Light – Absolute Reference Framework

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https://doi.org/10.5281/zenodo.20507053

May 2026

Abstract

L-ARF (Light – Absolute Reference Framework) is a classical framework in which light serves as the absolute reference in the universe. Time intervals and spatial coordinates are determined exclusively from the physical path length s traveled by a light signal and the speed of light c:

$$t = \frac{s}{c}. \tag{1}$$

From this foundation, the relativity factor $\mathrm{rf}(v, v')$ is derived, providing a unified transformation between inertial reference frames. The framework is derived systematically from 26 thought experiments covering all possible combinations of motion between two inertial reference frames. A central conclusion is that an observer in a closed inertial reference frame can determine whether the system is in absolute motion or absolute rest. L-ARF is free from contradictions and paradoxes.

1 Introduction

Physical theories are built on assumptions and postulates. A theory free from contradictions and paradoxes must rest on a solid and consistent foundation.

L-ARF is based on a single fundamental premise: light propagates in vacuum at constant speed c, independent of source and observer. Light thus constitutes the absolute reference in the universe.

From this premise — and from this alone — a complete framework for transformations between inertial reference frames is derived. The framework is based on 26 systematically conducted thought experiments [1] and has been applied to a number of concrete physical problems [2, 3, 5, 4].

This article presents L-ARF in its entirety: its foundation, its derivations and its conclusions.

L-ARF offers an alternative framework for analyzing physical phenomena involving light signals.

2 Fundamental Premise

L-ARF rests on a single fundamental premise: light propagates in vacuum at constant speed c, independent of source and observer. Light constitutes the absolute reference in the universe.

From this premise follows a natural definition of time. A time interval is determined exclusively from the physical path length s of a light signal and the speed of light c:

$$t = \frac{s}{c}. \tag{2}$$

There is no separate definition of time — time is a direct measure of the path traveled by light. This is the fundamental principle of the framework.

To perform operations between two velocities, both must be defined relative to the same reference frame [2]. The speed of light c is defined relative to vacuum — therefore the velocities of S and S' must also be defined relative to vacuum, that is, as absolute velocities v and v'. The relative velocity between a reference frame and the wavefront of a light signal is then $(c \pm v)$ and $(c \pm v')$ respectively.

3 Absolute Motion and Rest

An observer O is located in a closed inertial reference frame on the x-axis, midway between two points P_{left} and P_{right}, both at distance d from O. From these points, light signals are sent simultaneously toward O. The observer registers the arrival times t_{left} and t_{right}.

Absolute motion and rest refer to the direction of motion along the x-axis, that is, in the direction of the light signals.

3.1 The apparatus at absolute rest

When the apparatus is at absolute rest, the distance traveled by the light signals is equal from both sides. The signals reach O simultaneously.

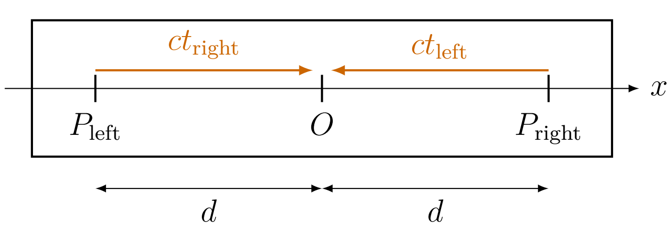

Figure 1: Absolute rest along the x-axis: $t_{left} = t_{right} = d/c$.

The arrival times are:

$$t_{\text{left}} = \frac{d}{c}, \qquad t_{\text{right}} = \frac{d}{c}. \tag{3}$$

Conclusion: in a real experiment, t_{left} and t_{right} are **measured**. If $t_{\text{left}} = t_{\text{right}}$, the apparatus is at absolute rest along the x-axis.

3.2 The apparatus moving to the right

When the apparatus moves to the right with velocity v, O moves toward the signal from P_{right} and away from the signal from P_{left}. The signal from P_{right} therefore reaches O first.

The light signals depart from their fixed origin positions P_{left} and P_{right}, which are fixed in vacuum and do not move with the apparatus. These origin positions are marked in the figures with dashed vertical lines.

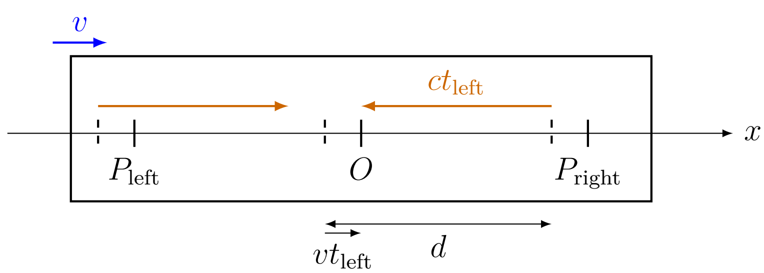

Figure 2: Motion to the right: the moment when the signal from P_{right} reaches O. The signal from P_{left} is still on its way. The origin positions of P_{left}, O and P_{right} are shown with dashed vertical lines — these points do not move.

During the time the signal from P_{right} travels from its origin position to O, the apparatus covers the distance vt_{left}. Therefore:

$$d = ct_{\text{left}} + vt_{\text{left}} = t_{\text{left}}(c + v) \quad \Rightarrow \quad t_{\text{left}} = \frac{d}{c + v}. \tag{4}$$

After this moment, the process continues until the signal from P_{left} reaches O.

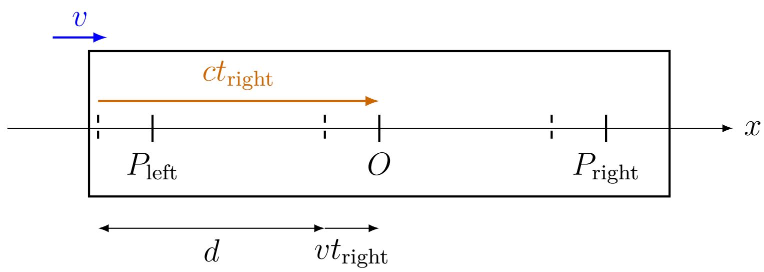

Figure 3: Motion to the right: the moment when the signal from P_{left} reaches O. The origin positions are shown with dashed vertical lines — these points do not move.

During the time the signal from P_{left} travels from its origin position to O, the apparatus covers the distance vt_{right}. Therefore:

$$d = ct_{\text{right}} - vt_{\text{right}} = t_{\text{right}}(c - v) \quad \Rightarrow \quad t_{\text{right}} = \frac{d}{c - v}. \tag{5}$$

Conclusion: in a real experiment, t_{left} and t_{right} are **measured**. If $t_{\text{right}} > t_{\text{left}}$, the apparatus is moving to the right along the x-axis.

3.3 The apparatus moving to the left

When the apparatus moves to the left with velocity v, O moves toward the signal from P_{left} and away from the signal from P_{right}. The signal from P_{left} therefore reaches O first.

The light signals depart from their fixed origin positions P_{left} and P_{right}, which are fixed in vacuum and do not move with the apparatus. These origin positions are marked in the figures with dashed vertical lines.

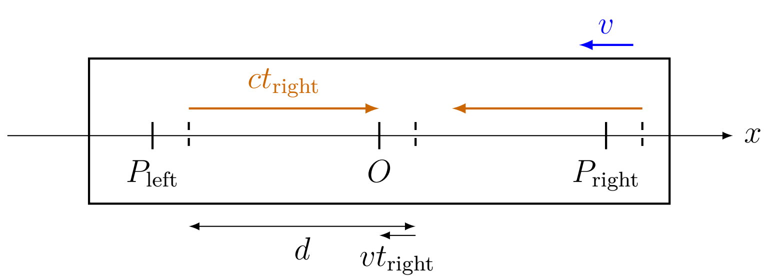

Figure 4: Motion to the left: the moment when the signal from P_{left} reaches O. The signal from P_{right} is still on its way. The origin positions of P_{left}, O and P_{right} are shown with dashed vertical lines — these points do not move.

During the time the signal from P_{left} travels from its origin position to O, the apparatus covers the distance vt_{right}. Therefore:

$$d = ct_{\text{right}} + vt_{\text{right}} = t_{\text{right}}(c + v) \quad \Rightarrow \quad t_{\text{right}} = \frac{d}{c + v}. \tag{6}$$

After this moment, the process continues until the signal from P_{right} reaches O.

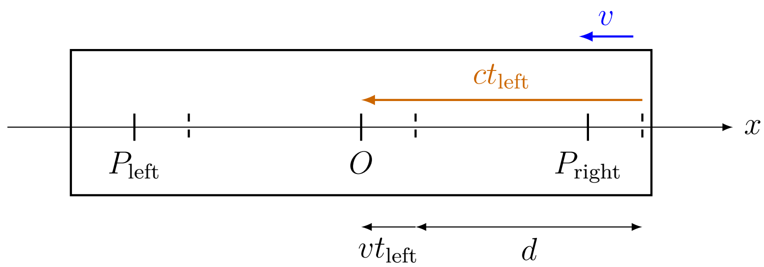

Figure 5: Motion to the left: the moment when the signal from P_{right} reaches O. The origin positions are shown with dashed vertical lines — these points do not move.

During the time the signal from P_{right} travels from its origin position to O, the apparatus covers the distance vt_{left}. Therefore:

$$d = ct_{\text{left}} - vt_{\text{left}} = t_{\text{left}}(c - v) \quad \Rightarrow \quad t_{\text{left}} = \frac{d}{c - v}. \tag{7}$$

Conclusion: in a real experiment, t_{left} and t_{right} are **measured**. If $t_{\text{right}} < t_{\text{left}}$, the apparatus is moving to the left along the x-axis.

4 The 26 Thought Experiments

All possible combinations of motion between two inertial reference frames S and S' are analyzed systematically in [1], with light signals from the right (R) and from the left (L). A total of 26 distinct thought experiments are identified, denoted R1–R13 and L1–L13.

The setup of each thought experiment follows the same principle as presented in the previous section:

- light signals depart from fixed origin positions in vacuum,
- the reference frames move with their absolute velocities,
- the coordinates of an event are calculated from the path length of the light signal and the speed of light c.

What distinguishes the experiments is the combination of the velocities and directions of S and S' relative to the origin position of the light signal.

For each experiment, the coordinates of the event are calculated:

$$E = (x, t) \quad \text{for reference frame } S \tag{8}$$

$$E' = (x', t') \quad \text{for reference frame } S' \tag{9}$$

A complete account of all 26 thought experiments with figures and derivations is found in [1].

The six distinct coordinate forms that appear are:

$$E = (x,\, t) = \left(c \cdot \frac{d}{c}, \frac{d}{c}\right) \qquad (S \text{ at absolute rest}) \tag{10}$$

$$E = (x,\, t) = \left(c \cdot \frac{d}{c+v}, \frac{d}{c+v}\right) \qquad (S \text{ moving toward the light source}) \tag{11}$$

$$E = (x,\, t) = \left(c \cdot \frac{d}{c-v}, \frac{d}{c-v}\right) \qquad (S \text{ moving away from the light source}) \tag{12}$$

$$E' = (x', t') = \left(c \cdot \frac{d}{c}, \frac{d}{c}\right) \qquad (S' \text{ at absolute rest}) \tag{13}$$

$$E' = (x', t') = \left(c \cdot \frac{d}{c+v'}, \frac{d}{c+v'}\right) \qquad (S' \text{ moving toward the light source}) \tag{14}$$

$$E' = (x', t') = \left(c \cdot \frac{d}{c-v'}, \frac{d}{c-v'}\right) \qquad (S' \text{ moving away from the light source}) \tag{15}$$

Here d denotes the distance between the origin position of the light source and the position of the reference frame at the start of the experiment.

5 The Relativity Factor $\mathrm{rf}(v, v')$ — the Central Concept

When the results of all 26 experiments are compiled, it becomes apparent that the transformation between coordinate systems can always be written:

$$x' = x \cdot \mathrm{rf}(v, v'), \qquad t' = t \cdot \mathrm{rf}(v, v') \tag{16}$$

where $\mathrm{rf}(v, v')$ takes 9 distinct forms:

$$\mathrm{rf}(v,v') = \frac{c+v}{c+v'}, \quad v>0,\ v'>0 \quad \text{(R11, R12, R13, L1, L2, L5)} \tag{17}$$

$$\mathrm{rf}(v,v') = \frac{c+v}{c}, \quad v>0,\ v'=0 \quad \text{(R10, L3)} \tag{18}$$

$$\mathrm{rf}(v,v') = \frac{c+v}{c-v'}, \quad v>0,\ v'>0 \quad \text{(R7, L4)} \tag{19}$$

$$\mathrm{rf}(v,v') = \frac{c}{c+v'}, \quad v=0,\ v'>0 \quad \text{(R9, L6)} \tag{20}$$

$$\mathrm{rf}(v,v') = 1, \quad v=0,\ v'=0 \quad \text{(R8, L8)} \tag{21}$$

$$\mathrm{rf}(v,v') = \frac{c}{c-v'}, \quad v=0,\ v'>0 \quad \text{(R6, L9)} \tag{22}$$

$$\mathrm{rf}(v,v') = \frac{c-v}{c+v'}, \quad v>0,\ v'>0 \quad \text{(R4, L7)} \tag{23}$$

$$\mathrm{rf}(v,v') = \frac{c-v}{c}, \quad v>0,\ v'=0 \quad \text{(R3, L10)} \tag{24}$$

$$\mathrm{rf}(v,v') = \frac{c-v}{c-v'}, \quad v>0,\ v'>0 \quad \text{(R1, R2, R5, L11, L12, L13)} \tag{25}$$

The expressions are interpreted as follows:

- $(c+v),(c+v')$ — S,S' moving toward the light source
- $(c-v),(c-v')$ — S,S' moving away from the light source
- $(c\pm 0)=c$ — S,S' at absolute rest relative to the light source

The expressions $(c \pm v)$ and $(c \pm v')$ represent the relative velocity between the respective reference frame S, S' and the wavefront of the light signal.

By absolute velocity we mean the velocity of the reference frame relative to vacuum, determined according to the method in Section 3.

6 The Coordinate Transformation

L-ARF provides a unified transformation of coordinates between two inertial reference frames S and S'. The transformation is based exclusively on the path length of the light signal and the speed of light c.

From the 26 thought experiments, six distinct coordinate forms were derived for the event E, E', depending on whether S and S' move toward the light source, away from it, or are at absolute rest. From these forms, the relativity factor $\mathrm{rf}(v,v')$ with 9 distinct expressions was identified.

The transformation is written:

$$x' = x \cdot \mathrm{rf}(v,v'), \qquad t' = t \cdot \mathrm{rf}(v,v'). \tag{26}$$

A fundamental property of this transformation is that x' depends only on x, and t' depends only on t — via the same factor $\mathrm{rf}(v,v')$.

There is no physical coupling between space and time.

7 Round-Trip Time of a Light Signal in a Moving Apparatus

7.1 The apparatus at absolute rest

The light signal departs from P_{left}, travels to P_{right} and is reflected back to P_{left}. Since the apparatus is at absolute rest, the distance is equal in both directions.

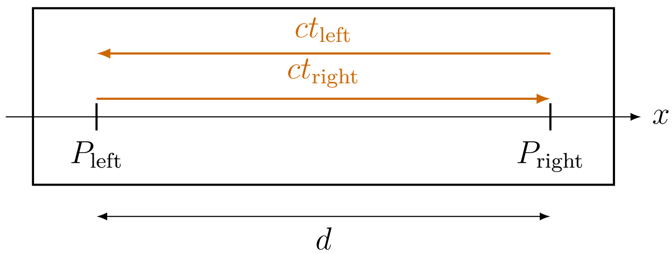

Figure 6: The apparatus at absolute rest: the light signal travels from P_{left} to P_{right} and back. The round-trip time is $t_0 = 2d/c$.

The time for the signal to travel from P_{left} to P_{right}:

$$t_{\text{right}} = \frac{d}{c}. \tag{27}$$

The time for the signal to travel from P_{right} to P_{left}:

$$t_{\text{left}} = \frac{d}{c}. \tag{28}$$

The round-trip time is:

$$t_0 = t_{\text{right}} + t_{\text{left}} = \frac{2d}{c}. \tag{29}$$

7.2 The apparatus moving to the right

The light signal departs from P_{left} at its origin position, travels to P_{right} and is reflected back to P_{left}. Throughout the process, the apparatus moves to the right with velocity v.

The origin positions of the light signals are fixed in vacuum and do not move with the apparatus. These origin positions are marked in the figures with dashed vertical lines.

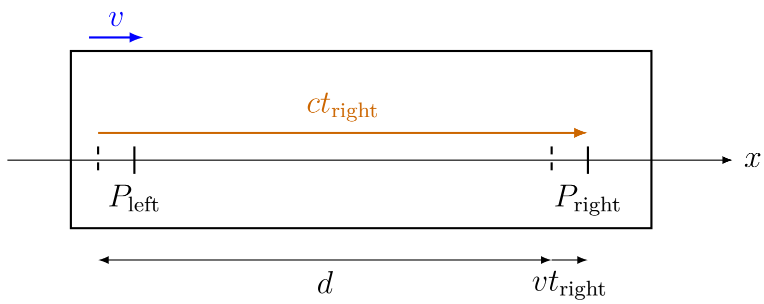

Figure 7: Motion to the right: the moment when the signal reaches P_{right}. The signal moves to the right.

During the time the signal travels from P_{left} to P_{right}, the apparatus covers the distance vt_{right}. Therefore:

$$d = ct_{\text{right}} - vt_{\text{right}} = t_{\text{right}}(c - v) \quad \Rightarrow \quad t_{\text{right}} = \frac{d}{c - v}. \tag{30}$$

When the signal reaches P_{right}, it is reflected and moves back toward P_{left}.

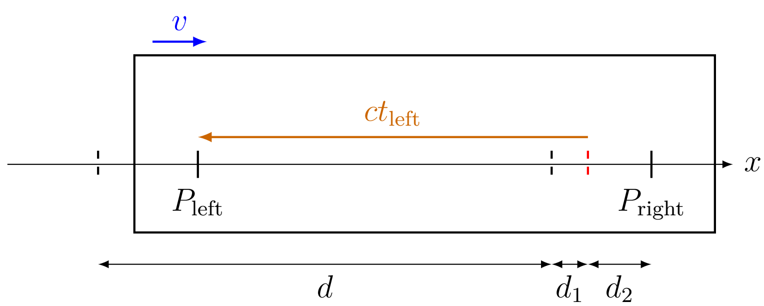

Figure 8: Motion to the right: the moment when the signal reaches P_{left}. The signal departs from P_{right}'s position at the reflection point (red) and moves to the left.
$d_1 = vt_{right}$; $d_2 = vt_{left}$.

During the time the signal travels from P_{right} back to P_{left}, the apparatus covers the distance vt_{left}. Therefore:

$$d = ct_{\text{left}} + vt_{\text{left}} = t_{\text{left}}(c + v) \quad \Rightarrow \quad t_{\text{left}} = \frac{d}{c + v}. \tag{31}$$

The round-trip time is:

$$t = t_{\text{right}} + t_{\text{left}} = \frac{d}{c - v} + \frac{d}{c + v} = \frac{2dc}{c^2 - v^2} = t_0 \cdot \gamma^2. \tag{32}$$

The round-trip time for an apparatus moving with velocity v is therefore γ^2 times longer than for the same apparatus at absolute rest:

$$t = t_0 \cdot \gamma^2. \tag{33}$$

The factor γ^2 is a function of v — this means that the round-trip time is not the same in two apparatuses with the same distance d between the mirrors but with different velocities. The higher the velocity, the longer the round-trip time.
This is a direct result of L-ARF — derived exclusively from the path length of the light signal and the speed of light c.

7.3 The apparatus moving to the left

Due to symmetry, the derivation is analogous to the previous case. The round-trip time is the same:

$$t = t_0 \cdot \gamma^2. \tag{34}$$

The factor γ^2 reappears in the L-ARF analysis of the GPS system [5].

The round-trip time of a light signal in a moving apparatus is γ^2 times longer than in an apparatus at absolute rest.

7.4 Examples

As a concrete example, the round-trip time is calculated for different values of d and v. Table 1 shows t_0, γ^2 and $t = t_0 \cdot \gamma^2$.

d	v	t_0 [s]	γ^2	t [s]
10 m	30 km/s	0.0000000667	1.0000000100	0.0000000667
10 m	225 km/s	0.0000000667	1.0000005625	0.0000000667
20 200 km	30 km/s	0.1346666667	1.0000000100	0.1346666680
20 200 km	225 km/s	0.1346666667	1.0000005625	0.1346667424

Table 1: Round-trip time $t = t_0 \cdot \gamma^2$ for different values of d and v.

The difference between t_0 and t is extremely small at these velocities. For larger distances d the difference becomes visible — as in the last row where $t - t_0 \approx 7.57 \times 10^{-7}$ s.

8 Relative Velocity in L-ARF

We consider two inertial reference frames S and S', both moving to the right with absolute velocities v and v', where $0 < v < v'$. At the starting moment, S and S' are located at the same point. To their right is the point O at distance d. The point O is at absolute rest in vacuum. In O, an event occurs that sends a light signal to the left.

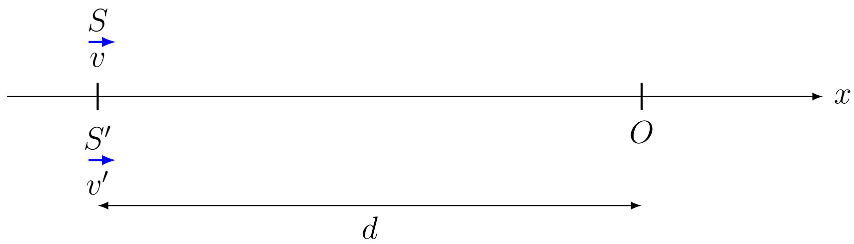

Figure 9: Starting moment: S and S' are located at the same point at distance d from O. The event occurs in O.

The light signal moves to the left from O with speed c. Since $v' > v$, S' moves faster toward the light signal than S and therefore reaches it first.

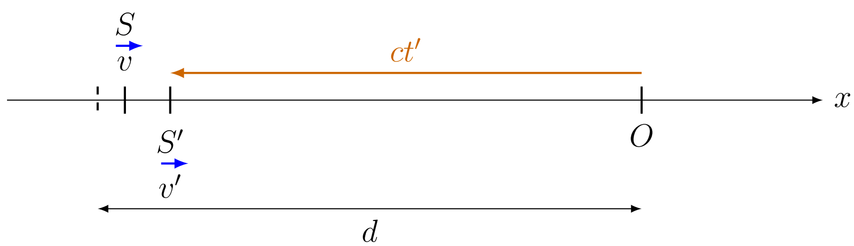

Figure 10: The moment when the light signal from O reaches S'. The origin position is shown with a dashed vertical line.

The light signal reaches S' after time t'. During this time, S' has moved the distance $v't'$ to the right. The path length of the light signal is:

$$ct' = d - v't' \quad \Rightarrow \quad t' = \frac{d}{c + v'}. \tag{35}$$

The light signal continues to the left and subsequently reaches S.

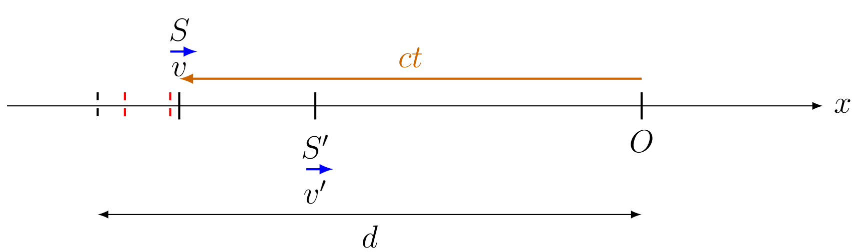

Figure 11: The moment when the light signal from O reaches S. The origin position is shown with a dashed vertical line. The positions of S and S' from Figure 10 are shown with red dashed lines.

The light signal reaches S after time t. During this time, S has moved the distance vt

to the right. The path length of the light signal is:

$$ct = d - vt \quad \Rightarrow \quad t = \frac{d}{c+v}. \tag{36}$$

L-ARF is based on the absolute velocities v and v' of the two inertial reference frames S and S'. In a concrete physical experiment, however, these velocities are not known — what is measurable is the relative velocity between S and S'.
From the two equations:

$$t' = \frac{d}{c+v'}, \qquad t = \frac{d}{c+v} \tag{37}$$

it follows that $0 < v < v'$ gives $0 < t' < t$ — the light signal reaches S' before S, which is consistent with the figures.
From the same equations we can express v and v':

$$v' = \frac{d}{t'} - c, \qquad v = \frac{d}{t} - c. \tag{38}$$

The relative velocity $r_v = v' - v$ then becomes:

$$r_v = \frac{d}{t'} - \frac{d}{t} = d\left(\frac{1}{t'} - \frac{1}{t}\right) = \frac{d(t-t')}{tt'}. \tag{39}$$

This result is derived for the case $0 < v < v'$. For the case $0 < v' < v$, analogously $t < t'$ and the relative velocity becomes $r_v = d(t'-t)/tt'$. The two cases can be summarized as:

$$r_v = \frac{d\,|t-t'|}{tt'}. \tag{40}$$

Here d, t and t' are measurable quantities — r_v can therefore be determined without knowledge of the absolute velocities v and v'.

9 Simultaneity in L-ARF

Simultaneity is defined as two or more events occurring at exactly the same point in time. In L-ARF, two central cases are analyzed [4].

Case 1: Two events — one observer

An observer O is located midway between two points P_{left} and P_{right} at distance d. At these points, two events occur that send light signals toward O. The observer registers the arrival times t_{left} and t_{right}.

This is precisely the setup analyzed in Section 3, in the subsections on the apparatus at absolute rest and in motion. The conclusion is:

- If $t_{\text{left}} = t_{\text{right}}$ — the two events are simultaneous in an absolute sense.
- If $t_{\text{left}} \neq t_{\text{right}}$ — the two events are not simultaneous in an absolute sense.

Case 2: One event — two observers

An event occurs at point O. Two observers S and S' move with absolute velocities v and v' and register the event at times t and t'.

This is analyzed in Section 8, where the light signal from O reaches S' at time t' and S at time t.

Conclusion

In L-ARF, simultaneity is absolute — not relative. Whether two events are simultaneous can be determined if positions and times are known. The answer then applies to all observers.

10 L-ARF and SR — a Confrontation

Both L-ARF and SR are based on the same physical observation: light propagates in vacuum at constant speed c, independent of source and observer. That is the only common ground.

The two frameworks differ fundamentally — in their assumptions, their methods and their conclusions. L-ARF is based on a single fundamental premise and derives everything from the physical path length of light signals. SR is based on two postulates and introduces concepts such as time dilation, length contraction and relative simultaneity as physical effects.

In SR, v is the relative velocity between S and S'. The speed of light c is assumed to be the same in all inertial reference frames — it is not defined relative to a specific reference frame such as vacuum. Therefore v and c in SR do not refer to the same reference frame, and expressions of the form $c \pm v$ do not satisfy the fundamental condition for operations between velocities: that both must be defined relative to the same reference frame [2]. In L-ARF, c, v and v' all refer to the same reference frame — vacuum — and the expressions $(c \pm v)$ and $(c \pm v')$ follow naturally.
The following table summarizes the central similarities and differences:

Aspect	**L-ARF**	**SR**
In common		
Speed of light	c constant in vacuum, independent of source and observer	c constant in vacuum, independent of source and observer
Domain of application	Inertial reference frames	Inertial reference frames
Differences		
Number of postulates	One fundamental premise	Two postulates
Absolute motion	Measurable via arrival times	Cannot be established
Relative velocity	$r_v = \dfrac{d\,\lvert t - t'\rvert}{tt'}$ — expressed via measurable quantities	v is by definition the relative velocity between S and S'
Transformation	$x' = x \cdot \mathrm{rf}$, $t' = t \cdot \mathrm{rf}$, independent	Lorentz transformation, couples x and t
Horizontal light clock	Arrival times reveal the absolute velocity of the apparatus	Requires length contraction to give consistent result
Space and time	No physical coupling	Coupled via γ
Time dilation	Does not exist as a concept	Physical effect
Length contraction	Does not exist as a concept	Physical effect
Simultaneity	Absolute, not used	Relative

Table 2: Comparison between L-ARF and SR.

11 Conclusions

L-ARF demonstrates that a single fundamental premise — the constancy of the speed of light in vacuum — is sufficient to derive a complete and consistent framework for transformations between inertial reference frames and to describe physical phenomena involving light signals.

Foundations

L-ARF rests on the following foundations:

- Light propagates in vacuum at constant speed c, independent of source and observer.
- Time is defined exclusively from the path length of the light signal: $t = s/c$.
- The origin positions of light signals are fixed in vacuum and do not move with the apparatus.
- Reference frames move with absolute velocities relative to vacuum.

Consequences

From these foundations it follows:

- Absolute motion and rest are measurable via the arrival times t_{left} and t_{right}.
- The relative velocity between S and S' can be determined from measurable quantities: $r_v = d\,|t - t'|\,/\,tt'$.
- The transformation between inertial reference frames is expressed through the relativity factor $\mathrm{rf}(v, v')$ with 9 distinct forms, derived from 26 thought experiments.
- x' and t' are transformed independently of each other via the same factor $\mathrm{rf}(v, v')$.
- There is no physical coupling between space and time.
- The round-trip time of light signals in a moving apparatus is γ^2 times longer than at rest.
- The concepts of time dilation and length contraction do not exist in L-ARF.
- L-ARF, based on 26 thought experiments [1], is free from contradictions and paradoxes.

L-ARF demonstrates that a single fundamental premise — the constancy of the speed of light in vacuum — is sufficient to derive a complete and consistent framework for transformations between inertial reference frames and to describe physical phenomena involving light signals.

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Statements and Declarations

Funding

No funding was received for conducting this study.

Competing Interests

The author has no competing interests to declare that are relevant to the content of this article.

Author Contributions

All ideas, scientific content, derivations and conclusions were developed solely by the author. AI-assisted tools were used for language editing, structural suggestions, and LaTeX formatting during the preparation of this manuscript.

Data Availability

No datasets were generated or analysed during the current study.