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The Light Clock Experiments and the Law of Reflection

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1. Introduction

Elementary classical physics tell 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.

One of the most important results of Special relativity (SR) is the effect of time dilation [1]. This phenomenon has apperently been demonstrated in many experiments, including muon experiment [2] and the experiment of synchronising two atomic clocks [3].

Many physics textbooks deal with the subject of time dilation. This phenomenon can be depicted using a device known as a light clock [4]. In this note it will be considered relation between various light clock experiments and the law of reflection.

2. Discussion and Conclusions

The light clock usually consists of two plane parallel mirrors M_1 and M_2 that face each other and are separated by a proper distance *d*, Fig. 1a. A light signal (or photon) originating from mirror M_1 is reflected back by mirror M_2 and finally returns to the location of mirror M_1, Fig. 1a. The light pulse traces out a path of length *2d.* Of course, the angles of light signal incidence and reflection are equal zero.

Now allow the same light clock to be moving with a certain relative speed $\boldsymbol{v}$ horizontally in the direction of positive x-axis. In this case, a stationary observer who is watching the light clock could design a following diagram, Fig. 1b. As previously, the light signal of mirror M_1 reaches mirror M_2 and reflects back to mirror M_1, Fig. 1a. Clearly, light signal will now travel a larger distance *2D.* The stationary observer concludes that this signal again follows the law of reflection i. e., the angle of light signal incidence (α_I) is equal to its angle of reflection (α_R), Fig. 1b.

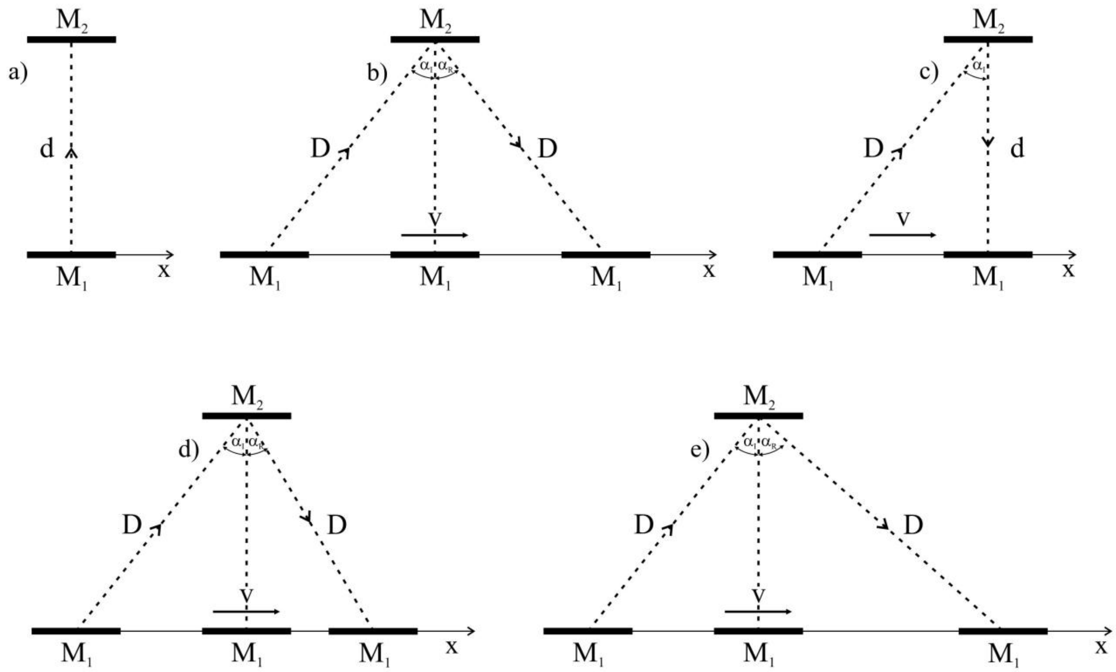

Fig. 1. Measurements and analysis for the light clock made in different frames.
(a): No relative motion; (b) – (e): the light clock moving at speed *v*.

Let us assume that the light clock makes full stop when the light signal reaches mirror M_2. The stationary observer determines that the light signal angle of incidence α_I is greater than zero but its angle of reflection α_R is zero degree, Fig. 1c. Of course, this observation disagrees with the law of reflection. In addition, if we are dealing with a single photon as the light signal any process of its detection at the mirror M_2 leads to its anihilation.

If the speed of the light clock after the light signal reaching mirror M_2 is lower than v then the angle of reflection α_R will be smaller than the angle of incidence α_I, Fig. 1d. In the opposite case, if this speed is higher than v the angle of incidence α_I will be lower than the angle of reflexion α_R, Fig. 1e. Similar effects would be observed if the light signal after reaching mirror M_2 travels at a speed lower ("slow light") or higher ("fast light") than c, for some reason.

All these observations also disagree with the law of reflection. My friends-physicists argue that this disagreement is a result of changing one inertial frame to another frame; though I am uneasy with this explanation. Indeed, SR states that "the velocity c of light in vacuum is the same in all inertial frames of reference in all directions and depends neither on the velocity of the source nor on the velocity of the observer" [Einstein, 1905]. It sounds rather strange that the direction of motion of light depends of the inertial frame.

References

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