Determination of the velocity of an opaque body moving uniformly by measurements inside it

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Research Article

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Determination of the velocity of an opaque body moving uniformly by measurements inside it

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Abstract

In this paper we show how the velocity of a moving uniform opaque body can be calculated without external references. This is done with the help of photodetectors, which measure the time of arrival of light from a point source to fixed equal distances inside the body. The calculation of the body's velocity is based on the postulates of the special theory of relativity that space is homogeneous, isotropic and the speed of light in vacuum is an invariant constant with a certain value independent of the velocity of the radiation source.

Keywords

Speed of light, opaque body, speed of movement, inertial reference system, time, distance.

1. Introduction

According to Einstein's special theory of relativity (STR), the speed of light in a vacuum is an invariant constant - it does not depend on the speed of the emitting source and determines the maximum possible speed of interactions. It has a value of C = 299 792 458 m/s.[1]
Time is not common to all systems and this is the main difference between it and the classical mechanics, according to which there is a single (absolute) time for all inertial reference systems. [2]. In order to use one and the same time here we will use only one inertial system.

It should be noted in the description that the speed of light *C* and the speed of motion of the inertial system *V* are vectors.

2. Propagation of a light signal from a point source in an inertial system

The setup of the virtual experiment is shown in Fig. 1. An observer O and a point light source S are firmly located at the center O of an inertial rectangular coordinate system K with axes X, Y and Z. The coordinate system moves uniformly with speed *V* in the direction of the X axis.

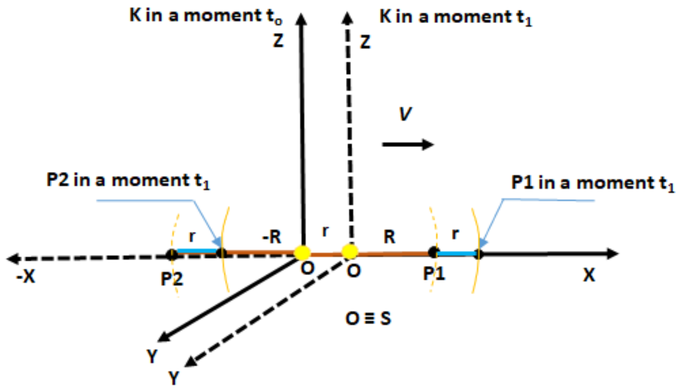

Fig. 1. Observer O and a point light source S, which are firmly connected to the origin O of a rectangular coordinate system K, moving at speed V

Two identical photodetectors with memory are mounted on the X axis at points P1 and P2 at equal distances R and –R from the center O. Both photodetectors have built-in precision clocks and can accurately register the time when a light signal reaches them.[4,5]

The time **t** flows in the same way in the system K along axis + X and along axis -X regardless of the value of the speed *V*, according to the STR. [3]

If at time $\mathbf{t_o}$ = 0, the clock of the observer and the clocks of the photodetectors are synchronized and at this moment we turn on the light source S, then since the speed of light *C* is invariant and does not depend on the speed of its source, it will pass for the same time t the distance R in both directions –X and + X. [6]

$$t = \frac{R}{C} \qquad (1)$$

At the same time t the coordinate system K will pass in the direction of *V* distance $r = Vt$.

Then the observer O, point P1 and point P2 will be shifted by a distance + r from their initial position. To reach point P1 the light front will have to travel a distance R + r, and to reach point P2 the light front will have to travel a distance R - r.

Therefore, the light signal will arrive at point P1 in time

$$t_1 = t + \frac{R}{C} = t + \frac{V}{C}t = (1 + \frac{V}{C})t$$

or in an inertial coordinate system, the time the light reaches point P1 at a distance R located in the direction of its motion with velocity *V* is

$$t_1 = (1 + \frac{V}{C})t \qquad (2)$$

The light signal will arrive at point P2 in time

$$t_2 = t - \frac{R}{C} = t - \frac{V}{C}t = (1 - \frac{V}{C})t$$

or in an inertial coordinate system, the time light reaches a point at a distance R located against the direction of its motion at speed *V* is

$$t_2 = (1 - \frac{V}{C})t \qquad (3)$$

Furthermore we have $t_1 > t_2$.

At $V = 0$, i.e. when K is stationary

$$t_1 = t_2 = t \qquad (4)$$

3. Determining the velocity of an opaque body moving uniformly

An observer O and a point light source S are located at the center of an arbitrarily oriented rectangular coordinate system K. The system K is located inside an arbitrarily chosen hollow opaque solid body. On both sides of the source S, as shown in Fig. 2, along the three axes of the coordinate system at equal distances x = -x = y = -y = z = -z = R are placed photodetectors, which accurately measure the time of arrival of the light front of the source S. If at time t_0 the observer turns on the light source and measure the arrival times of the light front t_x, t_{-x}, t_y, t_{-y}, t_z, t_{-z} in the photodetectors, then if $t_x = t_{-x} = t_y = t_{-y} = t_z = t_{-z}$ the body is stationary. If the times along any axis or simultaneously along all three axes differ, then the body moves.

If, for example, on the X axis the measured times t_x and t_{-x} differ so that $t_x > t_{-x}$, then the direction of the velocity component *Vx* is positive and vice versa.

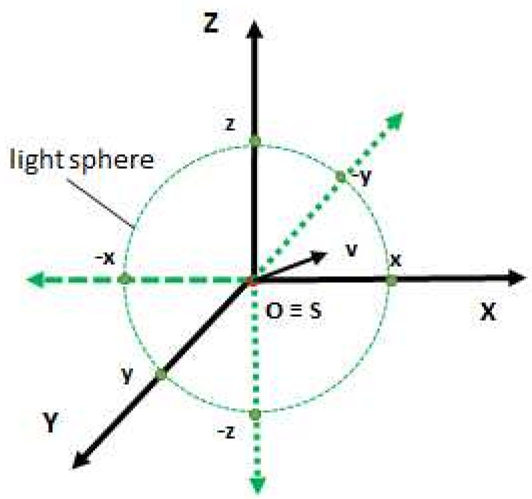

Fig.2. Determining the velocity of an opaque body moving uniformly

Having in mind (1) and the considerations above, and make substitutions in (2), we obtain

$$t_x = (1 + \frac{V_x}{C})\frac{R}{C} \quad (5)$$

Respectively

$$t_{-x} = (1 - \frac{V_{-x}}{C})\frac{R}{C} \quad (6)$$

If we multiply both sides of equation (5) by $\frac{C}{R}$ and make cancellation, then:

$$\frac{V_x}{C} = \frac{C}{R}t_x - 1$$

Therefore for V_x we get:

$$V_x = C(\frac{C}{R}t_x - 1) \quad (7)$$

Similarly, if we multiply the two sides of equation (6) by $\frac{C}{R}$, then after the transformations we receive:

$$V_{-x} = C(1 - \frac{C}{R}t_{-x}) \quad (8)$$

Applying the same considerations for V_x and V_{-x} we obtain the velocity components along the Y and Z axes

$$V_Y = C(\frac{C}{R}t_Y - 1) \quad (9)$$

$$V_{-Y} = C(1 - \frac{C}{R}t_{-Y}) \quad (10)$$

$$V_Z = C(\frac{C}{R}t_Z - 1) \quad (11)$$

$$V_{-Z} = C(1 - \frac{C}{R}t_{-Z}) \quad (12$$

If we denote by V_{ox} the velocity component along the X axis, then:

$$V_{ox} = V_x\text{, if } t_x > t_{-x} \quad (13)$$

$$V_{ox} = V_{-x}\text{, if } t_x < t_{-x} \quad (14)$$

$$V_{ox} = 0\text{, if } t_x = t_{-x} \quad (15)$$

Similarly, if we denote by $V_{\odot y}$ the velocity component along the Y axis, then:

$$V_{\odot y} = V_y, \text{ if } t_y > t_{-y} \quad (16)$$

$$V_{\odot y} = V_{-y}, \text{ if } t_y < t_{-y} \quad (17)$$

$$V_{\odot y} = 0, \text{ if } t_y = t_{-y} \quad (18)$$

And similarly, if we denote by $V_{\odot z}$ the velocity component along the Z axis, then:

$$V_{\odot z} = V_z, \text{ if } t_z > t_{-z} \quad (19)$$

$$V_{\odot z} = V_{-z}, \text{ if } t_z < t_{-z} \quad (20)$$

$$V_{\odot z} = 0, \text{ if } t_z = t_{-z} \quad (21)$$

Therefore, the required speed is

$$V = \sqrt{V_{\odot x}^2 + V_{\odot y}^2 + V_{\odot z}^2} \qquad (22)$$

4. Example of experimental verification

Let's mount an opaque non-flexible pipe with a length of 100 m in a wagon and create a vacuum in it. At one end we install a fixed point light source, and at the other end a photodetector. If the wagon is stationary, then according to (1), when the source is switched on, the light will travel the distance to the photodetector for a time t = $33.356409520 \times 10^{-6}$ s. If the wagon moves uniformly at a speed V = 100 km/h, then in the direction of movement of the wagon the light will reach the photodetector according to (2) for time $t_1 = 33.356412611 \times 10^{-6}$ s.

Therefore, the difference $t_1 - t = 309.06946026 \times 10^{-12}$ s. that is, 309.06946026 picoseconds, which is fully measurable with precise technique. [5,7,8]

5. Conclusion

We can determine whether or not an inertial system is moving using the independence of the speed of light from the radiation source and the invariance of its speed of propagation without an external observer.

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Figures

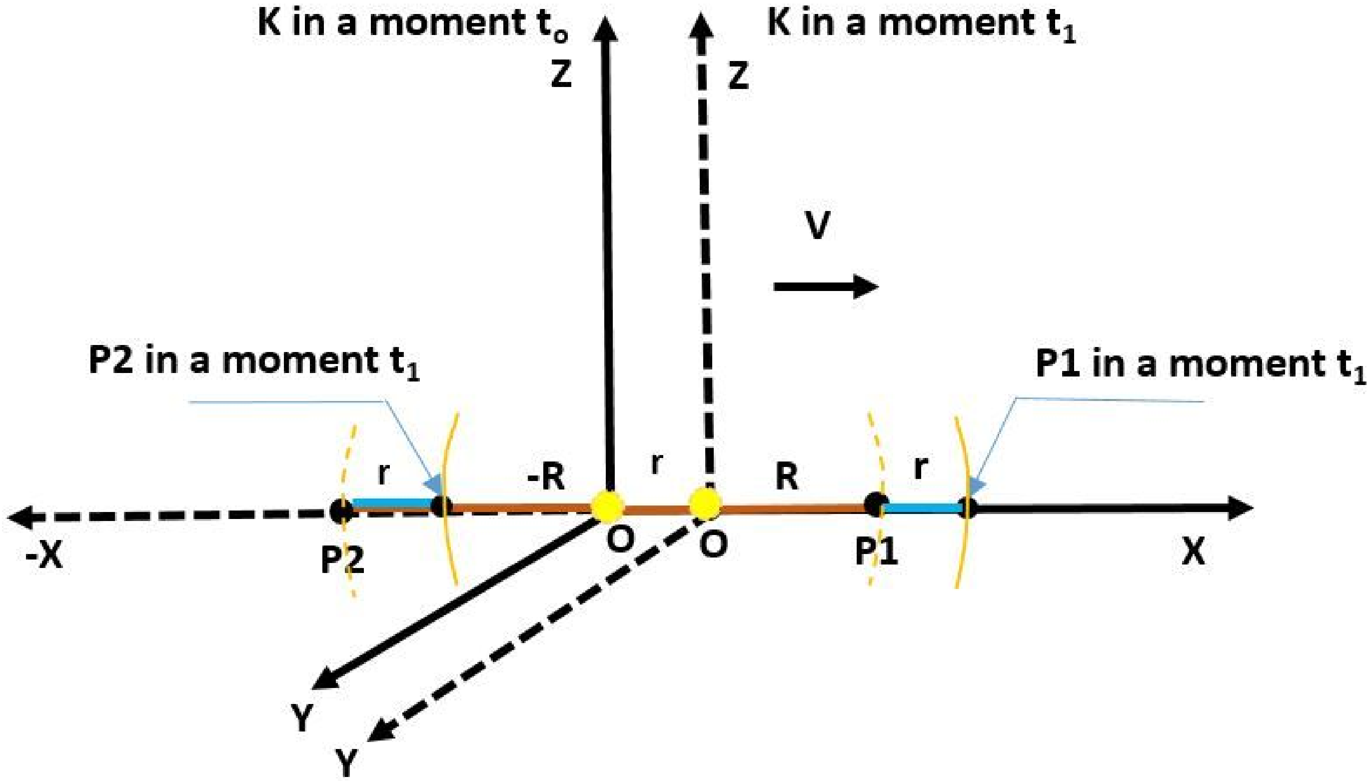

Figure 1

Observer O and a point light source S, which are firmly connected to the origin O of a rectangular coordinate system K, moving at speed V

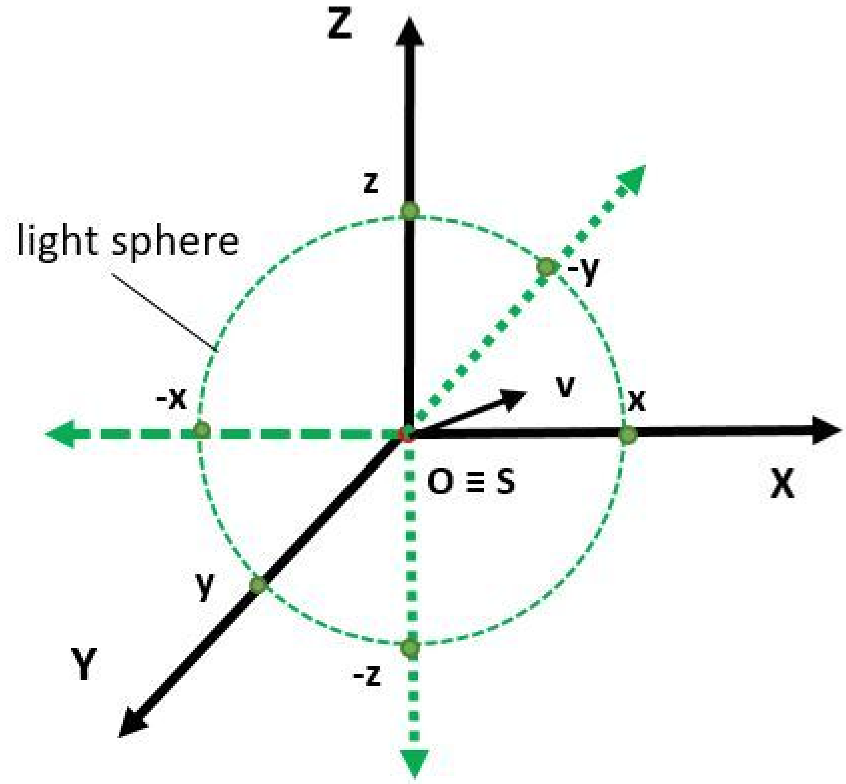

Figure 2

Determining the velocity of an opaque body moving uniformly