

7 The energy mass equivalence

Subject:

Einstein's energy mass relation $E = mc^2$.

Deficiencies:

In many schoolbooks and magazines we find the statement that Einstein's energy mass relation means that mass and energy are different manifestations of the same physical quantity, and energy and mass can be transformed one into the other [1]. If this statement was true, we could distinguish energy from mass. A decrease of energy would be associated with an increase of mass and vice versa. However, it is not true, and it is not what Einstein's relation tells us. According to this relation, mass and energy are the same physical quantity, measured with different units.

Origin:

Possibly the culprit is Einstein himself:

"It follows from the special theory of relativity that mass and energy are both but different manifestations of the same thing, a somewhat unfamiliar conception for the average mind. Furthermore, the equation ... in which energy is put equal to mass, multiplied for the square of the velocity of light, showed that a very small amount of mass may be converted into a very large amount of energy and vice versa. The mass and energy were in fact equivalent, according to the formula mentioned above."

Instead of saying "may be converted into" he should have said "corresponds to".

Disposal:

Teaching should make clear the following:

1. The quantity known before as energy also has the properties of the quantity known before as mass, namely weight and inertia. A charged battery is heavier than an empty one. Hot water is heavier than the same amount of cold water, a moving body is heavier than the same body at rest, and so on. The weight differences in these examples are so small, however, that it is impossible to measure them.
2. The quantity known before as mass has also the properties of the quantity known before as energy. At a first glance, this assertion seems unbelievable. A typical property of energy is that it allows us to do some useful work. So one might expect that with 1 g of sand one should be able to realize a work of $E = 1 \text{ g} \cdot c^2 = 10^{14} \text{ J}$, what is obviously not true. However, we can never take profit of all the energy contained in a system. With "compressed" air of 1 bar we cannot drive a jackhammer, with "warm" water of ambient temperature we cannot drive a thermal engine. With gasoline alone we cannot run a motor. We also need oxygen. So it should not be surprising that we cannot run or drive anything with 1 g of sand alone. We also need 1 g of anti-sand. But if we had the anti-sand, it would work.

[1] "...This pair annihilation is the conclusive proof of the famous Einstein's law $E = mc^2$ for the transformation of mass into energy."