'ASYMMETRIC AGING' OR ASYMMETRIC REASONING?

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Introduction

The 'principle of relativity' was restated by Einstein many times and, in the context of the special theory, all his definitions imply equivalence of 'two systems of coordinates in uniform translatory motion', i.e. 'inertial systems'. Thus, for example (emphasis added in all quotations):

> "The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of coordinates **in uniform translatory motion**" (1905[1], p.41).
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> "The laws by which the states of physical systems alter are independent of the alternative, to which of two systems of coordinates, **in uniform motion of parallel translation** relatively to each other, these alterations of state are referred (principle of relativity)" (1905[2], p.69).
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> "If a system of co-ordinates K is chosen so that, in relation to it, physical laws hold good in their simplest form, the same laws also hold in relation to any other system of co-ordinates K' **moving in uniform translation** relatively to K" (1916[3], p.111).
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> "The state of motion of the coordinate system may not, however, be arbitrarily chosen, if the laws of mechanics are to be valid (**it must be free from rotation and acceleration**). A coordinate system which is admitted in mechanics is called **'inertial system'**. The state of motion of an inertial system is according to mechanics **not** one that is **determined uniquely by nature**. On the contrary, the following definition holds good: a coordinate system that is **moved uniformly and in a straight line** relative to an inertial system is likewise an inertial system" (1919[4], p.224).
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> "The law of the constant velocity of light in empty space ... and the **equal legitimacy of all inertial systems** (special principle of relativity) ..." (1921[5], p.241;).
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> "When by the special theory of relativity I had arrived at the **equivalence of all so-called inertial systems** for the formulation of natural laws (1905), ..." (1934[6], p.279;).

There can be absolutely no doubt about the nature of the systems to which the theory of special relativity, developed in the 1905 Einstein's famous original paper, applies: they are inertial systems, free from rotation and acceleration, moving uniformly and in a straight line relative to each other, and hence in all respects equivalent and equally legitimate as reference frames for description of mechanical systems.

In this paper, Einstein derived (inter alia) two equations:

1) One transforms the length x of a rigid rod (or the x dimension of a rigid sphere) as directly measured when at rest in a stationary system or when it is measured in an moving inertial system by a co-moving observer (i.e., by 'method a'; p.41[1]), into a length x' which such a rod **appears** to have **when viewed from a stationary system** as it is uniformly moving relative to this system, with velocity v in the direction of its length (i.e., when measured using stationary synchronized clocks by 'method b'; p.41[1]). This equation is

$$x' = x\sqrt{(1-v^2/c^2)} \qquad (1)$$

where c is the velocity of light.

2) The other equation transforms the time t marked by a clock at rest in a stationary system, into time t' which is the 'time **marked**' by a moving clock of identical construction **when it is viewed from the stationary system.** This equation is

$$t' = t\sqrt{(1-v^2/c^2)}. \qquad (2)$$

There is an important difference in Einstein's formulation in these two cases. In the first case, he explicitly refers to an appearance (p.48[1]): "...whereas the Y and Z dimensions of the sphere do not **appear** modified by the motion, the X dimension **appears** shortened...". In the second case, he does not say that the moving clock appears to be slow compared to the stationary one, but that it is slow (p.49[1]): "...whence it follows that the time marked by the [moving] clock (viewed in the stationary system) **is** slow by $1 - \sqrt{(1-v^2/c^2)}$ seconds per second..." (emphases added).

Since the qualifier 'viewed from (in) the stationary system' is present in both cases, one is led to think that in both cases Einstein is referring to 'how things in a moving system appear to look when viewed from the stationary system' (an internally consistent interpretation of both Loretzian contractions as appearances naturally follows from Einstein's own exposition of his two 'measuring methods', (a) and (b), of rod length (p.41[1]); see Appendix for details).

However, it is obvious that the difference between his 'appears' in the first case and 'is' in the second is deliberate, never mind that, to unsophisticated readers, an 'is' with the qualifier 'when viewed form the stationary system' can only mean 'appears'. The difference is amplified by the following fact: After the paragraph on the 'length shortening' Einstein stressed the relativistic symmetry by concluding that (p.49[1])

> "It is clear that the same results hold good of bodies at rest in the 'stationary' system, viewed from a system in uniform motion."

He said nothing of the sort after the paragraph on the time lag of the moving clock. To the contrary, here Einstein drew attention to a 'peculiar consequence' which he summarized in three crucial sentences that amplify a lack of such symmetry in the clock behaviour. These sentences triggered the controversy about the 'clock paradox' lasting to this day. They read:

> It is at once apparent that this result still holds good if the clock moves from A to B in any polygonal line, and also when the points A and B coincide.
> If we assume that the result proved for a polygonal line is also valid for a continuously curved line, we arrive at this result:
> **"If one of two synchronous clocks at A is moved in a closed curve with constant velocity until it returns to A, the journey lasting t seconds, then by the clock which has remained at rest the travelled clock on its arrival at A will be $\frac{1}{2}tv^2/c^2$ second slow"** (p.49[1]; emphasis added).

Contrary to Einstein's categorical assertion, the one thing that is 'at once apparent' to many readers of his paper is that he is violating here the basic postulates of the 'principle of relativity' - one of the two pillars on which his whole special theory had been erected. Specifically,

1) If 'one of the synchronous clocks at A is moved', it must be accelerated to get moving - but for a moving system to qualify as an inertial system, its motion 'must be free of acceleration'.

2) If the moved clock then travels 'in a closed curve' relative to the stationary clock at rest in point A, then it definitely is not moving 'in a straight line' relative to A and is not 'free of rotation' as the special theory demands.

3) If, despite all this, both clocks are still regarded as belonging to inertial systems, then the asymmetric result violates their necessary property of 'equivalence'. The two systems are obviously *not 'equivalent and equally legitimate' if their role cannot be reversed.*

The first two violations can perhaps be excused, as has often been done, by insisting that the effects of acceleration can be neglected. But then, for this very reason, the third cannot be explained away. For if the acceleration effects can be neglected then the moving system can be regarded as practically, or approximately, inertial, by which the equivalence and equal legitimacy of the two systems is restored and the result should be symmetric. Then, however, the 'lag' can only be apparent as is the 'shortening effect' since two opposite lags *cannot be real at the same time* (Dingle's objection). On the other hand, if the first two violations are not excused, then the moving system is confirmed to be non-inertial, the special theory is not applicable and the above result is not relevant to the case in question.

Thus the 'clock paradox' leads to an even more profound and bizarre paradox: If the asymmetric aging predicted by the special theory is true then the theory is false because it denies its own founding 'principle of relativity': It makes it possible to identify a privileged stationary system and distinguish it from a moving system simply by comparing their respective clock readings.

A third possibility would be a sort of Pyrrhic victory: the theory is correct for truly equivalent abstract inertial systems (in which case all results would be symmetric) which, however, do not exist in reality. The real world does possess a privileged reference frame (cosmological, Machian, 'ether', or *other) and if the 'stationary' system of the special theory is identified with it, then the asymmetric* result may well be correct because the reversal admitted by the model is physically impossible in nature.

There is a hint of such thinking in Einstein's own exposition ofthe special theory with the aid of the well known 'train' example (1952[8], p.26). Here Einstein says that "unless **we are told** the reference body to which the statement of time refers, there is no meaning in a statement of the time of an event" (emphasis added).

The cardinal problem here is: **Who is going to tell us?** In a model, it can well be Einstein who *identifies the 'stationary' system by definition.* In nature, *it* presumably would have to be nature itself talking to us through some 'observable facts that can be experienced', i.e. obtained by an experiment, just as Einstein himself emphasized on many occasions.

Thought experiment No.1

> "The **fundamental principle** here is that the justification for a physical concept lies exclusively in its clear and **unambiguous relation to facts that can be experienced** ... The influence of motion (relative to the coordinates) on the form of bodies and on the motion of clocks, also the equivalence of energy and inert mass, follow from the interpretation of coordinates and time as **products of measurement** (1921[5],p.241; emphasis added).

In the following, a thought experiment is considered which attempts to simulate the procedure by which an actual experiment involving a 'journey along a closed curve' could conceivably be carried out and the necessary 'observable facts' produced. It will be performed by two experimenters (observers), Al and Bert, and only the products of their own experiences and measurements of v and t performed during the experiment will be admitted in the analysis. The only exception is the velocity of light, c, which they supposedly know from independent prior experiments.

The experiment is supervised by an unbiased reputable scientist who, for brevity, will be called Albert. The experimental setup consists of two identical trains, A and B, positioned side by side on two neighbouring tracks. Each track was built as a closed loop and contains a long parallel straight-line section extending to a considerable distance in both directions from the 'platform' where the two trains are standing. Both trains consist of rigid coaches of identical construction and equal lengths d as verified by Al and Bert at the platform by using a measuring rod supplied by Albert. The actual lengths of the two track loops are not known to the observers (they supposedly have no bearing of the experiment since the distance travelled does not appear in the formula to be tested).

Albert equips both observers with identical clocks and directs them to their respective trains. Al takes a window seat in train A and Bert the facing window seat in train B. Albert then marks the location of these two facing windows with a white line labelled "0" on the platform. Al and Bert open their windows, put their two clocks side by side, synchronize them and close the windows. At the time of their synchronization, both clocks show the reading, say, 00.00 (out of curiosity, Albert kept another identical clock with himself and set it to 00.00 at the same moment Al and Bert did).

A few seconds later, Albert pushed a button on his control panel on the platform and both Al and Bert noticed that they were drifting apart. Neither of them experienced any acceleration nor could see any external reference point on the ground throughout the whole experiment (Albert had arranged this deliberately) so they could not tell whether one or the other train (or both, for that matter) were moving (Albert, of course, knew but he kept it to himself since he was not part of the experiment).

The experiment required Al and Bert to determine the velocity, v, of their trains and the duration of their journey, t, which are needed to verify their asymmetric aging predicted by Einstein's formula.

In respect of the velocity, all they are able to do is to measure the velocity of the relative motion of their trains which is the only thing they can observe. To do this, they use their clocks and measure the intervals between the passage of a given number of coaches (each of length d as they had verified) in front of their respective windows. When they notice that two such successive measurements produce the same result, they conclude that the velocity of the motion has stabilized and, whichever of the two trains is actually moving, it is moving with a uniform motion with respect to the other (all these measurements are completed while the trains are on the parallel straight-line segments of the track). In this way, Al obtained a constant velocity v_A and Bert a constant velocity v_B.

Their next and final task was to take readings on their respective clocks at the moment when, after noticing that they are approaching each other again, they come to a relative rest facing each other. This stopping point was made to coincide with the starting point "0" at the platform. Carrying this instruction out, Al recorded time t_A and Bert t_B (on his own initiative, Albert also took a reading of his clock at the same moment the two observers did; it should be noted that Albert with his clock and his control panel has remained at location "0" at the platform during the whole duration of the experiment).

To modernize the imagery, the "0" location can be thought of as a given point in space and the two trains can be replaced by spaceships. The experiment could also be conceptually 'improved' by assuming that Al and Bert had been riding in their spaceships (in uniform relative motion) for some time and take readings of their own clocks when they pass each other for the first time and when they pass each other the next time, without stopping at the beginning and end of the experiment.

The following questions are to be answered:

1) Were the two measured velocities, v_A and v_B, the same?
2) Were the measured times, t_A and t_B, the same?

Second-guessing the conceivable outcomes of the experiment

a) If $v_A = v_B = v$ and $t_A = t_B = t$, then there was no 'asymmetric aging' of Al and Bert and the 'delay of the travelled clock' computed by the above formula would be a meaningless number. Thus, either the theory itself would have to be declared deficient or, at the very least, the above Einstein's claim about its applicability to a motion along a closed curve (or polygon) would be invalid.

b) If $v_A \neq v_B$ and/or $t_A \neq t_B$, then the experiment would be able to distinguish the states of the two observers thus proving their systems unequal. However, it could perhaps happen that the two velocities or times were different but they did not satisfy Einstein formula. Could the principle of relativity be violated only 'relatively', i.e. could the two systems be unequal without either being stationary? This perhaps could happen as indicated below.

c) Both cases (a) and (b) could be associated with two different physical setups of the experiment:
  (i) Either Al or Bert remains stationary at "0" and his colleague travels along a loop. In this case, if $t_A \neq t_B$, then the larger value would identify the 'stationary' observer.
  (ii) Al and Bert both travel along loops but one loop is longer than the other and its traveller moves faster (with respect to point "0") than the other. In this case, if $t_A \neq t_B$, the larger value would not identify a 'stationary' observer but, presumably, merely the observer who travelled more slowly, i.e. along the shorter loop (the result would still differ from Albert's and his alone would agree with Einstein's).

It thus seems to follow from a,b,c that an experiment involving a circular journey as described by Einstein could not, in the real world, lead to conclusive results because of at least one reason:
There is no way of finding out experimentally (i. e., 'without being told') which - if any - of the two systems can, or should, be regarded as stationary.

Thought experiment No.2

Einstein's 'journey in a closed loop' cannot be distinguished from the motion of the rim of a rigid disk K' rotating at a constant speed relative to a stationary system K. For such a disk taken as a whole Einstein denies the applicability of the special theory and even of Euclidian geometry because a "measuring rod applied to the periphery undergoes a Lorentzian contraction, while the one applied along the radius does not" (p.116[3]). Yet, to prove it he uses an argument based on a supposedly legitimate application of the special theory to the motion of the rim of the disk:

> "So, too, we are unable to introduce a time corresponding to physical requirements in K', indicated by clocks at rest relatively to K'. To convince ourselves of this impossibility, let us imagine two clocks of identical constitution placed, one at the origin of co-ordinates, and the other at the circumference of the circle, and both envisaged from the 'stationary' system K. By a familiar result of the special theory of relativity, the clock at the circumference - **judged from K - goes more slowly than the other**, because the former is in motion and the latter at rest. **An observer at the common origin of co-ordinates**, capable of observing the clock at the circumference by means of light, **<u>would therefore see it lagging</u> behind the clock beside him**. As he will not make up his mind to let the velocity of light along the path in question depend

explicitly on the time, **he will interpret his observations as showing that the clock at the circumference "really" goes more slowly than the clock at the origin.** So he will be obliged to define time in such a way that the rate of a clock depends upon where the clock may be" (p.116[3]; emphasis added).

Thus Einstein's treatment of the rim of a rotating disk is consistent with his 1905 treatment of the clock moving 'in a closed loop': here the body of the disk is 'discarded' and only its circumference is retained so that the 'Lorentz-untransformed' rigid radius does not enter the picture nor are there other concentric curves of different radii that would have to be assigned different times.

A crucial difference is that, in his 1905 treatment, he paid attention only to the moving clock itself but did not relate it in any way to either the distance represented by his 'polygon' or 'closed curve', or to the physical mode of the clock's transport along it. Had he done so, he might not have come up with the 'peculiar consequence' of the clock paradox and would not have to muddle his descriptions by pronouncements like 'the clock is slow when viewed from the stationary system' or, as above, 'judged from K, goes more slowly', observer *in* K '*would see it lagging*', or '*the clock "really" goes more slowly*'. In all these statements Einstein is obviously straining to avoid the word **appears** while not fully committing himself to **really is**. For what does, say, **"really" goes more slowly** really mean? Does the moving clock really go more slowly than the stationary one or does it not? If **"really"** does not mean **really** it can only mean **apparently** and then there is no paradox: the slower rate of the moving clock would be only as apparent as the shortening of the moving rod and this appearance would be symmetric: it would apply equally to a moving system viewed from a stationary one and vice versa.

In an attempt to shed more light on the problem and demonstrate that 'clock delay' cannot be divorced from 'rod shortening', the experiment No.1 will be repeated with the difference that Albert will stop playing hide-and-seek with the experimenters and the mechanical setup of the experiment will be considered as a whole.

Al will be designated to remain at rest at point "0" at the platform (stationary system K) and Bert to ride the train (moving system K') which will be travelling along a closed loop. The track will form a circle with a length D. The train will be constructed as a carousel, the coaches covering the whole track. There will be altogether n coaches, all of them constructed as rigid bodies (rods) of equal lengths, $d = D/n$. The track (itself in K) will be marked at intervals d so that it can be regarded as (an approximate polygon) consisting of n rigid segments of lengths d. There will be a network of points in K (including the points separating the segments of the track) with clocks synchronized as required by the special theory. There also are clocks in all coaches of the train, synchronized when the train was standing at rest on the track and therefore also synchronous with all the clocks in K.

All this information is given to both Al and Bert before the experiment. Al takes the position at one of the segments of the track (say, point "0"), Bert boards the train and Albert gets it moving. The train will operate at a constant speed like a merry-go-round and, to avoid the problem with the starting acceleration, the experiment proper will start only after a few rounds of the train over the loop when its motion has reasonably stabilized.

For the experiment, Al and Bert were instructed to take readings of their respective clocks when Bert passes point "0", say, for the tenth time and then again when he passes it the next, i.e. eleventh, time. In this manner, Al will get the duration of the round trip as t_A and Bert will get t_B. Al was also instructed to calculate the train velocity by taking $v_A = D/t_A$. This is all that is needed to check the validity of Einstein's claim that the duration t_B shown by Bert's clock will be shorter by $\frac{1}{2} t_A v_A^2 / c^2$ than Al's t_A.

However, to make the experiment more comprehensive and check the principle of relativity explicitly, Albert extended the experiment by instructing Al to measure the length of the train and the duration of its round trip by Einstein's 'method b' using the network of clocks synchronized in K; likewise, Bert was instructed to make a similar complete set of measurements (including the length of the track, the velocity and the trip duration) from the moving train. For this purpose, Albert had installed in the middle of every coach a device capable of marking its instantaneous position on the track and a similar device was placed in the centre of every segment of the track to mark its instantaneous position on the moving train.

Al was to go about his task in the following way: First he was to measure the length of one moving coach (whose rest length in K was $d=D/n$) by measuring with his measuring rod the distance between two neighbouring marks which had been made (by the devices located on the coaches) on the track in the same instant pre-specified by timers on the synchronized clocks. His measurement was supposed to check the prediction of the special theory that the moving coach should appear to be $d_A' = d\sqrt{(1-v_A^2/c^2)}$ metres long. Then he was to measure the time which it takes one coach to pass over one of the clocks on the track, by recording its readings at the passages of the centre points of two neighbouring coaches. According to the special theory, he was supposed to get $\Delta t_A' = \Delta t_A \sqrt{(1-v_A^2/c^2)}$ where Δt_A is the 'rest value' t_A/n.

Al now had the following problem: When he added up the n computed segments of length d' he did not get the full length of the train D but only a Lorentz-contracted $D'=D\sqrt{(1-v_A^2/c^2)}$; nor did he get the time t_A needed for one round trip of the train when he added up the n intervals $\Delta t'$ but only a Lorentz-reduced time $t'_A = t_A\sqrt{(1-v_A^2/c^2)}$. On the other hand, he also knew that these two reduced values had to apply to the whole round trip: the first coach actually did return to point "0", the train did not break up during the trip leaving somewhere a gap equal to the difference D-D' and there were exactly n coaches in the train.

Al's tentative conclusion was that both Lorentz-transformed values represented only apparent values, i.e. how the true values appeared when their 'projections' were measured from his stationary position while the measured objects were moving. This he saw confirmed by the fact that the speed of the train, when computed as D'/t'_A, remained the same v_A which he had obtained as D/t_A since the Lorentzian factors cancelled out. This made sense to him. However, to his surprise, when checking the 1905 Einstein's paper he found that only the length contraction was apparent while the shorter time of the moving train was real - that it was the time Bert's clock would actually show at the end of the round trip. Of course, he was anxious to make the measurements and check them with the computed values and, in particular, he was extremely interested in comparing his t_A with Bert's t_B.

At this point, Al realized that there was something wrong. He recalled that Albert had arranged for only a single pair of the neighbouring coaches to make marks on the track for the purpose of the measurement of the length of a moving coach by 'method b'. What would happen if all the coaches were instructed to leave marks of their centre points on the track? Since the train made the whole round trip and remained in one piece, there would have to be exactly n equally spaced marks on the track but then they would have to be d metres apart which contradicted the prediction of the special theory. He could not wait to see what the distance between the two marks Albert had left for him to measure actually are.

In the meantime, Bert was busy making his own measurements on the train. Keeping his eyes on the track for the ten preliminary rounds, he gradually got the impression that his train was actually standing still and that it was the track under its wheels that was rolling away. This did not surprise him - it merely reinforced his belief in the principle of relativity. He then performed the first part of the experiment by taking the reading of his clock at the tenth and eleventh passage of point "0". For the extended experiment he had to resynchronize all the clocks on the train which he did using the standard light-based method since, persuaded by Einstein's argument (see the later quotation from p.114[3]), he was convinced he had the same right to consider his train system K' to be stationary as much as Al had the right to regard the track system K as stationary. From there on, all his tasks mirrored those described in connection with Al and so did his conclusions, misgivings and impatience to do his measurements and compare results with Al's.

The questions to be answered are:

How did Al's and Bert's values, t_A and t_B, compare?

What would have been the spacings in the **complete set** of n marks made on the track by the train and between those made on the train by the devices on the track?

Second-guessing the results

If $t_B = t_A$, then there is no clock paradox, the special theory may be consistent but Einstein's application of it to the 'closed loop journey' is wrong.

If $t_B \neq t_A$ and $t_B < t_A$ by the amount given by Einstein's formula, then the principle of relativity would be contradicted since the two systems would not be 'equally legitimate' representatives of a stationary system. If $t_B < t_A$ but by a different amount than required by Einstein's formula, then both the principle of relativity and the applicability of the special theory to this case would be contradicted.

As for the spacings in the complete sets of the marks on the track and on the train, no other answer offers itself than an equal spacing by distances d, unless of course the special theory would cause the train to derail or both the train and the track to break.

Conclusions

The clock paradox, or 'asymmetric aging', seems to have resulted from Einstein's asymmetric reasoning about the effects of motion on the lengths and clock rates in a moving system when they are observed (measured) from a stationary system. In regarding the Lorentzian contraction of a 'rod' as **apparent and symmetric** while the slowdown of a 'clock' as **real and thus asymmetric**, Einstein seems to have contradicted his own postulate that, in the relativity theory, space and time are inseparable and cannot be treated independently - which is exactly what he did in Section 4 of 1905[1]. To quote his own pronouncements:

> "According to the special theory of relativity the four-dimensional continuum formed by the **union of space and time** (Minkowski) retains the absolute character which, according to the earlier theory, belonged to both space and time separately" (p.241[5]; emphasis added).
>
> "The **inseparability of time and space** emerged in connection with electrodynamics, or the law of the propagation of light. Hitherto it had been silently assumed that the four-dimensional continuum of events could be split up into time and space in an objective manner ..." (p.275[6]; emphasis added).

It seems odd that such a rigid inseparability and the traceability of both contractions to the same cause, namely the constancy of the velocity of light in all inertial systems, should lead to their completely different status: one is apparent, the other is real.

The reality of asymmetric aging may be exposed to doubt in the 1905 paper itself, namely because of its contrast with the Doppler effect analyzed in Section 7. The effect of the movement of a light source on the frequency of the emitted light depends on the direction of the motion, producing a red shift for +v and blue shift for -v. Yet, the frequency is nothing else than a 'clock rate' of the light source and a stationary observer sees it once accelerated and once retarded. However, these appearances have no effect on the actual frequency of the moving light source and here Einstein does not claim they do. Most important, in this case the effect is entirely symmetric - it would be observed by a moving observer if he were watching a stationary light source.

In summary, there seems to be no reason for a violation of symmetry of relativistic effects (principle of relativity) in inertial systems if the relativity principle is postulated even in the general theory for a non-inertial system K' moving in uniformly accelerated motion relatively to a stationary system K:

> "The mechanical behaviour of bodies relatively to K' [moving system] is the same as presents itself to experience in the case of systems which we are wont to regard as 'stationary' or as 'privileged'. Therefore, from the physical standpoint, the assumption readily presents itself that **the systems K and K' may both with equal right be looked upon as 'stationary'**, that is to say, **they have an equal title as systems of reference for the physical description of phenomena**" (p.114[3]; emphasis added).

However, only a real experiment - as opposed to a thought experiment based on logic alone - can resolve the 'clock paradox':

> "No answer can be admitted as epistemologically satisfactory (of course, an answer may be satisfactory from the point of view epistemology, and yet be unsound physically, if it is in conflict with other experiences), unless the reason given is an **observable fact of experience.** The law of causality has not the significance of a statement as to the world of experience, except when **observable facts** ultimately appear as causes and effects (p.113[3]; emphasis in the original).

Fortunately for the special theory, no real experiment can ever be performed and no observable facts of experience ever produced on the 'clock paradox' because, after all, no trully inertial systems can be physically realized in the real world where there is no escape from forces. For the same reason, the special theory can never be blamed for train derailments and broken rails. The fact is, however, that even Einstein's thought experiments could go terribly wrong when confronted with 'observable facts'. A glaring example was his perfectly logical justification of the superiority of socialist systems[7] based on public ownership of the 'means of production' over the capitalistic systems where this ownership is private. If such a thing could happen to a 70 year old world-famous scientist, why is it so difficult to admit that a 26 year old youngster could have simply gone three sentences too far in one of his first papers?

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APPENDIX

Space and time, scales and dials

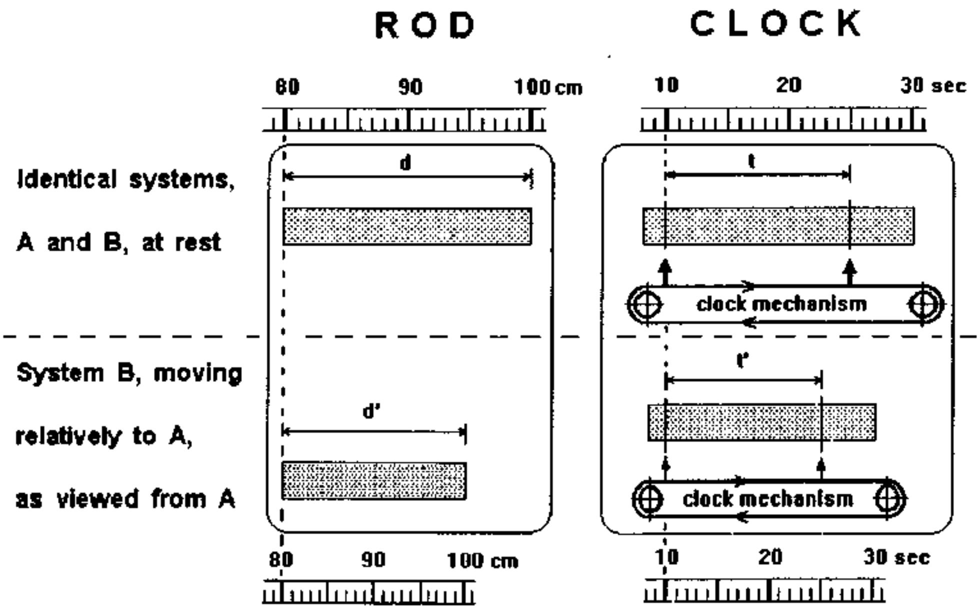
Space

When comparing the length d of a rod at rest in an inertial system ('stationary' system A) and the length which an identical rod appears to have when it is viewed from this system as it is moving relative to it in uniform translatory motion in the direction of its length ('moving' system B), the length of the moving rod is first 'projected' from B into A and the length of this projection, d', is compared with d.

Al who is servicing system A can compare these two lengths directly, without invoking any measuring scales, as indicated in the figure where the 'stationary rod' (of length d) and the projection (of length d') of the 'moving rod' are enclosed in a box. From this comparison, he can conclude with Einstein that the moving rod, 'when viewed in the stationary system' appears shorter than the rod at rest in this system. He can of course take his measuring tape, graded in cm for instance, and measure both lengths. In the case depicted in the figure, he would get d=20cm, d'=15cm.

Here it is obvious that these 15cm is not the length which Bert, travelling in system B, would get if he measured his rod directly with his own measuring tape. He would get 20cm as did Al for his rod. For if he laid his tape alongside his rod, both would appear shorter when 'viewed in the stationary system' so that Al would see 1cm on Bert's tape to be only $\sqrt{1-v^2/c^2}$ cm long when measured with his own tape. And the situation is completely symmetric: Bert would see 1 centimetre on Al's tape to be only $\sqrt{1-v^2/c^2}$ centimetres long as measured with his own.

The important point here is that, while **the length of the rod's image in A has been reduced, the image of the number of its measuring units has not.**



Time

When discussing time, Einstein starts with a mathematical description of motion of a material point:

> "If we wish to describe the motion of a material point, we give the values of its co-ordinates as functions of time. Now we must bear carefully in mind that a mathematical description of this kind has no physical meaning unless we are quite clear what we understand by 'time'"(pp.38-39[1]; emphasis in the original).

However, Einstein does not elaborate on this 'quite clear understanding' of time, i.e. he does not really define time. The closest he ever comes to such a definition is the following statement:

> "It might appear possible to overcome all the difficulties attending the definition of 'time' by substituting 'the position of the small hand of my watch' for 'time'"(p.39[1]).

On the same page he refers to 'positions of the hands' two more times and that is as far as his definition of time goes. He obviously means the positions of 'the hand' as it moves at a constant speed from one mark to the next on some dial. These marks are equally spaced and typically labelled in seconds. Einstein even uses the expression 'time marked by the clock' (p.49[1]) and the term 'seconds-clock' (p.36[8]).

Thus his definition - if it can be called so - is circular: Motion of a material point (or body) is specified by the times when it reaches specific positions on its trajectory and these times are specified by the motion of a clock's hand (which supposedly is a material point or body) from one specific position (mark) on its trajectory (dial) to another. Not much clarity is added in Einstein's later pronouncement:

> "In order to have a complete description of the motion, we must specify how the body alters its position with time; i.e. for every point on the trajectory it must be stated at what time the body is situated there. These data must be supplemented by such a definition of time that, in virtue of this definition, these time values can be regarded essentially as magnitudes (results of measurements) capable of observation" (p.10[8]; emphasis in the original).

Even though it is tautological (perhaps inevitably so), the definition emphasizes the fact that motion and time cannot be separated. This means, however, that Einstein's definition cannot be divorced from the concept of distance which is essential for the concept of motion as 'altering the position' of a point or body. This may be why the transformations of distance and time are formally given by exactly the same equations (1 and 2) in the special theory.

In Einstein's exposition, the similarity between 'rod shortening' and 'clock delay' is obscured by the implied but completely unessential assumption that the clock has a rotating hand whose tip is moving on a circular trajectory. The point is that a clock could equally well be constructed in such a way that its hand moves along a straight-line path. For example, there is no need for a circular dial and for the customary rotating 'hands' in a pendulum clock - its dial can be made linear and placed behind the driving weights which could easily carry a pointer in the shape of a 'hand' if desired.

In the following thought experiment, we will assume a clock with a straight-line movement of the 'hand' carried by a chain loop driven by some mechanical device as shown in the figure where the hand is represented by an arrow. Suppose Al who is making observations in the stationary system A is equipped with one such clock and Bert in the moving system B with (to quote Einstein) 'another clock in all respects resembling the one at A'. Both clocks are positioned parallel to the experimental rods Al and Bert were using in the 'rod shortening' experiment.

The important point is that the rates of the two clocks, i.e. the speeds of the motion of their hands, can be compared directly without making use of the dials (these can be covered with a masking tape for this purpose), in a similar way as was done with the rod lengths before: The dial in B is 'projected' into A where is has an image observed by Al. If this image is positioned parallel to Al's clock and both dials are masked, Al can observe only the motions of the clock hands and sees that the (image of the) hand of Bert's clock is moving more slowly than that of his clock. In particular, during the time in which 'his hand' moved the distance t, 'Bert's hand' covered only the distance t' as shown in the box in the figure. Al judges this 'delay' to be only apparent and caused by the apparent shortening of Bert's dial.

Al can now 'measure' the two times by removing the masking tape from his dial. Since the length of the dial is calibrated in seconds instead of centimetres the 'distance travelled' represents the 'time elapsed'. Al thus 'measures' his time as t=15 sec and Bert's time as t'=13 sec. He of course knows that Bert would measure 15 sec on his own dial while 'viewed in Bert's reference system' (measured on Bert's dial), Al's time would appear as only 13 sec.

For some reason, Einstein seems to have omitted the relativistic shortening of distances on the trajectory in B along which the hand of Bert's clock is moving and attributed (whether deliberately 'by definition' or inadvertently by omission) the reading on Al's dial to Bert's clock.

In the present interpretation, the time delay of the moving clock is only apparent, the relativistic symmetry is preserved and no 'clock paradox' arises. It is also consistent with the absence of any apparent rod shortening and clock slowdown if the rod and the clock in B are placed perpendicular to the direction of its motion.

As a matter of fact, Einstein's repeated allusions to 'hands' of clocks or watches with circular dials are in conflict with the special theory for the following reason. In any ponderable clock of such construction, a hand - whether the 12-hour, 1-hour or 1-minute - is merely a radial segment of a rotating disk and could be legitimately replaced with a whole disk made of a transparent material, with the 'hand' represented by a radial groove. However, as Einstein points out in the context of the general theory (p.116[3]), a unique time cannot be defined for a rotating disk as a whole since every point along its radius has a 'different time'. In the context of Einstein's theory, it thus is difficult to attach a clear meaning to "coincidences between the hands of a clock and points on the clock dial" (p.117[3]). The fact that, in spite of this, Einstein still postulates these 'coincidences' to define time uniquely indicates that he is exempting his clock from the consequences of his own theory; in other words, his 'clock' is not a real physical instrument but only an abstraction for 'measuring time by definition', so to speak, a different name for time itself. The only difference between the repudiated concept of 'Newtonian time' and the newly introduced substitute of 'Einsteinian clock' are only the properties by which these two abstract concepts have been endowed by definition: the former is rigid, the latter elastic.