The Principle of Relativity and the Speed of Light Postulate: Incompatible Concepts

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Relativists claim that Einstein's constancy of the speed of light postulate is a consequence of the principle of relativity. Perhaps they consider this as the strongest argument in defending Special Relativity. They maintain that their assertion is supported by the Michelson-Morley experiment, in which the Earth motion couldn't be detected—in accordance with the principle of relativity— on the basis that the speed of light is relative, defying the foreseen variation of the speed of a light ray with its propagation direction in relation to the Earth motion direction. Since the relativity principle is well accepted among physicists, relativists promote the idea that the constancy of the speed of light postulate follows from the relativity principle, thus making the former as legitimate as the latter. In this paper, the aforementioned claim is shown to be flawed, and has no valid justification; even more, the speed of light postulate is actually revealed to violate the principle of relativity.

The speed of light postulate doesn't follow from the principle of relativity: thought experiment

The principle of relativity states that the laws of physics are the same in all inertial frames. This means there's no particular physical parameter or process within an inertial frame that depends on, or could be an indication of, its state of motion. Consequently, under the principle of relativity, light must behave identically in all isolated inertial frames, since within an isolated inertial frame, an observer could not use any physical means to determine their state of motion. If the speed of light within an isolated inertial frame was dependent on the frame state of motion, using this dependency will enable the observer to determine their state of motion, which is impossible, according to the relativity principle. Not only the light has invariant behavior in all isolated inertial frames, but any physical phenomenon would exhibit the same behavior in all isolated inertial frames under the applicable laws of physics. Einstein argued that the laws of physics within an inertial frame are unchanged even when they are referred to from an other inertial frame: "*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 co-ordinates in uniform translatory motion*".[1]

Now, would the detection of the Earth motion using the speed of light, as was intended in the Michelson-Morley experiment[*], violate the principle of relativity? To answer this question, let's analyze the situation by considering the following thought experiment, offering a good analogy.

You are inside a ship traveling uniformly in a calm day through the still ocean. You wish to determine the ship speed. You know from the physics laws that the speed of sound in air under the current conditions is a well determined value of V m/s. Measuring the speed of sound inside the closed ship space, where the space air is moving (dragged) with the ship, will give you the same value, V, in line with the relativity principle, regardless of the ship speed, and won't be useful in determining the ship state of motion. However, measuring the speed of sound on the ship deck, in the open air, will give you a different value. It will be $V \pm U$, where U is the ship speed. Hence, knowing V, you can deduce U. Is the principle of relativity violated here? The answer is no. But, you were able to detect the ship motion by deploying measurements taken by interacting with an external frame – the open air "moving" relative to the ship.

In the Michelson-Morley experiment* (where the ether is equivalent to the air, light to sound, and ship to Earth, in our thought experiment), is the measurement taken within the isolated Earth frame, where the ether is "dragged" with the Earth, or in the "open" ether "moving" relative to the Earth? If we were to adopt the ether theory, since the Earth motion couldn't be detected, the ether must then be dragged with the Earth. Otherwise, the Earth motion would be detected (like detecting the ship motion with measuring the speed of sound), and such detection would not be a violation of the principle of relativity, since it would be the result of the external ether system being interacted with the relatively moving Earth frame. The applicable law of physics in this perspective states that the speed of light (respectively sound) has the determined value c (respectively V) relative to the ether (respectively air) rest frame. The speed of light (respectively sound) will then be measured as $c \pm v$ (respectively $V \pm v$) relative to a frame of reference moving with the speed v relative to the ether (respectively air), in line with the aforementioned law of physics. However, since the ether must be dragged with the Earth motion, the speed of Earth v relative to the ether is zero. Hence, the null result of the Michelson-Morley experiment,* similar to the null result in detecting the ship motion inside the ship (using the speed of sound) where the air is dragged with the ship.

It follows that, the constancy of the speed of light concept doesn't follow from the principle of relativity, as claimed by relativity proponents (basing their argument on the assumption that an inertial frame motion cannot be internally detected using light behavior variations with the inertial frame state of motion, as demonstrated by the Michelson-Morley experiment – which is not the case), but it's a postulate on its own, imposed by Einstein by assuming a new law of physics, dictating that any ray of light moves with a constant speed c relative to any inertial frame of reference, regardless of the light source state of motion.

The constancy of the speed of light principle violates the principle of relativity

Consider a train moving at a relativistic uniform speed on a straight path. A passenger is shooting at a target board fixed on a sidewall using both a dart gun and a laser gun. In both cases, he aims at the target center from a position such that the dart, or the laser ray, trajectory will be perpendicular to the target wall, thus in the transverse direction with respect to the train motion. The dart is ejected with sufficiently high velocity so that its trajectory can be approximated with a straight line over its relatively short range of motion. Suppose there is an observer on the ground examining the trajectories of the dart and laser ray from the moment of shooting till hitting the target board. Remember the passenger has aimed at the target center in both cases.

The ground observer will see the dart taking a slanted path, moving simultaneously toward the target in the transverse direction and along the direction of the train motion, keeping up with the target motion with the train, and approaching the target, until it hits its center. Obviously, the dart longitudinal velocity (equal to the train velocity) is acquired from the dart gun being in motion with the train.

In the case of the laser ray, there are three possible scenarios: (1) The laser ray photon behaves like the dart and hit the center, in which case it has a velocity component in the longitudinal direction, equal to the train speed, and acquired from the laser gun motion with the train; (2) the photon has a definite speed relative to a propagation medium, in which case it will hit the target center if the medium was carried (dragged) with the train, or will be lagging before and missing the target center, if the train was moving relative to the medium—the photon will be "drifted" backwards by the medium relative motion at the train speed, while approaching the target wall; and (3) the photon speed is independent of the laser gun (source) motion, and it requires no propagation medium, thus it will keep going in the same transverse direction it is shot at, without acquiring the gun speed, and will miss the target center that will have moved forward by the time the photon reaches the target—it will take a backward slanted path relative to the passenger, as the passenger frame is moving forward.

Scenario 1 is in line with Newton's emission theory of light,[**] and it is in conformity with the principle of relativity. Nothing about the dart behavior could indicate to the passenger the train state of motion. The dart will not miss the target center, regardless of the train state of motion.

Scenario 2 is in accordance with the ether theory. Here again, it is in conformity with the principle of relativity. In the case the ether is dragged with the train, the laser ray doesn't interact with any external system, and its trajectory toward the target center doesn't provide any clue to the passenger as to the train state of motion. Whereas, in the case the ether is not dragged, the ray hitting the target before its center indicates the train is moving relative to the ether, an external system relative to the train frame. This doesn't violate the principle of relativity, since the state of motion is indicated by an interaction with an external system, like in the case of determining the ship speed relative to the open air, by an observer in the ship frame, in our thought experiment above.

Scenario 3 reflects the special relativity assumption that light propagates in vacuum at the constant speed, c, relative to the observer, and it is independent of the source relative speed (the constancy of the speed of light postulate). Since, under this assumption, there's no reason whatsoever for the laser photon to follow the target longitudinal movement, since it will not acquire the laser gun velocity. The laser gun is aimed transversally (perpendicular to the train path) at the target center; a respective photon, from the ground observer perspective, will keep traveling solely in the transverse direction as the train assumes its motion (it will take a backward slanted path relative to the passenger, as it approaches the target wall). For the photon to hit the target center, it should be aimed at a well determined point ahead of the target center, relative to the forward direction, in such a way that its velocity longitudinal component (relative to the ground observer) is equal to the train speed. In such a case, the laser ray will take a forward slanted path relative to the ground observer, and a direct path (normal to the target wall) from the laser gun to the target center, relative to the train passenger.

It follows that, under the speed of light postulate, having to aim the laser gun ahead of the target center to hit the bullseye, would be an indication of the train state of motion for the train passenger. This is an obvious violation of the principle of relativity, since, using the speed of light postulate, the train passenger would be able to determine his frame (the train) state of motion (relative to the ground) internally, in isolation of any external reference frame or system (i.e., without interacting with any external reference). This will inevitably lead us to conclude that the speed of light postulate is, in fact, invalid.

The Michelson-Morley Experiment

The Michelson-Morley Experiment[2] was designed in the late 19th century to detect the ether (an assumed light propagation medium) "wind" created by the Earth motion through the ether-filled space (i.e., detecting the Earth motion through the ether).

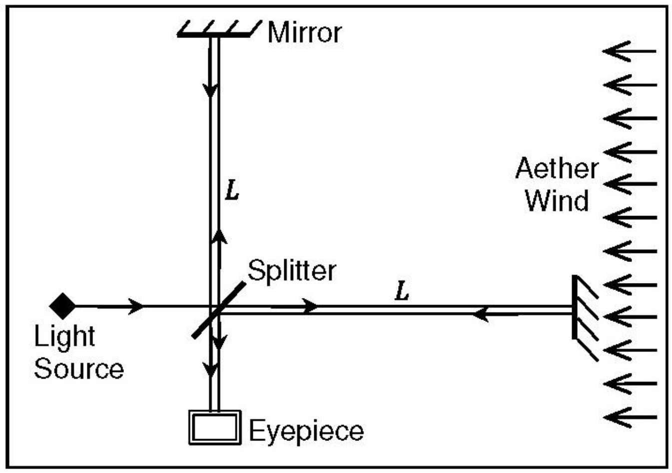

Fig.1 Michelson-Morley experiment setting

As light was supposed to travel at a constant speed with respect to the ether, the relative speed of light with respect to Earth would then depend on the light propagation direction with respect to the ether wind direction. Fig.1 illustrates the experiment principle. A light beam is sent to a semi silvered mirror placed at 45° angle to the beam direction, splitting it into two beams with directions perpendicular to each other. Each of the two split beams will then travel a distance L from the splitter before it is reflected back to it, and recombining with the other reflected beam in an eyepiece, producing an interference pattern. If the Earth is moving through the ether, it would create an ether wind blowing in the opposite direction to its motion, thus delaying the back-and-forth trip of the beam traveling longitudinally to the ether wind, with respect to the beam with the transverse motion. This time delay will cause the recombined beams to be out phase, thus a shift in the fringes from the position that would be expected under symmetrical beam trips was anticipated. However, no such shift was observed, even with much more sophisticated variations of the experimental setting providing very high accuracy of the measurements.

If the speed of light with respect to the ether was c, and the Earth relative velocity was V, then, as shown below, the total longitudinal travel time can be expressed as

$$T_l' = \frac{2L}{c}\frac{1}{1-\frac{V^2}{c^2}}$$

[*Forward direction:*

$$T_F = \frac{VT_F+L}{c} \Rightarrow T_F = \frac{L}{(C-V)}$$

Backwards direction:

$$T_B = \frac{L-VT_B}{c} \Rightarrow T_B = \frac{L}{(C+V)}$$

Therefore, the total longitudinal travel time is

$$T_l' = T_F + T_B = \frac{2L}{c}\frac{1}{1-\frac{V^2}{c^2}}]$$

Whereas, the total travel time for the transverse beam was

$$T_t = \frac{2L}{c},$$

as originally indicated by Michelson. Thus T_l' is greater than T_t by a factor of $1/(1 - V^2/c^2)$. However, this factor was reduced, as a corrected transverse travel time of

$$T_t = \frac{2L}{c}\frac{1}{\sqrt{1-\frac{V^2}{c}}}$$

[*Transverse direction:*
$c^2T_1^2 = L^2 + V^2T_1^2$, *where* T_1 *is the travel time of one way trip in the transverse direction. The total transverse travel time* T_t *is twice* T_1. *Hence,*

$$T_t = \frac{2L/C}{\sqrt{1-\frac{V^2}{c^2}}}\ ]$$

was introduced by Lorenz (1886), taking into consideration the light beam drifting. However, this new time difference still couldn't be conciliated, as the experiment exhibited null result in terms of fringe shift.

In an attempt to resolve this discrepancy, a length contraction hypothesis was proposed by Fitzgerald (1897) and Pointcaré (1905). According to this hypothesis, an object would contract along the direction of its motion by a factor of $1/\gamma$, with

$$\gamma = \frac{1}{\sqrt{1-\frac{V^2}{c^2}}},$$

being the Lorentz factor. It follows that, the light beam will end up traveling the contracted longitudinal distance L/γ, and the longitudinal travel time becomes

$$T_l = \frac{2L/\gamma}{c}\frac{1}{1-\frac{V^2}{c^2}} = \frac{2L}{c}\frac{1}{\sqrt{1-\frac{V^2}{c}}},$$

which is the same as the transverse travel time, thus justifying the Michelson-Morley null result. Elaborations on Lorentz contraction and consequent time dilation had led to the development of Lorenz transformations, and subsequently to the formulation of special relativity, where the ether was eliminated, and the velocity of light was assumed invariant with respect to all inertial frames of reference.

****The Michelson-Morley Experiment and Newton's Emission Theory***

It's worth mentioning that the Michelson-Morley null result is well compatible with the Newton's emission theory of light. In this perspective, the speed of light is c relative to its emitting source. Therefore, the speed of light will be c relative to the Earth frame (the source is in the Earth frame), and $\boldsymbol{c \pm V}$ relative to the ether frame ($c + V$ in the forward direction, $c - V$ in the backward direction, and $\sqrt{c^2 + V^2}$ in the transverse direction). It can be readily shown that the travel times of the back-and-forth trip of the beams traveling longitudinally and transversally are the same, and equal to

$$T_l = T_t = \frac{2L}{c},$$

whether calculated from the perspective of the Earth frame or the ether frame.

[*Forward direction:*
$T_F = \frac{VT_F+L}{c+V} \Rightarrow T_F = \frac{L}{c}$
Backwards direction:
$T_B = \frac{L-VT_B}{c-V} \Rightarrow T_B = \frac{L}{c}$
Therefore, the total longitudinal travel time is
$T_l = T_F + T_B = \frac{2L}{c}$
Transverse direction:
$(c^2 + V^2)T_1^2 = L^2 + V^2T_1^2 \Rightarrow T_1 = \frac{L}{c}$*, where* T_1 *is the travel time of one way trip in the transverse direction. The total transverse travel time* T_t *is twice* T_1*. Hence,*
$T_t = \frac{2L}{c}$]

The null result can therefore be justified by the Newton's emission theory of light.

[1]A. Einstein, Annalen der Physik **322** (10), 891 (1905).
[2]A.A. Michelson and E.H. Morley, Am. J. Sci. **34**, 333 (1887)