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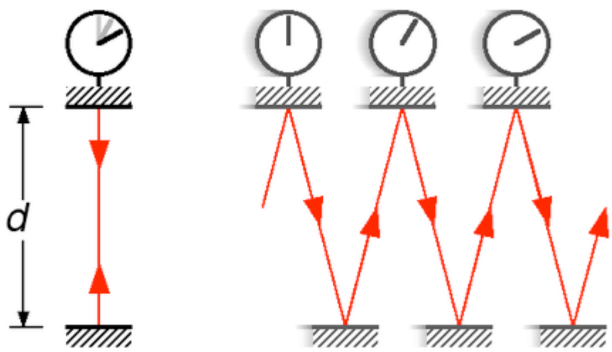
Criticism of the moving light clock

(On the didactics of special relativity)

1. The effects of special relativity - time dilation and space contraction - can be explained using the example of a moving light clock.

The observer S and the observer S' move past each other with the uniform relative velocity v. At the moment of their encounter, the observer S switches on his light clock which is perpendicular to the axis of motion. The beat of the light clock is determined by a photon which oscillates back and forth between two mirrors in the tube which is perpendicular to the axis of motion. From the point of view of the observer S, the photon spreads out at the tip of the light pulse from the lower to the upper mirror of the light clock. It covers the distance d with "speed of light" in the time t.

Now the question is asked, how the other observer S' "sees" (i.e., how he records them according to place and time in his reference frame) the two events of the photon's emission from the lower mirror and its arrival at the upper mirror. From his point of view, the photon travels a zigzag path in the light clock S moving past.



Source : https://de.wikipedia.org/wiki/Zeitdilatation#Lichtuhr

From the point of view of observer S', the path to be covered by the photon, which is inclined to the axis of motion, is in any case longer than the vertically oriented path d from the point of view of observer S.

According to the experimentally verified basic assumption of special relativity, the propagation of the photon occurs with "speed of light" both from the point of view of the observer S and from the point of view of the observer S'. The relative speed of the light source plays no role in the propagation of a light pulse. Considering this limitation and constancy of the "speed of light", the photon from the point of view of the observer S' cannot also cover the longer distance in the time span t, but only in the correspondingly longer time span t'. One and the same process (the time span between the event of sending out and the event of arrival) must therefore take longer by some factor from the point of view of the observer S' than from the point of view of the observer S.

At superficial evaluation of this strange consequence, one could think, the reason for this would be, that at the ("resting") observer S' the time is passing faster and faster with increasing relative speed, because then from his point of view more time would pass during the same process. This statement is not plausible, because at one observer different times can not pass different times because of different relative movements of other mass-points.

Also the opposite opinion, with the ("moving") observer S the time t would pass more and more slowly with increasing relative velocity, cannot be true. The thought experiment assumes a process defined from the point of view of the observer S (with an event at its beginning and an event at its end as well as a time span lying between these events). If this given process resp. this time-span is changed afterwards depending on the relative speed ("because time passes slower there"), one gets into a logical circle when judging the thought-experiment.

The insufficiency of the explanations cannot be changed by the reservation that the time at the ("resting") observer S' would not pass faster per se, but only from the point of view of the observer S, or that the time at the ("moving") observer S would not pass slower per se, but only from the point of view of the observer S'. Observers can record (measure) events in their frame of reference according to place and time and draw from them the superficial conclusions presented for other frames of reference. But they cannot directly observe the passing of time in another reference frame. With a light ray e.g. perpendicular to the axis of motion, one could draw the conclusion "that time passes slower there". With a light ray e.g. in the direction of motion, one could draw the conclusion "that time passes faster there".

The naive idea that a uniform relative motion of observers would affect the passing of time in the conventional sense (or the length of scales in the conventional sense), is not purposeful. The fact that a process can take different lengths of time from the point of view of two observers moving relative to each other rather fundamentally calls into question the traditional concepts of "time", "space", "speed" and "speed of light" themselves.

2 The direction in which this questioning must go is shown by the impossibility of calculating the extent of the extension of the process duration from t to t' on the basis of Newtonian mechanics.

From the point of view of the observer S, the calculation of the time span t' would have to be based on the right-angled triangle formed by the distance v*t (the path of the observer S' along the common axis of motion), the distance c*t (the path of the photon of his light clock perpendicular to the axis of motion) and the hypotenuse c*t' (the searched photon path).

However, the correspondingly longer time span t' due to the greater length of the hypotenuse of this triangle would have the consequence - based on the view of observer S' - that observer S would move away with his light clock during the process not only by the distance v*t, but by the longer distance v*t'. On the path c*t' corresponding to the hypotenuse of the described triangle, the photon would - from the point of view of observer S' - miss the upper end of the light clock of observer S, who is already too far away. The time span t' determined by the on the basis of this triangle cannot be correct.

3. the calculation must follow a different approach, consistently based on the premises of special relativity: from the point of view of each of the two observers, the "speed of light" c of the photon, the relative velocity v of the observers and the spatial distance perpendicular to the axis of motion of two events have the same value.

From the point of view of the observer S, the photon begins its propagation at the lower end of the light clock S (event E1) and ends it at the upper end of the light clock (event E2). This process takes the time span t. To determine the time span t', which this process takes from the point of view of the observer S', one has to ask, based on the above three conditions, which path the photon has to take from the point of view of the observer S', starting from the lower end of the light clock S (event E1), so that it reaches the upper end of the light clock of the observer S after the time span t' has elapsed (event E2). The answer results from a right-angled triangle consisting of the distance v*t' (by which observer S has moved away from observer S'), of the distance c*t (the length of the light clock perpendicular to the axis of motion, which is the same for both observers) and of the distance c*t' (the searched path of the photon).

From this it follows that the process duration t' is longer than the process duration t by the so-called "Lorentz factor" 1/sqr(1-v2/c2). The observers agree on the time of occurrence of the first event E1 (their encounter), but not on the time of occurrence of the second event E2. There are two different but equally valid answers to the question of how far apart they are at the time of the occurrence of the second event (v*t and v*t', respectively).

If the constant effective propagation (the "speed of light") is set "1", then in the triangle the relative velocity v can only assume a value between 0 and 1 (it is a percentage of the "speed of light"). The Lorentz factor simplifies to t' = t/sqr(1-v2). That the relative velocity v cannot exceed the effective propagation (the "speed of light") c follows from its definition and not from any mysterious physical barriers.

4 The evaluation of the thought experiment with the moving light clock is misled by the statement that a photon has "speed of light" for every observer. With the use of the traditional concept of "speed" to describe the propagation of light pulses, the Newtonian understanding of time and space is adopted and cemented. This leads e.g. to theories that high velocities could change time and space. The changes would turn out in such a way that for the propagation of photons always the "speed of light" would come out.

The fundamental changes in the basic concepts of time, space and speed are not sufficiently appreciated:

A photon cannot overtake another photon. A spherical wave of light cannot overtake another spherical wave of light. These facts are upstream of the concepts of time, space and velocity.

In case of common propagation of two photons at the tip of two light-pulses, which are emitted at the same place at the same time by two light-sources moving to each other, the length of the propagation of the one light-pulse from the point of view of the one reference frame must be different from the length of the propagation of the other light-pulse from the point of view of the other reference frame, because although the two photons are always together at the same place (one photon cannot overtake another), the mutually moving starting points of the light pulses (the light sources) have moved away from each other by the end of the process - depending on the relative speed and the duration of the process.

Quite naturally, there is a common propagation of the two photons at the tip of light pulses if both observers emit one light pulse each in the same direction along their axis of motion when they meet. In one of his essays from 1905, Albert Einstein used this constellation as the basis for calculating the conversion factor for the different time spans.

But not time or space in the previous sense, but the length of the propagation of a light pulse emitted by an observer gains fundamental importance in this view. The propagation of an effect (e.g. in the form of the propagation of a photon, which is emitted by a light source resting at the observer) always covers the space, which it needs in time for it. In other words: From the point of view of an observer, time is what passes when a light pulse propagates from the event of its emission to the event of its arrival. Space is what is traveled when a pulse of light propagates from the event of its emission to the event of its arrival. From the point of view of the observer in question, the length of the propagation of a light pulse from its start from a light source at rest with him (event E1) to its arrival at a target (event E2) is both the amount of time and the amount of space that lies between these two events from his point of view. To measure the length of the propagation of his light pulse, the observer need only halve the total time taken by a light pulse reflected at the second event from its emission to its return to him. This "half-time reflection" applies absolutely. It does not depend on the "state of motion" of an observer when light propagates in a vacuum.

From the difference of the propagation-lengths of coordinated light-pulses follows for observers moving to each other the difference of the space-distances and the time-spans, which lie between the events of the sending E1 and the arrival E2 from the point of view of different observers. The length of the propagation of a light-pulse emitted by an observer (at most fictitiously) is from now on its measure of space and time. The absolute substantial time and space of the Newtonian theory are replaced by a relational conception of time and space, which is linked to the finite and constant propagation of action. Newtonian mechanics descends to an approximate calculation for low relative velocities with no intrinsic truth value.

These considerations can now also be used as a basis for the thought experiment with the moving light clock. Each of the observers moving towards each other sends out a light pulse from a light source at rest near him when they meet (event E1), so that the photons at the tip of the two light pulses propagate together until they arrive together (e.g. at the opposite mirror of a light clock) (event E2). To remain with the above example, the observer S emits his light pulse perpendicular to the axis of motion, while the observer S' emits his light pulse at such an angle to the axis of motion that the said joint propagation of the photons occurs. The angle (or ratio of t to t') is obtained as above from the right-angled triangle with sides t, v*t' and t'. It builds on the three premises of special relativity and in this constellation ensures that the photon emitted by observer S' arrives at the top of observer S's light clock together with the photon emitted by observer S. The effect is no longer a result of the triangle. The effect no longer results from the mutual "observing" of photons (which is not comprehensible according to Newtonian mechanics), but from the joint propagation of photons. Not mysterious changes of time and space in Newtonian sense, but the finite and constant effect-propagation is the reason for the effects of special relativity.

The popular scientific explanations complicate this solution - which in itself is free of contradictions due to the break with Newtonian mechanics - by the added philosophical interpretation that the extension of the process duration t' would be caused by the fact that from the point of view of the observer S', the time t would pass more slowly for the "moving" observer S. The more quickly the observer S moves, the more slowly time passes for him. "The faster the observer S moves, the slower time passes for him. " "At very high velocities v, time almost stops" (cf. M. Carrier, Raum-Zeit, Berlin/New York: Walter de Gruyter (2009), 35). "Moving clocks go slower" (University of Vienna, F. Embacher, "Time Dilation"; http://homepage.univie.ac.at/franz.embacher/SRT/Zeitdilatation.html). "Jill is aging more slowly because she's moving!" (University of Virginia, M. Fowler, Galileo and Einstein, Special Relativity: What Time is it?; http://galileo.phys.virginia.edu/classes/109.mf1i.fall03/lectures09.pdf). The above question about the trajectory of the photon from the point of view of the observer S' is posed entirely in the orbits of Newtonian thought and is thus complicated: From the point of view of the observer S' "moving" with the velocity v, by which factor must the time t pass slower at the observer S, so that the photon can begin its propagation with c at the meeting of the two observers at the lower end of the "moving" light clock S and end it at its upper end?

The claimed change of the course of time and thus the change of the process duration at the observer S "from the point of view of the observer S'" leads to a logical circle at the thought experiment, because at the observer S the length of the light clock and thus the process duration form the unchangeable starting point of the thought experiment. Furthermore, from the point of view of observer S', the light pulses of observer S would have to propagate within the framework of a slower time process for some directions, but within the framework of a faster time process for other directions. The "observation" of a uniformly slower passing of time at the moving observer S does not take place.

The objection that only the mean values of composite light propagations returning to the origin of their propagation at observer S should ever be studied is not valid (M. Pössel, "Von der Lichtuhr zur Zeitdilatation", in: Einstein Online Vol. 04 (2010), 1101; https://www.einstein-online.info/spotlight/LichtuhrZeitdilatation/):

"Watch out, fake light clock!

Occasionally one sees animations with light clocks ticking twice as fast as the ones shown here. With them, the counter jumps over on the one hand when the pulse reaches the upper mirror, and on the other hand when it reaches the lower mirror. Such light clocks lead the simple principle of operation ad absurdum, because how does the counter know when the pulse reaches the lower mirror? This information would first have to be laboriously transferred from the lower mirror to the counter. However, this transmission cannot be accomplished faster than the speed of light. In particular, the information would not reach the counter before the light pulse itself had already arrived back at the upper mirror. "

Why a measured value (the "seeing" of a photon described above) should be absurd, just because it is communicated later, is not comprehensible.

The contradictory nature of the assertion of a slower passing time is not changed by animations in which a flashing light clock aligned perpendicularly to the direction of motion gives the impression that the observer at rest can watch time passing more slowly for the observer in motion. All clocks of his system are supposed to be affected by this slowing down (cf. e.g. M. Pössel, "Von der Lichtuhr zur Zeitdilatation" in: Einstein Online Vol. 04 (2010), 1101; https://www.einstein-online.info/spotlight/LichtuhrZeitdilatation/; "Obviously, from my point of view, the moving light clock goes much slower than my own light clock of the same construction. (...) Judging from my space station, all the clocks of the space station moving relative to me go slower than my own clocks. Just as the moving clocks run slower, all the processes on the other space station run slower for me - five-minute eggs take longer to cook and still have the right consistency in the end, and the pianist on board the other station playing the Minute Waltz takes considerably more time to do so than is normal performance practice. ").

The oblique light paths "seen" by observer S' in this example originate from a photon emitted by observer S normal to the axis of motion, which triggers a blink when it returns to him. Each blink is recorded in the coordinate system of observer S' according to the Lorentz transformation of time and place. With increasing relative velocity, from the point of view of the observer S', the light paths and thus the time spans between the flashing signals lengthen (as above, the time span t' compared to the defined time span t).

The decrease of frequency of the blinks accompanying the increase of relative velocity is therefore nothing else than the (relativistic) transversal Doppler effect from the point of view of the observer S'. A Doppler effect, however, has nothing to do with any other passing of time in the sphere of the uniformly moving object. It occurs reciprocally with the observers without distinguishing one of them (principle of relativity). Time does not pass more slowly for any of them because of this. One cannot seriously claim that time passes more slowly in a distant ambulance with a following horn because one hears the tones more deeply.

In summary, the constancy of the "speed of light" is not due to the fact that a substance "time", which would be measured with any "objective" clock, and a substance "space", which would be measured with an "objective" rigid scale, would always change in the sphere of a moving observer in such a way that for the "speed of light" always the same value comes out. The said constancy is rather a consequence of the fact that photons cannot overtake each other and that the length of the propagation of a light pulse represents both the time elapsed during this process and the space covered in the process. Therefore, for a photon, the ratio of the distance traveled to the time required to do so must necessarily be "1" from the point of view of all observers. The constant propagation of effects gives birth to space and time in the ratio of 1:1. The "speed of light" is constant by definition, even if it is measured with conventional scales and clocks instead of a light clock.

The popular scientific presentation with its fascinating assumption of a slower passing time in the "moving" observer disregards the scientific principle of parsimony. Time is not a substance that could pass slower or faster. The results of the thought experiment speak for the correctness of the view of Leibniz, who held against Newton that time is a relation (cf. *S. Clarke*, Der Briefwechsel mit G.W. Leibniz von 1715/16, Übers. *Ed Dellian*, Hamburg, Meiner (1990)).

Vienna, 14 September 2021

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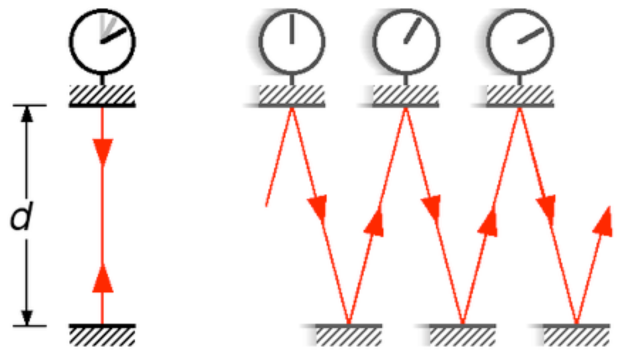
Appendix:

1) German Wikipedia edition:

https://de.wikipedia.org/wiki/Zeitdilatation#Lichtuhr

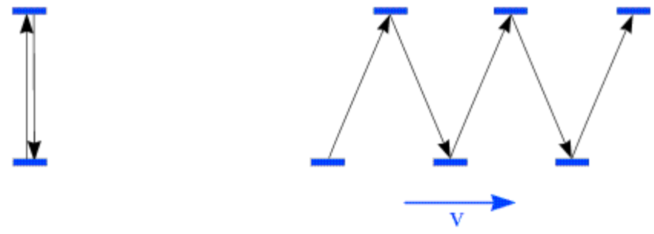
as of 7/17/2019



"If a light clock A [at rest in system A] is given, from the point of view of an observer moving along with it (i.e. at rest relative to it) [from the point of view of system A] a flash will need the time T0 = d/c for the simple path between the mirrors. (...) If a second light clock B [the light clock at rest in the other system B, which is now to be "observed" from system A] is now moved perpendicularly to the connecting line of the mirrors with the velocity v, the light must, from the point of view of the A-observer, cover a greater distance between the mirrors than with clock A. Assuming the constancy of the speed of light, **clock B** therefore **moves slower than clock A for** the A observer. The time T' = d'/c, which the light flash needs for the simple path d' between the mirrors, is obtained by the Pythagorean theorem $d'^2 = d2 + (vT')^2$. By substituting the expressions for d and d' and solving for T', one finally obtains T' = T0 * $1/sqr(1-(v/c)^2)$ (...)."

2) Franz Embacher, University of Vienna:

https://homepage.univie.ac.at/franz.embacher/SRT/Zeitdilatation.html as of 7/17/2019

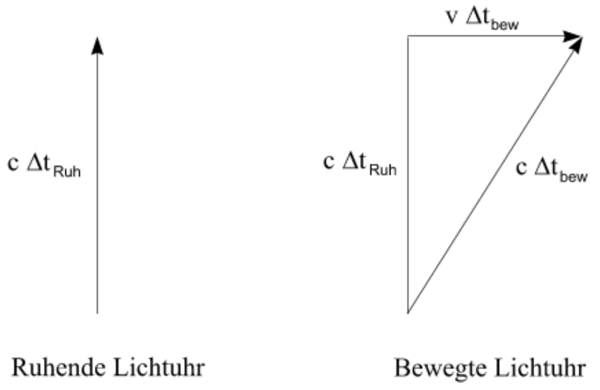


Ruhende Lichtuhr Bewegte Lichtuhr

"The left graph shows the light clock [S] from the point of view of an observer who is at rest opposite to it, i.e. from the point of view of its rest system. We now ask what the same process looks like in an inertial system moving against it [from the point of view of system S'], where the direction of motion is supposed to be transverse to the direction of travel of the photons. For an observer in this new system [from the point of view of system S'], the light clock [S] is moving, and we denote the value of its velocity by v. The photons will travel along oblique paths in the moving system [from the point of view of system S'] - this is shown in the right part of the above figure. We can also just as well imagine that two light clocks of identical design are available and we consider [from the point of view of the system S'] one at rest (left) [a light clock S'] and one moving with velocity v (right) [a light clock S].

All photons represented here have the same velocity. However, the distance from the lower to the upper mirror is longer [from the point of view of the system S'] for the photon of the moving light-clock [S] than for that of the light-clock at rest [S'], and therefore a longer period of time passes [from the point of view of the system S'] until it gets from the one to the other mirror! (...) The length of time that a process takes in one inertial frame is not necessarily equal to the length of time that passes during the same process in another inertial frame. The moving light clock [S] has a longer period [from the point of view of the system S'] than the stationary one. This means that the process of photon commuting, when observed from a moving system [S'], is slower [longer duration cycles occur less frequently] than in the rest system of the light clock [S] . ... this effect ... is often summarized in a concise way with the words **"moving clocks go slower"** and is called time dilation ('time dilation').

(...)



The duration of the process in the rest system of the light clock [from the point of view of the system S] is denoted by ΔtRuh. The distance of the two mirrors is therefore c ΔtRuh, since c is the velocity of the photon. (...).

Seen from the moving system [from the point of view of the system S'], a time interval passes during the same process, which we do not know at first and denote by Δtbew. The distance covered by the photon (...) has therefore [from the point of view of the system S'] the length c Δtbew. As distance of the two mirrors we adopt the value c ΔtRuh determined in the rest system. During the process the upper mirror has advanced by the distance v Δtbew (since the light clock in this system moves [from the point of view of the system S'] with the velocity v to the right). Altogether these three lengths form a right-angled triangle. (...)

$(c\ \Delta tRuh\ )^2 + (v\ \Delta tbew\ )^2 = (c\ \Delta tbew\ )^2$

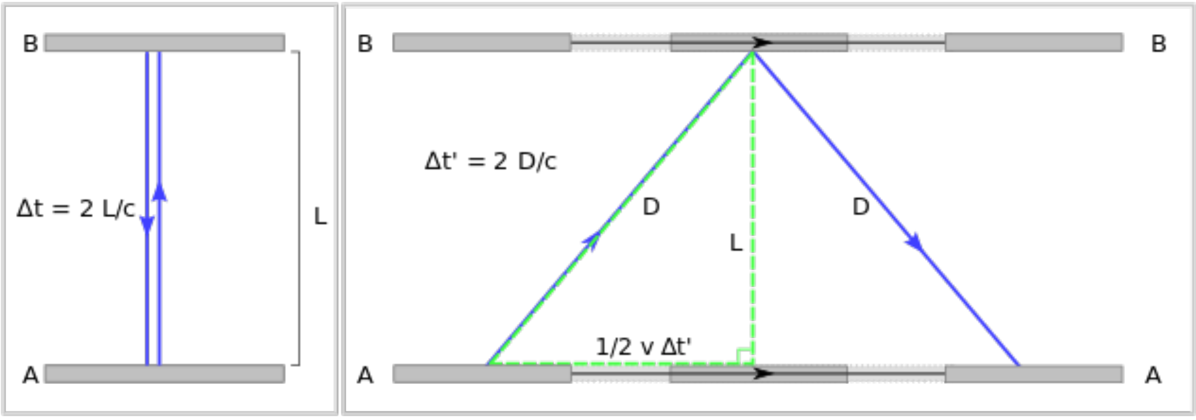
(...)

'A clock moving with velocity v goes [from the point of view of system S'] slower than in its rest system by a factor of $(1 - v2/c2)^{-1/2}$.' "

3) English Wikipedia edition:

https://en.wikipedia.org/wiki/Time_dilation

as of 7/17/2019



"In the frame in which the clock is at rest (diagram on the left), the light pulse traces out a path of length 2L and the period of the clock is 2L divided by the speed of light: ...

From the frame of reference of a moving observer traveling at the speed v relative to the resting frame of the clock (diagram at right), the light pulse is seen as tracing out a longer, angled path. Keeping the speed of light constant for all inertial observers, requires a lengthening of the period of this clock from the moving observer's perspective. That is to say, in a frame moving relative to the local clock, this clock will appear to be running more slowly. Straightforward application of the Pythagorean theorem leads to the well-known prediction of special relativity: (...)."

{"In the reference frame ["resting" system S] in which the clock rests (diagram on the left), the light pulse [the photon at the tip of the light pulse] follows a path of length 2L. The period of the clock is 2L divided by the speed of light. ... From the point of view of the frame of reference of an observer [from the point of view of the "stationary" system S to the left] traveling at velocity v relative to the stationary system of the clock [S] (diagram on the right), the light pulse is seen as following a longer, angled path. **In order to keep the speed of light constant for all inertial observers**, the clock of this clock [the process duration t of the clock at rest in system S] must become longer [t' is longer than t] from the point of view of the moving observer [from the point of view of system S']. **That is**, **in a frame of reference that is moving relative to the local clock** [from the point of view of system S'], **that clock** [the clock at rest in system S] **appears to be running slower**. The simple application of the Pythagorean theorem leads to the well-known prediction of special relativity (...). "}