. Einstein only meant that the *coordinate* of mass is different, *ignoring the units*. The *uniform* mass remains the same!
We must be well aware that formula (7) is a mathematical formula, not a formula of measurement technology! That does not make these formulas incorrect as long as we realize that formula (6) and (7) are *coordinate-only* formulas!
The challenge is evident: *Einstein's formulas need reinterpretation and repair.*

Uniform formulas by reintroducing the units

To solve the misinterpretation of Einstein's formulas in measurement technology, the units are now *reintroduced* in the formulas to become "uniform formulas", according to the *principle of uniform measurements.*
For example, the formulas (7), and (5) formulated in *its uniform formats* are:

$m.[\mathrm{kg}] = \mathrm{m}_0.[kg_0]$ *uniform* mass of proton in the LHC (9)
$\mathrm{F}.[\mathrm{kg.m.s}^{-2}] = \mathrm{m.a}.[\mathrm{kg.m.s}^{-2}]$ *uniform* force (10)

These formulas may look strange initially, but will help to understand Einstein's Relativity. In formula (10) it is obvious why the units are normally ignored, the same observer and units on both sides of the equation. However, in formula (7) of Einstein's Relativity, the units and observers differ on both sides of the "=" sign, formula (9) includes the different units!

According to Noether's laws, the constants and the laws of nature have to be invariant to location and time in order to ensure energy and momentum conservation within a reference frame. In other words, within a Noether frame the constants of nature like the speed of light "c" and the Newton constant "G" are invariant to location and time.
A Noether frame is a Euclidean ("straight") reference frame. The unit meter [m] is defined by the distance that light travels in 1 / c seconds in vacuum. The speed of light "c" is constant, so we may conclude that the proper unit meter [m_0] dilates by the boost-factor "γ" too relative to the unit [m]:

$[m_0] = \gamma.[\mathrm{m}]$ proper unit meter dilation (11)

Note the consistency in unit variation between the proper observer and the LHC observers, see formula (1), (7), and (11)! The proper basic units second, meter, and kilogram dilate by the boost-factor "γ" compared to the SI units of the Noether frame, for example the Noether frame of the LHC. We have now arrived at the point where we can interpret/repair Einstein's formulas.

Einstein's Special Relativity now explained in uniform measurements

We saw that Einstein's formulas are "coordinate-only formulas". Einstein's expressions as "measuring stick contraction" or "length contraction" get a very different meaning and become specific by taking into account the changing units.
The uniform values (multiplication of coordinate and unit) do not change but the unit meter gets larger at speed, so the coordinates (length, width, and height) get smaller, formulated as follows:

l_0	$= \mathrm{l} / \gamma$	*proper coordinate* length contraction	(12)
w_0	$= \mathrm{w} / \gamma$	*proper coordinate* width contraction	(13)
h_0	$= \mathrm{h} / \gamma$	*proper coordinate* height contraction	(14)

It means all proper *coordinate* values, as measured by a proper observer, are smaller by the boost-factor "γ" compared to the *coordinate* values as measured by the observers within the Noether frame. Now you can see why the expression "length contraction" is a bad (non-specific) description of formula (12).
Formulas (6), (7), (12), (13), and (14) are *coordinate-only* formulas. The protons circling in the LHC *do not deform*, *their uniform length, width, and height remain equal*, whatever the speed of these protons are within the LHC: "*there is simultaneous proper coordinate length, width, and height contraction as well as proper unit meter dilation*".

High-speed measurements

How do we as observers within a Noether frame actually measure high-speed objects? How do we measure proper values? At the LHC for example, it is more a question of deduction than actual measurements.
An important help is our "invariance postulate": "*Noether space-time coordinates, proper particle property coordinates, and Noether units are invariant to a change in circumstances*". The dependence of a variable on its speed and thus by its boost-factor "γ" within the Noether frame, is symbolized by *italic* print.

For example, the proper mass coordinate of a proton "m_0" in the LHC is invariant to speed relative to the LHC installation. We consider the LHC installation to be the Noether frame and our SI units to be the Noether units. We know the circumference of the LHC in SI units meter [m], we measure and control the time the protons go around in SI units second [s]. This determines the speed "v" of the protons and thus the boost-factor "γ" within the LHC (Noether) frame, usually about 7,500.
Based on the invariant proper mass "m_0" and its boost-factor "γ" within the frame, we can deduce the coordinate mass "*m*" of the proton, see formula (7).

Based on $E = m.c^2$, we can compute the energy provided by a collision of two protons: $2\gamma.m_0.c^2$, or 2.25 x 10^{-6} [J]; a collision which creates short-lived muons and other particles. If it would be a muon going around the LHC at the same speed, which has an average *invariant proper lifetime* "dT_0" of 2.2 microseconds, we know that it survives the boost-factor longer in the SI units of the LHC observers, namely 7,500 times longer on the clocks of the LHC observers: 16.5 milliseconds.

Note that both the *uniform* energy "E_u" of the proton collision and the *uniform* lifetime "dT_u" of the muon are measured the same by all observers: $E_u = E$.[J] = E_0.[J_0] and $dT_u = dT$.[s] = dT_0.[s_0].
The principle of uniform measurements, the invariance postulate, and Noether's conservation laws combine into a powerful tool to analyze Special Relativity experiments, like the experiments within the LHC.

Note that Special Relativity formulas, like the formulas in this document, must not be confused with the relativistic Doppler Effect. The relativistic Doppler Effect also includes the time delay of the measurement itself and the effect on the momentum of received light of a moving source and/or receiver within the Noether frame.

Resolution to the Ehrenfest paradox of Special Relativity

We have seen the resolution of the Ehrenfest paradox by the *simultaneous proper coordinate contraction* of length, width, and height of the disk, formulas (12) to (14), and the *proper unit meter dilation* of formula (11). *The solid disk does not deform*, the *uniform* measurements remain the same as measured by all observers. The Ehrenfest paradox is solved by the principle of uniform measurements.

Resolution to the twin paradox of Special Relativity

The twin paradox is as follows: Beatrice goes on a high-speed tour around the universe. Her speed is so high that her clock slows down considerably, see the formulas (1) and (3). However, according to Einstein's theory of Special Relativity, reference frames are equal, so the clock of her twin brother Albert should also slow down relative to her. Who is the youngest when Beatrice returns to her twin brother Albert on earth?

The resolution is simple, *reference frames are not equal*. The inequality of reference frames is proven by the muons, created by the solar wind high in our atmosphere, which reach the surface of the earth in spite of the limited proper and invariant lifetime of muons.
The clock of the hypothetical proper observer of a muon ticks slower than the clocks on earth caused by its high speed and boost-factor.
The clocks on earth are not influenced by the speed of the earth towards the muons, as you would argue if reference frames would be equal. The Hafele-Keating experiment also confirms the slower cesium clocks at high speed, there is little doubt about the inequality of reference frames.

The inequality of reference frames is also confirmed by the Schwarzschild solution, the clock of the proper observer slows down relative to the clocks on the massive earth. Reference frames of physics are not equal, the reference frame of the massive earth is dominant over the reference frame of a proper observer of a muon.
The dominance of reference frames is depending on the amount of contained mass and is measured by the difference in (cesium) clock speed.

So, when Beatrice returns from her universal trip and meets her twin Albert on earth again, Beatrice is much younger, the universal frame is dominant over the earthly frame.

Conclusion

Einstein's theories are cast in mathematical formulas using *coordinates only*. It sets the stage for a repair of Einstein's Relativity such that Noether's demands of energy and momentum conservation are met. The use of "uniform formulas" based on the "principle of uniform measurements" and the "invariance postulate" allow us to unite Einstein's Relativity with Noether's laws and with measurement technology as it is applied at the LHC at CERN.

Our books

In our other books we resolve the problems of General Relativity solutions with the same methodology; there is no need for the introduction of "singularities" in black holes or "dark energy" in the universal model. You may freely download the first three chapters of our book "Repairing Special Relativity", at www.loop-doctor.nl; We hope that you get as many "aha" experiences as we did.

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