# 8. The constant phase-velocity of light

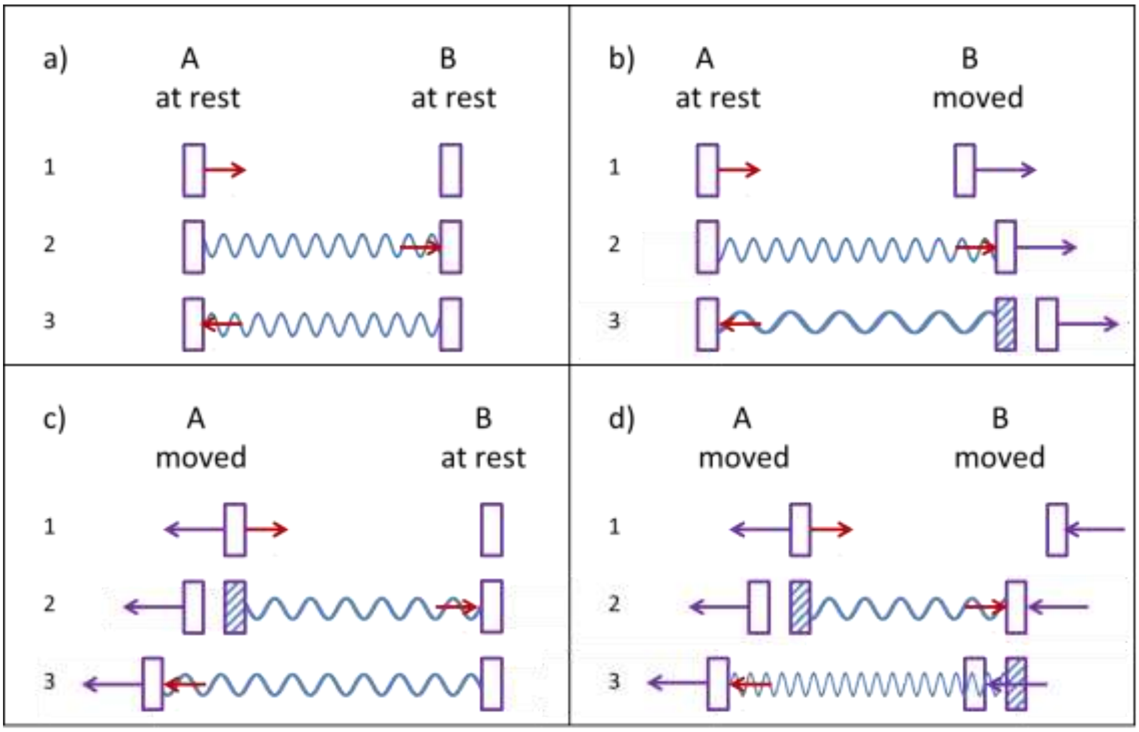
The topics discussed so far showed exact conformance with the explanations presented in many other important and undisputed publications. In the following the observations of transmitted signals with constant frequency will reveal an aspect, however, that is in contradiction to established interpretations. These can only be solved when the constant phase velocity of light is considered; this issue is therefore of great relevance for Special Relativity and the most important part of the examinations presented here. Subsequently it will become clear, that the assumption of a system at absolute rest in the universe is generally in contradiction to Special Relativity but when using the principle of constant phase velocity, it is just a special case inside the theory without violating basic experimental results.

## 8.1 Incoherency with Special Relativity using the standard derivation

In Figs. 8.1a and 8.1b the situation is illustrated, that two observers A and B exchange light signals. At the beginning (position no. 1) a signal is transmitted from observer A, and at no. 2 it is received from B and reflected immediately. At position no. 3 observer A is receiving the returning signal and the experiment comes to an end. Observers A and B are either at rest relative to each other (case a, d and g) increase the distance (case b and c) or approaching each other (case e and f). The transmitted and received signals are analyzed. It is well-known that transmitted signals with a constant frequency leaving a moving system are received with a higher frequency by a second observer when they approach each other, and the frequency is lower in the opposite direction. The relation is described by

$$f' = \frac{1}{T'} = f_0 \left( \frac{1 + \frac{v}{c}}{1 - \frac{v}{c}} \right)^{1/2} = f_0 \cdot \gamma \left( 1 + \frac{v}{c} \right) \qquad (8.01)$$

It is considered that the frequency of a moved observer is lower by the factor $\gamma$ because of time dilatation. The values for the calculated frequency $f$, the covered distance $a$, the necessary time $t$ and the number $n$ of the oscillations in these intervals are presented in the following tables.

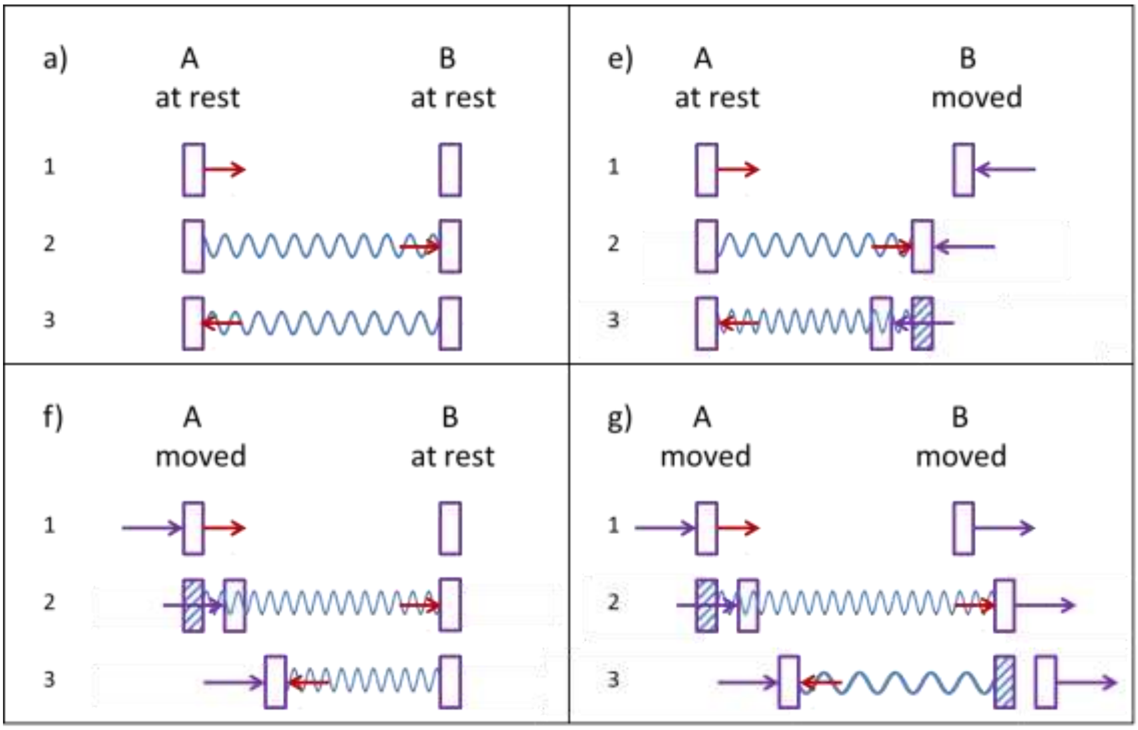



1: Emitting signal from A
2: Receiving at B, reflection to A
3: Receiving at A

| Case | $f_A$ | $f_{A\to B}$ | $f_B$ | $f_{B\to A}$ | $f_A$ |
|---|---|---|---|---|---|
| a | $f_0$ | $f_0$ | $f_0$ | $f_0$ | $f_0$ |
| b | $f_0$ | $f_0$ | $f_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{1/2}$ | $f_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ | $f_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ |
| c | $\frac{f_0}{\gamma}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ |
| d | $\frac{f_0}{\gamma}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}$ |

| Case | $a_{A\to B}$ | $a_{B\to A}$ | $t_{A\to B}$ | $t_{B\to A}$ | $n_{A\to B}$ | $n_{B\to A}$ |
|---|---|---|---|---|---|---|
| a | $a_0$ | $a_0$ | $t_0$ | $t_0$ | $n_0$ | $n_0$ |
| b | $a_0\frac{1}{1-\frac{v}{c}}$ | $a_0\frac{1}{1-\frac{v}{c}}$ | $t_0\frac{1}{1-\frac{v}{c}}$ | $t_0\frac{1}{1-\frac{v}{c}}$ | $n_0\frac{1}{1-\frac{v}{c}}$ | $n_0\frac{1}{1+\frac{v}{c}}$ |
| c | $a_0$ | $a_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ | $t_0$ | $t_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ | $n_0\left(1-\frac{v}{c}\right)$ | $n_0\left(1+\frac{v}{c}\right)$ |
| d | $a_0\frac{1}{1+\frac{v}{c}}$ | $a_0\frac{1}{1-\frac{v}{c}}$ | $t_0\frac{1}{1+\frac{v}{c}}$ | $t_0\frac{1}{1-\frac{v}{c}}$ | $n_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ | $n_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ |

Fig. 8.1a: Exchange of signals between observers A and B and analysis of the resulting frequencies and oscillation periods




1: Emitting signal from A
2: Receiving at B, reflection to A
3: Receiving at A

| Case | $f_A$ | $f_{A\to B}$ | $f_B$ | $f_{B\to A}$ | $f_A$ |
|---|---|---|---|---|---|
| a | $f_0$ | $f_0$ | $f_0$ | $f_0$ | $f_0$ |
| e | $f_0$ | $f_0$ | $f_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{1/2}$ | $f_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ | $f_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ |
| f | $\frac{f_0}{\gamma}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ |
| g | $\frac{f_0}{\gamma}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}$ | $\frac{f_0}{\gamma}\cdot\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)^{1/2}$ | $\frac{f_0}{\gamma}$ |

| Case | $a_{A\to B}$ | $a_{B\to A}$ | $t_{A\to B}$ | $t_{B\to A}$ | $n_{A\to B}$ | $n_{B\to A}$ |
|---|---|---|---|---|---|---|
| a | $a_0$ | $a_0$ | $t_0$ | $t_0$ | $n_0$ | $n_0$ |
| e | $a_0\frac{1}{1+\frac{v}{c}}$ | $a_0\frac{1}{1+\frac{v}{c}}$ | $t_0\frac{1}{1+\frac{v}{c}}$ | $t_0\frac{1}{1+\frac{v}{c}}$ | $n_0\frac{1}{1+\frac{v}{c}}$ | $n_0\frac{1}{1-\frac{v}{c}}$ |
| f | $a_0$ | $a_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ | $t_0$ | $t_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ | $n_0\left(1+\frac{v}{c}\right)$ | $n_0\left(1-\frac{v}{c}\right)$ |
| g | $a_0\frac{1}{1-\frac{v}{c}}$ | $a_0\frac{1}{1+\frac{v}{c}}$ | $t_0\frac{1}{1-\frac{v}{c}}$ | $t_0\frac{1}{1+\frac{v}{c}}$ | $n_0\left(\frac{1+\frac{v}{c}}{1-\frac{v}{c}}\right)$ | $n_0\left(\frac{1-\frac{v}{c}}{1+\frac{v}{c}}\right)$ |

Fig. 8.1b: Exchange of signals between observers A and B and analysis of the resulting frequencies and oscillation periods

It is not possible for both observers to decide based on a frequency analysis whether they belong to system a), d), g) or b), c) resp. e), f). Considering the number of oscillations between the observers, however, it should be clear that A and B according to the "principle of identity" (see chapter 1.6) in cases d) and g) for the signals coming and going (situation 2 and 3) should measure the same values. A similar situation exists for b) and c) resp. e) and f). It is obvious at first sight and without calculation that this cannot be the case. In the following this will be discussed in detail.

In the tables of Fig.8.1a and 8.1b the results for the frequencies measured by an observer at rest are shown. It is incorporated, that the generated frequencies in a moving system appear to be reduced by the factor $\gamma$ for an observer at rest. In the second part of the table the values for the distance $a$, the travelling time for the signal exchange $t$ and the number $n$ of the oscillations in these intervals are presented. The number of oscillations is calculated using

$$n = f \cdot t \tag{8.02}$$

If the light signals are passing through an interferometer and have the possibility for interaction, the observer at rest should be able to monitor interference patterns. Turning the system by a degree of 90° towards the direction of motion the interference effect should disappear.

Out of these considerations it is clear, that a discrepancy between the results of the number of oscillations between the moving system and the system at rest exists. Corresponding to the presented diagrams the observations in these systems should be completely different. According to this general theoretical approach the principle of relativity is violated here.

Not surprisingly in reality this is not the case, however. The explanation for this is that measurements by the moving observer cannot directly be compared with that of an observer at rest. Because of the dependency of measurements of electromagnetic waves on time and space, the two observers would find different results using this approach. To resolve the problem, it is therefore necessary to introduce the phase velocity, which is equal to the speed of light for both observers.

When considerations of phase velocities are used, the conformity between the numbers of oscillations detected by the two observers can be derived without difficulty. This is in particular valid for the results in the discussed cases a, d and g. Because of the impact of this important feature the effect of phase velocity is discussed in detail in the following chapter.

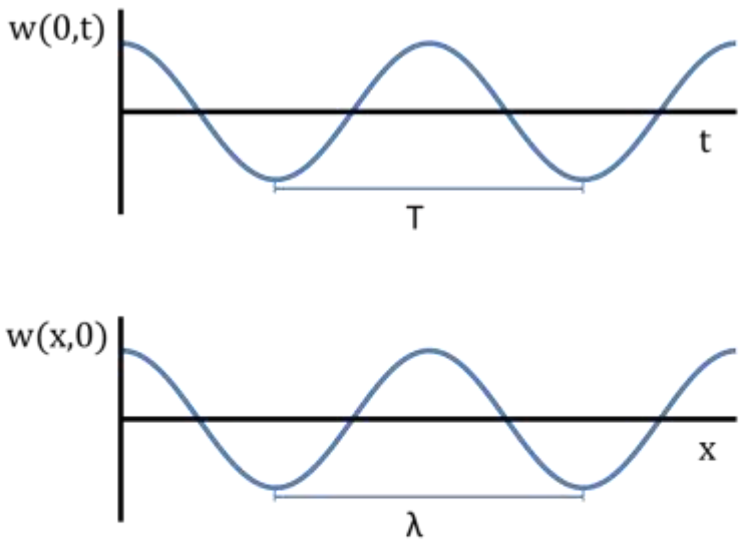
## 8.2 Concept of phase velocity to overcome the discrepancies for observers

During an exchange of signals between two observers, which are generally using light beams for transmission, in a standard case harmonic oscillation will be used. It is not possible to integrate these oscillations directly into a space-time-diagram (i.e. in a Minkowski-diagram). In short summary waves are typically considered in a way, that one of the variables (i.e. time) is looked at as constant and the other (for this example: space) is varying. Taking the simple example of a wave, which is produced when a stone is thrown into water, the investigation could be performed by taking a picture and measuring the distance of the wave peaks (in this case time is constant). If in a further measurement the distance is kept constant, e.g. by measuring a small cork moving up and down, then the frequency of the wave can be calculated by measuring the time between two defined points e.g. the maxima. Out of the combination of these measurements the velocity of the wave, which is travelling with a certain phase velocity, can be calculated. It is also possible, however, to observe the moving maxima in a direct way and measure the dependencies of time and the traveled way by taking a video.

The situation can be described as follows: The oscillation is dependent on space ($x$) and time ($t$) and is corresponding to the following equation [46a]

$$w(x,t) = A_0 \cos\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x - \alpha\right) \tag{8.10}$$

In this case $A_0$ is the amplitude, $T$ is the oscillation time (considering a stationary view), $\lambda$ is the oscillation length (considering constant time) and $\alpha$ is the angle at the starting point.




$$\alpha = 0, \qquad x = 0$$

$$w(0,t) = A_0\, cos \frac{2\pi}{T} t$$

$$\alpha = 0, \qquad t = 0$$

$$w(x,0) = A_0\, cos \frac{2\pi}{\lambda} x$$

Fig. 8.2: Oscillation diagram for constant space ($x = 0$) and constant time ($t = 0$) with starting point $\alpha = 0$

A major simplification is possible, when the variation of space *and* time of a certain point of the wave (i.e. the maximum) is defined as constant (see Fig. 8.3). In this case the cosine remains unchanged, and it applies

$$\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x - \alpha = const. \tag{8.11}$$

After differentiation of this equation

$$\frac{\Delta t}{T} - \frac{\Delta x}{\lambda} = 0 \qquad (8.12)$$

the phase velocity $u$ of this point will be described by

$$u = \lim_{\Delta \to 0} \frac{\Delta x}{\Delta t} = \frac{\lambda}{T} \qquad (8.13)$$

Without the dispersion by a medium (as it is the case in a vacuum), the formula develops to

$$u = \frac{\lambda}{T} = c \qquad (8.14)$$

This derivation using the mathematical concept of differential quotient and limes provides a good explanation of the physical principle [46a], more complex deductions with 4-vector and gradient are also possible and obviously come to the same solution [27].

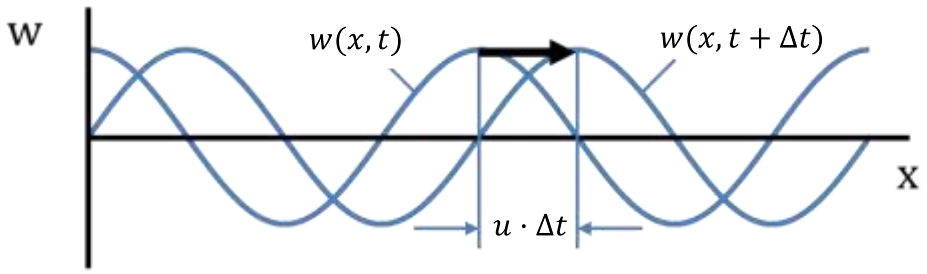



Fig.8.3: Phase velocity $u$ as propagation speed of defined parts of the oscillation (i.e. the maximum)

Thus, the main conclusion is that the phase velocity of an electromagnetic wave measured in any arbitrary inertial system is **exactly equal to the speed of light**. In Fig. 8.4 the phase velocity is presented as a function of space and time. Because it obviously shows a linear characteristic the graph will be a straight line with origin zero and, after scaling, it will display an angle of 45° to the $x$- and $t$-coordinate. The right part of the diagram is showing in addition the graphs for a moving observer with velocities of $v = 0.2c;\ 0.5c; 0.8c$.

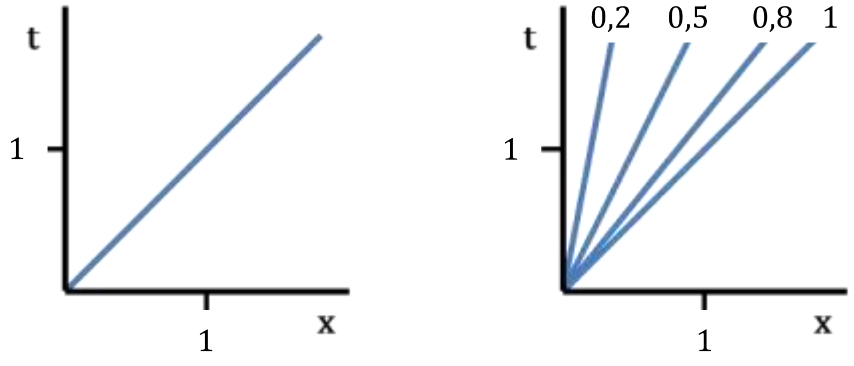



Fig. 8.4: Left: Phase velocity as a function of time and space (scaled diagram)
Right: Velocities of moved observers with different speed added

At this point it becomes clear, that this presentation is exactly coherent with a Minkowski-diagram. This means, that a phase-propagation (i.e. the maximum of a wave) can be taken as a short light pulse and therefore it can be incorporated in diagrams of this type and evaluated in the same way.

In Fig. 8.5 a situation like this is illustrated. The presentation of this diagram seems to be unusual at first sight. Having a closer look, however, some important issues can be derived from it, so that the appearance of this Minkowski-diagram will be discussed in detail in the following. Many important examinations are possible, but a clear arrangement in one diagram would not be reasonable because of the quantity of information. So, it was decided to use in Figs. 8.6 and 8.7 the same chart, covering additional information while others were skipped.

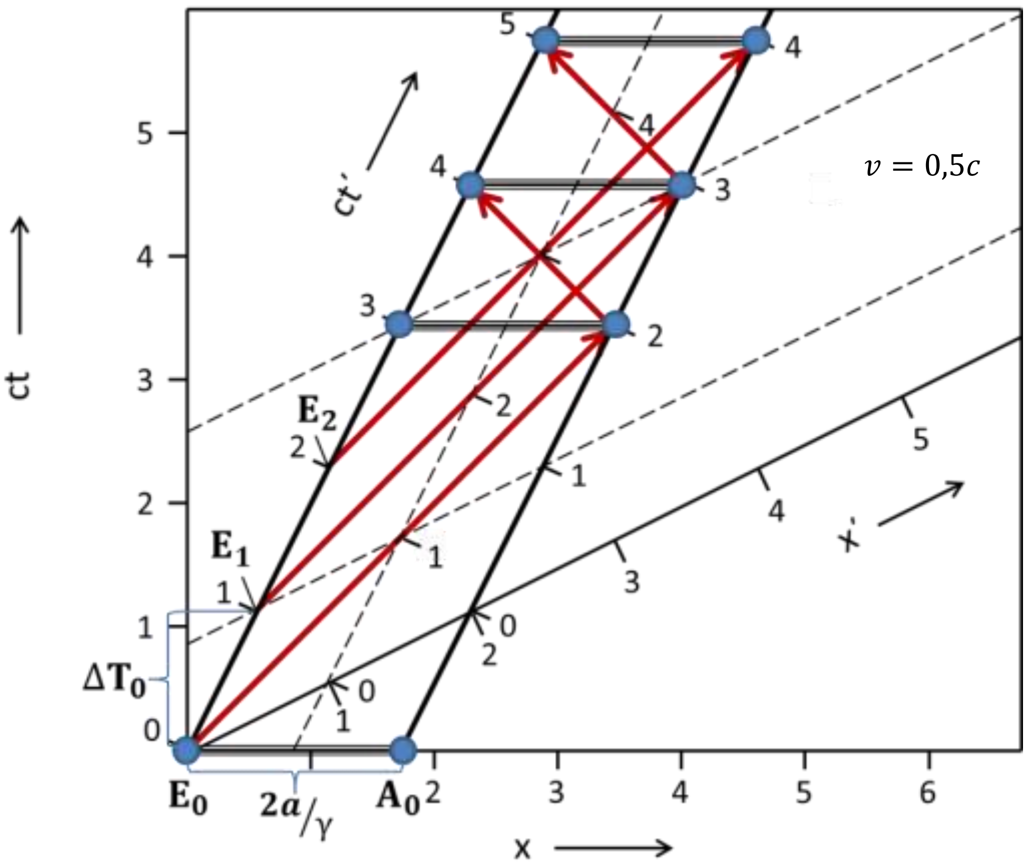



Fig. 8.5: Minkowski diagram for the exchange of signals inside a moving system

First the general setting of the chosen experiment shall be discussed: A laboratory with the length $2a$ is moving relative to another observer at rest with the speed $v = 0{,}5\ c$. The diagram is scaled to 1 concerning space and time (this means that $a = 1$ for a laboratory at rest). At time zero the moving observer starts from point $E_0$ with the transmission of a harmonic oscillation of 1Hz and is beginning with a maximum. The oscillation is reflected at point A and sent back to E.

The observer at rest will find, that the moved laboratory has a length of $2a/\gamma$. Because of his view on the time dilatation in the moved system, he will additionally find that the oscillation will end at $\Delta T_0 = \gamma$ (at point $E_1$). The following maxima will therefore start at $E_1$, $E_2$ etc. and can also be interpreted as separate pulses and so it is possible to record them in this diagram as well.

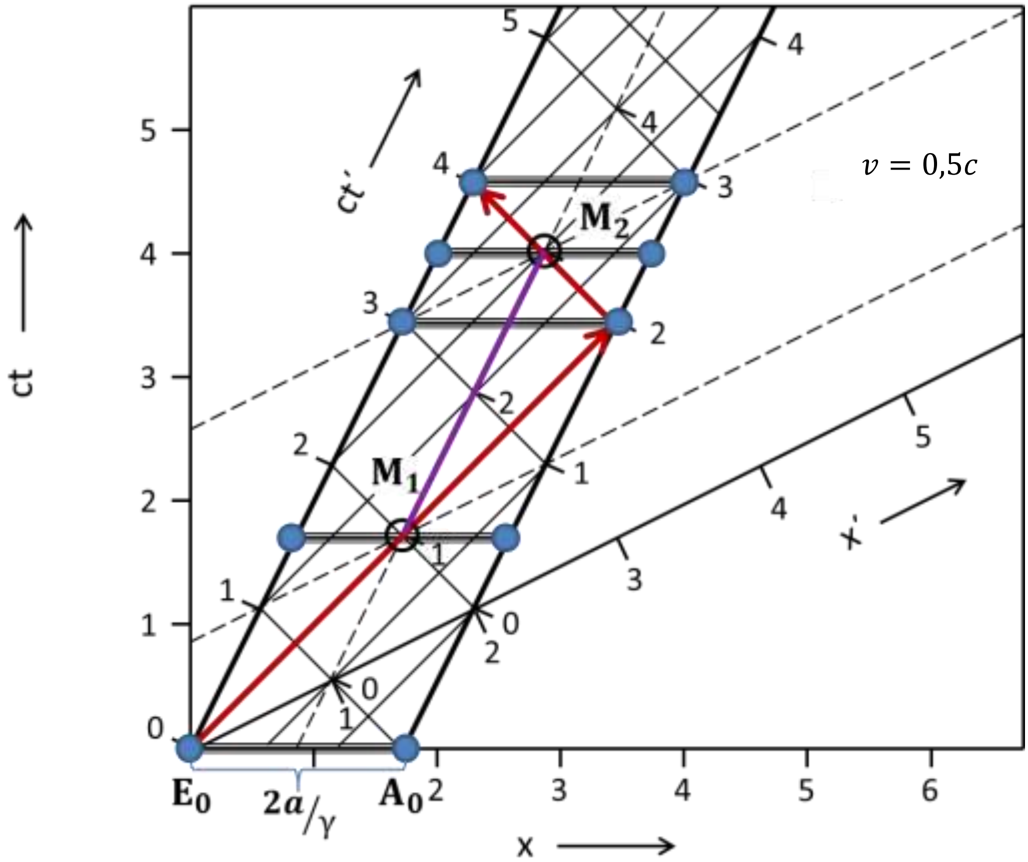



Fig. 8.6: Minkowski diagram for the exchange of signals in a moving system (middle section), variation of Fig. 8.5

The maximum of the oscillation it is moving at a speed of $v = c$ and is reaching the middle at

$$t_{M_1} = \frac{1}{\gamma \cdot \left(1 - \frac{v}{c}\right)} \tag{8.15}$$

(see Fig. 8.6) Point A will be reached after twice the time. When the wave is reflected, the point $M_2$ will be passed at

$$t_{M_2} = \frac{2}{\gamma \cdot \left(1 - \frac{v}{c}\right)} + \frac{1}{\gamma \cdot \left(1 + \frac{v}{c}\right)} = \gamma \cdot \left(3 + \frac{v}{c}\right) \tag{8.16}$$

This is exactly the value, that would be yielded by a pulse emitted from $E_2$ (equivalent to the maximum of a wave) which leads to

$$t_{M_2} = 2\gamma + \frac{1}{\gamma \cdot \left(1 - \frac{v}{c}\right)} = \gamma \cdot \left(3 + \frac{v}{c}\right) \tag{8.17}$$

This calculation shows that the situation in the middle of the moved laboratory reveals exact the same conditions compared to an observer at rest. In the latter case a signal would be emitted by $E_0$, that after reflection arrives back at $t = 3$ in the middle of the laboratory. Another signal, that is sent from $E_0$ at $t = 2$ would reach the middle at the same time. This is as already presented also valid for the moved observer when phase velocities are considered.

The relations presented here can easily be transferred to other situations, if for example frequency, geometry or other conditions are modified. This is leading to the general statement, that the measurement of the number of oscillations under no circumstances can be used to measure the state of motion of an inertial system.

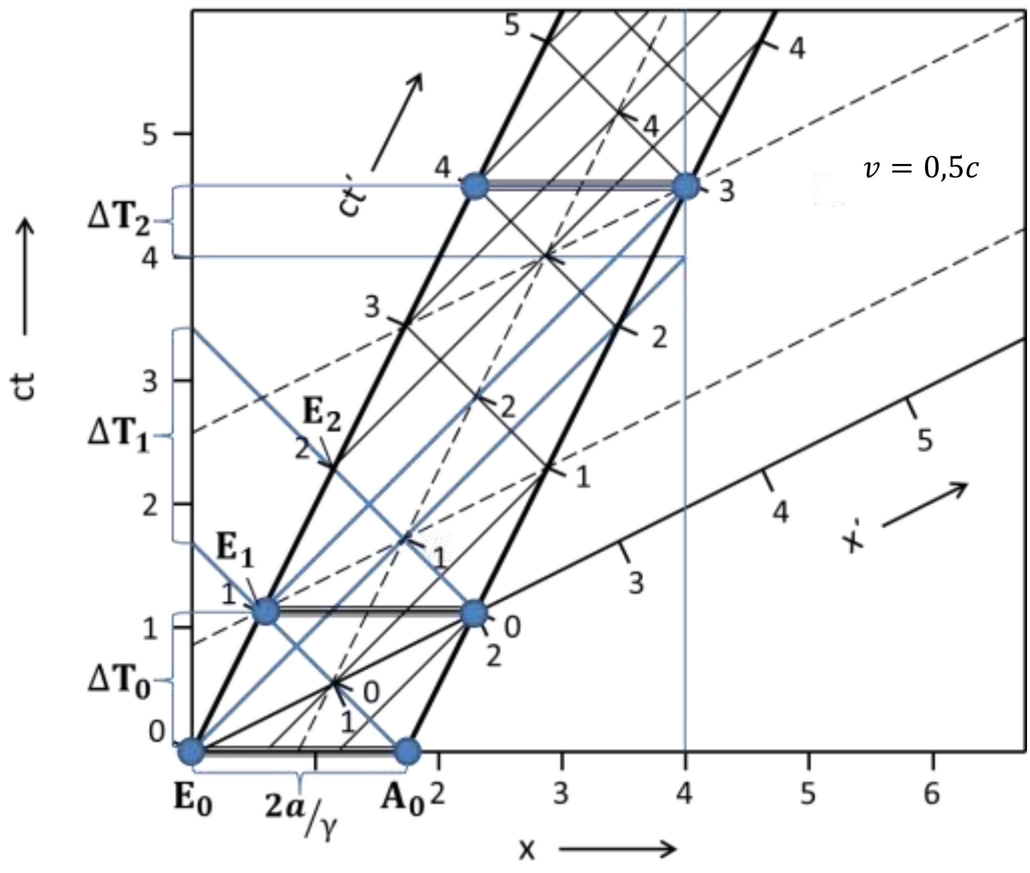



Fig. 8.7: Minkowski diagram for the exchange of signals in a moving system, variation of Fig. 8.5

Furthermore, the values for oscillation time and frequency of an observer at rest shall be derived out of this diagram. If the testing object is increasing the distance the value is

$$\Delta T_1 = \frac{1}{f_1} = \frac{1}{\gamma \cdot \left(1 - \frac{v}{c}\right)} \tag{8.18}$$

and when it is approaching

$$\Delta T_2 = \frac{1}{f_2} = \frac{1}{\gamma \cdot \left(1 + \frac{v}{c}\right)} \tag{8.19}$$

This is in accordance with standard publications (i.e. [46b]).

As main result it is possible to prove, that concerning the radiation of light in any arbitrary inertial system the phase velocity of the light emitted by one source is equal to the measurement of the speed of light in any of these systems (this is of course not the case for the simple example of surface waves on water!). The important finding derived by the considerations presented here, is that during the transition from an arbitrary inertial system to another not the speed of light, but the phase velocity remains unchanged. It was clearly shown that this is required by the theory of Special Relativity and otherwise contradictions would appear.

In the literature the importance of phase velocity in connection with Special Relativity is treated very differently. In a normal case it is not mentioned at all in books, lecture notes or publications, but there is an exception in the work of R. K. Pathria [16]. Herein the "invariance of phase velocities" between systems moved relative to each other is examined in extenso, but no further consequences concerning the theory are discussed.

The discovered relations are of great importance for the theory. It is interesting, however, that it is not possible to find this concept in the literature up to now. Because of this reason it is necessary to reconsider classical experiments, in particular those of Michelson-Morley and also Kennedy-Thorndike. It will be demonstrated that the use of the concept presented here will lead to a different understanding of the results. This will be presented in detail in chapter 9.

Finally, it is possible - before developing the theoretical background further - to present a first result of the examinations:

- It is possible, that the universe is at absolute rest and all electromagnetic waves are travelling with the speed of light $c$ inside this system.
- Observers in any inertial system with an arbitrary velocity relative it can only measure the phase velocity of these waves and doing this they will find also the same value of $c$.

At first these perceptions will be used to carry out new interpretations of classical experimental results. After further discussions finally in chapter 13 a proposal for modification of the theory of special relativity will be presented.