AMBIGUITIES IN TEACHING PHYSICS: THE CASE OF WEIGHT AND ENERGY-MASS

Tatjana Mulaj, *Polytechnic University of Tirana, Albania*

Zenun Mulaj, *University of Tirana, Albania*

In teaching literature for high school and university and in journals for physics education, there are a few cases where one physical quantity is used in an ambiguous way. Thus, there is no accepted opinion about the meaning of the weight. Especially, there is a wide discussion whether to use or not to use the rest and relativistic mass concepts. In the same time there is no defined interpretation of energy-mass relation.

In this paper this problem is treated and our opinion about it is expressed.

1. Introduction

One of the difficulties of learning physics, which in many cases makes physics not very likeable for students, is the ambiguity in using physical concepts. So there is no unique determination of such concepts as weight, mass and relation energy-mass in the Special Theory of Relativity; there is no distinction between physical fields, such as electromagnetic or gravitational fields and mathematical concept of scalar or vector fields; the majority of authors considers second Newton's law as physical law, meanwhile others use it to determine mass (force) where force (mass) is chosen as the primary concept. Some times, we meet ambiguities in the same textbook. The situation in teaching physics in high school and in the undergraduate level is intolerable.

In this paper we are treating two widely used concepts: the *weight concept*, which is used also in everyday life, and in modern times is linked to the very curious phenomenon, the wheightlessness and *mass and its relation to energy*, which is one of great changes caused by TSR in our worldview about nature.

2. Weight concept

Galili [1] has carried out a complete study of ambiguity in using the weight concept, and it would not have been necessary to treat it again, if the problem had taken its definitive solution.

Mankind has begun to construct the weight concept since its origin, from the feeling of heaviness one has when holding a thing in his arm. With this concept is linked the weighing and balance. In the development of physics, some concepts have not the same meaning as in everyday life, as is the case of heat and temperature. We think that, for the concept of weight, this difference is not only unnecessary but it makes difficult the correct use of this concept.

As is mentioned in [1], in American literature, with rare exceptions, *the weight of the body is the force of gravity* [2]. According to this definition, the weight of the body may be diminished only in the case, where the body is far from the earth or, in other planets, and the wheitlessness can be achieved only in the location very far from all celestial bodies, but in any case, in earth conditions, the weight of the object can be increased.

In other cases, as in [3], the weight is determined in the following way: *the contact force that an object exerts on whatever is supporting it is called the weight of the object*. This definition of weight is used also in well-known books of Appell [4] and Kaempffer [5]. In this case, where the object is moving with acceleration, the weight of the object may be diminished, increased or be zero. So, the wheightlessness can be achieved very easy in earth conditions; everybody can experience it in jumping. The wheightlessness, which is demonstrated very beautifully by cosmonauts, is the same as in earth conditions, but it lasts more. In this manner there are not used the apparent and true weight, "weightlessness" or apparent "weightlessness".

It is worth mentioning that the determination of weight by the International Organization of Standards in 1992, is: *the weight of the body in a specified reference system is that force which, when applied to the body, would give it an acceleration equal to the local acceleration of free fall in that reference system*, which by our opinion is not correct.

3. Mass and energy – mass relation

In the literature there are three opinions about mass concept in the Theory of Special Relativity.

a. According to the first opinion [6], [7], the mass is a relativistic quantity as space coordinates, time, velocity, linear momentum, energy, etc. Based on this, relativistic mass and rest mass are used. The relativistic nature of mass is expressed by the known formula:

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

where m is relativist mass and m_0 is rest mass.
The relation of mass and energy

$$E = mc^2 \tag{2}$$

has general meaning: every kind of energy has its equivalent mass and every change of energy of particle or system is associated with the change of its mass and vice-versa; the photon has mass $m = h\nu/c^2$.

b. The second opinion states that there is only one mass with the same nature in classical and relativist physics. This opinion is shared by the majority of specialists in Particle Physics. In [8], [9] the expression (1) has no sense and the relation (2) is only between mass and rest energy; the photon has no mass.

c. The third opinion states that the mass and energy are treated as the same quantity; the energy can be converted to mass and vice-versa.

The special nature of relativist mass related to other quantities in TSR is shown by the fact that it is not invariant and doesn't make a 4 – dimensional couple with another quantity as for example, space coordinates and time, linear momentum and energy etc. This is the main reason that the majority of physicists do not use relativist mass at all. But replacing it with classical mass, and treating it as invariant, only superficially resolves the problem. In TSR there are other invariant quantities such as proper time, proper length, but there are also, relativist time, relativist length. The only quantity, which stands in special position in TSR, is the velocity of light, but the justification for this role is out of TSR. We don't think the mass case is the same.

The relation of mass with energy, accepted only for rest energy, makes a great discrimination between different forms of energy. Moreover, the rest energy of the system contains all energies of its particles. It is hard to accept that the nature makes such differentiations: kinetic energies of particles of the system contribute to the mass of the system, but kinetic energy of the system, as a whole, does not.

In this framework, we think that the physics of the photon is more reasonable in accepting Einstein's conclusion expressed in [10]: *if the system emits energy L, in the form of radiation, its mass will be diminished by* L/c^2. It is hard to accept that photon has no mass but the system of two equal photons, propagating in different directions, has mass.

We think that, all three opinions are equivalent with one another, except in the cases where their supporters pretend to prove the priority of one opinion upon another, or, in the worst cases, to proclaim other opinion/s as wrong, even when these opinions are formulated or stated by Einstein, Heisenberg, Feynmann or Hawking.

According to Heisenberg, mass and energy are essentially the same concepts. If instead of mass (or proper mass) we use proper energy, the known energy – momentum relation

$$E^2 - p^2c^2 = m^2c^4 \tag{4}$$

gets the form

$$E^2 - p^2c^2 = E_0^2 \tag{5}$$

in complete analogy with the other relation of TSR:

$$(dt)^2 - (dr)^2 / c^2 = (dt_0)^2 \tag{6}$$

What about the unanimous use of equation (4) instead of (5) in particles physics? We think that this is only to preserve links with Newtonian Physics, where the mass concept is a crucial one. If we write in Newtonian Physics E_0/c^2 instead of m, nothing will change, but it is difficult or impossible to introduce this theory in this way.

Acknowledgments: One of us (Z.M) likes to gratefully acknowledge the hospitality of the Feza Gursey Institute of TUBITAK, Turkey, where the part of this work was done under support of NATO-PC Program.

[1] Galili I. In "Thinking Physics for Teaching" (ed. C. Bernardini etc), Plenum Press, NY, 1995.
[2] Serway R. A. Physics, Sounders College Publishing, 2002, (… its magnitude [of the force of gravity] is called the **weight** of the object); in the 1992 edition: the force exerted by the earth on a body is called the **weight** of the body **W**.
[3] Marion J. B., Hornyak W.F., Physics, Sounders College Publishing, NY, 1982.
[4] Appell P. Traite de Mecanique Rationnelle, (in Russian), 1960.
[5] Kaempffer F.A. The elements of Physics, (in Russian), 1972.
[6] Rindler W., Physics Today, Letters, May 1990.
[7] Ray d' Inverno, Introducing Einstein's Relativity, Clarendon Press, Oxford, 1992.
[8] Okun L., Physics Today, June 1989.
[9] Adler C. Am. J. Phys. 55, 1987.
[10] Einstein A., Ann. Phys. (Leipzig) 17, 1905 (in Russian).