A letter to EJP

John Roche asks "What is mass?"

R. I. Khrapko
Moscow Aviation Institute, 125993, Moscow

Abstract

Roche's paper "What is mass" advocates a historical predecessor of mass. It impedes teaching because presses on inadequate concept of mass.

European Journal of Physics has published a long paper of John Roche, which is entitled "What is mass?"[1]. In the author's opinion, 'mass' is 'matter', or a mass is a body itself rather than a property of matter or of the body, i.e. 'mass' is synonymous with 'quantity of matter', and 'mass' is synonymous with 'body'.

To illustrate the opinion the author presents a NASA spokesman's statement that muscle mass and bone mass are lost during space journeys. But to my mind, this conception of mass is fit for a shop assistant which sells meat and bone at a market rather than for an author of a respectable physical journal.

In accordance with the opinion the author insists on the literal meaning of the text of a common problem: "A mass m_1 collides with a mass m_2…". He does not think that a writer of the problem implied that a body of mass m_1 collides with a body of mass m_2. But in my opinion, the sense of the problem text is just that very sense. I present here as an example a common problem from the textbook [2]: "A bullet of mass 4.54 g is fired horizontal into a 2.41 kg wooden block…" (p. 226).

Considering a mass as a body itself, not as a property of the body, the author discredits the trivial idea of three different properties of matter: inertial mass, active and passive gravitational masses. He wrote: "Indeed, to say a given body has three 'masses' seems rather extravagant and contrived. Using this approach, what is to stop us creating further 'masses'?" (p. 231). I will answer this question. We have only two laws, $F = m_g GM/r^2$ and $F = m_i a$, which involve only three masses, m_g, M, m_i. The Roche's sentence proves that he does not understand the equivalence principle and the sense of the Eotvos experiment.

Considering, following Newton, mass as the quantity of matter the author does not give an up-to-date definition of mass. Nevertheless, one can conclude that the author implies some comparison of a body with the standard kilogram. Therefore the Roche's mass is, apparently, a common rest mass with all its defects (see [3, 4]).

It is straightforward that Roche disclaims an existence of the relativistic mass:

> "If we wish to measure relativistic mass, then it is necessary to measure the mass of the moving body using standard kilograms at rest. But this is impossible. Clearly, relativistic mass, $m = m_0/\sqrt{1-v^2/c^2}$, or $m = \gamma m_0$, is not a well-defined concept, and seems to be no more than a mathematical artefact".

The author keeps silence about strict methods to measure mass of moving bodies. For example, R. Feynman suggested [5]:

> "We use the term *mass* as a quantitative measure of inertia, and we may measure mass, for example, by swinging an object in a circle at a certain speed and measuring how much force we need to keep it in the circle. In this way we find a certain quantity of mass for every object" (p.9-1).

R. Feynman also wrote [6]:

> "The theory of relativity was developed, which proposed that no matter what the origin of the mass, it *all* should vary as $m_0/\sqrt{1-v^2/c^2}$. … When Einstein and others began to realize that it must always be that $U = mc^2$, there was great confusion" (p. 28-4).

J. Roche thinks that one must not interpret mass as inertia because mass is matter itself but inertia is a property of matter. He is afraid that such a radical interpretation will be almost a guarantee of ambiguity (p. 232). So he impedes the use of the concept of mass in physical reasoning because of the separation the mass from inertia. For example, when a dependence of the cyclotron angular velocity $\omega = qB/m$ on a speed of the moving particle is discussed, the author is forced to write

$$\omega = qB/i_t,$$

where $i_t = \gamma i_0$ is the "transverse inertia" of the moving particle. The author is proud that the formula relates ω, q, B, i_t, and not explicitly the mass.

Considering, following Newton, mass as the quantity of matter J. Roche gives lots of references (more than 100) in his favor. But he has ignored authoritative objections against Newton's concept of mass, for example, a Feynman's statement:

"The mass of an object changes when it moves, because of the conservation of energy. Because of the relation of mass and energy the energy associated with the motion appears as an extra mass, so things get heavier when they move. Newton believed that this was not the case, and that the masses stayed constant. When it was discovered that the Newtonian idea was false everyone kept saying what a terrible thing it was that physicists had found out that they were wrong. Why did they think they were right?"

"Energy and mass are equivalent, and so Newton's interpretation that the mass is what produces gravity has been modified to the statement that the energy produces the gravity". [7]

M. Born explained [8],

"This is impossible that mass is a constant quantity peculiar to each body. The mass of one and the same body is a relative quantity. It is to have different values according to the system of reference from which it is measured, or, if measured from a definite system of reference, according to the velocity of the moving body" (p. 269).

"In ordinary language the word *mass* denotes something like amount of substance or quantity of matter, these concepts themselves being defined no future. The concept of substance is considered self-evident. In physics, however, as we must very strongly emphasize, the word *mass* has no meaning other than that gives by the formula $\mathbf{P} = m\mathbf{v}$. It is the measure of the resistance of a body to changes of velocity" (p. 33).

R. Feynman and M. Born died, and people who can't understand "What is mass?" held up heads.

J. Roche does not refer to Feynman and Born, but he has referred to M. Jammer six times. And it only is worse, because J. Roche concealed Jammer's point of view. I am forced to quote from M. Jammer [9].

"Defining mass as the coefficient of velocity in the expression for the momentum, we see that the velocity dependence of mass is given by the general formula $m = m_0/(1 - v^2/c^2)^{1/2}$". (p. 160).

"In virtue of the relation $d\tau = dt\,(1 - v^2/c^2)^{1/2}$,

$$\mathbf{P} = \frac{m_0}{(1-\beta^2)^{1/2}}\mathbf{v}\,.$$

Identifying – as in classical mechanics – the coefficient of the velocity in the expression for the momentum as the "mass" of the particle, we obtain

$$m = \frac{m_0}{(1-\beta^2)^{1/2}}$$ " (p. 165).

"With increase of velocity, mass increases. It is thus also obvious that all associations with the historical predecessor of mass, the *quantitas materiae*, are completely severed, as they were in the electromagnetic theory of matter. Otherwise one would have to draw the conclusion that motion creates matter, a result against which Bullialdus, in 1639, vehemently protested (p. 171).

Poincare's arguments lead necessarily to the following relation between electromagnetic energy and inertia:

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

where m is the change of inertial mass and E the energy involved (absorbed or emitted)" (p. 181).

Also I would like to quote from R. C. Tolman [10],

"The masses of two particles, which by hypothesis have the same value, say m_0, when at rest, become inversely proportional to $\sqrt{1-u^2/c^2}$ when moving with the velocity u, so that we may now write

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

as the desired expression for the mass m of a moving particle in terms of its velocity u and mass at rest m_0" (Sec. 23. The mass of a moving particle).

J. Roche did not refer to my paper "What is mass?" which was published four times [3], though there are arguments that he has read the paper. These arguments are not confined reduced to that he, possibly, used the heading of the paper. In his survey of definitions of mass he mentioned a "mass defined operationally without explanation". Possibly, he mentioned my definition [3] (see also [11]):

"Mass is a measure of inertia of a body, i.e. the coefficient of proportionality in the formula $\mathbf{P} = m\mathbf{v}$. The operation used to define a momentum is essentially as follows. When a certain obstacle causes a moving body to stop, a force $\mathbf{F}(t)$ is measured with which the body acts on the obstacle during retardation. The body's initial momentum equals the integral $\mathbf{P} = \int \mathbf{F}(t)dt$ by definition".

It is important that I submitted another paper entitled also "What is mass?" to EJP on Apr. 4, 2001, but the paper was rejected without refereeing because "they did not feel that my paper fell within the scope of the journal".

At large, we must recognize that Roche's paper advocates a historical predecessor of mass and it impedes teaching because it presses on inadequate concept of mass. The author is a supporter of the rudimentary concept of mass as `quantity of matter'. He does not understand that mass is a property of matter and especially that "it must always be that $U = mc^2$". He does not accept an idea of relativistic mass the same as early opponents of special relativity could not accept the relativity of time. The lifetime t of an unstable particle or of an astronaut varies with speed as its inertial mass: $t = \tau / \sqrt{1 - v^2/c^2}$.

It is appropriate to quote here from Max Planck:

"An important scientific innovation rarely makes its way by gradually winning over and converting its opponents: it rarely happens that Saul becomes Paul. What does happen is that its opponents gradually die out and that the growing generation is familiarized with the idea from the beginning: another instance of the fact that the future lies with youth. For this reason a suitable planning of school teaching is one of the most important conditions of progress in science" [12].

Unfortunately, the great idea of relativistic mass is carefully isolated from youth.

References

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