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The Energy of the Electron

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As is known, all forms of energy can be transformed into each other. The energy can be neither created nor destroyed, but only transferred from one object to another or transformed from one form into another. Mass can also neither be created nor destroyed. Some objects have several forms of energy at the same time and the total energy of the object is the sum of all these energies. For example, a moving electrically charged particle (with mass m>0) has pure mechanical energy, electric energy of the electric field, and magnetic energy. Thus, the total energy is

$$E = E_k + E_e + E_m$$

Some physicists neglect all forms of energy of the moving electron except the pure mechanical kinetic energy and claim that the "classical" energy formula cannot be applied when an electron is moving at high velocities. Such consideration is obviously wrong, because the energy of electromagnetic fields, depending on the velocity, changes in a different way than pure mechanical energy. The question whether an electron has a pure mechanical mass has never been answered definitely.

When the pure mechanical energy is considered, it is easy to see that this energy is the same whether the mass or the observer is considered to be moving. This is not the case for a charged particle - a moving observer cannot generate a magnetic field on a charged particle at rest, while a moving charged particle has a magnetic field even if it is considered to be at rest. Hereby it is clear that a medium must exist, relative to which the charged particle moves. Movements relative to empty space are not definable and cannot be distinguished from rest. In empty space there is nothing which could act on the particle, therefore no field can exist made of empty space. A field is a certain state of a medium.

According to O. Heaviside [1], the electric and magnetic energies of a moving charged sphere are

$$E_e = \frac{q^2}{2\varepsilon_o r} \cdot \frac{1 - v^2/c^2}{4} \left[1 + \frac{\frac{3}{2}}{1 - v^2/c^2} + \frac{\frac{3}{2} \tan^{-1} \frac{v/c}{(1 - v^2/c^2)^{\frac{1}{2}}}}{(v/c)(1 - v^2/c^2)^{\frac{3}{2}}} \right]$$

$$E_m = \frac{q^2}{2\varepsilon_o r} \cdot \frac{1 - v^2/c^2}{4} \left[1 + \frac{2\, v^2/c^2 - \frac{1}{2}}{1 - v^2/c^2} + \frac{\left(2\, v^2/c^2 - \frac{1}{2}\right) \tan^{-1} \frac{v/c}{(1 - v^2/c^2)^{\frac{1}{2}}}}{(v/c)(1 - v^2/c^2)^{\frac{3}{2}}} \right]$$

Heaviside noticed that his calculations could not be completely correct, because the existence of Heaviside ellipsoid presupposes an infinite speed of propagation of the electromagnetic field.

Similar (non-relativistic) calculations of Lorentz [2] lead to the following results with some approximations (many authors use different physical units, so the formulas would have to be adjusted)

$$E_{\text{em}} = \frac{q^2}{6\pi r} \cdot \left(\frac{1}{(1-v^2/c^2)^{\frac{1}{2}}} \right) \text{ or } \Delta E_{\text{em}} = \frac{q^2}{6\pi r} \cdot \left(\frac{1}{(1-v^2/c^2)^{\frac{1}{2}}} - 1 \right).$$

The two results are compared in figure 1. It is obvious that the Heaviside result shows a better agreement with the data of the Bertozzi experiment [3]. The black curve shows the energy of the electron when the pure mechanical kinetic energy or the kinetic energy of the mechanical mass (i.e., the energy of the electron if it were not electrically charged)

$$E = \frac{1}{2} m_e v^2$$

is added. Thus, the difference in energy between the moving electron and the electron at rest is

$$\Delta E = \frac{q^2}{6\pi r} \cdot \left(\frac{1}{(1-v^2/c^2)^{\frac{1}{2}}} - 1 \right) + \frac{1}{2} m_e v^2 \text{ or } \Delta E = m_e c^2 \cdot \left(\frac{1}{(1-v^2/c^2)^{\frac{1}{2}}} - 1 \right) + \frac{1}{2} m_e v^2$$

It is obvious that almost the entire kinetic energy of the moving electron is stored in the kinetic energy of the electromagnetic field of the electron.

If in Bertozzi's experiment protons are used instead of electrons, the electromagnetic energy remains the same. However, Einstein claims that the energy of any mass is proportional to the relative velocity according to

$$\Delta E = \text{mc}^2 \cdot \left(\frac{1}{(1 - v^2/c^2)^{\frac{1}{2}}} - 1 \right)$$

(this is independent of whether the observer or the mass is "moving"). He tries to justify his claim by asserting, "We notice that these results ... are also valid for ponderable material points, because a ponderable material point can be made into an electron (in our sense) by the addition of an electric charge, no matter how small."[4] This claim is obviously without foundation because the electromagnetic energy is a function of the electric charge and the mechanical mass does not appear in the formula at all.

Some authors claim to have confirmed Einstein's postulate [5], but none of them measured the velocity and energy of protons separately, as Bertozzi did.

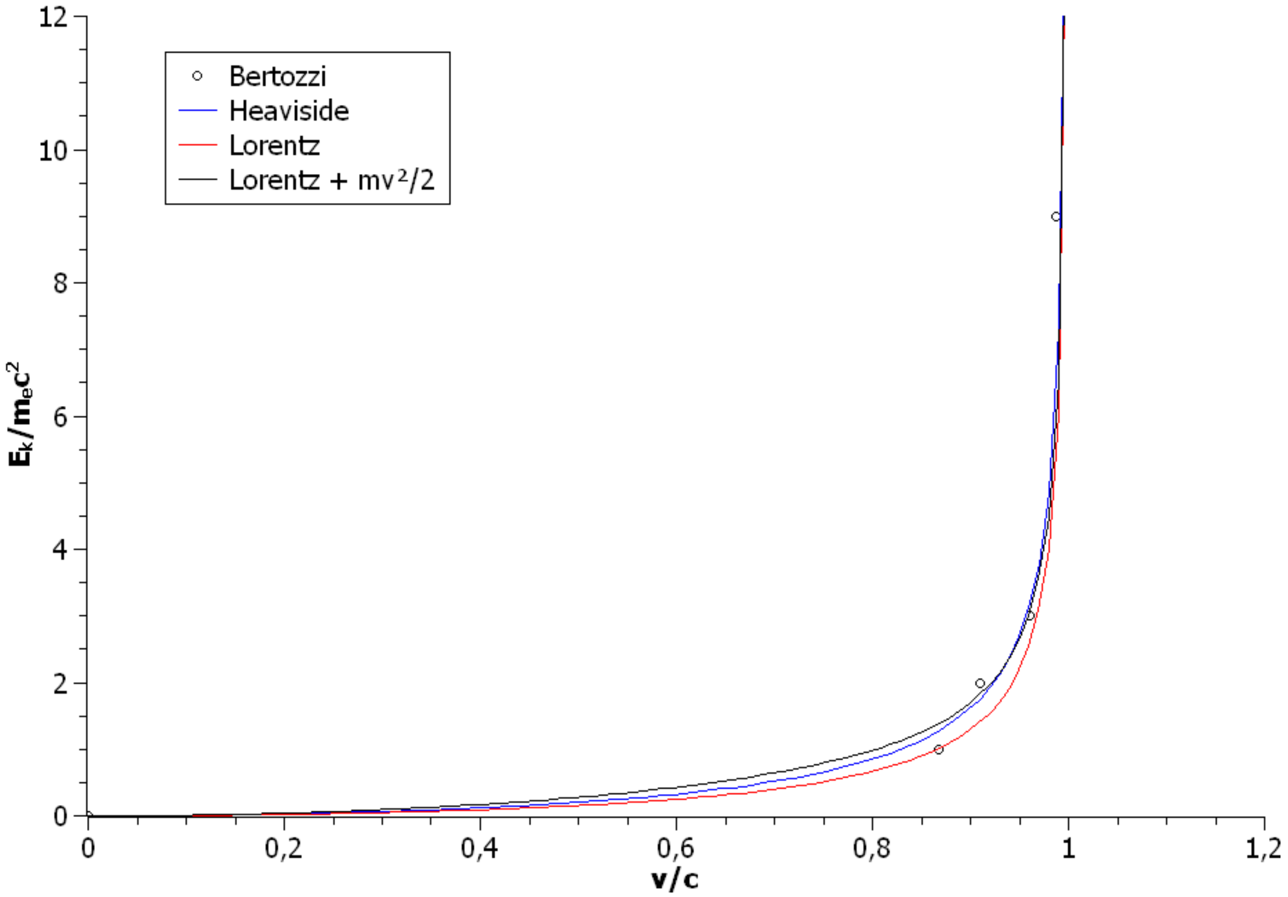

Figure 1: Electromagnetic energy of the moving electron according to Heaviside and Lorentz. The circles represent measured values according to Bertozzi.

1. O. Heaviside, Electrical papers London (1892)
2. H. A. Lorentz, Electromagnetic phenomena in a system moving with any velocity smaller than that of light (1904)
3. W. Bertozzi, "Speed and Kinetic Energy of Relativistic Electrons", American Journal of Physics (1964)
4. A. Einstein, "On the Electrodynamics of Moving Bodies" (1905)
5. V.P. Zrelov, A.A. Tiapkin and P.S. Faragó,Sov. Phys. JETP 7, 384 (1958).