Why relativistic mass should be studied in depth, not rejected

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Abstract

As mass is defined as the measure of the *resistance* a particle offers to its acceleration and as it is an experimental fact that a particle's resistance to its acceleration increases when the particle's velocity increases, it follows that the concept of relativistic mass reflects an experimental fact.

I think the present status of relativistic mass in spacetime physics should not be silently tolerated.

On the one hand, the physics community is divided[1] – some firmly reject the concept of relativistic mass (e.g., in papers entitled "The Virus of Relativistic Mass in the Year of Physics" [14]), whereas others continue to regard it as an integral part of spacetime physics[2] including even in introductory textbooks and books published this and last year [16].

On the other hand, both mass and relativistic mass appear to be equally supported by the experimental evidence – since mass is defined as the measure of the *resistance* a particle offers to its acceleration (which is the accepted definition based on the experimental evidence) and since it is also an experimental fact that a particle's resistance to its acceleration increases as the particle's velocity increases, it follows that the particle's mass increases when its velocity increases.[3] Therefore the concept of relativistic mass also reflects an experimental fact – the increasing resistance a particle offers when accelerated to velocities close to that of light.

A common objection against the relativistic mass is that it is not an invariant and its use is even regarded as a result of misunderstanding [17]:

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[1] Despite the discussions in the *American Journal of Physics* [1]-[4], *Physics Today* [5]-[8] and the *The Physics Teacher* [9]-[13].

[2] Despite that during the last three decades physicists have witnessed (or rather endured), as Max Jammer put it [15], "what has probably been the most vigorous campaign ever waged against the concept of relativistic mass."

[3] It cannot be stated that it is sufficient to say it is the particle's energy that increases with its velocity, because the crucial experimental fact is the *increasing resistance* the particle offers to its acceleration and the measure of this resistance is the particle's mass. It is this resistance, which ensures that a particle cannot be accelerated to a velocity greater than that of light, because the particle's resistance (i.e., its relativistic mass) approaches infinity as its velocity approaches the velocity of light.

> The concept of 'relativistic mass' is subject to misunderstanding .... First,[4] it applies the name mass – belonging to the magnitude of a 4-vector – to a very different concept, the time component of a 4-vector.

It is true that the magnitude of the four-momentum is proportional to the rest (proper) mass m_0, whereas the four-momentum's time component is proportional to the relativistic mass m. But, the situation is exactly the same with respect to proper and coordinate time – the magnitude of the displacement four-vector $\mathbf{\Delta x}$ (connecting two events on a timelike worldline) is proportional to the proper time $\Delta\tau$, whereas the coordinate time Δt is the time component of the four-vector $\mathbf{\Delta x}$. So, if we cannot talk about relativistic mass, by the same argument we should talk only about proper time, which is an invariant, and deny the name 'time' to the coordinate time, which is frame-dependent (thus denying the relativistic time dilation because it is the coordinate time that "dilates," i.e., that changes relativistically like the relativistic mass which also changes relativistically).

There exists indeed a serious difficulty involving the relativistic mass m – the relativistic generalizations of kinetic energy and Newton's second law cannot be obtained by merely replacing the classical (Newtonian) mass m_N with m in the classical expressions. Moreover, in the general case, the relativistic force acting on a particle is not parallel to its acceleration and it also appears that the relativistic mass behaves as a tensor[5] because a particle's resistance to its acceleration is *different* in different directions; it is greatest along the particle's velocity (serving as the mechanism that prevents a particle's velocity from exceeding that of light). But this difficulty is rather an open question which provides an excellent opportunity to finally start systematically looking into the origin and nature of the *resistance* a particle offers when accelerated (an open question in classical physics) and of the *increased resistance* a particle offers when accelerated to velocities approaching that of light (an open question in spacetime physics).

As both the fact that the very definition of mass demonstrates the need of relativistic mass in spacetime physics and the overwhelming experimental support for relativistic mass cannot be ignored because there are some difficulties with this concept, relativistic mass should be studied in depth, not rejected.

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[4] This and the second point of the alleged misunderstanding are addressed in more detail in [18].

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