# How to Solve the Clock Synchronization Problem to Measure the One-Way Speed of Light and Change a Second-Order Experiment to First-Order

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**Abstract**

Measuring the one-way speed of light is deemed impossible because it requires synchronizing distant clocks which in turn depends on the one-way speed of light. The constancy of the one-way speed of light in the Special Relativity theory is therefore an assumption that is not based on any direct experimental evidence. In this paper a new method to synchronize distant clocks and measure the one-way speed of light at the same time is explained. Traditionally, clock synchronization and one-way speed of light measurement are seen as two separate procedures. This paper reveals a novel yet simple way to turn a second order (time-of- flight) light speed experiment into a much more sensitive first-order experiment.

## Introduction

The question of whether absolute motion can be detected is still an unresolved problem in physics. A method to test this would be to measure the one-way speed of light between two points. Such experiments are first-order and are much more sensitive than second-order experiments which involve two-way speed of light.

However, measuring the one-way speed of light is deemed impossible [1] because it requires synchronizing distant clocks which in turn depends on the one-way speed of light. Therefore, the constancy of the one-way speed of light in the Special Relativity theory is an assumption not based on any direct experimental evidence. In this paper a new method to synchronize distant clocks and measure the one-way speed of light *at the same time* is explained. This paper reveals a novel yet simple way to turn a second-order (time-of-flight) light speed experiment into a much more sensitive first-order experiment.

## Synchronizing distant clocks, measuring the one-way speed of light

Consider a physicist doing a light speed experiment in a closed lab on Earth or somewhere in space (Fig.1). There are two clocks $C_1$ and $C_2$ in the lab, each with their own associated light transmitters and detectors to exchange time signals. The distance between the clocks is equal to $D$ .

The experiment is setup to measure the one-way speed of light in the lab. For this a light pulse is transmitted from clock $C_1$ to clock $C_2$ and the one-way speed of light could be determined from the distance $D$ and the time it takes the light pulse to travel from $C_1$ to $C_2$ . Suppose that a light pulse is transmitted from clock $C_1$ at time $t = t_1$ and detected at clock $C_2$ at time $t = t_2$ . Therefore, the one-way speed of light would be:

$$\frac{D}{t_2 - t_1}$$

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For this, the clocks $C_1$ and $C_2$ need to be synchronized first (Fig.1). The new procedure is as follows.

The time of clock $C_1$ is set to $t_0 = 0$ and at the same time a short synch light pulse is sent to clock $C_2$. We assume that the lab is moving with some unknown velocity *v* relative to an unknown reference frame. Although we have assumed the lab is moving with velocity *v*, we synchronize the clocks by assuming isotropy of the speed of light. Therefore, upon receiving the synch pulse, the time of clock $C_2$ is set to:

$$t_1 = \frac{D}{c}$$

However, this synchronization procedure will result in clock $C_2$ lagging behind clock $C_1$ by an amount:

$$\delta = \frac{D}{c-v} - \frac{D}{c} = D\,\frac{v}{c(c-v)}$$

Now, at some later time $t_2$ , let clock $C_2$ emit time signal back to clock $C_1$ . At this instant the time of clock $C_1$ will be:

$$t_2 + \delta = t_2 + D\,\frac{v}{c(c-v)}$$

Clock $C_1$ will receive the time signal at:

$$t_2 + D\,\frac{v}{c(c-v)} + \frac{D}{c+v}$$

which is the *actual* time of clock $C_1$ . The $c+v$ is because clock $C_1$ and the time signal are moving in opposite directions.

However, the *calculated* time of clock $C_1$ will be:

$$t_2 + \frac{D}{c}$$

The difference between the *actual* and *calculated* times of clock $C_1$ will be:

$$\Delta = t_2 + D\,\frac{v}{c(c-v)} + \frac{D}{c+v} - \left[\, t_2 + \frac{D}{c} \,\right]$$

$$\Delta = D\,\frac{v}{c(c-v)} + \frac{D}{c+v} - \frac{D}{c} = \frac{2D}{c}\,\frac{\frac{v^2}{c^2}}{1-\frac{v^2}{c^2}}$$

From knowledge of the difference between the actual and calculated times of $C_1$ , that is $\Delta$ , the value of the velocity *v* and hence the one-way speed of light can be determined from the above equation.

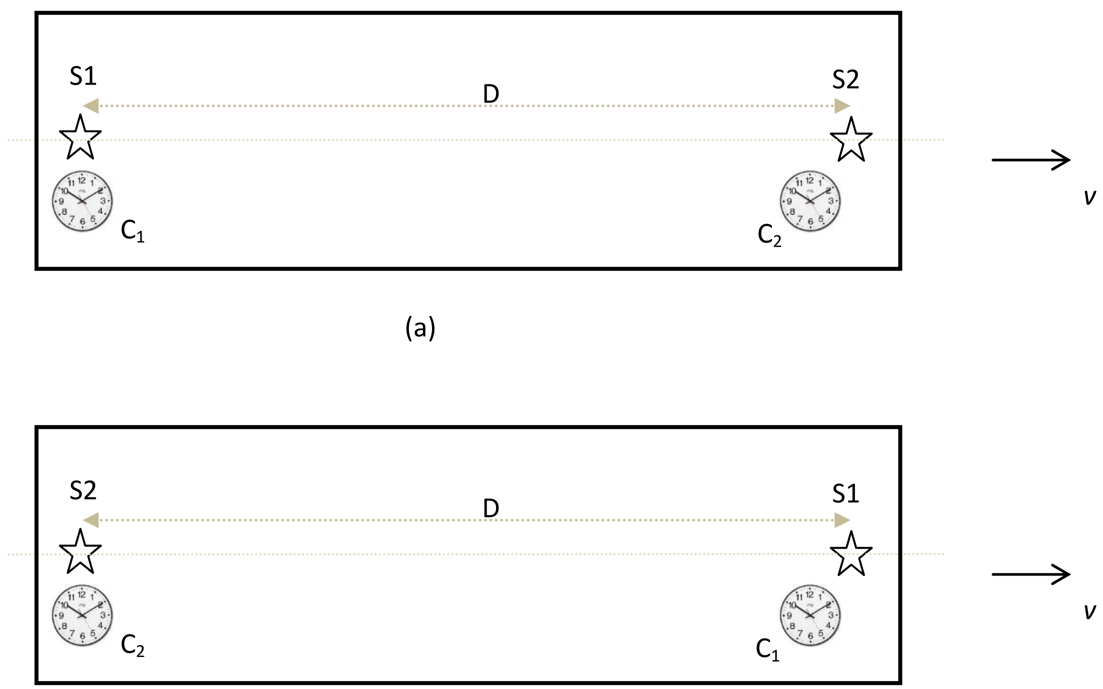
Therefore, this is a procedure that synchronizes and measures the one-way speed of light at the same time, without making any assumptions, unlike Special Relativity, on the isotropy or non-isotropy of the speed of light.


Fig. 1

## Turning a second-order experiment to first-order

Although we have successfully shown how to synchronize distant clocks and measure the one-way speed of light unambiguously in the last experiment, the experiment is a second-order experiment because Δ is a function of $v^2/c^2$ and such experiments are known to be much less sensitive than first order experiments.

Next we will see a novel yet simple and clear method in which this second-order experiment can be turned into first-order, distant clocks can be synchronized and the one-way speed of light can be measured unambiguously.




(b)

Fig. 2

The time of clock $C_1$ is set to $t_0 = 0$ and at the same time a short synch light pulse is sent to clock $C_2$ (Fig.2a). Again we assume that the lab is moving with some unknown velocity $v$ relative to an unknown reference frame. Although we have assumed the lab is moving with velocity $v$, we synchronize the clocks by assuming isotropy of the speed of light.

Therefore, upon receiving the synch pulse, the time of clock $C_2$ is set to:

$$t_1 = \frac{D}{c}$$

However, this synchronization procedure will result in clock $C_2$ lagging behind clock $C_1$ by an amount:

$$\delta = \frac{D}{c-v} - \frac{D}{c} = D\,\frac{v}{c(c-v)}$$

Next the two clocks (and their associated light emitters and detectors) exchange positions as shown ( Fig.2b ). Now, at some later time $t_2$ , let clock $C_2$ emits time signal to clock $C_1$ . At this instant, the time of clock $C_1$ will be:

$$t_2 + \delta = t_2 + D\,\frac{v}{c(c-v)}$$

Clock $C_1$ will receive the time signal at:

$$t_2 + D\,\frac{v}{c(c-v)} + \frac{D}{c-v}$$

which is the *actual* time of clock $C_1$ .

However, the calculated time of clock $C_1$ will be:

$$t_2 + \frac{D}{c}$$

The difference between the *actual* and *calculated* times of clock $C_1$ will be:

$$\Delta = t_2 + D\,\frac{v}{c(c-v)} + \frac{D}{c-v} - \left[t_2 + \frac{D}{c}\right]$$

$$\Rightarrow \quad \Delta = D\,\frac{v}{c(c-v)} + \frac{D}{c-v} - \frac{D}{c}$$

$$\Rightarrow \quad \Delta = 2D\,\frac{v}{c(c-v)} = \frac{2D}{c}\,\frac{v}{c-v}$$

$$\Rightarrow \quad \Delta = \frac{2D}{c}\,\frac{\frac{v}{c}}{1-\frac{v}{c}}$$

From knowledge of the difference between the actual and calculated times of clock $C_1$ , that is $\Delta$ , the value of the velocity $v$ and hence the one-way speed of light can be determined from the above equation. We can also see in the last equation that $\Delta$ is a function of $v/c$ .

The last two experiments are similar in that in both cases clock $C_1$ first sends a synch pulse to clock $C_2$ , which sets its time based on the isotropy of the speed of light. Then after some time, clock $C_2$ sends back time signal to clock $C_1$, which then calculates the time based on the assumption of isotropy of the speed of light by using the time signal from $C_2$ and compares it with its own time.

However, in the second experiment *the positions of the clocks are exchanged and this simple procedure turned a second-order experiment into a much more sensitive first-order experiment*!

Therefore, unlike the Special Relativity theory that just assumes constancy of the one-way of the speed of light without any direct experimental evidence, we have shown how to experimentally determine the one-way speed of light unambiguously without making any prior assumptions.

## Conclusion

The problems of the one-way speed of light and synchronization of distant clocks are century old problems that are some of the consequences of the theory of relativity. These were not seen as problems in classical physics. This paper has finally resolved this puzzle by using a novel yet simple method that has been overlooked for more than one century. Traditionally, the procedure of clock synchronization has always been seen as separate from the procedure of one-way light speed measurement. With this approach, the difficulty in clock synchronization led not only to the difficulty in measurement of the one-way speed of light, but also to the conclusion and belief that the one-way speed of light is fundamentally impossible to measure. This paper has shown that this conclusion is incorrect.

Glory be to God and His Mother, Our Lady Saint Virgin Mary

## References

1. One-way speed of light , Wikipedia

https://en.wikipedia.org/wiki/One-way_speed_of_light