Mass, energy and reference frames

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My reflections on the theory of special relativity have led me to propose a new approach,[1] questioning certain principles relating to mass and energy.

The first aim of this note is to explain my conception of these two notions, with particular reference to the operation of changing the Galilean reference frame.

It then proposes a physical explanation for the phenomenon of clock desynchronisation observed between two reference frames in relative motion. This explanation was inspired by Mach's principle.

1. Notions of mass and energy in current physics

Mass is a physical quantity intrinsically attached to a body; it is one of the characteristics of elementary

Weighing mass" is used in the definition of gravitational attraction, while "inert mass" is used in the fundamental principle of dynamics. In Newtonian mechanics, these two masses are declared equal, which constitutes the "principle of equivalence".

One of the properties of mass is the postulate that the mass of a body does not depend on the reference frame in which the body is considered ("principle of invariance of mass").

Kinetic energy (which is the energy related to the speed of a body in a given reference frame) is proportional to mass. It depends on the reference frame considered.

As far as energy is concerned, the theory of special relativity has brought about a major change compared with Newtonian mechanics: a body, even at rest, has its own energy, which represents the total energy that can be released by the complete disappearance of the matter making up that body. This energy is given by Einstein's relation :

$$E = m\,c^2$$

In this relationship, m represents the "relativistic mass" which allows the kinetic energy to be integrated:

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

[1] See "*Another approach to relativity*" Table of contents in the appendix.

The rest mass m_0 is always considered invariant to a change of reference frame. [2] Note that this implies that the total energy of a body is a function of the reference frame to which it is attached.

2. Questions about reference frames

Léon Brillouin examined the notion of frame of reference. [3] He explained that, from the moment an experiment is carried out in a *frame of reference*, it cannot be considered as a simple *set of* coordinates, in particular because of the need to take account of the principle of action and reaction. He concludes with these words:

"*A frame of reference does not constitute a piece of unreal geometry anymore; it is a heavy laboratory, built on a rigid body of tremendous mass, as compared to masses in motion.*"

Beyond this, we can ask ourselves the following question: if an experiment takes place in a given frame of reference, what are we to make of the observation of this experiment from another frame of reference?

Can we consider all Galilean reference frames to be equivalent with respect to an experiment, as the theory of special relativity does? Or should we admit that, for a given experiment, there is a privileged reference frame, in which the total energies of the bodies involved in the experiment are known and the actions that modify these energies are defined?

On the other hand, if energy is supplied to a body to increase its speed in a given frame of reference, then the body is transferred to another frame of reference where its speed is different, what happens to the kinetic energy acquired in the first frame of reference (and an integral part of the total energy)?

Another question: is there a physical explanation for the desynchronisation of clocks between two frames of reference in relative motion?

The new approach to relativity tackles these questions in a different way from current physics, as will now be explained

3. Basics of the new approach to relativity

My new approach to relativity was motivated by the observation that the dilation of time, predicted by the theory of special relativity, leads to a contradiction: if we consider two Galilean reference frames Σ and Σ' (moving rectilinearly and uniformly at speed u relative to Σ), the experiment of setting a clock in motion at speed u from the reference frame Σ allows us to assert that time passes more slowly in Σ' than in Σ, but the opposite assertion can be made by considering the setting of a clock in motion at speed $-u$ from Σ'. [4]

[2] Consequently, it was agreed to reserve the term "mass" for the resting mass. In view of the proposals set out below, this convention is departed from in Note 1 above.
[3] L. Brillouin "*Relativity reexamined*" Academic Press, Inc. 1970 (reprinted by Amazon)
[4] Clock paradox experiment. Cf. note "*Another approach to relativity*" paragraph 2.3.4.
You can also refer to Herbert Dingle's book "*Science at the Crossroads*" 1972 (republished by GogLiB).

3.1. By abandoning the deformation of space and time, can we propose an alternative to the theory of special relativity while retaining the principle of relativity and the relativistic law of composition of velocities, which seem to be validated by experiment?

A simple hypothesis is that time flows universally (which means that there is no dilation of durations), but that the synchronisation of clocks in each reference frame does not lead to the absolute time of Newtonian mechanics because of the existence of a speed limit. On the other hand, space is considered to be absolute (there is no contraction of lengths between reference frames).

But if we abandon the hypothesis of a deformation of space and time in a moving frame of reference relative to a supposedly fixed frame of reference, how can we explain the delay of moving clocks or the increase in the lifetime of atmospheric muons compared with muons at rest, phenomena that have been verified experimentally?

3.2. The proposed answer is to replace the invariance of the rest mass by the invariance of the total energy

If, after being set in motion, the clocks are delayed and the muons have a longer life, it is because their energy has increased.[5] Kinetic energy cannot be erased by a change of reference frame; it is carried away by a body that has been set in motion and remains present in another reference frame where the body is at rest. This means that, in this second frame of reference, the rest energy - and therefore the rest mass - of the body has increased

The invariance of total energy must be understood in the following way: if, in the reference frame Σ, the rest mass of a body is equal to m_0 , in the reference frame Σ' moving at speed u relative to Σ, this body must be assigned the rest mass :

$$m'_0 = \gamma\, m_0 \qquad (1)$$

with

$$\gamma = \frac{1}{\sqrt{1-u^2/c^2}}$$

This is valid for writing down in Σ' the laws of physics describing the experiment taking place in Σ. On the other hand, if a body at rest in Σ, with a known rest mass m_0 , is transferred to Σ', any experiment in Σ' using this body will have to assign it a rest mass :

$$m'_1 = m_0/\gamma$$

We will return to this point in paragraph 5 of the note.

We check[6] that assumption *(1)* is consistent with the following coordinate equations:

$$x' = \gamma^2\,(x - ut) \qquad (2)$$

[5] The note "*Delay in atomic clocks*" offers an explanatory analysis. Other types of clocks may not be affected by a change in energy.
[6] Cf. note "*Another approach to relativity*" paragraph 3.2.2.

$$t' = \gamma^2 (t - ux/c^2)$$

These equations differ from Lorentz's formulae by the coefficient γ^2 (instead of γ). **This coefficient reflects the absence of dilation of space and time:**

$$\Delta x' = \Delta x \;\; si \;\; \Delta t' = 0 \quad et \quad \Delta t' = \Delta t \;\; si \;\; \Delta x' = 0$$

The inverse equations are: $x = x' + ut'$ *(3)*

$$t = t' + ux'/c^2$$

There is no longer a one-to-one correspondence between reference systems.

3.3. The reference frames are therefore no longer equivalent. For a given experiment, it has to be accepted that the reference frame in which the experiment takes place is the privileged one.

Conducting the experiment in this reference frame implies that the rest energies of the bodies involved are known. In any other frame of reference, the rest energies used to describe the experiment must be consistent with those of the base frame of reference.

In the reference frame of the experiment Σ, the total energy of the bodies is the real (we will say "true") physical energy at any moment. On the other hand, in another reference frame Σ', if we can consider the energy at rest to be "true", the application of the relation $E' = m' c^2$ leads to "apparent" energies that are different from the "true" energies calculated in Σ.

Perhaps this is the limit of the principle of relativity: the laws of physics are expressed identically in all inertial reference frames, provided we accept that certain absolute quantities (such as total energy) can take on different 'apparent' values from one reference frame to another.

3.4. Finally, the new approach proposed is based on a different conception of the notion of event.

An experience can be seen as a succession of events, an event being a fact that occurs at a given point and time. Does the privileged frame of reference of experience also differ from the others in terms of the notion of event?

Let's assume that all Galilean reference frames are linked together by the definition of a common instant of time origin when the origins of the spatial reference frames coincide.

Assuming the universality of the flow of time (no dilation), any event is characterised by the duration T, which separates it from the common instant of origin.

We will say that an event is "produced" in a reference frame Σ if the time(date) displayed by the clock of the point to which it is attached is identical to this time. This is of course the case for events corresponding to an experiment in Σ.[7] In other reference frames, the event is perceived at a time (date) different from T (unless it is perceived at the origin point of the reference frame), because of the desynchronisation of clocks between reference frames.[8]

In Newtonian mechanics, there is no distinction between "produced" and "perceived" events, because time is absolute.

In the theory of special relativity, no such distinction is made either, which leads to a one-to-one change of coordinates: it is assumed that the conjunction of two points with coordinates x in Σ and x' in Σ' constitutes the same event 'produced' simultaneously in both reference frames. [9]

This is where the contradiction comes in: if time is not absolute, an event cannot be considered as 'produced' in all frames of reference, with the exception of the event used to define the common instant of origin.

3.5. The differences between SRT and our new approach can be summarised as follows:

- The theory of special relativity postulates that all Galilean reference frames are equivalent with respect to events and experiments; this choice is consistent with the principle of invariance of rest mass by change of reference frame. It implies a deformation of space and time between reference frames in relative motion.
- The proposed new approach considers that an event or experiment is necessarily linked to a privileged frame of reference; this choice implies replacing the invariance of rest mass by that of total energy (Einsteinian) when a body is transferred from one frame of reference to another. On the other hand, space and time are no longer distorted.

In the theory of special relativity, we can consider that relativity is pushed to its maximum extension (!). From my point of view, the resulting dilation of time leads to a contradiction. And the absolute physical character of total energy is not taken into account.

3.6. Our new approach to relativity has proved fruitful in treating gravitation using an energetic approach instead of general relativity.

The gravitational shift of the clocks is interpreted as a consequence of the variation in their rest energy as a function of their distance from the gravitational source.[10] This hypothesis has enabled us to formulate laws within the framework of dynamics without distortion of space and time.

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[7] In the reference frame of the experiment, by definition of synchronisation, the time given by any clock in the reference frame represents the time that has actually elapsed.
[8] See chapter 4 below.
[9] See the full analysis of the conjunction between points with coordinates x and x' in the note *"Another approach to relativity*" paragraph 2.4.2.
[10] See "*Another approach to relativity*" in chapter 5.

We then introduced a gravitational field model able to justify these laws, recover the fundamental principle of dynamics and relate the concept of wave-particle duality to the field's renewal characteristics.[11]

4. Explanation of clock desynchronisation

The desynchronisation of clocks between two frames of reference in relative motion results in observers seeing a distorted image of the other frame of reference at the same instant in one frame, since the clocks in the other frame mark different times depending on their position:

According to equations *(3)*: at time t in Σ: [x,t] → [$x' = x - ut'$, $t' = t - ux'/c^2$]

at time t' in Σ': [x',t '] → [$x_1 = x' + ut_1$, $t_1 = t' + ux_1/c^2$]

We have seen that, in the context of the theory of special relativity, [x',t'] gives back [x,t] because of the effect of the deformation of space and time, in addition to the effect of desynchronisation.

The desynchronisation of clocks is linked to the existence of a speed limit.[12] This is the speed of displacement of energy c: the speed of gravitational waves[13] or electromagnetic waves, which is identical in all frames of reference

So how can we physically explain the phenomenon of desynchronisation?

In a Galilean frame of reference, the operation of synchronising the clocks is based on the fact that, by definition of such a frame of reference, two identical experiments, offset by translation and rotation in space, take place with the same durations. Conversely, we could say that it is the fact of synchronising the clocks so as to assign the same duration to the experiments that makes the reference frame Galilean.

Ernst Mach hypothesised that the inertia of material objects would be induced by all the other masses in the universe

As a consequence of this hypothesis, the Galilean reference frames, considered, as we have seen, as massive "frames of reference", appear in some way to be "in equilibrium" with the rest of the universe, i.e. immobile in relation to the frame constituted by all the masses of this universe.[14]

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[11] See note on "*Gravitational field, Fundamental Principle of Dynamics and Quantum Mechanics*".
Table of contents appended.

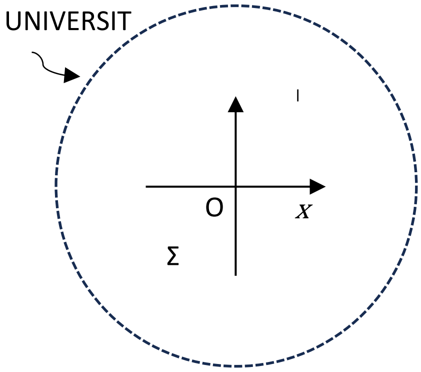
[12] Cf. note "*Another approach to relativity*" paragraph 2.3.

[13] As defined in the note
"Gravitational field, Fundamental Principle of Dynamics and Quantum Mechanics" paragraph 1.1.3.

[14] The Wikipedia article on *Mach's Principle* states that local inertial reference frames are affected by cosmic motion and the distribution of matter.
Julian Barbour and Herbert Pfiste (eds.), "*Mach's principle: from Newton's bucket to quantum gravity".* (proceedings of the conference held in Tübingen in July 1993), Boston, Basel and Berlin, Birkhäuser , coll. "Einstein studies" (n° 6), August 1995, 1re ed.

The question then arises: how can two Galilean reference frames in relative motion both satisfy this condition?

Our answer is as follows: this is only acceptable if time cannot be considered as absolute; we must observe a time shift from one frame of reference to another.



In a Galilean frame of reference, interaction with the masses of the universe results in exchanges of energy at speed c (via field refreshment waves).

For a point of abscissa x, the transmission of interactions along the Ox axis is shifted by a time $T = x/c$ relative to the origin O of the reference frame.

Let's now consider the reference frames Σ, assumed fixed, and Σ' moving at speed u along the Ox axis.

If time was absolute, the transmission offset along Ox' in Σ' would be modified in Σ by the value: $\Delta T' = uT'/c = ux'/c2$

Since Σ' is Galilean, this variation in the offset must be compensated for by desynchronising the clocks of Σ' with respect to Σ.

We find the expected relationship : $t' = t - ux'/c2$

This result remains true if we consider interaction in any direction. If we denote by α the angle of this direction with respect to Ox', the shift is written :

$$\Delta T' = u\ (x' \cos\alpha/c)\ (u/\ c \cos\alpha) = \ ux'/c2$$

5. Questions still raised by the new approach

5.1. What form does the kinetic energy acquired by a body take?

The question does not arise in Newtonian mechanics or in the context of special relativity since kinetic energy is considered only as an apparent energy that depends on the reference frame.

In the proposed new approach, we have seen that kinetic energy, which is part of total energy, is not lost when a body is transferred from one frame of reference to another. But the division between rest energy and kinetic energy is modified.

In a given reference frame, a variation in kinetic energy_ and therefore in total energy _ results in a variation in the boundary radius of the gravitational field

What does this mean for elementary particles?

5.2. On the way to the physics of particles of unknown mass?

When a particle is assumed in a reference frame, the rest mass that must be assigned to it is a function of its past, which led to it being given a certain total energy. Two identical particles with different histories do not necessarily have the same rest mass.

This opens the door to many new questions, for example about particle emission spectra or mass balances in experiments.

And what could the consequences be for the standard model of elementary particles?

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