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The "Color" of Light in the Light Clock Experiment

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A fundamental tenet of Special relativity (SR) is that the light speed c ($\approx 3\times10^8$ m s^{-1}) is constant in all inertial frames.[1] From this postulate, time dilation inevitably results [2]. Simply speaking time dilation can be defined as the phenomenon that a clock at rest shows the time interval ΔT_0 which is shorter than the time interval ΔT when it is moving with a speed υ. Physicists usually "use" as a clock a "traditional" light clock of SR ((hereinafter "the light clock") to illustrate this phenomenon and to derive the time dilation expression

$$\Delta T = \Delta T_0 /\sqrt{1 - \upsilon^2/c^2)}$$

where $1/\sqrt{1 - \upsilon^2/c^2)}$ is the Lorentz-Einstein or the time dilation factor γ.

Elementary physics tells us that when a ray of light strikes a plane mirror, the light ray reflects off the mirror. According to the law of reflection, the angle of incidence equals the angle of reflection. In our previous paper [2], we have shown that when the light clock stops then the light angle of incidence is greater than zero but its angle of reflection is zero degrees. This observation disagrees with the law of reflection.

We will consider the light clock experiment and the associated blueshift of the reflected light, i.e. the "colors" of the incidence and reflected light.

The traditional light clock usually consists of two plane-parallel mirrors M_1 and M_2 that face each other and are separated by a distance d, Fig. 1a. A light beam originating from mirror M_1 reaches mirror M_2. We will employ a monochromatic light beam, which traces out a path of length d.

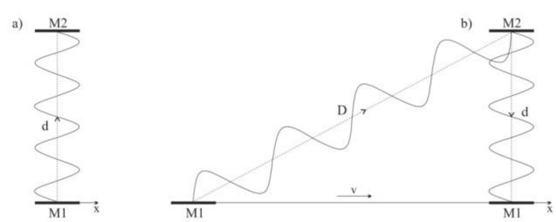

Figure 1: a) the light clock at rest and b) moves at a speed υ and then abruptly stops. See the text.

[1] It is important to note here that Ziefle [1, and references therein] demonstrated that SR is not compatible with the constancy of light that is measured on Earth.

After reaching mirror M_2 the light beam reflects to mirror M_1 following the law of reflection [2]. Now allow the same light clock to be moving with a certain relative speed υ horizontally in the direction of the positive x-axis. The light beam of mirror M_1 reaches mirror M_2 traveling the larger distance D. After reaching mirror M_2 the light beam would reflect to mirror M_1 according to the law of reflection [2].

Allow the light clock to make a full stop when the light beam reaches mirror M_2. In this case, a stationary observer who is watching the light clock could design the following diagram, Fig. 1b. Of course, the number of periods would be identical for the incidence and reflected lights. We know that the frequency equals the speed of light divided by the wavelength (or $\nu = c/\lambda$) then the number of their wavelengths would be also the same. In expression,

$$d = \mathcal{N}\lambda_d \text{ and } D = \mathcal{N}\lambda_D$$

where λ_D is the wavelength of light emitted by M_1 and λ_d is the wavelength of light reflected by M_2. $\mathcal{N}$ can be approximated as a very large natural number if it is larger or equal to say 10^4 [3].

Since $\lambda_D > \lambda_d$ the reflected light has a different "color" with a shorter wavelength than the incidence light or the reflected light is blueshifted. In other words, the stationary observer finds that the energy of the reflected light is higher than the energy of the incident light. The question is now where does this extra energy come from?

The intrinsic energy of the photon emitted by this clock in rest (the reflected light) and in motion (the incidence light) would be $h\nu_0$ and $h\nu$, where h (= 6.63×10^{-34} J sec) is Planck's constant and ν_0 and ν_0 are the corresponding frequencies. The only possible answer to the above question would be that the difference between the two energies $h\nu_0 - h\nu$ is equal to the relativistic kinetic energy of this clock or

$$E_K = h\nu_0 - h\nu \quad \dots (1)$$

where $h\nu_0$ and $h\nu$ are the intrinsic energy of the photon emitted by the light clock in rest and in motion, respectively. This is by the law of conservation energy. Eqn. (1) shows that if the speed of the light clock υ tends to zero (or $\upsilon \to 0$) then $h\nu \to h\nu_0$ or E_K (= $h\nu_0 - h\nu$) $\to 0$. If this speed approaches the speed of light c then $h\nu \to 0$ or E_K (= $h\nu_0 - h\nu$) $\to h\nu_0$.[2]

If the rest mass of the light clock is m_0 then this theory says that its relativistic mass m would increase by the Lorentz-Einstein factor or

$$m = m_0/\sqrt{(1 - \upsilon^2/c^2)} \dots (2).$$ [3]

SR now gives the following equation for the relativistic kinetic energy of this clock

$$E_K = mc^2 - m_0c^2 \dots (3).$$

[2] Mathematically speaking, $h\nu = h\nu_0\sqrt{(1 - \upsilon^2/c^2)}$. In other words, the intrinsic energy of a photon depends on the speed of its source.

[3] Of note, Ziefle [4, and references therein] shows that the explanation of the inertial mass increase by SR violates the Principle of energy conservation.

Combining eqns. (2) and (3) we find that the relativistic kinetic energy of the light clock (or in general of a massive particle) is given by

$$E_K = \{[1/\sqrt{(1- \upsilon^2/c^2)}] - 1\}m_0c^2 \quad \ldots (4).$$

If the speed of the light clock υ tends to zero (or $\upsilon \to 0$) then E_K ($= h\nu_0 - h\nu$) $\to 0$. However, when the speed of the source υ approaches the speed of light c then according to the above equation E_K ($= h\nu_0 - h\nu$) $\to \infty$. This contradicts the above conclusion for $\upsilon \to c$ drawn from eqn. (1) based on the Principle of energy conservation. Moreover, the value of $h\nu_0$ (or ν_0) is initially fixed in the above thought experiment there is no way to make $h\nu_0 - h\nu \to \infty$.

The question which arises now is how to explain this discrepancy.

One possibility is that the law of conservation energy does not hold in the above thought experiment. However, this law is a fundamental concept of physics.

If the law of energy conservation holds then eqn. (4) for the relativistic kinetic energy of the light clock described – i. e. of a massive particle in general - is not correct. It follows that eqns. (2) and (3) of SR are not correct either. This is a serious statement because this theory formulated by Einstein in 1905 is one of the cornerstones of modern physics.[4]

The only possible explanation is that the traditional thought experiment with the light clock cannot be used to demonstrate time dilation and hence length contraction. As we pointed out in previous communication [5], it appears that the thought experiment with the "traditional" light clock appears to need at least some rethinking.

References

[1] R. G. Ziefle, *Einstein's special relativity violates the constancy of the velocity c of light under one-way conditions and thus contradicts the behavior of electromagnetic radiation*. Physics Essays 34, 275-279 (2021).

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[3] P. I. Premović, The *Big Bang Universe and the Principle of energy conservation.* The General Science Journal, December 2021.

[4] R. G. Ziefle, *Refutation of Einstein's relativity on the basis of the incorrect derivation of the inertial mass increase violating the principle of energy conservation. A paradigm shift in physics.* Physics Essays 33, 466-478 (2020).

[5] P. I. Premović, *The "bizarre" case of the "rod light clock"*. The General Science Journal, December 2021.

[4] Ziefle [1] argued SR is an unrealistic theory.