Tachyons

From the pioneering paper of J.C. Maxwell and the later paper "On the Electrodynamics of Moving Bodies" by A. Einstein, it was clear that the speed of electromagnetic waves including light is a universal constant. H. Hertz discovered these electromagnetic waves, and J.C. Bose and G. Marconi demonstrated their long distance propagation.

In Einstein's study the mechanical behavior of matter was changed in accordance with the two relativistic principles. This required that length (along the line of relative motion) contracted, time expanded, and the effective mass of a particle increased by motion. These effects were controlled by the factor

$$\gamma = \left[1 - \frac{v^2}{c^2}\right]^{-1/2} \tag{1}$$

where v is the relative velocity between two frames (taken to be less than the speed of light). This quantity becomes infinite when $v = c$. Based on these considerations, Einstein asserted that not only is the speed of light a constant, but it is also an upper limit (never reached) for material particles moving in empty space.

The relativistic expression for the energy of a moving particle is

$$E = mc^2 = \gamma m_0 c^2 \tag{2}$$

which increases without limit when v approaches c. Therefore, it had long been assumed that the theory of relativity has established the speed of light as the highest speed allowed. However, Sudarshan and collaborators showed that this need not rule out propagation faster than light [1]. After all, when light is produced it is produced with a speed c, and not by accelerating a particle to the speed c. So, if there are particles which have a speed greater than the speed of light they should also be *produced* with such a speed.

The possible existence of such faster than light particles was brought to greater public attention by the (late) Gerald Feinberg, who christened them "Tachyons".

Tachyons can exhibit unusual and fascinating properties which must be carefully proven to be consistent. It is not surprising that a number of apparent paradoxes have been proposed involving tachyons. In the relativistic relations

$$E^2 - c^2p^2 = m_0^2 c^4, \quad v = \frac{c^2 p}{E}, \tag{3}$$

if $v > c$ then $m_0^2 c^4 < 0$, which means that m_0 must be pure imaginary! However, tachyons can never be brought to rest in the reference frame of inertial observers with subluminal velocities. Hence the imaginary rest mass of a tachyon is not observable by us. This implies that the *proper* lengths and *proper* lifetimes of tachyons are also imaginary and unobservable. However, this is no stranger than photon rest mass being zero. In both cases we will never see them at rest; m_0 is just a parameter in the calculation. We can then say that $m_0 = im_*$, where m_* is called the *meta-mass*. The expression for its energy is then

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

Another objection could be that in this case the energy E could appear positive to one observer but negative to another. This can be resolved if in the second frame of reference the particle looks as it was absorbed first and emitted later. This is called *the reinterpretation principle*. Although both observers will still disagree on the direction in which the particle travels, energies seen by both will be positive. It follows that the negative energy cannot be used to extract infinite energy.

Can we interchange cause and effect? What is causality and how do we determine that one event is the cause and the other is the effect? The answer is that the causal connection is an invariant connection - the earlier one is the cause and the later one is the effect! So, yes, the cause and effect would be seen by a suitably moving observer as being interchanged. There is no universal emitter or universal absorber for tachyons, as this is observer dependent. Sudarshan and Bilaniuk have examined such questions in detail and resolved all apparent paradoxes [2]. They have also investigated causality and space-like signals [3].

The quantum field of tachyons presents several novel features including the reinterpretation principle [4–6]. One could ask the question: if there were primordial tachyons, how would they manifest? Narlikar and Sudarshan studied this question and concluded that they would have disappeared by now [7].

The visual appearances and other manifestations of tachyons have been extensively studied by E. Recami [8].

To date, no tachyons have been detected. It would be a great pity if they do not exist. With only electromagnetic (or neutrino) astronomy, we do not have the possibility of knowing what is the present situation in far away places. We can only do cosmic archaeology. For two-way communication over very large distances we need tachyons. Without them we cannot escape far beyond our solar system.

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