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Relativistic Time Contraction Again?

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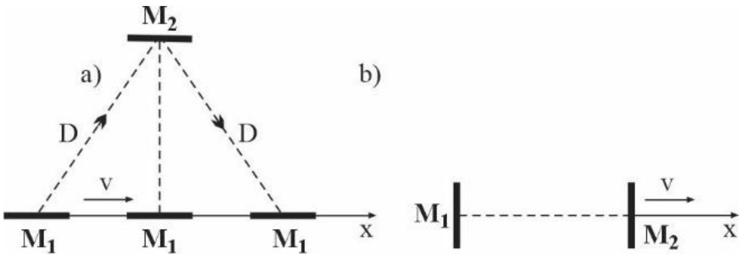
Time dilation and length contraction are two important effects of Special relativity (SR). These two effects depend upon the second postulate of this theory that the speed of light c ($\approx 3 \times 10^8$ m sec^{-1}) is the same in all inertial frames of reference. In general, the SR time dilation is a prerequisite for SR length contraction, which occurs only in the direction of motion of the moving frame.

Time dilation of SR can be easily derived from the thought experiments using the traditional light clock. Readers may find many physics textbooks that describe these experiments. However, it has been recently shown that the so-called "novel" light clock shows time contraction [1]. This raised the question: which of these two clocks is relativistically right?

The traditional light clock consists of two plane parallel mirrors M_1 and M_2 facing each other at a distance d apart, as in Fig. 1a. The lower mirror M_1 has a light source at the center that emits a photon (or light signal/pulse) at 90 degrees in the direction of mirror M_2. For the light clock at rest, this is the (proper) time $T_0 = d/c$.



Suppose that this clock to be moving horizontally with a relative speed υ in the direction of the positive x-axis, Fig. 1b. SR states that it will take a longer time for the photon to reach mirror M_2, the (improper) time T_{SR}. This theory shows that T_0 and T_{SR} are related by the following formula: $T_{SR} = T_0/\sqrt{(1-\upsilon^2/c^2)}$, where $1/\sqrt{(1-\upsilon^2/c^2)}$ is the Lorentz factor or the time dilation factor. Thus, the stationary observer measures time dilation for the moving classical light clock

$$\Delta T_{SR} = T_{SR} - T_0 = T_0\,\{[1/\sqrt{(1-\upsilon^2/c^2)}] - 1]\}.$$

If $\upsilon \to c$ then $\Delta T_{SR} \to \infty$ and if $\upsilon \to 0$ then $\Delta T_{SR} \to 0$.

Let us now perform the experiments using the same light clock as in Fig. 1a but now aligned and moving along the positive x-axis, as shown in Fig.1b. Obviously, if this clock is resting, the time interval is $\Delta T_0 = d/c$. SR now predicts that the length of the light clock will simultaneously decrease according to the length contraction equation $L = L_0\sqrt{(1 - \upsilon^2/c^2)}$ or $\Delta L = L_0 - L = L_0[1 - \sqrt{(1- \upsilon^2/c^2)}]$. If there is only time contraction, then

$$\Delta T_C = \Delta L/c = L_0/c[1 - \sqrt{(1- \upsilon^2/c^2)}] = T_0[1 - \sqrt{(1- \upsilon^2/c^2)}].$$

If $\upsilon \to c$ then $\Delta T_C \to \Delta T_0$. If $\upsilon \to 0$ then $\Delta T_C \to 0$. If both dilations occur simultaneously the total dilation

$$\Delta T = \Delta T_{SR} + \Delta T_C = T_0 \{[1/\sqrt{(1 - \upsilon^2/c^2)}] - 1]\} + T_0[1 - \sqrt{(1- \upsilon^2/c^2)}] = T_0 [1/\sqrt{(1 - \upsilon^2/c^2)}] - \sqrt{(1- \upsilon^2/c^2)}].$$

If If $\upsilon \to c$ then $\Delta T \to \infty$ and if If $\upsilon \to 0$ then $\Delta T \to 0$.

Reference

[1] P. I. Premović, *Relativistic light clock experiments: time dilation or time contraction?* The General Science Journal.