Proposal to Measure Absolute Velocity Using Two Independent Clocks

J.P. Wesley

Abstract

A toothed wheel rotated by an electric clock motor chops a laser beam. A second wheel a distance L *from the first again chops the beam. The resultant intensity is a linear function of the angle through which the second wheel rotates during the time light travels the distance* L, $\Delta t = L/(c - v_L)$, *where* v_L *is the absolute velocity of the laboratory in the direction* L. *Two beams are oriented so that the chopping increases the intensity of one and decreases the intensity of the other. Comparing these two intensities with the intensities of two beams traveling in the opposite direction directly yields the desired absolute velocity* $2v_L = c^- - c^+$ *electronically. The correct relative angular phase, determined by the intensities, is obtained by rotating one of the wheels together with its motor. The magnitude and direction of the absolute velocity of the solar system is obtained by fixing* L *in the north-south direction at a northern latitude and measuring* v_L *over a 12-h period.*

Key words: absolute velocity with independent clocks

1. HISTORICAL BACKGROUND

Roemer[1] in 1676 and Halley[2] in 1694 showed that the observed one-way velocity of light depends upon the velocity of the observer. When the Earth approaches Jupiter with the velocity v_e, the observed one-way velocity of light is $c + v_e$; and when the Earth recedes from Jupiter, the observed one-way velocity of light is $c - v_e$. In particular, the observed time between the eclipses of Jupiter's moons is $\Delta t^+ = \Delta t(1 - v_e/c)$ when the Earth approaches Jupiter, and $\Delta t^- = \Delta t(1 + v_e/c)$ when the Earth recedes from Jupiter. Knowing the Earth's velocity v_e and the mean period Δt, Roemer was the first to measure the speed of light; thus

$$c = 2\Delta t v_e/(\Delta t^- - \Delta t^+). \tag{1}$$

Conversely, knowing the value of c and assuming the velocity of light is c fixed with respect to absolute space or ether, Roemer's data could be used to plot the elliptical motion of the Earth relative to Jupiter without any other astronomical information being necessary.

Bradley[3] in 1728 showed that the observed one-way velocity of light depends upon the transverse velocity of the observer. In particular, the observed velocity of light viewed transverse to the velocity of the Earth $\mathbf{v}_e$ is $\mathbf{c} + \mathbf{v}_e$ at one time of the year, and a half year later it is $\mathbf{c} - \mathbf{v}_e$. Thus *all* stellar objects lying in a direction normal to the ecliptic are observed to execute a small annual circle the circumference of which subtends the angle α, where

$$\tan \alpha = v_e/c. \tag{2}$$

Measuring the angle of aberration α and knowing the value v_e, Bradley obtained a value for the velocity of light in agreement with Roemer. Again, conversely, knowing the value of c and assuming the velocity of light to be c fixed relative to absolute space, Bradley's data could be used to plot the Earth's circular motion.

Michelson and Morley[4] performed their famous experiment in 1887. Their null result was predicted as a Doppler effect using absolute space and time by Voigt,[5] who was the first to present the equations that are now inappropriately called the "Lorentz transformation." Voigt's result is most readily obtained by linearizing the invariant $c^2k^2 - \omega^2 = c^2k'^2 - \omega'^2$, where $\mathbf{k}'$ is the propagation constant and ω' is the angular frequency for a moving source and observer and $\mathbf{k}$ and ω are for a stationary source and observer.[6] The frequent erroneous claim that the Michelson-Morley result reveals the velocity of light to be isotropic independent of the absolute velocity of the observer is based upon a general ignorance of the Doppler effect. There are always *two* wave velocities associated with any Doppler effect (sound or light), the *phase velocity* and the *velocity of energy propagation.* In general, these two velocities are neither in the same direction nor equal in magnitude. The *phase velocity* of light $\mathbf{c}'$ for an ether wind of absolute velocity $\mathbf{v}$ in the negative x direction, according to the Voigt-Doppler effect, is given by

$$\mathbf{c}' \text{ (phase)} = (c_x - v)\hat{i} + (c_y\hat{j} + c_z\hat{k})/\gamma, \tag{3}$$

where $\hat{i}$, $\hat{j}$, and $\hat{k}$ are unit vectors in the Cartesian coordinate directions and

$$\gamma = 1/(1 - v^2/c^2)^{1/2}. \tag{4}$$

The magnitude of the *phase velocity* for light from Eq. (3) is given by

$$c' \text{ (phase)} = c(1 - \mathbf{v} \cdot \mathbf{c}/c^2). \qquad (5)$$

[For sound, $\mathbf{c}'$ (phase) $= \mathbf{c}(1 - \mathbf{v} \cdot \mathbf{c}/c^2)$.] In contrast, the *velocity of energy propagation* is given simply (for sound as well as light) by

$$\mathbf{c}^* \text{ (energy)} = \mathbf{c} - \mathbf{v}. \qquad (6)$$

The Michelson-Morley experiment, involving interference, depends on the *phase velocity* $\mathbf{c}'$, Eq. (3), and not the *velocity of energy propagation* $\mathbf{c}^*$, Eq. (6). The null Michelson-Morley result is easily predicted using Eq. (1). Even Michelson seems to have been ignorant of the *two* velocities associated with a Doppler effect, since he made the mistake of thinking his experiment would detect $\mathbf{c}^*$, as given by Eq. (6). It may be noted that neither $\mathbf{c}'$ not $\mathbf{c}^*$ are isotropic, even though $\mathbf{c}'$ yields a null result for the particular Michelson-Morley setup.

Sagnac[7] in 1913 divided a light beam into two beams that were reflected in opposite directions around a closed loop to then form an interference pattern. When the setup was rotated, the fringe pattern shifted in such a way as to indicate that the light velocity of the beam in the direction of rotation of the mirrors was decreased to $c^- = c - v$, where v was the tangential velocity of the mirrors, while the light velocity counter to the rotation was increased to $c^- = c + v$. No relative motion of source and observer was involved. Sagnac explained his result in the most obvious and simplest way possible. He claimed that the velocity of light was c with respect to a fixed luminiferous ether.

Michelson and Gale[8] performed the Sagnac experiment using closed optical paths on the rotating Earth at a northern latitude. Comparing the fringe shift for a large loop with a small loop they deduced the absolute velocity of rotation of the Earth. In principle, their observations could be carried out instantaneously, in contrast to the Foucault experiment which required many hours. Thus they could determine essentially the *linear* tangential velocity of the rotation of the Earth's surface. Michelson and Gale brought the Sagnac experiment out of the laboratory and showed that the velocity of light is c relative to the fixed ether independent of any rotations of equipment.

Conklin[9] in 1969 was the first to measure the absolute velocity of the solar system by measuring the 3°K thermal cosmic background anisotropy. He assumed the thermal cosmic background was isotropic and that the velocity of light was c relative to absolute space or a fixed ether. An observer moving with the absolute velocity through the cosmic background will intercept more light in the forward direction than the rearward direction as a linear function of v.[10] The best value for the absolute velocity of the solar system by this method is probably that found by Henry[11] in 1971, who found $v = 320 \pm 80$ km/s, right ascension $\alpha = 10 \pm 4^h$, and declination $\delta = -30 \pm 25°$.

Marinov[12] in 1974 measured the absolute velocity of the solar system by an ingenious "coupled mirrors" experiment. A mirror was mounted on one end of a cylinder rotating with an angular frequency N. The time it took light to travel the length of the cylinder L, $\Delta t^+ = L(c - v_L)$, was determined by the angular displacement $\Delta\varphi^+$ relative to the first mirror of a second mirror mounted on the other end of the rotating cylinder. The angle was measured interferometrically; thus

$$\Delta\varphi^+ = (8\pi^2 RNL/\lambda)/(c - v_L), \qquad (7)$$

where R is the radius of the cylinder, and λ is the wavelength of light used. Using an identical setup for light propagated in the opposite direction down the cylinder, he measured the relative fringe shifts using two independent photodetectors and a Wheatstone bridge. The absolute velocity of the laboratory v_L in the direction L was then given by

$$v_L = (\lambda c^2/8\pi^2 LRN)(\Delta I/I_{max}), \qquad (8)$$

where $\Delta I/I_{max}$ is the difference in the output of the two photodetectors to the maximum output of one. The magnitude and direction of the absolute velocity of the Earth, and thus the solar system, was obtained by taking measurements for different orientations of L during the day. From the fact that the velocity of light is c with respect to absolute space or the ether in the closed laboratory, Marinov measured the absolute value of the solar system as $v = 300 \pm 20$ km/s, $\alpha = 13.3 \pm 0.3^h$, $\delta = -21 \pm 4°$. This result, which is in agreement with other determinations, is the most accurate to date.

Marinov[13] in 1984 again measured the absolute velocity of the solar system by mounting two toothed wheels on the ends of a rotating shaft. A laser beam was chopped by the first toothed wheel and then by the second. The amount of light, as measured by a photodetector, passing through the second toothed wheel depended linearly upon the angle through which the second toothed wheel rotated with respect to the first during the time it took light to travel between the two toothed wheels a distance L. The alignment was chosen such that the amount of light passing through the second toothed wheel was an increasing linear function of the mismatch; thus

$$\Delta I^+ = I^+ - I_0 = K\Delta t^+ = KL/(c - v_L), \qquad (9)$$

where the proportionality constant $K = 4\pi RN/b$, b is the width of the gap between teeth, R is the radius of the wheel, and N is the number of rotations per second. The intensity I_0 was chosen as 1/2 the maximum possible intensity to maximize the sensitivity. A second independent laser beam was sent through the rotating toothed wheels in the opposite direction and was detected by an independent photodetector. The alignment was again chosen so that the intensity was an increasing linear function of the mismatch as indicated in Eq. (9) with v_L being replaced by $-v_L$. The absolute velocity of the laboratory v_L in the direction L was then given by

$$v_L = c(\Delta I^+ - \Delta I^-)/(\Delta I^+ + \Delta I^-). \qquad (10)$$

The intensity differences were accurately measured by balancing the output of the two photodetectors in a Wheatstone bridge. The direction and magnitude of the absolute velocity of the Earth, and thus the solar system, were obtained by fixing the shaft L in the north-south direction at a northern latitude and taking observations over a 12-h period. Marinov reports an absolute velocity of the solar system by this method as $v = 360 \pm 40$ km/s, $\alpha = 12 \pm 1^h$, $\delta = -24 \pm 7°$ in agreement with prior observations.

2. DESCRIPTION OF THE PROPOSED EXPERIMENT

The experiment proposed here involves two independent rotating toothed wheels driven by two independent clock motors. The two toothed wheels are assumed to rotate at the same rate to a very high accuracy over the period that an observation is made. Since the two toothed wheels are independent of each other, they can be separated by a large distance L with a corresponding increase in the time for light to travel between the two

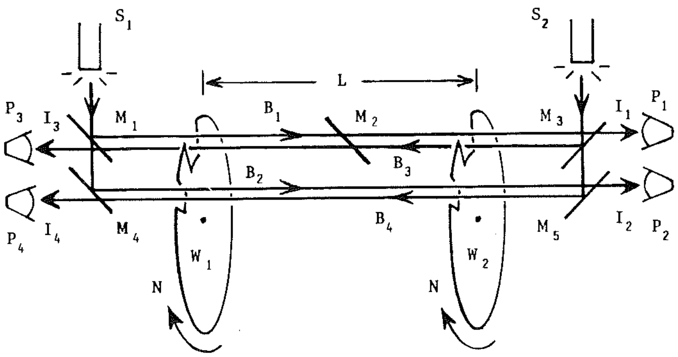

Figure 1. A diagram of the proposed experimental setup showing the two laser sources, the two toothed wheels, the four light beams involved, and the four photodetectors.

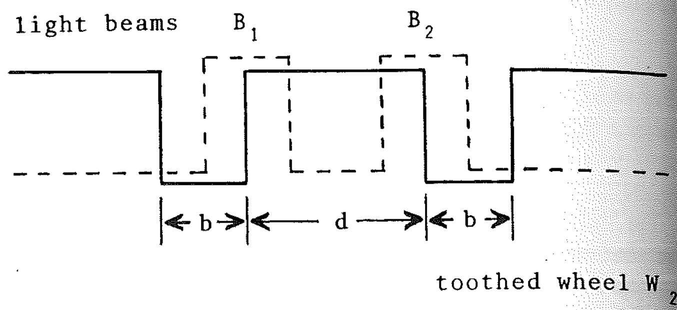

Figure 2. Diagram showing the intensity of light beams B_1 and B_2 from toothed wheel W_1 (dashed lines) illuminating the toothed wheel W_2 such that beams B_1 and B_2 are a distance d apart rather than $b + d$ apart as when leaving toothed wheel W_1.

toothed wheels, $\Delta t^+ = L(c - v_L)$, and with a corresponding increase in the accuracy of the determination of v_L.

It is frequently claimed that the relative angular phase of two such independent rotating wheels (or clocks) cannot be known, and, therefore, the proposed experiment cannot yield any results. This claim is entirely unwarranted, because the desired relative phase can be obtained to great accuracy while both wheels are rotating by simply turning one of the toothed wheels with its clock motor until the appropriate intensities (such as indicated in Fig. 1) for light beams passing through the two wheels are obtained. For two ordinary electric clocks supplied by the same commercial current source, or for two independent quartz clocks, the drift of the relative phase, once having been set, is completely insignificant over the time observations are made. A readjustment of the relative phase can always be made in any case.

The experimental setup is diagrammed in Fig. 1. Two toothed wheels 1 and 2 a distance L apart are rotated in the same sense at the same rate by two clock motors (not shown). Light from laser S_1 is reflected at the semitransparent mirror M_1 to yield light beam B_1. The beam B_1 is chopped by the toothed wheel W_1. After passing through the semitransparent mirror M_2 (which is included simply to make all four beams optically equivalent) and traveling the distance L, beam B_1 is again chopped by toothed wheel W_2. After passing through the semitransparent mirror M_3, the resultant intensity I_1 is detected by the photodetector P_1. Light from laser S_1 is also transmitted through the semitransparent mirror M_1 and is reflected from the semitransparent mirror M_4 to yield the light beam B_2. The beam B_2 is then chopped by the toothed wheel W_1. After traveling the distance L, beam B_2 is again chopped by the toothed wheel W_2, beam B_2 passes through the semitransparent mirror M_5 to yield a light intensity I_2 detected by photodetector P_2. It may be seen from Fig. 1 that beams B_3 and B_4 arising from laser S_2, are similarly chopped and similarly yield intensities I_3 and I_4 detected by photodetectors P_3 and P_4.

Beams B_1 and B_2 are passed through neighboring gaps of width b between the teeth of width d of toothed wheel W_1. The distance between beams B_1 and B_2 as they pass from toothed wheel W_1 is $b + d$ from center to center. The mirrors M_1 and M_4 can be adjusted so that the second toothed wheel W_2 is illuminated by beams B_1 and B_2 closer together a distance d apart from center to center, as shown in Fig. 2.

When the toothed wheels are rotating, the teeth of toothed wheel W_2 move with the velocity $V = 2\pi RN$, where R is radius of the wheel and N is the number of rotations per second. If the teeth of W_2 are assumed to move to the right as shown in Fig. 2, then, after the time $\Delta t = L/(c - v_L)$ the intensity I_1 is increased from $I_{\max}/2$ to

$$I_1 = I_{\max}/2 + I_{\max} VL/b(c - v_L), \tag{11}$$

where $I_{\max}$ is the maximum intensity possible when the toothed wheels are stationary and the gaps are aligned. Similarly, the intensity I_2 is decreased from $I_{\max}/2$ to

$$I_2 = I_{\max}/2 - I_{\max} VL/b(c - v_L). \tag{12}$$

The intensities I_3 and I_4 are similarly given by

$$\begin{aligned} I_3 &= I_{\max}/2 - I_{\max} VL/b(c + v_L), \\ I_4 &= I_{\max}/2 + I_{\max} VL/b(c + v_L). \end{aligned} \tag{13}$$

From Eqs. (11) and (12), and (13) the absolute velocity of the laboratory in the direction L is then given by

$$v_L = c\frac{(I_1 - I_2) - (I_4 - I_3)}{(I_1 - I_2) + (I_4 - I_3)}. \tag{14}$$

A negative result indicates that v_L is in a direction opposite to that assumed in Eqs. (11) through (14).

The above expressions for I_1, I_2, I_3, and I_4, Eqs. (11), (12), and (13) are simplified expressions chosen for expositional purposes. The instantaneous intensities will change as the entrance toothed wheel rotates and chops the original incident beam. The beam illuminating the exit toothed wheel will then change with time. The photodetectors are chosen, however, to register the time-average intensities and not instantaneous intensities. Considering time averages, the constant $I_{\max}$ appearing in Eqs. (11) through (14) should be replaced by an appropriate constant K times $I_{\max}$. The value of this constant K (which may be easily measured experimentally) is a matter of indifference since, in the final formula (14) it cancels out above and below the line on the right. The effect of diffraction, which is small for a laser beam, is identical for all four beams, and it merely changes the value of K, which remains a matter of indifference.

3. ALIGNMENTS NECESSARY

The alignment of beam B_1 relative to beam B_2 can be done with the two toothed wheels stationary. Observation of intensity differences can assure the correct alignment. When B_1 relative to B_2 is correctly aligned, with W_1 fixed, changing the angular position of W_1 can yield an intensity I_1 as a zero minimum when $I_2 = I_{max}$. Moving W_2 a distance $b/2$ then yields $I_2 = I_{max}/2 = I_1$ and $I_1 - I_2 = 0$. A further displacement $b/2$ yields I_2 as a zero minimum and $I_1 = I_{max}$. The relative alignment of B_3 relative to B_4 can be similarly done. No precise alignment of B_1 and B_2 relative to B_3 and B_4 is necessary. The constant I_{max} must be adjusted to be the same for all four beams. The constant I_{max} becomes KI_{max} when the toothed wheels are rotated with time and the intensity is averaged.

The appropriate relative angular phase of toothed wheel W_2 with respect to toothed wheel W_1 when both wheels are rapidly rotating at the same rate can be obtained by statically rotating wheel W_2 together with its clock motor until all four intensities are roughly equal (about $KI_{max}/2$) and $I_1 - I_3$ and $I_4 - I_2$ are each a minimum and $(I_1 - I_3) - (I_4 - I_2) = 0$. These conditions may be readily deduced from the optimum situation as prescribed by Eqs. (11) through (14).

4. ERRORS

Since the intensities are measured as the outputs of photodetectors, the differences $(I_1 - I_2)$, $(I_4 - I_3)$, $[(I_1 - I_2) - (I_4 - I_3)]$, $(I_1 - I_3)$, $(I_4 - I_2)$, and $[(I_1 - I_3) - (I_4 - I_2)]$ can be measured with great accuracy electronically using a Wheatstone bridge or an equivalent network. There is at least a fractional improvement of 10^3 involved in measuring intensity *differences* using a bridge as compared with measuring each of the intensities separately and subsequently subtracting arithmetically.

As may be seen from Eq. (14), the final determination of the absolute velocity of the laboratory v_L in the direction L depends only upon intensity differences and the accepted numerical value of c (currently based upon standing electromagnetic wave measurements). The error to be associated with v_L is then to be experimentally estimated by the reproducibility of results after realigning the apparatus and readjusting adjustable parameters.

The rotational velocities of the two toothed wheels remain essentially the same over the time that a measurement is made. If there were any significant drift of the relative angular phase of the two toothed wheels, it could be readily detected experimentally as a drift of $(I_1 - I_3) - (I_4 - I_2)$ away from zero.

The distance between the toothed wheels L need not be known. Similarly, the tangential speed of the two toothed wheels $V = 2\pi RN$, and the radius R and angular frequency N need not be known. Also, the gap width b need not be known. Nevertheless, the larger the combination $2\pi RNL/bc$, the greater the sensitivity, because this measures the fraction of the maximum signal I_{max} that can be used to obtain significance. The combination $2\pi RNL/bc$ should be as close to unity as possible (but less than unity for the theory presented here). A particular numerical example may be considered for two toothed wheels placed a kilometer apart, $L = 10^5$ cm, with radii $R = 20$ cm, rotating at $N = 100$ times a second, with gaps between teeth of $b = 0.2$ cm. The combination $2\pi RNL/bc \approx 0.2$. This means that three-place accuracy should be readily attainable.

5. ABSOLUTE VELOCITY OF THE SOLAR SYSTEM FROM ABSOLUTE VELOCITY OF THE LABORATORY

Fixing the length L to the Earth in the north-south direction at the colatitude θ, the observed velocity v_L in terms of the absolute velocity of the Earth v_E is given by

$$v_L = v_E[\cos(\varphi - \varphi_0)\sin\theta\sin\theta_0 + \cos\theta\cos\theta_0], \tag{15}$$

where φ is the angular position of the apparatus in the equatorial plane as a function of the sidereal time of day,

$$\varphi = 2\pi t/T, \tag{16}$$

where $T = 24$h, φ_0 is the sidereal equatorial position of the absolute velocity of the Earth, and θ_0 is the colatitude of the absolute velocity of the Earth. As a function of the time of day, v_L is a maximum when $\varphi = \varphi_0$, or

$$v_L\,(\max) = v_E\cos(\theta - \theta_0). \tag{17}$$

When v_L is a minimum $\varphi = \varphi_0 + \pi/2$ and Eq. (15) yields

$$v_L(\min) = v_E\cos\theta\cos\theta_0. \tag{18}$$

The colatitude θ_0 of the absolute velocity of the Earth from Eqs. (16) and (17) is then given by

$$\tan\theta_0 = \cot\theta\,[v_L(\max) - v_L(\min)]/v_L\,(\min), \tag{19}$$

and the magnitude of the absolute velocity of the Earth is

$$v_E = \{[v_L(\max) - v_L(\min)]^2\csc^2\theta + v_L^2(\min)\sec^2\theta\}^{1/2}. \tag{20}$$

Consequently, it is only necessary to take observations of v_L over a 12-h period. Knowing the date when the observations are made, the absolute velocity of the solar system can be readily obtained from the absolute velocity of the Earth.

6. ADDED COMMENT

It may be noted that if sources and detectors are rotated with the toothed wheels, an identical result is predicted. There will then be no relative motion between sources and detectors, as for the Sagnac experiment. Only the rotation with respect to absolute space or the ether is then involved.

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Résumé

Une roue dentée, entrainé par un moteur électrique d'horloge, découpe un faisceau laser. Une deuxième roue dentée, à une distance L *de la première, découpe une seconde fois le faisceau. L'intensité résultante est une fonction linéaire de l'angle dont tourne la deuxième roue dans le temps où la lumière traverse la distance* L, $\Delta t = L/(c - v_L)$, *où* v_L *est la vitesse absolue du laboratoire dans la direction* L. *Deux faisceaux sont dirigés de manière que l'intensité de l'un est augmentée et celle de l'autre est diminuée par le découpage. Les intensités de ces faisceaux sont comparées aux intensités de deux faisceaux dirigés en sens opposé. La vitesse absolue,* $2v_L = c^- - c^+$, *est alors mesuré directement de manière électronique. La bonne phase relative des deux roues dentées, déterminée par les intensités, est obtenue en faisant tourner l'une des roues de conserve avec son moteur. Grandeur et direction de la vitesse absolue du système solaire sont trouvées en fixant* L *en direction nord-sud à une latitude septentrionale et en mesurant* v_L *pendant une période de 12 h.*

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J.P. Wesley
Weiherdammstrasse 24
7712 Blumberg, West Germany