TIME and the SPEED of LIGHT - a NEW INTERPRETATION

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SYNOPSIS. The Theory of Special Relativity has two requirements in relation to the behaviour of light. The first is that the speed of light is independent of the speed of its source. The second is that the speed of light is measured as a constant by observers in Inertial Frames, who are travelling at uniform speed relative to each other. The first requirement is confirmed as correct in this paper; the second is contradicted. The fact that a light signal that is sent both clockwise and anticlockwise, around a path on a rotating disc, takes different times to return to the source, was discovered by Sagnac over eighty years ago. An explanation of this phenomenon is put forward, which leads to the conclusion that time recorded aboard a moving object does not differ from the time recorded by a stationary observer, and that the dimensions of moving and stationary objects are the same. It is also shown from tests that electromagnetism does not to depend solely on relative motion. A new theory is put forward which is in conformity with both the Michelson-Morley and Sagnac experiments, and with tests on electromagnetism.

NOTATION

A	area
c	speed of light
F	fringe shift
γ	2 transformer
λ	wavelength of light
p	momentum
r	radius
s	distance
t	time
v	velocity
ω	angular velocity

INTRODUCTION

In dealing with the behaviour of light, the Theory of Special Relativity has two consequences, as shown by Einstein (**1** pp. 38 to 46). The first is that that the speed of light is independent of the speed of its source; the second is that the speed of light is measured as a constant by observers in Inertial Frames who are travelling at uniform speed relative to each other. The first requirement is confirmed as correct in this paper. Practical tests done by the French scientist G. Sagnac (**2**) between 1910 and 1914 will be described in detail, and the results will be shown to clash with the second requirement. A theory will be suggested which fits the experimental facts of the Sagnac tests, which is also in accord with other test results on the behaviour of light and electromagnetism, and which maintains the equivalence of mass and energy ($E = mc^2$).

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SAGNAC EFFECT

The fact that a light signal, that is sent both clockwise and anticlockwise around a path on a rotating disc, takes different times to return to the source was discovered by Sagnac over eighty years ago. This effect, known as the Sagnac effect, is an unsolved fundamental problem in Physics. It has very important consequences, which have been overlooked by previous investigators.

Hasselbach and Nicklaus (1993) (**3**) list many explanations of the Sagnac effect to be found in the literature, as proposed by various authors over the intervening years. They sum up the situation by saying *"This great variety (if not disparity) in the derivation of the phase shift constitutes one of the several controversies that have been surrounding the Sagnac phase shift since the earliest days of studying interference in rotating frames of reference"*. Several references to each suggested explanation are listed in their paper; in all of these references one finds attempts to explain the effect by assuming that the movement of the disc is, in some way, affecting the behaviour of the light.

However, it will be shown that the movement of the disc has no influence whatsoever on the behaviour of the light. This proposal is the only one that fits all the experimental results.

It is of historical interest to note that Sagnac proposed that the effect was a proof that light travelled relative to a supposed *"ether"*. However, as the existence of an ether was shown to be unnecessary by Einstein (**4**), that explanation lapsed.

SAGNAC TEST

A schematic representation of the test done by Sagnac is shown in Fig.1. A light source at point S emits light to a beam splitter at point C. Some of the light traverses the path SCDEFC, and is then reflected to an "observer" at O. Some of the light goes the other way, around SCFEDCO. The whole apparatus can rotate with an angular velocity ω. The light source S and the "observer" O (in reality a photographic plate) are both fixed to the rotating apparatus, and rotate with it.

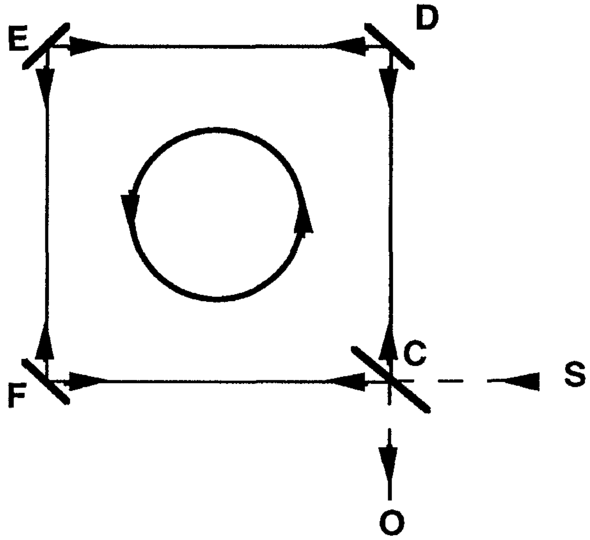


Fig. 1. Sagnac Test

When the disc is stationary, light sent around in opposite directions will arrive back at the same instant at point C. The beam splitter at C acts as an interferometer and is used to display this static situation and to determine whether any change occurs when the disc is set in motion. [The theory of interferometry is outlined in textbooks on physics e.g. Young (**5**).] In the static case, the interferometer produces fringes (dark and bright bands) where the light recombines, following its traversing of a circuit.

When the disc is spinning, the observer detects a shift in the fringes to one side, indicating that the two light signals are out of phase and do not return to point C at the same instant. The shift is by the same amount, but in the opposite direction, when the direction of rotation is reversed.

Sagnac derived the difference in time, dt, between the times taken by the light to traverse the path in opposite directions, as

$$dt = 4A\omega \div c^2 \qquad (1)$$

where small terms are ignored, A is the area enclosed by the light path, and c is the speed of light. Note that the interferometer that displays this time difference is on board the rotating disc.

Sagnac showed experimentally that the centre of rotation can be away from the geometric centre of the apparatus, without affecting the above result. He also showed that, although the mirrors move as the disc rotates and as the light moves around the circuit, this movement has a negligible effect on the magnitude of the fringe shift.

In order to get an idea of the magnitude of the Sagnac effect, it is helpful to calculate the disc-rotation speeds necessary to obtain significant fringe shifts. Consider Fig. 2, where the light path is confined to a circle of radius r. The equation which expresses the relationship between interference fringes and time differences.[see Young (**5**)] is F=dt [c÷λ], where F is the number of fringe shifts detected and λ is the wavelength of the light used. From equation (1) and, since $v = r\omega$ for circular motion, where v is the tangential velocity of a point on the circle, one has

$$F = \frac{4\,A\,\omega}{c\,\lambda} = \frac{4\pi\, r\, v}{c\,\lambda} \qquad (2)$$

In order to obtain a fringe shift of one fringe, using a disc of 1m radius, the velocity around the perimeter of the circuit has to be only about 13 m/s.

That this is so can be seen by setting F =1, r =1, $\lambda = 5500 \times 10^{-10}$ m (a typical figure), and $c = 3 \times 10^{8}$ m/s in the above equation.

OTHER SAGNAC-TYPE TESTS and DEBATE

The first known Sagnac-type test performed was carried out in 1911 by Harress (**6**), a young German student (who was unfortunately killed in the 1914-18 war). He carried out tests on the refraction of light. His apparatus was similar to Sagnac's, consisting of a rotating disc carrying a light emitter and photographic recorder (both fixed in the laboratory); light signals were sent around the disc in opposite directions. Von Laue (**7**), in 1920, showed that the Sagnac effect could be detected in Harress's numerical results.

Pogany (1926-28) (**8**) repeated the Sagnac tests. By using more sturdy apparatus and higher speeds of rotation he obtained a fringe shift 25 times greater than that achieved by Sagnac (F = 1.8 versus F = 0.07 fringe), thus reducing the experimental error and allowing the fringe shift to be measured with greater accuracy.

To indicate the accuracy of more modern Sagnac-type tests, Macek and Davis (1963) (**9**) give the accuracy of the laser equipment used as 1 in 10^{12}. In 1913, when Sagnac carried out his tests, the accuracy was about 1 in 10^{2}.

Langevin (**10**), in 1921, commented on the practical tests done by Sagnac, and claimed that the effect, i.e. the observed time difference dt, had to be in accord with the Theory of Relativity. He said that because that Theory fitted the *"whole of the known experimental facts"* of physics in general, the tests had to be explicable by that theory. In 1935, however, Prunier (**11**) published a note questioning Langevin's reasoning, and argued that the practical tests were not explained by relativity. There followed a series of papers, by Dufour (**12**) and Langevin (**10**) in which was debated the question whether or not the effect was in accord with the Theory of Special Relativity and whether an apparatus could be constructed to settle the question. This debate ended in stalemate.

Dufour and Prunier then collaborated in a series of dissimilar Sagnac-type practical tests. Firstly, in 1937 (**13**), they rigorously repeated the original Sagnac tests. They then repeated the method used by Pogany (**8**), who had the light emitter fixed in the laboratory, but had the photographic recorder on the disc. They then carried out the experiment with both the light emitter and the photographic recorder taken off the disc, and set up fixed in the laboratory (the set-up adopted by Harress).

It should be noted that, in all these cases, the *interference of the light signals occurs on board the spinning disc,* i.e. the interferometer (fringe detector) is always fixed to the disc; the photographic recorder, which is either on or off the disc, then captures the image of the fringe shift. The experiment where the photographic equipment is off the disc is the more complicated of the two. Two extra lenses are required to send the image out from the disc and on to the photographic plate fixed in the laboratory; consequently, the spread of the readings widens from ±5% in the case where the record is made on board the disc to ±15% when it is off the disc.

In 1939, Dufour and Prunier carried out their final experiment. They did a test with both the beginning and end of the light path on the spinning disc, but with the middle portion of the path reflected off mirrors *fixed* in the laboratory (directly above the disc). In this test, they had both the light emitter and the photographic recorder fixed in the laboratory. [Note: by "on the spinning disc" is meant that the light is confined to a path by a set of mirrors which are fixed to, and rotate with, the disc.]

The fringe shifts resulting from all the above Dufour and Prunier tests were the same as in their original Sagnac-type tests. This fact is of critical significance in understanding what is occurring, as will be discussed later.

In 1942 Dufour and Prunier published a composite paper reviewing their total experimental work to date. At the end of this paper they state that *"the relativity theory seems to be in complete disagreement with the result which was garnered from the experiment"*.
This was the end of the debate, and the matter

was not resolved. This present paper takes up the problem left unresolved in 1942, and a solution is proposed that fits the test results.

The reader is referred to a paper by Post (1967) (**14**) for an historical review of the Sagnac effect.

TWO POSSIBILITIES

Consider now the following question:

At what speed is the light travelling relative to the rotating observer? There are two possibilities and only one can and must be correct.

(a) The light, viewed from aboard the disc, is observed to travel at a relative speed of c.

(b) The light, viewed from aboard the spinning disc, i.e. by an observer rotating with the disc, is observed to travel at a relative speed not equal to c.

Note that we are not defining the two possibilities as being in Inertial Frames, nor is there any mention of Relativity Theory. A simple question is being posed, and the answer will be derived below.

DERIVATION of FORMULA

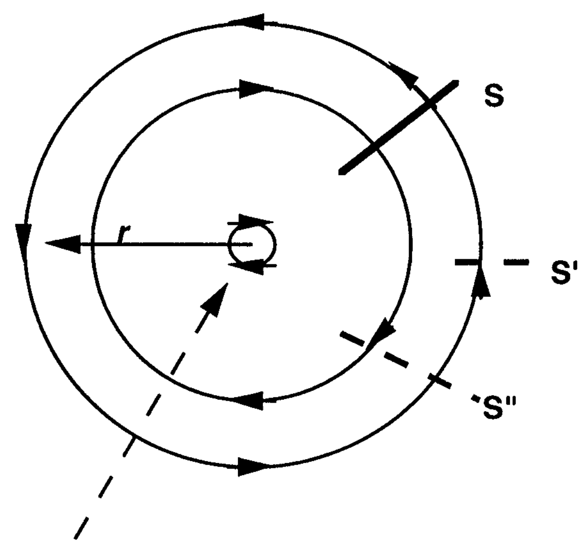
A derivation of equation (1), will now be given. Consider the theoretical circular model shown in Fig. 2. The light source and the interferometer are at S, and both are fixed on the rotating disc. Let t_0 be the time taken for a light signal to traverse the circumference of the circle and to return to the source/interferometer, when both the disc and the observer are stationary. Thus, t_0 is the path length $2\pi r$ divided by the speed of light,

$$t_0 = \frac{2\pi r}{c} \qquad (3)$$

A light signal is emitted from the light source; a portion of the signal goes clockwise (denoted by the inner line on Fig. 2), and some goes anticlockwise.

Consider firstly the situation as observed by an observer stationary in the laboratory.The anticlockwise signal is going against the rotation of the equipment and will return to the light source when the source and interferometer are now at S'. The signal travelling clockwise, with the direction of rotation of the equipment, will return to the interferometer at S".

Let ds' be the distance SS' and ds" the distance SS". Let t' be the time measured by an observer situated in the stationary laboratory for the light to go from S to S' in the anticlockwise direction.



Whole apparatus turning at ω clockwise

Fig. 2 Circular Sagnac Test

The time measured by that observer is

$$t' = \frac{2\pi r - ds'}{c} \qquad (4)$$

But, t' is also the time taken for the disc to move a distance ds' in the clockwise direction. Therefore $t' = ds' \div v$ ($v = r\omega$), $ds' = t' v$ and, from (4),

$$ds' = \frac{[2\pi r - ds']\, v}{c}$$

$$\frac{ds'}{v} = \frac{2\pi r}{c + v},$$

or

$$t' = \frac{2\pi r}{c + v} \qquad (5)$$

Note that equations (4) and (5) both give the time recorded by a stationary observer; the equations simply state this time in different mathematical terms. We shall see the use of equation (5) below.

Following similar calculations one gets for t'', the time measured by a stationary observer for the light to go from S to S" in a clockwise direction,

$$t'' = \frac{2\pi r}{c - v} \qquad (6)$$

Subtracting equation (5) from (6), the difference between the times for the light to go clockwise and anticlockwise is

$$dt = \frac{2\pi r}{c - v} - \frac{2\pi r}{c + v} = \frac{4\pi rv}{c^2 - v^2}$$

and, since $v = r\omega$, and πr^2 is the area A of a circle, one has

$$dt = 4 A \omega \div (c^2 - v^2), \qquad (7)$$

The v^2 term is negligible for practical tests and may be ignored, giving Equation (1).

However, this time difference has been derived for a stationary observer, fixed in the laboratory.

This time difference agrees with the fringe shift recorded on the interferometer.

But the interferometer is rotating with the disc. How is is then that the interferometer rotating with the disc records the same time difference?

This means that the time recorded in the fixed laboratory and on board the disc are identical.

To answer this question, consider options (**a**) and (**b**) given in the previous section "Two Possibilities".

Consider firstly option (**a**) where the light is assumed to travel at a speed of c relative to the observer regardless of the movement of that observer. Because a fringe shift F is detected it follows from the equation $F = dt\,[c+\lambda]$ that it must be dt that is changing, (c and λ are constants). This is clear from considering the position relative to the observer on board the disc; as far as this observer is concerned the path length is $2\pi r$ for one circumference of the disc, and that is the path that the light signal *appears* to that observer to have travelled. If the light had travelled at a speed of c relative to this observer then no fringe shift could be observed on board the disc. But a fringe shift is observed, and thus the light signal cannot travel at a speed of c relative to the observer on the disc.

Can there be a possibility that for some reason *time must change* aboard the spinning disc?

Abolghasem *et al.* (1989) (**15**) following this reasoning, say that one would have to *"redefine time or rather 'correct' the local time interval of two adjacent events by an amount, so that the speed of light becomes the same in both directions. This corrected, or 'natural time' interval guarantees the clocks on the rotating disc to be Einstein-synchronised"*.

Further Langevin (**10**) suggests *"adopting a local time that is not uniform, but changing by* $\pm 2\omega A \div c^2$*"*.

It is not clear whether these authors are suggesting that the proposed "local time" changes are relativistic effects (in the relativistic sense of time altering at high velocities). In any case, it will be shown in a later section that, even were such a relativistic time change to arise, it would be *ten million times smaller* than the time difference (equation (1)) effect recorded in typical Sagnac-type tests.

Therefore, assume that possibility (**b**), is the correct option, so that the speed of light is not confined to a *relative* speed of c.

Abolghasem *et al* describe this solution as that which *"causes the velocity of light to be locally different in opposite directions"*

Langevin says that were this the case, "*light speed would vary with the direction between c - ωr and c + ωr*". Note that while both authors discuss the possibilities, neither realised that Relativity Theory could not, as we will see, explain the dilemma.

It should be stressed that, in all the tests, the interferometer *on board the disc* records the fringe shift corresponding to equation (1), *and that it is solely aboard the disc that the interference occurs, which causes the fringe shift.* This fringe shift may be photographed from on or off the disc.

We see above that equations (4) and (5) are mathematically equivalent; they both give the same time interval.

Equation (4) may be restated as follows; the observer in the fixed laboratory observes that the disc moves a distance dS' while the light completes a distance of $2\pi r$ - dS' around the other direction from S to S'. The equation describes the time interval as it would be discerned by the observer in the laboratory.

Equation (5) may be restated as follows; the moving observer *thinks* that the light has, *relative to oneself,* completed one revolution of the disc (2π r) at speeds of $c \pm v$ in the two opposing directions. This is the *relative* speed of the light; the absolute speed is always c.

Equation (5) describes the same time interval as it is measured by the interferometer aboard the spinning disc (also t'). Note that equation (4) does not apply to the observer on the disc because the numerator is the distance that the light signal travels as observed by an observer in the fixed laboratory. The observer on the disc could, by marking the disc against a spot in the laboratory, deduce that the disc had moved a distance ds' (relative to the laboratory), while the light was travelling a complete circuit relative to the observer on the disc.

It is to be noted that t' [the time defined earlier as the time recorded in the stationary laboratory in deriving equation (4)] is the same as the time recorded aboard the spinning disc, as shown above.

It is important to appreciate the above distinctions, because it is at the core of the explanation of the Sagnac effect.

Because the interferometer on board the moving disc records a fringe shift, the relative speed of light to that spot, (which is being photographed from on or off the disc) is c ± v, while the absolute speed of the light remains as c.

Now consider a single light signal travelling in one direction only, in this case the anticlockwise direction. The difference in times recorded for the stationary-disc case and for the single signal to travel from S to S' is, from equations (3) and (5),

$$t_0 - t' = \frac{2\pi r}{c} - \frac{2\pi r}{c+v} = \frac{2\pi r v}{c(c+v)}$$

Therefore, the difference in time dt' is

$$dt' = t_0 - t' = t_0 v \div (c + v) \qquad (8)$$

For small values of v the difference is $t_0 v \div$ c. As v approaches c, dt' approaches $t_0 \div 2$, and the speed of light relative to the observer is then 2c.

Similarly, for the clockwise direction, letting t'' be the time for the signal to arrive back at point S", one has

$$dt'' = t'' - t_0 = t_0 v \div (c - v) \qquad (9)$$

In this case, as the speed approaches c, the result becomes infinite because the light and the Point S are travelling in the same direction, and the time for the light signal to gain one complete circuit on the Point S is infinite. At low velocities, the result is again $t_0 v \div$ c.

From equations (3 to 9), the time differences for the two directions are also expressible as

$$dt' = t' \frac{v}{c} \quad \text{and} \quad dt'' = t'' \frac{v}{c} \qquad (10)$$

Because, $ds' \div v = t'$ and $ds'' \div v = t''$, equations (10) may be written as

$$dt' = ds' \div c \text{ and } dt'' = ds'' \div c. \qquad (11)$$

By subtracting equation (4) from equation (3) we also get the first of the two equations (11).

From the above discussion we conclude that::

The Sagnac effect is thus seen to be a measure of the difference in the times taken by the two light signals, while they are away on their travels in the two opposing directions.

Another way of stating this is to say that the light is behaving as if the rotating disc did not exist.

The Sagnac effect shows that the light is operating independently of the spinning apparatus.

It was stated earlier that it would be shown that the fact the spinning disc was not an Inertial Frame would be irrelevant. This is now clear.

Many authors contend that, because the spinning disc is not an Inertial Frame, the Theory of Special Relativity does not apply. This problem does not arise because the light is simply travelling in the Frame of the Stationary Laboratory, and not in the Frame of the spinning disc.

The Sagnac effect is *not so much an "effect"*, but rather it is a confirmation of this fact. Because the light ignores the movement of the disc, the Theory of Special Relativity is not relevant to any "behaviour of the light on a rotating Frame". The light has no activity aboard the disc.

CIRCULAR PATH VERSUS STRAIGHT LINE

In this section it will be shown that the conclusions derived from the Sagnac effect, in relation to a spinning disc, apply equally to motion in a straight line.

We saw in the previous section that the light was behaving independently of the spinning disc. If, as has been demonstrated, it has been oblivious to the movement of small discs of varying radii such as used in the tests, then it will also ignore a disc of immense radius; this leads to the conclusion that it will not be affected in any way by the movement of an object in a straight line, which is the limit of an infinitely large circle.

Therefore it follows that an observer aboard an object which is *travelling off in a straight line, at constant speed relative to the laboratory*, will record the speed of light *relative* to oneself as c ± v. Thus, this observer will record the same time as the observer in the laboratory. Defining both these Frames as Inertial i.e. ones in which Newton's first Law applies, we derive that the speed of light measured in the moving Frame is not the constant c relative to the moving observer. This conclusion is in direct contradiction of the requirements of the Theory of Special Relativity on the behaviour of light.

If light were sent in two opposite directions from aboard an object which was travelling in a straight line, the two signals of the light would not ever again meet to be compared. The literature refers to the Sagnac effect as arising from the rotation of the spinning disc simply because it is only upon such an apparatus that an interference pattern can be examined.

COMPARISON of the SAGNAC EFFECT with SPECIAL RELATIVITY

While the following discussion is not relevant to the conclusions drawn in the previous section, it is included for completeness. It should be remembered, in reading this section, that none of the arguments therein are in any way a defence of the conclusions of this paper.

Einstein (**1**) accepted that movement on a closed polygonal circuit (and indeed in a closed curved path) has the same consequence as movement in a straight line, when considering the question of measurement of distance or time (1905 paper, p.49, last paragraph). Having derived his formula for straight line movements, he said *"it is at once apparent that this result still holds good if the clock moves from A to B in any polygonal line", and that "if we assume that the result proved for a polygonal line is also valid for a continuously curved line, we arrive at this result: If one of two synchronous clocks at A* *is moved in a closed curve with constant velocity until it returns to A, the journey lasting t seconds, then by the clock which has remained at rest the travelled clock on its arrival at A will be 1/2 t v^2/c^2 second slow. Thence we conclude that a balance-clock at the equator must go more slowly, by a very small amount, than a precisely similar clock situated at one of the poles under otherwise identical conditions"*

Because Einstein accepted that the Theory of Special Relativity applied equally to motion in a straight line, to motion in a polygonal path and in a closed circuit, it can thus be taken that that Theory can be assessed against the Sagnac test results. The problem caused by the non-conformity of the Sagnac test results with the Theory cannot be avoided, since Einstein himself had no difficulty in applying his Theory to rotating Frames e.g. the spinning Earth, compared with a stationary Frame (an observer at a Pole).

Because many investigators claim that the Sagnac effect is made explicable by using the Theory of Special Relativity, a comparison of that theory with the actual test results is given below. It will be shown that the effects calculated under these two theories are of very different orders of magnitude, and that therefore the Special Theory is of no value in trying to explain the effect.

The Theory of Special Relativity stipulates that the time t' recorded by an observer moving at velocity v is slower than the time t_0 recorded by a stationary observer, according to

$$t_0 = t'\gamma \qquad (12)$$

where $\gamma = (1 - v^2 \div c^2)^{-0.5}$ and t_0 and t' are the times recorded by the respective observers. Using the Binomial Theorem to expand γ, $(1 - v^2 \div c^2)^{-0.5} = 1 + (v^2 \div 2c^2)$ + terms involving $v^4 \div c^4$ or less, so that from equation (13).

$t_0 = t' [1 + (v^2 \div 2c^2)]$

Thus dt_R, the Relativity time ratio, is given by

$$dt_R = \frac{t_0 - t'}{t_0} = \frac{v^2}{v^2 + 2c^2} \qquad (13)$$

The derivation of the corresponding Sagnac ratio dt_S is as follows:

Let t_0 be the time for a light signal to traverse the circumference of a stationary disc, and t' be the time for a light signal to traverse the circumference of a spinning disc, as recorded by the observer on the disc. Directly from equation (8)

$$dt_S = \frac{t_0 - t'}{t_0} = \frac{v}{c + v} \qquad (14)$$

Note that, for a circular path, t_0 is the same in both cases, namely $2\pi r \div c$.

The ratio of dt_S to dt_R is therefore

$$\left[\frac{v}{v + c}\right]\left[\frac{2c^2 + v^2}{v^2}\right] = \left[\frac{2c^2 + v^2}{v(v + c)}\right]$$

When v is small as compared to c, as is the case in all practical experiments, this ratio reduces to 2c ÷ v.

Some authors imply that the Sagnac effect could be explained by the Theory of General Relativity. Apart from the fact that any acceleration is radial, the effect would be minuscule, as is the effect calculated under the Theory of Special Relativity.

Thus the Sagnac effect is far larger than any purely Relativistic effect. For example, considering the data in the Pogany test (**8**), where the rim of the disc was moving with a velocity of 25 m/s, the ratio $dt_S \div dt_R$ is about 1.5×10^7. Any attempt to explain the Sagnac as a Relativistic effect is thus useless, as it is smaller by a factor of 10^7.

Referring back to equation (1), consider a disc of radius one kilometre. In this case a fringe shift of one fringe is achieved with a velocity at the perimeter of the disc of 0.013m/s. This is an extremely low velocity, being less than 1m per minute. In this case the Sagnac effect would be *50 billion times larger* than the calculated effect under the Relativity Theory. This example is given to illustrate that there is no question of any relativity effect explaining the fringe shift at these velocities, since relativistic effects could only arise at great velocities. For a disc the size of the equatorial section of the Earth, the velocity required for one fringe is only $2x10^{-6}$m/s. This figure is given for comparison with the equatorial clock rotating with the Earth.

Apart from the difference in magnitude, there are other conceptual differences. In the actual Sagnac test, the difference between the moving and stationary cases was a time gain, or time loss, depending on the direction of travel. Relativity predicts that there should always be a time loss, regardless of the direction of travel.

Can it be, however, that both a Sagnac effect and an effect calculated under the Theory of Special Relativity can co-exist? This was assumed by Langevin (**10**) and Post (**14**); they showed that applying Relativity Theory had an infinitesimal effect on the result, which stood unaltered as the basic Sagnac effect. In other words, in a Sagnac-type experiment, is it possible that there is a Relativity effect, even though it is too small, in comparison with the Sagnac effect, to be detected? That this cannot be so is seen from the fact that, as mentioned before, a fringe shift is detected and that thus the behaviour of the light on the spinning disc does not evince a speed of c relative to the observer on board the disc.

In setting out the two requirements for the behaviour of light under the Theory of Special Relativity Einstein (**1**) stated "*light is always propagated in empty space with a definite velocity c which is independent of the motion of the emitting body*" and "*any ray of light measured in the moving system, is propagated with the velocity c, if as we have assumed, this is the case in the stationary system*".

The speed of the light is confirmed in the Sagnac test to be independent of the speed of the source of the light. This is in conformity with the former requirement. The latter requirement is that the speed of light is constant, as measured by observers in all Inertial Reference Frames. Accepting Einstein's logic for application of the theory to both a polygonal shape, and to a clock on the rotating Earth at the equator, would require option (**b**), in the "Two Possibilities" section above to be true. It would require that the light be measured as travelling at a speed of c relative to both the observer aboard the spinning disc and the observer in the fixed laboratory. The tests show that this is not so.

However, as we have seen, this debate is unnecessary, because the light is not affected by the rotating disc.

We thus see that the Sagnac effect is not to be confused with an effect calculated under the Theory of Special Relativity.

The results of the Sagnac test indicate that the two requirements of the Theory of Special Relativity quoted above are mutually exclusive, at least in Sagnac-type tests. They show that, if the light velocity is independent of the motion of the source, then it is not at the same time measured as identical, by observers who are travelling relative to each other.

DISTANCE and TIME UNCHANGED

Let us accept that the analysis in the previous sections is correct, and that light is not confined to travel at a speed of c relative to all observers in Inertial Frames. In this, and the following section, some consequences of this are discussed.

The Theory of Special Relativity requires that the measuring instruments in one Inertial Frame must record different results from those in another Inertial Reference Frame, when these frames are moving relative to each other. [For an observer to measure velocity, a ruler (rigid rod) and a clock can be used.] It follows from this that rulers shorten and that the time recorded on clocks would run slow at higher speeds.

However, such a conclusion is not necessary because, in reality, it is the *relative speed* of the light, and not the time, that is changing.

It can be concluded that, referring to Inertial Frames, motion in a straight line at constant speed will not affect the measurement of time or distance aboard a moving object, as compared with the time or distance measured by a stationary observer.

The factor γ, to be applied in all relativistic calculations on distance or time, is a direct consequence of the second requirement of the Theory of Special Relativity. The derivation of this is seen on p.46 of Einstein's first 1905 paper (**1**), in which he put forward the theory.

It is solely to distance and time that the amendment has to be made to the Theory of Special Relativity. The application of that Theory to other aspects of physics is not being questioned in this paper.

It is suggested that space and time are absolute, not relative; and that absolute space is a basic coordinate frame for all measurements in the Universe. This means that the speed of light has an absolute limit of c, but may have a speed relative to an observer that is less or greater than c.

This explains the behaviour of superluminal objects that are observed in outer space. Such objects are observed from Earth as separating from each other at speeds of up to ten times the speed of light. Four such objects (three quasars and one radio galaxy) had been identified by 1977 - see Cohen et al.(**16**) This is now explicable by a calculation of the relative speeds of the objects as viewed by an observer on Earth, where the objects are separating at high speed, while also approaching our galaxy, with a small angle of separation subtended to Earth.

PARADOXES

The so-called "clock paradox" or "twins paradox", is a consequence of Relativity which has generated much controversy over the past ninety years. The Theory of Special Relativity predicts that one twin who travels away from Earth at very high speed and returns after a long number of years will appear to the twin who has remained on Earth to have aged less.

It can be claimed that, strictly in accord with Relativity, the reverse should also hold, namely that the twin who remained stationary on Earth should also appear to be younger, to the traveller on the return of the latter to Earth. That this is so can be seen by considering twins in outer space who pass each other at high speed; neither twin can determine which is "receding" from the other. These twins could go off on a circuit as defined by Einstein and quoted earlier. Thus, on reuniting **both** twins would observe the other to be younger at the same instant. This apparent contradiction is the paradox. Most texts deny the second half of the comparison, by claiming that only one of the twins ages less and there are many and varied supposed solutions to justify this one-sided relativity. Some say the one-sided aging occurs solely during the reversal of direction at the far end of the journey for the twin who goes away. Rindler, in 1982, (**17**), on the other hand, says that the aging occurs at the initial acceleration phase of the departing twin. Such attempts at justification are presumably to avoid the difficulty of explaining how each of the two twins will, on reuniting, observe the other to be younger, at the same instant.

Dingle (1972) (**18**) gives a blow by blow description of the paradox controversy, which raged between him and Prof. W.H. McCrea, and others. This controversy continues, among other protagonists, to the present day. While some authors argue that the paradox does not make sense, none offer a solution which "explains" it away. Dingle forecast dire consequences for mankind were the Theory not amended in such a way that the paradox was dispelled. However, the "paradox" does not in reality arise, because there is no alteration in time with speed, as proved by the Sagnac-type tests.

Consider now the conundrum quoted by Zukav (1991) (**19**) (in a Chapter aptly titled "General Nonsense") where he considers two concentric circles of different radii revolving with the same angular velocity, so that two points, one on each circle, joined by a line passing through the centre of the circles are moving at different velocities ($v=r\omega$). He applies the Theory of Special Relativity, and states *"the ratio of the radius to the circumference of the small revolving circle is not the same as the ratio of the radius to the circumference of the large revolving circle"*. This is because, according to the Theory of Special Relativity, distance contracts with increasing velocity, when measured along the direction of motion. Thus, distance to an observer on the larger circle contracts relative to that measured by an observer on the smaller circle. This situation leads to a changing value of π, or to different measuring standards for measuring the radii, from those used to measure the circumferences. This deduction is contradicted by the Sagnac tests, because there is no diminution of the distance along the perimeter of a circle with increased speed.

Another strange consequence of the Theory of Special Relativity is that, under uniform motion, it is only the dimensions in the direction of travel which contract, dimensions perpendicular to the direction of motion being unaffected. This leads to the conclusion that a sphere travelling away at high speed would be observed to contract to a disc. An oft-quoted amusing result of the Theory is that a fast moving long ladder can be fitted into a short stationary garage - see Rindler 1982 (**16**). These situations do not arise.

FLYING CLOCKS

Haffle and Keating (**20**), in 1972, conducted tests with four cesium clocks, where the clocks were flown Eastward and Westward in aeroplanes around the Earth. The results of these investigations are often quoted as proof that time changes with speed, as predicted by the Theory of Special Relativity. It will be shown here that the tests were of insufficient accuracy to draw the conclusion that time is altered. They used the Theory of Special Relativity to forecast a difference in time between that recorded by flying clocks, and the time recorded by a standard station at Washington, USA.

All four clocks were predicted to lose time flying Eastward; two of the four did so, one gained time, and one showed no significant change. On the Westward journey, the clocks were required by the theory to gain time; two did so, one lost time, and one showed no significant change (the same clock that showed no difference on the Eastward journey)

It is normal for a particular cesium clock to show a drift rate relative to a standard clock station, which records the average of several very accurate clocks. Indeed, individual clocks can display inexplicable gradual, or sudden, *changes* in drift rate. Sudden drift changes can be, in extreme instances, as large as 1 μs per day; the differences forecast by the authors over the total flight time of six days were of the order of one-tenth of that.

The behaviour of the clocks during the ten days prior to the tests, and during the five days after the tests, showed that the results were highly dependent on the period in which the tests were actually performed. The changes during the flight periods were radical for three of the clocks. A clock that had been gaining time prior to flight was seen to be losing time after the flight. Other clocks suffered changes in their rate of drift during the flight period, by a factor of two or three. It is not known at what stage of any flight such changes in behaviour occurred, because no clock could be compared with the ground reference station during flight.

Despite the fact that one of the four clocks on each of the Eastward and Westward journeys showed time changes of opposite sign to those predicted by the Theory, Haffle and Keating still took the average of all four clocks; **the average turned out to be of the same order, but of opposite sign, to the time changes of the aforementioned aberrant clocks.** Taking the average of the time changes recorded by the four clocks does not provide evidence, on which a conclusion may be based.

Realising the somewhat disparate behaviour of the four clocks, the authors proceeded to make corrections to these results. Whenever, during flight, one clock displayed a sudden change in drift rate relative to the other three, its rate change was ignored. Had but one such correction been made, there could have been some credibility in this procedure; but fourteen such sudden rate changes were ignored, with seven of these on one clock. These corrections changed the results derived by the average method from -66ns to -59ns going Eastward, and from +205ns to +273ns going Westward. It was not possible for the authors to make corrections to offset possible *gradual* changes in drift pattern. The results predicted by their theory were -40ns and +275ns, which were very close to the published experimental results.

It is of interest to note that a previous test, carried out over some weeks in 1970, and referred to in the Haffle and Keating paper, resulted in no discernible gain or loss during the flights. It is evident that tests of a far more accurate nature are required to discern the effect, if any, of transportation on cesium clocks.

COMPATIBLE SOLUTION

The Sagnac results do not contradict the results of the Michelson and Morley experiment (1887) (**21**). In that test, the speed of light was measured to be the same, whether measured in the direction of the motion of the Earth on its orbit around the Sun, or at right angles to that direction.

A solution is now needed, which fits both the Sagnac and Michelson-Morley experiments, and which also agrees with the requirement of the Theory of Special Relativity quoted earlier, and which is confirmed by the Sagnac tests, namely that the speed of light is independent of the speed of the source.

One possibility is that light, on Earth, travels with respect to a coordinate frame fixed relative to the Earth. Katz (**22**) says (when commenting on the Fizeau experiment on the behaviour of light in moving water) that *"the speed of light in a medium must clearly be with respect to a coordinate frame fixed in the medium, for the very structure of the medium, the position of its atoms and molecules, provides a preferred reference frame"*. In water, the speed of light is 0.75c, but this speed is increased (decreased) when the water is moving with (against) the direction of the light signal.

As is the case for all media, light travels in air at a speed less than c (which is the speed in a vacuum). The speed is c divided by the index of refraction of the medium; for air the index is 1.0003. No distinction has yet been made in this paper between the speed of light in a vacuum and in air, because the difference is so small.

It is proposed that light travels in all directions in the atmosphere at a speed of 0.9997c, and is unaffected by the motions of the Earth, or by the motion of any observer.

Under this proposal, when light escapes from the Earth, it travels at c in free space, relative to the point where it escapes from the atmosphere; this is analogous to the case where light escapes from water (where it travels at 0.75c) to air, whereupon it assumes the speed of light in air.

The synchronisation of clocks on Earth, using signals reflected off satellites, would require a slight amendment, to take into account the change in the speed of the light as it leaves and reenters the atmosphere.

ELECTROMAGNETISM

In a test done in 1917 Pegram (**23**) showed that, using a solenoid carrying a steady D.C. current:

1. A stationary short straight isolated radial conductor, inside a stationary solenoid, is not charged (as would be expected).

2. The stationary radial conductor, inside the rotating solenoid, is not charged. **This is certainly not as would be expected.**

3. When both the solenoid and the conductor are rotating there is a charge. Again **this is not as would be expected.**

These tests accord with the conclusions in this paper in relation to the behaviour of light, which is also an electromagnetic phenomenon.

If the current in the solenoid is flowing, relative to the laboratory, and is not moving with the moving solenoid, then the tests make sense. Altrnatively, if the magnetic field was relative to the laboratory and not to the spinning magnet, the results would also make sense. Pegram stated that Faraday was of the latter opinion, but this seems to have been overlooked in the meantime.

Pegram said *"the generation of an electromotive force is not simply a questiion of the relative motion of the conductor and the solenoid which furnishes the magnetic field"*.

In a 1990 leader in Nature (**24**) John Maddox, the editor, posed a problem similar to No. 2 above and stated that if there were no charge in such a case *"relativity has vanished out the window"*. In the leader he was discussing a theoretical claim by a Bulgarian exile (Marinov) that in such a test there would be no charge.

$E = mc^2$ MAINTAINED

In many texts (e.g. Young (**5**)), the derivation of $E = mc^2$ begins with time dilation and distance contraction. To sustain the theory put forward in this paper, an alternative explanation is required, because that famous formula is not being questioned. In this respect, it is interesting to note that Lorentz (**25**, p.24) had published the relationship between energy, mass and the square of the speed of light in 1904, a year before Einstein published his first paper (in which he stated that time and distance differed aboard moving objects). Also, in 1906, Einstein in a "thought experiment", by considering solely the momentum of photons as they moved from one end of a closed box to the other, came to the $E = mc^2$ equivalence - see French (**25**, p.16).

The rest of the results concerning mass and energy follow directly from $E = mc^2$ and the relationship $E=pc$ where p is the "virtual" momentum of a photon. French (p.20), using these relationships, derives other mass and energy relationships such as $E = E_0\gamma$ and $m = m_0\gamma$. The theory put forward in this paper does not question these equivalences.

The matters disproven in this paper will not cause any dire consequences. The result should give a better insight into the behaviour of electromagnetic phenomena. There may be phenomena that do not appear to fit with the theory proposed here, but the basic, simple and incontrovertible experimental practical tests described in this paper must be explained by *any proposed theory.*

The General Theory of Relativity is not addressed in this paper: The effect of the conclusions of this paper on the wider realm of physics will require separate publication.

TESTS TO BE DONE

It would give confirmation of the theory in this paper were the following tests to be carried out.

1. A Michelson-Morley test on the moon, where there is no atmosphere. It would be interesting to determine whether the result is different from that on Earth.

2. A Sagnac test on the moon would show if the light travelled relative to fixed space, and ignored the movement of the moon.

3. Both of those tests repeated in space off a satellite or rocket.

4. A repeat of the Pegram tests would confirm the conclusion concerning electromagnetism.

CONCLUSIONS

1. Light, which is sent around the circumference of a rotating disc, in opposite directions, does not travel at the same speed c, relative to an observer aboard that disc. This was first demonstrated by Sagnac in 1913, and repeated, with ever greater accuracy by many investigators over the intervening years.

2. The explanation put forward for the Sagnac effect in this paper is that light travels in the co-ordinate frame of the laboratory, even when it is generated aboard a spinning apparatus. and that the behaviour of light is unaffected by the motion of the apparatus.

3. This leads to the deduction that distances and time as measured by an observer aboard a spinning disc are the same as those measured by an observer in the stationary laboratory; they are also the same aboard any object that is moving with uniform speed relative to the stationary laboratory. This does not agree with the Theory of Special Relativity.

4. Tests done, which purport to prove that the timekeeping of clocks varies with speed, are of insufficient accuracy to support such a theory.

5. It is suggested that light travels at a constant speed of 0.9997c with respect to a coordinate frame fixed relative to the Earth. This proposal fits with the Michelson-Morley and Sagnac tests, and with the first requirement of the Theory of Special Relativity, (that the speed of light is not affected by the speed of its source).

6. The relative motion of a conductor and a current carrying solenoid is not the determining factor in whether there is a charge across the conductor.

7. Time and space are absolute. A relative, but not an absolute, speed of light in excess of c is possible. This explains the appearance of objects in outer space, that are observed to travel at relative speeds greater than the speed of light.

8. Some experiments could be performed to test the conclusions of this paper.

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