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Notes by KESWANI

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COORDINATES IN RELATIVITY THEORY

I. THE SPECIAL THEORY OF RELATIVITY (SR)

There are two issues which have to be sorted out:

One: the geometry of space-time, mathematically speaking, the Minkowskiam line-element, is not really admissible. I shall quote Cornelius Lanczos, a mathematician of relativity and also a friend of Einstein. (C.Lanczos, Einstein Decade, 1905-15, Elek Science, London, 1974.) The three space coordinates (x, y, z) and the time coordinate (ict, $i=\sqrt{-1}$) do not satisfy the concept of rational measure and time has an imaginary measure.

Lanczos says, "These are the natural minimum conditions that any rational 'measure' has to satisfy in mathematics. In the Gauss-Riemann type of geometry all these conditions are satisfied, at least for points, which are not too far from one another.

In the four dimensional geometry of Minskowski- accepted also by Einstein- these conditions are no longer satisfied, because the time square appears in nature's Pythagorean theorem with a negative sign. This has disastrous consequences. The 'distance zero' belongs to points, which can be millions of miles away from one another. The ordinary concepts of 'neighbourhood' are completely swept away. On the other hand, Riemannian geometry operates unmistakably with neighbourhood constructions without which the fundamental 'curvature tensor' becomes meaningless. How can one reconcile these apparent contradictions? Certainly Gauss and Riemann would have considered an 'indefinite line element' as a geometrical monstrosity even if one can operate with it in the formal mathematical sense".

Likewise the British mathematician, Forsyth in his book, Geometry of Four Dimensions, lamented: "The notion was propounded by the mathematicians: the added dimension, which they have incorporated in an abstract geometry, is coordinate in quality and in possibilities with the three dimensions familiar already in conception of triple space. The forth dimension has been appropriated by some physicists, for what is called a 'natural' geometry, without any requirement as to coordinates in quality and in possibilities with the three dimensions familiar to experience". (A.R.Forsyth, in preface to Geometry of Four Dimensions, Cambridge University Press, 1930, p.viii.)

Lancsoz has recorded that when he discussed these incongruities with Einstein, he admitted its seriousness and felt very uncomfortable with an indefinite line element. Einstein's words were " The indefinite metric offers a puzzle which must arise from some deep seated source". So there is a challenge to meet.

II Another issue is the structure of Lorentz Transformations Equations:

$$x'=\beta\,(x-vt),\ y'=y,\ z'=z,\ t'=\beta(t-vx/c^2).\qquad \beta=1/(1-v^2/c^2)^{1/2}$$

vx/c^2 is a strange entity. Eddington struggled over more than one page to conclude that this is due to non-simultaneity.

It will be noticed that the transverse coordinates are not affected by transformation. It was a legacy from the days of Fitzgerald in the 19th Century to think of an effect in the direction of motion (x coordinate) in the propagation of light rays going in the x-direction, which will cause contraction of bodies and space (within). Lorentz maintained this idea. Poincare in his paper of 5 June 1905 published in Compte Rendu, referred to it in the passing: "One sees that in this transformation the x-axis plays a preferential role, but one can evidentally construct a transformation in which this role will be played by any arbitrary line passing through the origin."(See English translation by G.H.Keswani and C.W.Kilmister in Brit.J.Phil.Sci, 34,1983,p.350).

We beg to differ. As to contractions of time and space the fact is that it is now established experimentally, without a shadow of doubt, that when a clock travels, in a plane, in a round trip it will find on return that his clock has gone slower as the theory shows, than the base clock, which did not undergo infusion of energy for the flight. If the clock goes slow the space must contract too, and the velocity of light will be constant.

Obviously all matter in the plane is subjected to slowing (at the fundamental level all matter has its own rhythms), not only in the direction of the single line(x – coordinate) of flight.

I emphasize that the moved body is subjected to a dynamic operation involving energy. So all space of the moving space contracts and time in it, at all points take place, and goes slow. Then only will the velocity of light within the moving system, be constant.

Conformal Transformations:

So the following Conformal Transformation should prevail,

$$\mathbf{x' = x^*/\beta\ ,\ y' = y/\beta\ ,\ z' = z/\beta,\ t' = t/\beta,\ x^* = (x\text{-}vt),\qquad \beta = 1/(1 - v^2/c^2)^{1/2}\ ,}$$

which will ensure isotropy, homogeneity, the Principle of Relativity and Constancy of the velocity of light, within any inertial system. I derive this transformation smoothly in the essay in the sequel.

Incidentally, β in Lorentz Transformation, the vehicle of Special Relativity, is the same as for the Conformal Transformations, and many oddities of Lorentz Transformations will disappear with Conformal Transformations. There is no question of creation of the imaginary √-1 time because this is not a physical entity. The distress of Einstein and Lancsoz evaporates and all the four dimension stand symmetrically.

Humbly I put this proposition before the reader.

- Derivation of the modulus of Conformal Transformation.

II THE GENERAL THEORY OF RELATIVITY (GR)

PRINCIPLE OF EQUIVALENCE

It is a misnomer. It considers only linear acceleration under the Principle of Equivalence which Einstein regarded "complete physical equivalence of the systems of coordinates", one accelerated and other under the action of gravitation. (The Meaning of Relativity, 1950, Methuen Pub. p. 56)

Einstein gave a thought-experiment of a person in a lift (unfortunately) in free fall, which is still popular. The occupant will be travelling "freely" inspite of acceleration.

The present author had given the exact calculation showing that the earth in its orbit in free-fall goes slower in GR. The idea and approximate figure of slowing was given by Einstein's associate and biographer, B. Hoffmann, (Nature, p.218,667&756, 1968), G.H.Keswani gave the exact solution (Nature, p.220,148, 1968).

These showed that time-rate is affected by the gravity and motion, although the earth is in free-fall in its orbit.

As to rotational motion, measurement of which is possible without reference to other bodies, (Rotation of the earth, Foucault's Pendulum, etc.), Poincaré, questioned: "Can a thing turn without turning with respect to something?" (H. Poincaré, Science and Hypothesis, Dover Pub., p. 114). **This problem is unsolved. However, Einstein's greatest discovery is the effect of gravity on the measure of Space and Time, so important in Astrophysics.**

Principle of Covariance

In his great paper of 1916, Einstein postulated the General Principle of Co-Variance (Article 3, The Principle of Relativity, Dover, P. 159) "……….to regard all imaginable systems of coordinates, on principle, equally suitable for description of nature." He introduced tensors with which most of his paper is occupied. The only fecunding equation was:

$$\frac{d^2 x_\tau}{dt^2} = -\frac{1}{2}\frac{\partial g_{44}}{\partial x_\tau} \qquad (\tau = 1,2,3) \ldots\ldots (67)$$

$$\nabla^2 g_{44} = \kappa\rho \ (\rho = 8\pi G/c^2) \ldots\ldots (68)$$

For the field of a point-mass he just wrote down the results as below, saying these were "first approximation" :

$$g_{44} = \left(1 - \frac{\alpha}{r}\right), \ldots\ldots (70)$$

and $$g_{11} = -1 \left(1 + \frac{\alpha}{r}\right)$$

where, $$r = +\sqrt{x_1^2 + y_2^2 + z_3^2}$$

and $$\alpha = \frac{2\,MG}{c^2\, r} = 1.87 \times 10^{-27}$$

G is gravity constant as measured by the Newtonian Theory. r is the radius of spherical mass.

He did not see that g_{44} and g_{11} values given above will yield a flat space-time!
But he asserted, "Euclidean geometry does not hold even to a first approximation."

He did not calculate the advance of the perihelion of the planet mercury in one Earth's century. He just put it down. $\varepsilon = 24\pi^3 a^2 /[T^2 c^2 (1-e^2)]$ …… ……. (75)

Einstein refers to his paper of 1915 which did not have full and correct equations yet, of the gravity field, and used approximation to get the result of 43 seconds. (Refer to pages 160, 161, 163 and 164 of the same paper of Einstein mentioned earlier.) In his final 1916 paper exact metric was NOT derived, and reference was made to the (approximation) of 1915 for the calculations!

We now go to the correct outer metric of a spherical body, and how the Principle of Covariance has been used upon the coordinates of the body.

Einstein's Principle of Covariance

It means that a law of physics should mathematically be such that it has the same form in all Coordinate Systems (CS) (Like Maxwell's Equations.) When singularities arise as they do in the case of the Schwarzschild metric given below, all kinds of substitutions for coordinates have been used without regard to their physical meaning. But coordinates must be measurable quantities if we are talking of physics.

$$ds^2 = dr^2 / (1-2MG/c^2r) + r^2 (d\theta^2 + \sin^2\theta\, d\varphi^2) - (1- 2MG/c^2r)\, c^2dt^2$$

Consider, for example, the most popular substitutions posited by Kruskal for 'removing' the singularity. (Kruskal , M.D., Phys.Rev.119, 1743,1959.)

Kruskal's new coordinates are (u, v, θ, ϕ); he states that the task is "to seek a spherically symmetric *CS* in which the radial light rays everywhere have the slope $dx_1 / dx_4 = \pm 1$".
Kruskal writes down the metric outside of the "singularity" { $r = 2m$ }: $-m = MG/c^2$

$$\underline{ds^2 = f^2(dv^2 - du^2) - r^2(d\theta^2 + \sin^2\theta\, d\phi^2)}$$

f is required to depend on r alone, but v and u are taken to be composite functions of r and t. With these enormous assumptions, made in two shakes of a lamb's tail, the transformations for the exterior, $r > 2m$, and the quadrant $u > v$ in the plane of the new variables are given as:

$$u = \{(r/2m) - 1\}^{1/2} e^{r/4m} \cosh(t/4m)$$

$$v = \{(r/2m) - 1\}^{1/2} e^{r/4m} \sinh(t/4m)$$

$$f^2 = 32\,(m^3/r)e^{-r/2m} \quad \{\text{NB: not } t, \text{ only } r\}$$

These new coordinates are regarded as analytic extension of the Schwarzschild metric as the singularity does not arise with the two new coordinates.
Differentiating the equations for u and v, it is easily seen that the total differentials du and dv diverge with $r \to 2m$ (the "singularity"). If $r < 2m$, u and v become imaginary.
Apart from the arbitariness of the assumptions, the following questions arise:

(i) The physical meaning of the new variables is completely absent. How are the coordinates (u,v) to be measured? This is physically the most important question.

(ii) When the new variables are composite functions of m/r and t, the amalgam of coordinates becomes physically intractable. Can we then say, at all, that the metric has spherical symmetry?

(iii) In Kruskal's analysis $dx_1/dx_4 = \pm 1$, hence $du/dv = \pm 1$, so that the radial "light rays" have slope unity, i..e the radial velocity of light is everywhere c (presumably). But while f has the dimension of length, u and v (composite functions of the measurable variables r and t) are both dimensionless. Is u then the radius, and v the time? Hardly. And what is t/m?

Indeed, Kruskal was just lightening his algebra by taking the coefficients of du^2 *and* dv^2 to be identical (f^2), without any physical justification.

ETHER

PROOF

First, a **proof of physical properties** of the ETHER, so-called, degraded as "empty space". These are properties measurable and have been measured in the laboratory with great accuracy, in fact Exact Units are involved.

A note on space will be in the book I am putting together, on THE FOUNDATIONS OF RELATIVITY, and it will form a small portion of the first chapter of the book, containing basic elements. The inspiration for this came from Dr.Duffy last year. I am really following the path where Maxwell left it.

I am enclosing the pieces on **Space**, **Time,** **Maxwell**, **M-M Experiment** and **Greatest Equation Ever & Ether In Space**. I will get help from BJPS and OUP for publishing the book.

Indeed, Maxwell drew pictures of electromagnetic fields passing through the ETHER showing the two intertwined fields out of phase moving with the velocity of light in synchrony and sinusoidal flow in the ETHER.

THE NAME ETHER

ETHER is a beautiful name from Greek. It was regarded the transmitting medium permeating all spaces in the cosmos. Its adjective, etherial, meant heavenly. It was also called "celestial". In ancient cosmology it was the element filling all space (OED, vol. I, page 636).

In his 1905 paper on relativity right in the beginning Einstein dismissed the "the light medium", i.e., ETHER and said, "the phenomenon of electrodynamics as well as of mechanics possesses no properties corresponding to the idea of absolute rest."

Also, gradually the whole physics community after the Michelson-Morley experiment dropped the conception of physical ETHER. The Encyclopedia Britannica recorded in 1979 that "with the formulation of the special theory by Einstein in 1905 and acceptance of it by scientists, generally, the ETHER hypothesis was abandoned……." (P.976 Micropedia, NOT Macropedia which does not deal with ETHER at all, my 1979 edition).

Incidentially, Maxwell had for 3 years (1864-67) undertaken Michelson's experiment (almost like Michelson's) rotating turntable, spectroscope, and two telescopes using sunlight. He

wrote the results in a letter to Huggins, Astronomer. Excerpts from Maxwell's results are given below, and has been little noticed.

"I have tried this experiment at various times of the year since the year 1864, and have never detected the slightest effect due to the earth's motion. If the image of the spider-line is hid by the intersection of the cross lines in one position, it remains hid in precisely the same way in the other position, through a deviation corresponding to one-twentieth of the distance of the components of the line D could be easily detected". (0.3 Å)

"This experiment seems rather to verify Fresnel's theory of the ether; but the whole question of the state of luminiferous medium near the earth, and of its connexion with gross matter, is very far as yet from being settled by experiment."

I wonder why he did not say that velocity of light is constant because ETHER controls and determines that exact performance of light. As far as I know I brought Maxwell's letter to light. I have learned this from Maxwell. When I had been studying in the Library of the Royal Society of London for 3 months after I got an Award from the Nuffield Foundation.

So, as to the name, why not just "ETHER", back with its pristine glory in the words of the poet Pope:

All the unmeasured Ether
Flames with light.
…. POPE

GREATEST EQUATION EVER & ETHER IN SPACE
A GIFT FROM MAXWELL

REQUIREMENT:

Simplicity of structure, independence, steeped in fundamentals of importance to physics, deep ramifications, elucidate what are still thorny questions, like what is space? How it is that the velocity of light is constant while emitters and most absorbers are in very large motions (fraction of light's velocity)?

The velocity of light, c is the queen of fundamental constants and its definition given below in terms of two other constants of nature is by far the greatest equation ever. This is a great gift of J.C.Maxwell. (I am not talking of his famous equations of propagation of electromagnetic waves.)

THE EQUATION

Here is the equation, succinct, of three letters which is minimum for an equation.

$$c^2 = 1/\epsilon_0 \mu_0, \text{ regarded as exact .}$$

Appearance does not have any indication of this equality. It keeps a great secret within itself.

1. It is simple, naked and is in the small class of exact equations.

ϵ_0 is the permitivity of "empty" space, and μ_0 is it's permeability.

Their respective values are :

ϵ_0 $8.854\ 187\ 818\ \ 10^{-12}$ F/m (Exact)
μ_0 $4\ \pi \times 10^{-7}$ Hm^{-1} (Exact)

c in turn, permeates many equations of other important fundamental constants, such as the fine-structure constant, Rydberg constant and Stefan-Boltzman constant. Even in the

energy $\leftrightarrow$ matter equation, $E= mc^2$, would fail if c were not constant ; c has multifarious and key positions.

This equation contains answer to the **question**:

Why is velocity of light constant in vacuum not affected by the emitters with a fraction of light-velocity, or of the receiver also in motion, and more importantly why that exact figure of velocity (km/sec)?

Answer: the velocity of light is determined by the Physical properties of the transmitting (so-called empty) space. It is not vacuum. What was called aether exists as properties of space, dimensionally. It is like resistance to electricity. Incidentally, impedance of vacuum is also exact (376.730 313 461 Ω)

In all humility, this explanation is mine, none other has given before.

Is this exact equation for c universal, in the whole cosmos and say, inside a black hole? In exceptionally ultra high density bodies and fields one should expect that the values of ϵ and μ would be different. But the astronomers are getting radiation at constant velocity. Otherwise, there would be no consonance in Astronomy, if not chaos. So the exceptions are few and far between.

These physical properties of space are real, in the nature of entropy, not affecting the senses.

Endowed with physical properties, such as permitivity and permeability, the so called empty space is surely the ether which exists beyond doubt. Indeed, this opens another window to research to determine how the gravity travels through the "empty space" and through matter, unhindered and where does gravitational potential reside, which we experience every day – even in play! What other properties does it have? How does gravity as field, force, potential, energy travel through "empty" space?

INERTIAL SYSTEMS (IS) FOR REFERENCE OF EVENTS IN SPACE AND TIME

We begin by saying that there is lack of understanding of the concept of IS. It is understood that all IS at rest (?) or in Uniform Motion of translation (1st Law of Newton) are ABSOLUTELY ALIKE. We say, yes if and only if they have the same history (de Sitter[1] was the first to say so, about the history of previous motion in 1911 although he did not give the cause of it.). For example, when a body (clock, or (S` matter), on earth or lab when set into motion, time and space of the new IS will be reduced in all the 4 dimensions (Eddington's Lilliput.)

An observer within an IS (carrying a Cartesian 3-D frame with coordinate-marks and dotted with clocks) has generally speaking, its own space as, Minkowski[2] said - space which is homogeneous and isotropic.

Lorentz's "local-time", Einstein's "time" of any system, and Minkowski's "Proper Time" mean exactly the same physically, i.e., are the same entity, same measure.

Let us take the system of the Sun, in which an IS is at rest (but it's rotation remains). Its motion in The Galaxy and objects beyond, has little effect on time, i.e., change in it's rhythm. However, there would be an effect on time of its own gravitational field.

If the earth were at rest relative to the IS of the Sun, as mentioned above, the time at the location where the earth is, would be different (faster) because the gravity field of the Sun is weaker on the earth.

Time will be affected by the change in orbital motion in an elliptical path, as calculated by Banesh Hoffmann[3] and G.H.Keswani[4]. (6.6×10^{-10}Sec.) Correspondence between the two of us is enclosed, also as reference the two annexure of the two letters to Nature, are attached.

Next, coming to the earth's surface, the time at any place will additionally be affected by the rotation about its axis $*(1 - \omega^2 r^2/c^2)^{-1/2}$, and r which varies with the latitude. Also the elevation, i.e., the distance above the mean sea level, the geoid, affects the time. The three international Time-Keepers of the world in USA, Germany and Japan who are busy synchronizing their clocks constantly, have to apply corrections, day in and day out. There exist essentially different IS on the earth itself.

Lastly, take the case of the objects with their clocks set into motion relative to the earth in translatory or rotational motion relative to the earth say, a satellite. These clocks also record and reckon changes relative to the stationary clocks of the earth. These objects and clocks constitute their own inertial system, each by itself depending on the velocity communicated to it.

*It is experimentally established beyond any doubt that change is not dependent on the acceleration ($\omega^2 r$) but the velocity (ωr). Acceleration is the mediating cause, the slowing depends on the instantaneous velocity (ωr).

The most dramatic is the slowing of time of clocks flown in aeroplanes, including Concorde.

Since the velocity of light has to remain the same, each IS has, also, its own space. Contraction of time and space has to be, by the same factor, viz., $\beta = (1-v^2/c^2)^{-1/2}$, otherwise IS (S`) also will not be homogeneous and isotropic, and velocity of light the same. There is no option. Either all the four coordinates contract in time and distance, or none at all.

However, the Principle of Relativity of motion applies to them all. The law of physics within all inertial systems are experimentally and invariably found to be the same in all IS.

The IS of the Sun, Earth and other objects are different. The earth is a good approximation to an inertial system. The IS of the Sun is a better example to an ideal IS. There space and time measures differ. In other words when the motion of the clock, in its own is at rest, viz. force-free, the system within itself has the same laws of physics, as any other IS.

There is no reciprocity between two bodies S and S′ of the same origin one at rest at the origin and another (S′) set into motion relative to the first (S). Additional energy $v^2/2c^2$ is infused and inertia of S′ is enhanced, leading to a new dynamics, but conformal to each other.

TO SUMMARIZE: THE RHYTHM OF CLOCKS BEGINS WITH THEIR ORIGIN, SAY THE EARTH (IT ALSO APPLIES TO THE SOLAR SYSTEM). ALL MATTER ON THE EARTH HAD THE SAME ORIGIN AND RHYTHM, BUT IT CHANGES WITH IT'S LOCATION (GRAVITY) AND MOTION. (THE RHYTHM OF TIME AND THE MEASURE OF DISTANCE, BOTH). DO WE COLLECT CELESTIAL MATTER IN PEREGRINATIONS OF THE SUN, THE GALAXY, CLUSTERS…..? THIS MATTER COULD HAVE DIFFERENT HISTORYAND RHYTHMS OF TIME.

Strangely, all the exponents of Relativity maintain that there is complete identity and reciprocity between S and S′, as the following statements shows.

(i) A. S. Eddington[5]: " There is a complete reciprocity between *S* and *S′*."

(ii) W.Pauli[6]: "The Lorentz contraction is not a property of a single measuring rod taken by itself, but is a reciprocal relation of two such rods moving relatively to each other."

(iii) R.C.Tolman[7]: "Time Dilation (is) an entirely verifiable mutual property of clocks in relative motion, even as the Lorentz contraction could be regarded as a verifiable mutual property of metre sticks in relative motion."

(iv) C.Møller[8]: "When we keep in mind that the systems *S* and *S′* are equivalent, it is obvious that a clock at rest in *S* similarly will lag behind the clock of *S′*.".

(v) Bergmann[9]: "Thus the rate of the clock appears slowed down, from the point of view of *S,* by the factor $\sqrt{1 - v^2/c^2}$...". P " An observer connected with either frame of reference finds the rate of clocks in the other system slow.

(vi) J.L.Synge[10]: "Thus the moving clock appears to be slowed down."

(vii) W.H.McCrea[11]: "… a moving clock appears to go slow."

(viii) A.P.French[12]: "Equally unfortunately it is suggested that some essential change occurs in the operation of the clock itself, that the physical basis of its operation has somehow been modified, whereas it is a central feature of relativity theory that just the opposite is true."

(ix) N.D.Mermin[13], our last example: "Two inertial observers in relative motion must each see the other's clock as running at the same rate".

(x) At a meeting [20] in 1911, the following exchange took place:

Prof. Prašil. " In his famous essay *Space and Time*, Minkowski wrote about the nature of dilation, that the latter is a concomitant circumstance of the state of motion. He makes it absolutely independent of any physical influence. Lorentz on the other hand, when he was explaining Michelson's experiment, stated outright this conjecture that it may well be good to assume that such a change in length is brought about by the influence of the ether or of molecular forces. These are two things that I cannot reconcile."

Prof. Einstein: " Allow me to answer with a comparison. It has to do with the second law of thermodynamics, the law of the limited convertibility of thermal energy. If one takes the assumption of the impossibility of a *perpetuum mobile* of the second kind as the starting point of the argument, then our law appears as almost an immediate consequence of the basic premise of the theory. But if one bases the theory of heat on the equations of motion of molecules, then our law appears as the result of a long series of most subtle arguments. Just as here both of these routes have their undeniable justification, so the above-mentioned points of view of Minkowski on the one hand and of Lorentz, on the other, seem to me completely justified."

RECIPROCITY OF REMARK (GHK) : INTERIAL SYSTEMS HAS BEEN A MISCONCEPTION AND AN OBSTACLE TO THE CORRECT UNDERSTANDING AND TEACHING OF RELATIVITY.

REFERENCES

1. W.de Sitter, *On the bearing of the Principle of Relativity on Gravitational Astronomy, Mon.Not.Roy.Astro.Soc*., 71, 388 (1911). See page 392.

   Quote: " Every point has thus its own proper-time, which is independent of the system of reference, but depends on the state of motion of the point and on its previous history."

Incidentally, de Sitter refers to Poincare and Minkowski, but not Einstein at all in this paper.

2. See: P.L.Gallison, Minkowski *Space-Time. Historical Studies in the Physical Sciences.* The Johns Hopkins Univ. Press, 1979.
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13. Mermin, N.D., 1998: *Am.J.Phys. 66,* 1077.
14. Einstein, A., 1911 on The Theory of Relativity, see vol.3 of papers, Princeton University press, p.355,1993.

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Dear Dr. Keswani:

It has been on my mind for a long time to reply to your letter of last November, and I apologise for not having done so before. I hope you do not think me rude to have delayed so long. I have been so extremely busy that there has been no chance to write before, and I have been waiting for the issues of BJPS to return from the bindery so that I could make copies of your articles and of the ensuing discussion. It is a pity that you did not look me up when you were in the United States. Not knowing you, I can not tell whether we would have liked each other or not, but certainly that would have nothing to do with your views on scientific matters, and though I do not wholly agree with you, and in some cases believe you may be in error, I have a high respect for your acuity and your knowledge. The question of what Poincare, Lorentz, and Einstein had in mind is extremely difficult, and it needs a great deal of study. You may be interested in the following remark by Poincare on page 212 of SCIENCE AND HYPOTHESIS (Doven) at the top: "… some day, no doubt, the ether will be thrown aside as useless." This is rather surprising in view of Poincare's seeming reliance on the concept of an ether in many of his writings, and it goes to show that probably none of the people involved had absolutely clear-cut ideas. On page 150 of your reply to Dingle and Levinson you reiterate that Einstein spoke of absolute effects when he compared a moving and a stationery clock. But In his 1905 paper Einstein is careful to say that he uses "moving" and "stationary" only as convenient terms (which he puts in quotation marks) and not as having any real significance. I do believe that there has been much too little credit given to Poincare, at least before the appearance of Whittaker's book, but I also believe that Einstein quite genuinely had something that neither Lorentz nor Poincare had. However, it is important to remember that all theories are bad when examined closely. For example, as Einstein himself pointed out to me, his 1905 paper assumes the existence of rigid rods but shows that they cannot exist. There are other difficulties, too. But the mark of genius is precisely that it finds a valuable path through an intellectual quicksand by a process that is far from being coldly logical. Look at Maxwell's original papers on electro-magnetism and see how self-contradictory they are. He himself freely conceded that they were. Yet he found the equations that others could not. There are numerous analogous instances in the history of science.

I hope I am forgiven for not having written much sooner. Please send me reprints of your future papers. And many thanks for your Christmas card.

All good wishes,

Sincerely yours,

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Dear Dr. Keswani:

You are quite correct in your recent article in Nature in which you point out that the effect on clock rates at preihelion and aphelion is greater than that given in the article by Sproull and myself by a factor of 4/3, and your own derivation is much neater than the previous one. I should appreciate receiving a reprint or two when they are available.

Meanwhile, your reference to your paper in Brit. J.Phil.Sci. led me to all three of your papers on the Origin and Concept of Relativity in that journal, and I read them with great interest. Unfortunately, they were just about to go to the bindery and I was lucky even to find them still available. If you have reprints of them, I should like to have one of each of the three articles.

On referring to the rough notes that I made as I was reading them, I checked your point about Einstein making an error on page 57 when he spoke of an expanding wave front of light being ellipsoidal when viewed from the moving system. (I may not have written down your exact words) But Einstein was not talking of a moving wave front of light. He was talking of a spherical surface enclosing a light complex. This mathematical surface has a constant radius, R. What moves with the speed of light is its center. The surface is thus not that of a spherical light wave. It is just a mathematical surface designed to enclose a particular light complex, and it seems to me that there is no reason why it should be expected to remain spherical when viewed from the moving system. This is tied in with the matter you discussed on page 27 of your paper II, where I am inclined to think that Einstein is consistent. But I should like to have chance to have your papers in front of me, and shall welcome their arrival.

I was not clear as to what you meant by your last sentence in your Nature article. The principle of equivalence is only meant to be valid locally, and when one is considering perihelion and aphelion the curvature of space-time becomes significant. I will admit, however,

that initially, I had precisely the same view, namely that because the bodies (clocks) were essentially in free fall their rates should be the same. Only after I performed the calculation and found the rates were different did I realize that the principle of equivalence did not apply for such great distances.

Sincerely yours,

Banesh Hoffman

J. C. Maxwell (1831-1879)
(Harbinger of Relativity)

Einstein had portraits of three scientists in his study in Princeton, of Newton, Faraday and Maxwell, all British. However, as Prof. C.Domb [(1)] remarked in Nature on the occasion of the centenary of Maxwell's death, the quality of his genius became apparent only in the twentieth century [(2)].

His talents were not fully recognized or assimilated in his own country during his lifetime. In Germany, Boltzmann, Helmholtz and Hertz, after a long study understood and propagated his electromagnetic equations and theories. Hertz was the first to measure the frequency and wavelength of electromagnetic waves. Boltzmann's admiration of Maxwell bordered on reverence, which historically got united into Maxwell-Boltzmann statistics.

In his own country Maxwell tried but did not get professorship in Edinburgh University, which, however, later conferred a L.L.D. upon him. He was not knighted or buried in Westminster Abbey, as Newton was. Perhaps, one could say about his equations what the German poet Rilke said about Buddha, that they would survive until the sun burns. This cannot be said even about Newton's laws of motion because on the cosmological scale they fail, for example a body set into motion will be affected by the gravity field, of the universe (such as in the de Sitter or Robertson-Walker universe). The Second Law of Thermodynamics may, however, survive, notwithstanding the terror of Maxwell's Demon. By the way, the physicist Heinz London [(3)] had announced that he was prepared to burn at the stake for the Second Law.

Importantly, for this essay, a great injustice has been done to Maxwell in not recording and recognizing his intimations of relativity of (uniform) motion, which were enough clear and penetrative. It is little known that Maxwell [(4)] was the first to use in 1876 the phrase "the doctrine of relativity of all phenomena", mechanical or electromagnetic, and this exactly in the sense and substance in which it is understood and can be sustained today. He was singularly the Prophet of relativity, and used this philosophic word, meant to signify relativity of motion.

He was the first to have transformed electromagnetic quantities from one system of coordinates to another system in relative motion of translation, and concluded, "the electromotive intensity (in the moving system) is expressed by a formula of the same type. Note the words "same type", which means "of the same form", while the magnitudes of various parameters vary generally. Only the relationships are the same when viewed mathematically. It is the form, which is invariant, not the content! This is true of Maxwell's equations, according to the special theory of relativity as well, where the magnitudes of the electric and magnetic fields change with the motion of the inertial systems, relative to the sources of the fields.

Maxwell, not only discovered that light consists in the propagation of oscillating electric and magnetic fields which interact and are coupled together, but also said that the velocity of light (in vacuum) is constant. He [(5)] wrote in his Treatise, "This velocity, therefore, which indicates relation between electrostatic and electromagnetic phenomena,

is a natural quantity of definite magnitude, and the measurement of this quantity is one of the most important researches in electricity."

Mark the words, "natural quantity" and "definite magnitude" in the last sentence. He meant that the velocity of light was what we now call a "fundamental constant of nature". It is not merely a conversion constant, but the most palpable thing with which we see the whole world, physical and physiological!

And yes, the related researches reached a climax only after a century in the 1970's, when the velocity of light was determined in the laboratories, in which the velocity was measured by determining frequency and wave-length, here-and-now, not by the time-of-flight techniques, but by the measurement of the frequency (ν) with an accuracy better than one-part in 10^{13}, and wave-length (λ), with an uncertainty in the determination of c as the product $\nu \times \lambda$ of two parts in 10^9. Laser light and interferometers were used. This led finally to the adoption, as an international standard, a definite figure of
2997925458 cm^{-1} as the exact value.

As we shall see in the sequel, in experiments using starlight from the galaxies, Maxwell implicitly assumed not merely the constancy of the velocity of light, but also invariance of this velocity, no matter how the source of light moved, a point perceived by Poincare[(6)] later, even more perspicaciously.

For more than a century it has been known too well that the emitting sources, per se, such as nuclei, electrons and atoms invariably in rapid motion and yet having no effect on the emitted velocity of light on earth, as from the heavens, in disregard of the ballistic Newtonian dynamics.

According to Newtonian dynamics the velocity of light measured on earth should be the vector sum of the velocity of light relative to the actual emitter (electrons of the emitting atom, for example) and the gross motion of the emitter relative to the earth, but, strangely, this is not the case, which is well established experimentally.

Maxwell devotes a lot of space in his Treatise to the measurement of the velocity of light. He was a master of dimensional analysis, which is now little taught. He[(7)] not only dealt with the theory, but also participated in these experiments and found the velocity to be 2.88 x $10^8 ms^{-1}$. Ten years earlier in 1856 Weber and Kohlrausch [8] got a figure of 3.1074 x $10^8 ms^{-1}$, using the method of units for the first time.

The present writer has argued that since the velocity of light in free space is,
$c = 1/\sqrt{\varepsilon_0 \mu_0}$ where ε_0 is the permitivity and μ_0 is the permeability, of "empty" space which is endowed with definite physical properties of permitivity and permeability, therefore, space could not be regarded as a non-reactive nothing!
It is little known that Maxwell [9] made instrumentation to detect the effect of the ether (luminiferous medium, if it existed), on the light received from the stars. The instrumentation, essentially, consisted of a spectroscope, two telescopes and three achromatic prisms, apparently mounted on a turntable in order that one may "reverse the whole instrument so that the rays pursue an opposite path with respect to the earth's motion" in the orbit. Writing in the year 1867, he said, "I have tried this experiment at various times of the year since 1864, and have never detected the slightest effect due to

the earth's motion. If the image of the spider-line is hid by the intersection of the cross lines in one position, through a deviation corresponding to one-twentieth of the distance of the components of the line D (i.e., D_1 and D_2) could be easily detected."

One-twentieth of the of the difference between these two-D lines would be 0.3 Å, corresponding to a velocity relative to the putative ether of 15 kms^{-1}, accuracy remarkable for 1860's.

Two effects " different and independent were the subjects of the experiments."

(i) Doppler effect due to the motion of the star relative to the earth-observer, assuming that the "substances in the star have the same properties as substances found on the earth."

This quote and the assumption are very important, in the context of time dilation of the special and general theories of relativity, as we shall see elsewhere in our essays.

(ii) The other subject was the effect, if any, of the motion of the ether (luminiferous medium) relative to the earth, on the direction of a ray from the star refracted by the achromatic prisms.

Item (i) above was the subject of Huggin's paper referred to earlier. The word "Doppler" shift had however then not been introduced yet.

Item (ii) was the matter of Maxwell's investigation over a period of three years.

Whatever may be the merits of the theory and anticipation of Maxwell, he emphatically said that "never detected the slightest effect due to the earth's motion", on the direction of the rays of the of the star-light passing through his achromatic prisms at any time during the 3 years' observations, confident that the apparatus he used was accurate enough to detect the slightest effect, if there was one, by the putative ether at rest relative to which the earth changed its state of motion when orbiting.

Whatever may be the theory, it was a null experiment. He also expressed doubts about observations showing positive results obtained earlier by M.Fizeau on the rotation of the plane of polarization of light and one based on diffraction by M.Angström. Maxwell therefore seemed to believe that motion of the earth relative to the ether of the type assumed, was undetectable. In his letter [10] dated 22 Nov. 1876 to Bishop Ellicott he called ether "as a most conjectural hypothesis." This was three years before his death.

Even earlier, although in his letter of 1867 to Huggins mentioned before, Maxwell expressed some confidence in Fizeau's experiment on the velocity of light in moving water, he added, " This experiment seems rather to verify Fresnel's theory of the ether; but the whole question of the state of luminiferous medium near the earth and of its connection with gross matter is very far as yet from being settled by experiment."

We shall comment on the Fresnel's theory, heavily loaded with unreasoned assumptions, and the Fizeau experiment and its relevance to Einstein's development of relativity theory elsewhere in these essays. Einstein had said repeatedly that he was moved by Fizeau's experiment, undoubtedly superb, technically, and intriguing (and the aberration of starlight), but little by the Michelson-Morley experiment.

It is surprising that E.T.Whittaker, most painstaking and erudite, does not mention Maxwell's letter to Huggins and the related experiments in his history of the theories of ether and electricity.

We reproduce as Appendices II and III at the end of this essay, Maxwell's letter of 10June, 1867 to Huggins and article 600 of the Treatise regarding the transformation of electrical quantities to moving axes. The reader may, refer to the joint paper of Prof. C.W. Kilmister[11] and the present author, [included in these essays] for more details of Maxwell's prophetic vision of relativity.

Some quotations from Maxwell's Matter and Motion of **1876** in the sequel will be in place, to show Maxwell's understanding of his "doctrine of relativity" of motion christened and enunciated by him.

From: Maxwell's Matter and Motion. (Reprinted by Dover Pub.)

P.12 "All our knowledge, both of time and place is essentially relative."

P.22 " The phrase absolute velocity has as little meaning as absolute position."

P.36 "For the expression "at rest" has no scientific meaning, and the expression "in motion, "if it refers to relative motion, may mean anything, and if it refers to absolute motion can only refer to some medium fixed in space."

P.81 "There are no landmarks in space, one portion of space is like every other portion, so that we cannot tell where we are. We are, as it were on an unruffled sea, without stars, compass, soundings, wind or tide, and we cannot tell in what direction we are going.

We have no log which we can cast out to take a dead reckoning by; we may compute our rate of motion with respect to the neighboring bodies, but we do not know how these bodies may be moving in space."

P.83 "But though it is impossible to determine the absolute velocity of a body in space, it is possible to determine whether the direction of a line in a material system is constant or variable.

For instance, it is possible by observations made on the earth alone, without reference to the heavenly bodies to determine whether the earth is rotating or not."

He then quotes some lines from Milton's [12] Paradise Lost (Book VIII line 160-163).

> Whether the sun predominant in heaven.
> Rise on the earth, or earth rise on the sun;
> He from the east his flaming road begins,
> Or she from west her silent course advance.

To establish absolute character of rotational motion, Maxwell quoted Newton's rotating pale experiment, carrying it in his thought to the earth's pole, oblateness of the earth's figure and Foucault's pendulum.

Strange, Poincaré was to echo these ideas of Maxwell! Are we to believe that Poincare and Einstein did not know of Maxwell's related work?

P.90-91 "The energy of a material system can only be estimated in a relative manner. System contains a part, the value of which cannot be determined except by the arbitary

selection of an origin. The only origin which would not be arbitary is the centre of mass of the material universe, but this is a point the position and motion of which are quite unknown to us."

As to gravitation the following remarks go deep.

P.111 "This is the most remarkable fact about attraction of gravitation, that at the same distance it acts equally on equal masses of *substances of all kinds*."

P.119-120 "We have also found that the gravitation of equal masses at equal distances is the same whatever be the nature of materials of which the masses consist. This we ascertain by experiments on pendulums of different substances, and also by a comparison of the attraction of sun on different planets, which are not probably alike in composition. The experiments of Baily on spheres of different substances placed in a torsion balance confirm this law."

Of course, Maxwell is talking about the equivalence of inertial mass (as cause of inertia against change of state of rest or uniform motion) and gravitational mass (as agent of force).

It would be pettifogging to conceive of the latter mass as comprising other types of masses, i.e., as distinctively two different entities, one attracting and the other as attracted. The action is simply, reciprocal, between any set of masses. Even in the case of forces between electrical charges, where the forces may be attractive or repulsive, no such distinction is made or need be made.

MAXWELL AND RIEMANNIAN GEOMETRY

There is a curious reference to Riemannian geometry in a hurried handwritten letter dated 9 Nov., 1874, a part of which is reproduced below. Maxwell [13] received this from his friend of school days, the mathematician P.G.Tait, who developed the theory of quaternions created by R.W.Hamilton.

"…Why it is bosh to say the Riemannsche Idea may, if it be found true, gives us absolute determinations of position. Are not the max. & min. curvatures at any point of a given surface just as good coordinates as you could desire – though a little hard to work with, because (& only because) we are all, as yet, miserable duffers in mathematics? Why not, then the three numbers corresponding to the Riemanian affair? Answer this at once please, as I wish to get the Lecture into sheet (sic)". What exactly was brewing in Tait's mind? Was he thinking of the idea that physics at a given event (point) is determined by the local curvatures? We do not have Maxwell's reply.

The Genius of Maxwell

What is noteworthy in Maxwell's work is his sweep of numerous ethereal ideas marked by intense intuition about light, electromagnetic propagation and kinetic theory of heat, and related conceptions of critical experiments. And all this, not in a competitive spirit or atmosphere, but free from ambition, arising from a natural taste and insight, propelled by a passion to know.

The versatility of Maxwell can be seen from his researches in the kinetic theory of gases. A good example, is the derivation of the formula for the distribution of velocities of like molecules in all manner of motion:

The number of molecules dN in the velocity range, v to (v+dv) is given as:

$$dN = 4\pi N \left(\frac{mh}{\pi}\right)^{3/2} e^{(-m\,h\,v^2)} v^2\, d\,v$$

where, N = total number of molecules, m = mass of a molecule,
and h = a constant.

The constant h was later found to be equal to 1/(2k T), where k is Boltzmann's constant, and T the temperature.

The remarkable fact is that this is an asymmetrical distribution, unlike the Gaussian (normal) distribution.

$$f(x) = \frac{q}{\sqrt{\pi}} e^{-q^2 x^2}$$

where, f (x) = number of observations with deviation x, from the mean value, and
q = a constant giving a measure of precision.

Incidentally the present author has not seen a derivation of the formula for normal distribution. The mathematicians perhaps believe that the formula was derived by the physicists who in turn seem to believe that it was the mathematicians.

Einstein's [14] singular estimate of Maxwell was expressed in his tribute on the centenary of his birth in 1931. After calling Newtonian mechanics as perhaps the greatest advance in thought that a single individual was ever privileged to make, he came to the next great change (which) will be associated with the names of Faraday, Maxwell and Hertz. "*The lion's share in this revolution fell to Maxwell…"*(p.268)

"…After Maxwell they (people) conceived physical reality as represented by continuous fields… This change in the conception of reality is the most profound and fruitful one that has come to physics since Newton…"(p.269)

The third most successful creation of theoretical physics, "Quantum Mechanics", according to Einstein makes no claim to describing physical reality itself (in a deterministic way) but rather "the probabilities of the occurrence of a physical reality." (p.270). He thought that in the long run the physicists would not be content with it.

He ended by saying, "We shall then, I feel sure, have to return to the attempt to carry out the programme which may be described properly as the Maxwellian…"(p.270).

References:

1. C.Domb, Nature, 282, 235 (1979).
2. See G.H.Keswani, Nature 283, 330 (1980). Reproduced in Annexure I.
3. Biographical Memoirs of the Fellows of Roy. Soc. (London), 17, 442 (1971).
4. J.C. Maxwell, Matter and Motion, Dover Pub., p.80.
5. J.C.Maxwell, A Treatise on Electricity and Magnetism, vol.ii, 3rd ed., 413, Dover Pub. (Ist ed. of 1887; 2nd ed. by Niven, no change; 3rd ed. by J.J.Thomson, no change).See Annexure III
6. H. Poincare, La mesure du Temps, Rev. Met. Mor., 6, 371 (1898).
7. J.C.Maxwell, Phil.Trans of Roy.Soc. London, 99,643 (1868) and Report of British Association, 1869, p.436. See Treatise, pp.418 & 436.
8. W. E. Weber and R. H. A. Kohlrausch, Pogg., Ann 99, 10-25 (1856).
9. W. H. Huggins, Phil. Trans. of Roy. Soc. (London), 158, 531 (1868). Maxwell's letter forms a part of Huggin's paper. It is a letter dated 10 June 1867 buried inside the paper, and has gone unnoticed. The present author tried, without success, to get the particulars of the apparatus from the Kings College, University of London, where Maxwell was a Professor till 1865, when he retired to his estate at Glenlair. Letter reproduced in Annexure II.
10. See: Dictionary of Scientific Biography, vol. ix, Ed.- in-Chief C. S. Gillispie, Princeton, 1974. Article on Maxwell by C. S. Gillispie.
11. G.H.Keswani and C.W.Kilmister, Intimations Of Relativity: Relativity Before Einstein,Brit.J.Phil. Sci. 34, 343-354 (1983).
12. Milton had met Galileo in his youth.
13. In the library of late Prof. Derek de Solla Price, at the Yale University. The present author got a copy of handwritten letter from Prof. Price when he visited him in 1980.
14. 14. James Clerk Maxwell: A Commemoration Volume, Cambridge Univ. Press, 1931

Annexure I

Clerk-Maxwell Centenary

From : Nature, vol. 283, 330 (1980).

Sir, - It is not my intention to spoil the effect of the perfect tribute paid by Professor Domb in *Nature* (15 November, page 235) to Maxwell on the occasion of the centenary of his death. But could I be permitted to make a minor point and to mention Maxwell's ideas about the principle of relativity of motion?

Professor Domb's remark that the true quality of Maxwell's genius became apparent only with the development of twentieth century physics, might lead some to believe that his genius was lost on his immediate successors in the nineteenth century. Far from it. Perhaps, Boltzmann gave the most eloquent praise to Maxwell's equations (of electromagnetism). On reading these equations Boltzmann exclaimed, "War es ein Gott, der diese Zeichen Schrib?" *Was it a God, who wrote these signs? (Mensch. Physiker. Philosph.* Berlin, 1957, page 31.)

The word "relativity" was first coined by Samuel Coleridge in the year 1834 but he used it in a philosophical sense. It appears that Maxwell was the first ever to use the word relativity with reference to the doctrine of relativity of motion, and this not only for mechanical but also for electromagnetic phenomena. True, he suggested experiments to determine the putative motion of the Earth relative to the "ether" and in fact made an experiment himself to measure this motion, using a rotating spectroscope, prism and partially silvered mirrors but got a negative result *(Phil. Trans.* 1868, page 532). Therefore, Maxwell was not sure whether motion relative to the ether could be observed, but he ultimately moved to a firm belief in the relativity of all phenomena.

It is not widely known that in *A Treatise on Electricity and Magnetism* published in the year 1873, Maxwell devoted two articles, to the modifications of the equations of "electromotive intensity" when referred to moving axes. Using a method which is questionable, he yet came to the conclusion that "the electromotive intensity (in the moving system) is *expressed by a formula of the same type",* and added, "In all phenomena, therefore, relating to closed circuits and the currents in them, *it is indifferent whether the axes to which we refer the system be at rest or in motion."* This was more than an intimation of things to come.

Four years later in the year 1877, Maxwell published the book *Matter and Motion,* in which he used the word 'relativity' and affirmed, "Our whole progress up to this point may be described as a gradual development of the *doctrine of relativity of all physical phenomena."*

Obviously he expected that the principle would be found to be universally valid. Penetrating deep into the future he proclaimed, "There are no landmarks in space ... we have no log which we can cast out to take a dead reckoning by we may compute our motion with respect to our neighbouring bodies, but we do not know how these may be moving in space."

However, he thought as Newton before him did, that the doctrine of relativity broke down in the case of rotational motion, saying, "But though it is impossible to determine the absolute velocity of a body in space, it is possible to determine whether the direction of a line in a material system is constant or variable. For instance, it is possible by observations made on the Earth alone, without reference to the heavenly bodies, to determine whether the Earth is rotating or not." Maxwell then quoted Newton's bucket-experiment, carrying the bucket in thought to the North Pole. However, finding the calculated depression of the water-surface in the bucket too small for measurement, Maxwell remarked that the most satisfactory experimental proof was Foucault's pendulum, the rotation of which (except at the equator) establishes the absolute rotation of the Earth, although the stars and the pendulum are in no visible manner connected.

Probably Poincaré, who developed these ideas soon after, and used the phrase "Le principe de relativité," followed in Maxwell's footsteps and, of course, travelled farther. How could otherwise, we explain the exact transliteration of "relativity" into "relativité"?

Yours faithfully,

G.H. Keswani
Tata Institute of Fundamental Research, Bombay, India

Annexure II

On the Influence of the Motions of the Heavenly Bodies on the Index of Refraction of Light.

Let a source of light be such that it produces *n* disturbances or vibrations per second, and let it be at such a distance from the earth that the light requires a time T to reach the earth. Let the distance of the source of light from the earth be altered, either by the motion of the source of light, or by that of the earth, so that the light which emanates from the source *t* seconds afterwards reaches the earth in a time T′.

During the *t* seconds *nt* vibrations of the source of light took place, and these reached the earth between the time T and the time t+T′, that is, during *t*+T′-T seconds. The number of vibrations which reached the earth per second was therefore no longer *n*, but $n \frac{t}{t+T'-T}$.

If v is the velocity of separation of the source of light from the earth, and V the velocity of light between the bodies relative to the earth, then v*t* = V(T′-T), and the number of vibrations per second at the earth will be $n \frac{V}{V+v}$.

If Vo is the velocity of propagation of light in the luminiferous medium, and if v_o is the velocity of the earth,

$$V=V_o - v_o ,$$

and the wave-length will be increased by a fraction of itself equal to

$$\frac{v}{V_o - v_o}$$

Since v_o only introduces *a* correction which is small compared even with the alteration of wave-length, it cannot be determined by spectroscopic observations with our present instruments and it need not be considered in the discussion of our observations.

If, therefore, the light of the star is due to the combustion of sodium, or any other element which gives rise to vibrations of a definite period, then the light, when it reaches the earth, will have an excess or defect of rays whose period of vibration is to that of the sodium period as V+v is to V.

As an example, let us suppose the star to be fixed and the earth to be moving directly away from the star with the velocity due to its motion round the sun. the coefficient of

aberration indicated that the velocity of light is about 10,000 times that of the earth in its orbit, and it appears fro the observations of Angstrom and Ditscheiner that the wave-length of the less refrangible of the lines forming D exceeds that of the other by about one-thousandth part of itself. Hence, if the lines corresponding to D in the light of the star are due to sodium in the star, these lines in the starlight will be less refrangible than the corresponding lines in a terrestrial sodium-flame by about a tenth part of the difference between D_1 and D_2.

When the earth is moving towards the star, the lines will be more refrangible than the corresponding terrestrial lines by about the same quantity.

The effect of the proper motion of stars would of course have to be compounded with the effect of the earth's own motion, in order to determine the velocity of approach or separation.

To observe these differences of the light from stars, a *spectroscope* is necessary, that is, an instrument for separating the rays of different periods; and it is immaterial in what direction the refraction of the light through the prisms takes place, because the *period* of the light is the thing to be observed by comparison with that of a terrestrial flame.

If, instead of a spectroscope, an achromatic prism were used, which produces an equal deviation on rays of different periods, no difference between the light of different stars could be detected, as the only difference which could exist is that of their period.

If the motion of a **luminiferous** medium in the place where the experiment is made is different from that of the earth a difference in the deviation might be expected according to the *direction* of the ray within the prisms, and this difference would be nearly the same whatever the source of the light.

There are therefore two different and independent subjects of experiment. The one is the alteration in the period of vibration of light due to the relative motion of the stars and the earth. The fact of such an alteration is independent of the form under which we accept the theory of undulations, and the possibility of establishing its existence depends on the discovery of lines in the stellar spectra, indicating by their arrangement that their origin is due to the existence of substances in the star having the same properties as substances found on the earth. Any method of observing small differences in the period of vibration of rays, if sufficiently exact, will enable us to verify the theory, and to determine the actual rate of approach or separation between the earth and any star.

The other subject of experiment is the relation between the index of refraction of the ray and the direction in which it traverses the prism. The essentials of this experiment are entirely terrestrial, and independent of the source of light, and depend only on the relative motion of the prism and the luminiferous medium and on the direction in which the ray passes through the prism.

The theory of this experiment, however, depends on the form in which we accept the theory of undulations. In every form of the theory, the index of refraction depends on the retardation which a ray experiences on account of having to traverse a dense medium instead of a vacuum. Let us calculate this retardation.

Let there be a transparent medium whose thickness is *a*, and let it be supposed fixed. Let the luminiferous ether be supposed to move with velocity *v* in air, and with velocity V′ within the medium. Let light be propagated through the ether with velocity V in air and with velocity v' within the medium. Then the absolute velocity of the light will be $v + V$ in air and $v'+V'$ within the medium, and the retardation, or difference of time in traversing a thickness a of the medium and an equal thickness of air, will be

$$a\left(\frac{1}{v'+V'}-\frac{1}{v+V}\right);$$

and the retardation *in distance* reckoned as at the velocity, V will be

$$a\left\{\frac{V}{V'}\;1-\frac{v'}{V}\left(\frac{V^2}{V'^2}-\frac{v}{v'}\right)+\left(\frac{v'^2}{V^2}\;\frac{V^3}{V'^3}\right)-\frac{v^2}{v'^2}\right\}\;\&\;c$$

Now, according to every form of theory, $\frac{V}{V'}=\mu$, the index of refraction, and according to Fresnel's form of the theory, in which the density of the medium varies as μ^2, the equation of continuity requires that $\frac{v}{v'}=\mu^2$. In this case the second term disappears and the retardation is $a\mu$ -1) + terms in $\frac{v'^2}{V^2}$ which may be neglected, as V is more than 10000 times *v*.

Hence, on Fresnel's theory, the retardation due to the prism is not sensibly affected by the motion of the earth. The same would be true on he hypothesis that the luminiferous ether near the earth's surface moves along with the earth, whatever the form of the theory of the medium.

Since the deviation of light by the prism depends entirely on the retardation of the rays within the glass, no effect of the earth's motion on the refrangibility of light is to be expected. Professor Stokes (Phil. Mag. 1846, p.63) has also given a direct proof of this statement, and the experiment of Arago confirms it to a certain degree of exactness.

In order to test the equality of the index of refraction for light moving in opposite directions through a prism, I employed in 1864 the following arrangement.*

I made use of a spectroscope constructed by Mr. Becker, and provided with a tube at right angles to the axis of the observing-telescope carrying a transparent plate of parallel glass placed between the object-glass and its focus, go as to reflect the light which enters the tube along the axis of the telescope towards the object-glass. In this tube is placed a screen with a vertical slit, in the middle of which is a vertical spider-line so arranged that its virtual image formed by the first surface of the glass plate coincides with the crossing of the spider-lines of the telescope at the principal focus of the object-glass. The coincidence

is tested by observing the cross lines through the other telescope, with the two telescope's facing each other. The eyepiece of the second telescope is then removed, and a plane mirror is placed at the focus of the object-glass, perpendicular to the axis, and the telescopes are so adjusted that light entering by the side tube is reflected down the axis of the first telescope, traverses the prisms in succession, enters the second telescope, is reflected by the mirror at its focus, and emerges from the telescope parallel to its direction at incidence; it then traverses the prisms in the reverse order, and is brought to a focus at the cross lines of the first telescope.

If the deviation of the rays in passing through the prisms from east to west differs from that produced during their passage from west to east, the image of the vertical spider-line formed by the rays which have traversed the prisms twice will not coincide with the intersection of the spider-lines as before.

I have found, however, that when the instrument is properly adjusted, the coincidence is so perfect with respect to ray so fall refrangibilities, that the image of the vertical spider-lines is seen with perfect distinctness, though the rays which form it have passed twice through three prisms of 60°. If we observe the coincidence of this image with the intersection of the spider-lines at the focus when the rays pass through the prisms first

* This is interesting. (G.H.K)

In the direction of the earth's motion and return in the opposite direction, we may then reverse the whole instrument so that the rays pursue an opposite path with respect to the earth's motion. I have tried this experiment at various times of the year since the year 1864, and have never detected the slightest effect due to the earth's motion. If the image of the spider-line is hid by the intersection of the cross lines in one position, it remains hid in precisely the same way in the other position, though a deviation corresponding to one-twentieth of the distance of the components of the line D could be easily detected.

On the other hand, M. Fizeau has observed a difference in the rotation of the plane of polarization according as the ray travels in the direction of the earth's motion or in the contrary direction, and M. AngstrÖm has observed a similar difference in phenomena of diffraction. I am not aware that either of these very difficult observations has been confirmed by repetition.

In another experiment of M. Fizeau, which seems entitled to greater confidence, he has observed that the propagation of light in a stream of water takes place with greater velocity in the direction in which the water moves than in the opposite direction, but that the acceleration is less than that which would be due to the actual velocity of the water, and that the phenomenon does not occur when air is substituted for water. This experiment seems rather to verify Fresnel's theory of the ether; but the whole question of the state of luminiferous medium near the earth, and of its connexion with gross matter, is very far as yet from being settled by experiment.

James Clerk Maxwell

June 10, 1867

Annexure III

J.C.Maxwell, "A Treatise on Electricity and Magnetism", vol.ii, printed in 1954, Dover.(Ist ed. of 1887; 2nd ed. by Niven, no change; 3rd ed. by J.J.Thomson, no change)

p.241: *In the Modification of the Equations of Electromotive Intensity when the Axes to which they are referred are moving in Space.*

[Article 600.]Let x', y', z' be the coordinates of a point referred to a system of rectangular axes moving in space, and let x, y, z be the coordinates of the same point referred to fixed axes.

Let the components of the velocity of the origin of the moving system u, v, w, and those of its angular velocity $\omega_1, \omega_2, \omega_3$ referred to the fixed system of axes, and let us choose the fixed axes so as to coincide at the given instant with the moving ones, then the only quantities which will be different for the two system of axes will be those differentiated with respect to the time. If $\frac{\delta x}{\delta t}$ denotes a component velocity at a point moving in rigid connexion with the moving axes, and $\frac{dx}{dt}$ and $\frac{dx'}{dt}$ those of any moving point, having the same instantaneous position, referred to the fixed and the moving axes respectively, then

$$\frac{dx}{dt} = \frac{\delta x}{\delta t} + \frac{dx'}{dt}, \qquad (1)$$

with similar equations for the other components.

By the theory of the motion of a body of invariable form,

$$\frac{\delta x}{\delta t} = u + \omega_2 z - \omega_3 y,$$

$$\frac{\delta y}{\delta t} = v + \omega_3 x - \omega_1 z, \qquad (2)$$

$$\frac{\delta z}{\delta t} = w + \omega_1 y - \omega_2 x.$$

Since F is a component of a directed quantity parallel to x, if $\frac{dF'}{dt}$ be the value of $\frac{dF}{dt}$ referred to the moving axes it may be shown that

$$\frac{dF'}{dt} = \frac{dF}{dx}\frac{\delta x}{\delta t} + \frac{dF}{dy}\frac{\delta y}{\delta t} + \frac{dF}{dz}\frac{\delta z}{\delta t} + G\omega_3 - H\omega_2 + \frac{dF}{dt}. \qquad (3)$$

Substituting for $\frac{dF}{dy}$ and $\frac{dF}{dz}$ their values as deduced from the equations (A) of magnetic

induction, and remembering that, by (2),

$$\frac{d}{dx}\frac{\delta x}{\delta t} = 0, \quad \frac{d}{dx}\frac{\delta y}{\delta t} = \omega_3, \quad \frac{d}{dx}\frac{\delta z}{\delta t} = -\omega_2 \quad , \tag{4}$$

we find

$$\frac{dF'}{dt} = \frac{dF}{dx}\frac{\delta x}{\delta t} + F\frac{d}{dx}\frac{\delta x}{\delta t} + \frac{dG}{dx}\frac{\delta y}{\delta t} + G\frac{d}{dx}\frac{\delta y}{\delta t} + \frac{dH}{dx}\frac{\delta z}{\delta t} + H\frac{d}{dx}\frac{\delta z}{\delta t} - c\frac{\delta y}{\delta t} + b\frac{\delta z}{\delta t} + \frac{dF}{dt}. \tag{5}$$

If we now put

$$-\psi' = F\frac{\delta x}{\delta t} + G\frac{\delta y}{\delta t} + H\frac{\delta z}{\delta t}, \tag{6}$$

$$\frac{dF'}{dt} = -\frac{d\psi'}{dx} - c\frac{\delta y}{\delta t} + b\frac{\delta z}{\delta t} + \frac{dF}{dt}. \tag{7}$$

The equation for *P,* the component of the electromotive intensity parallel to x, is, by (B),

$$P = c\frac{dy}{dt} - b\frac{dz}{dt} - \frac{dF}{dt} - \frac{d\psi}{dx}, \tag{8}$$

$$P' = c\frac{dy'}{dt} - b\frac{dz'}{dt} - \frac{dF'}{dt} - \frac{d(\psi + \psi')}{dx}, \tag{9}$$

for the value of *P* referred to the moving axes.

[Article 601.] It appears from this that the electromotive intensity **is expressed by a formula of the same type,** whether the motions of the conductors be referred to fixed axes or to axes moving in space, the only difference between the formula being that in the case of moving axes the electric potential ψ must be changed into $\psi + \psi'$.[16]

In all cases in which a current is produced in a conducting circuit, the electromotive force is the line-integral

$$E = \int \left(P\frac{dx}{ds} + Q\frac{dy}{ds} + R\frac{dz}{ds}\right) ds, \tag{10}$$

taken round the curve. The value of ψ disappears from this integral, so that the introduction of ψ has no influence on its value. **In all phenomena, therefore, relating to closed ciruits and the currents in them, it is indifferent whether the axes to which we refer the system be at rest or in motion.** See article 668. (Emphasis added)

Note: Even according to S.R., it is the form of Maxwell's equations which remains invariant, but the electromagnetic quantities do not remain the same. Only the velocity of light is invariant.

SO, MAXWELL WAS THE FATHER OF RELATIVITY, LORENTZ NOT, POINCARE NOT, EINSTEIN NOT.

THESE THREE WERE OFFSHOOTS ON OF WHICH EXTENDED IN HANDS OF EINSTEIN.

MICHELSON MORLEY EXPERIMENT MAXWELLL AND EINSTEIN

One of the loveliest experiments performed by Maxwell, a forerunner of the Michelson Morley (M-M) experiment using interference star-light, a rotating turntable on the earth with telescopes, prisms and spectroscopes which were trained in different directions with the changing direction of the orbital motion of the earth, round the year, etc., has been mentioned in the present book in the essay on Maxwell. The experiment extended over three years, 1864-67, and was reported in the Phil. Trans. of the Roy. Soc. (London), buried inside the main article by the astronomer William Huggins in 1868. Unfortunately the instruments used were not preserved and the exact design is not known. It was a null experiment.

One must presume that Michelson knew about it. At any rate, Michelson had responded in 1881, to Maxwell's[1] letter published posthumously in 1880 in which he had said that in terrestrial methods of determining the velocity of a light-ray which retraces its path, any velocity which the earth might possess with respect to the ether would affect the time of the double passage, only by an amount proportional to the "square of the constant of aberration", that is v^2/c^2 order of magnitude. The M-M experiment of 1887 was essentially a search for possible change in the velocity of light arising from the change in the orbital velocity of the earth relative to the inertial system in which the Sun is at rest. This inertial system was hypothesized as an all-pervading medium of some kind, which was the putative carrier of electromagnetic waves, like air in the case of sound waves.

This experiment conclusively showed that light propagates isotropically and with the same velocity in all directions, as the earth courses along its path in the ecliptic round the Sun. The to-and-fro velocity of light (c) was found to be constant in all directions. It must be mentioned that there was no motion of the source of light relative to the instrumental set-up on the turntable used in the experiment. So, the experiment showed that the hypothetical luminiferous aether does not exist.

1 See : E.T. Whittaker, A History of the Theories of Aether and Electricity, the Classical Theories, Thomas Nelson & Son, enlarged edition of 1951. (Followed by second vol. In 1953). See page 390 of the first volume.

The experiment has nothing to say about the invariance of c, that is, the velocity of light is constant also when there is relative motion between the source and the observational set-up (for short, the observer). Then the velocity of light will be measured to be the same in the system (S) in which the source of light is at rest, as well as in the system (S') of any other inertial moving observer.

The experiment also leads to the inference, that the motion of the inertial frame of the Sun, relative to which the changes in the orbital velocity of the earth take place, has also no effect on the isotropy of propagation of light in various directions in the M-M type (null) experiments on the earth. Let us remember that the Sun is also in motion, orbital in the galaxy, and transnational along with the galaxy. The component of the Sun's velocity in 'space' along the axis of the interferometer also changes as it is turned around.

When we look into different direction to the stars as Maxwell did in his experiment, the motion of the sun relative to the star is also to be considered.

As Eddington[2] pointed out, the M-M experiment did not prove directly that the one-way velocity of light is constant in all directions, but that the average velocity to-and-fro was constant! The result of the Michelson-Morley shows that the average velocity of light is the same in all directions on the moving earth.

Einstein was often asked the question whether he knew about the M-M experiment before his relativity paper, with the implication, if he did not: How could it be? In most literature an impression is created that the M-M experiment inevitably led to the theory of relativity.

Joos[3], himself, working with an improved apparatus, at the Zeiss plant in Jena, capable of recording one thousandth of the width of a fringe, had repeated the M-M type experiment and also found no shift.

2. A.S. Eddington, The Mathematical Theory of Relativity, Cambridge Univ. Press, 1924 ed., reprinted later, p.19.
3. G. Joos, Theoretical Physics, trans. by Ira M. Freeman, Blackie & Sons, 1947, reprint of 1934, p. 226.

Einstein wrote a foreword to the book of Bergmann[4] on relativity who simply says: "The outcome of the Michelson-Morley experiment would, therefore, suggest that the ether is dragged along with the earth, as far as the immediate neighbourhood of the earth is concerned."

Miller[5] in his superb book struck a balanced note on whether Einstein knew of the M-M experiment and so to what effect it had on him. He wrote:

QUOTE: "By 1905 Einstein would have known of the result of Michelson's experiment, since it was discussed in the last chapter of Lorentz's (1895). But its genetic role in fashioning the relativity theory is another matter. Holton (1973e) has argued cogently that we should take Einstein at his own word that Michelson-Morley experiment had "at most an indirect effect" on Einstein's thinking toward the special relativity theory." **UNQUOTE.**

The experiment only showed that the putative ether does not exist; in other words the space is empty (in which material bodies and radiation and other fields could, reside or travel).

Well, in the 19th century, one of the possibilities entertained was that the Earth carries the ether along with itself and the M-M experiment does not falsify this possibility although this assumption runs into other difficulties (aberration, for example).

Fizeau's experiment was believed to show that the moving water (velocity u) was partially dragging the ether around the earth. The compounded velocity was neither c/n + u, nor c/n, but something in between. Here n is the refractive index of the flowing water.

Michelson was an experimenter of the same class as Newton, Faraday, Fizeau, Helmholtz and Rutherford. His experiments on the velocity of light will have a place in the history of physics.

4. P.G.Bergmann, Introduction to the Theory of Relativity, Prentice-Hall of India Pvt. Ltd., 1969, reprint of 1942 American edition, pages. 27-37.
5. A.I.Miller, Albert Einstein's Special Theory of Relativity, Addison-Wesley Pub. Co., 1981, p.91.

It was difficult to imagine then that waves could travel without a medium, and that the field itself could oscillate, travel forward and carry energy. Even the great Maxwell did not clearly say that electromagnetic oscillating fields travel by themselves, following his equations, although he was very doubtful in the last few years of life, that there was any experimental evidence for the luminiferous ether. (Please see the essay on Maxwell in the present book.)

It was against this background that the M-M experiment was undertaken.

We now return to the theme: Einstein and the M-M experiment. In his lecture in Japan at Kyoto Univ. on 14 Dec. 1922, he stated his position and the interpretation of the M-M experiment, very clearly. We quote Einstein[6] :

QUOTE: "It was more than seventeen years ago that I had an idea of developing the theory of relativity. While I cannot say exactly where that thought came from, I am certain that it was contained in the problem of the optical properties of moving bodies. (Please see the essay on the Fizeau Experiment and aberration of star-light in this book.) While I was thinking of this problem in my student years, I came to know the strange result of Michelson's experiment…. This was the first path which led me to the special theory of relativity.

Since then I have come to believe that the motion of the earth cannot be detected by any experiment though the earth is revolving round the Sun". **UNQUOTE**

There is, however, no statement regarding the constancy of the velocity of light in this lecture of Einstein, in the context of the M-M experiment. But he said later in the lecture that since the electromagnetic equations of Maxwell and Lorentz were correct and if they also held in the reference frame of the moving body, that would lead to the concept of the invariance of the velocity of light, i.e., invariance follows from these equations. But that is a different matter.

6. A Einstein, How I Created the Theory of Relativity, Lecture given in Kyoto on 14.12.1922, trans. by Y.A. Ono, 45-47 (1982).

Moreover, there is no reason given in the lecture by Einstein why the absence of the ether should mean that only relative motion is observable, generally, or that the velocity of light is invariant under change of coordinates in relative motion. Actually, it only meant that light or electromagnetic field of Maxwell's equations propagates by itself without a carrier, equally in all directions. There was simply no effect of relative motion between the source of light and the receiving apparatus.

Shankland[7] had five meetings during the years 1950-54 with Einstein, with M-M experiment as the main theme.

He had meticulously recorded the conversations immediately after the meetings. However, he published these conversations long after Einstein's death in 1955. (Part I was submitted to the American Journal of Physics only on 11 Sept. 1962, about 2 months before Bohr's death on 18th Nov. 1962. Einstein had castigated Bohr in the words, "he thinks of himself as a prophet", in the first conversation of 4th Feb. 1950.) We quote Shankland below.

QUOTE: (4 Feb. 1950 meeting, page 48, Part I): When I asked him how he had learned of the Michelson-Morley experiment, he told me that he had become aware of the writings of H.A. Lorentz, but only after 1905 had it come to his attention! Otherwise, he said,"I would have mentioned it in my papers".

He continued to say the experimental results which had influenced him most were observations on stellar aberration and Fizeau's measurements on the speed of light in moving water. "They were enough", he said.

(24 Oct. 1952 meeting, page 55 Part I) : I asked Professor Einstein where he had first heard of Michelson and his experiment. He replied, "This is not so easy, I am not sure when I first heard of the Michelson experiment. I was not conscious that it had influenced me directly during the seven years relativity had been my life. I guess I just took it for granted that it was true." However, Einstein said that in the years 1905-1909, he thought a great deal about Michelson's result, in his thinking about general relativity. He then realized (so he told me) that he had also been conscious of Michelson's result before 1905 partly through his reading of the papers of

7. R. S. Shankland, Conversations with Albert Einstein, Amer. J. Phy. 31, 47-57 (1963); Part II, 41, 895-901 (1973)

Lorentz and more because he had simply assumed this result of Michelson to be true. **UNQUOTE.**

Incidentally, Shankland[8] recorded:

QUOTE: Michelson did not like the relativity theory. He told Einstein this (more than once) and he also heard it from others. Einstein laughed and added, "You know we were very good friends!" Michelson said to Einstein that he was a little sorry that his own work had started this "monster". **UNQUOTE**

Did it?

Actually, the M-M experiment had urged and inspired Poincare` during the years (1895-1905), to regard ether as superfluous in so far as it was believed to be a carrier of electromagnetic waves, and also established isotropy of space around, for light propagation. This indeed follows from the elimination of the ether. The experiment cleared the way, but was not connected directly, and could not lead logically, to the Principle of Relativity of Motion, much less to the invariance of light-velocity in vacuum. This experiment rather showed that all inertial systems, like the earth, are isotropic and homogenous[9].

Ehrenfest[10] who succeeded Lorentz at Leiden tells us that, "Stationary ether meant for Lorentz, just as it already did for Fresnel, stationary with respect to something like the world of the fixed stars."

The null result was necessary but not sufficient to assert that only relative motion can possibly be detected for electromagnetic, as for mechanical, phenomena. The experiment with the null result does not show that the Maxwell's equations remain invariant in form when going over from one inertial system to another, because only one system of the earth in motion was in the picture.

8. R. S. Shankland, ibid., Part I, p. 56.
9. G. H. Keswani : Origin and Concept of Relativity, Brit. J. Phil. Sci. Part I, 15, 286-306 (1965) : Part II, 16, 19-32 (1905). Incidentally, Prof. Shankland much agreed with these papers!
10. Collected Scientific Papers of Paul Ehrenfest, North-Holland Pub. Co., 1959, p. 474.

It needs to be emphasized that the shift in the interference fringes was expected, if there was an independent medium between the two, i.e., the source and the observer, and if, the earth was moving through this medium. But there was no motion between the source and the observer and the shift did not occur.

After 1905, the Sun and the stars were used as "emitters" of light, with a large motion between the emitters and the observer. These related experiments of D.C. Miller (in 1925) and R. Tomaschek (in 1924) came up in the conversations between Einstein and Shankland[2]. Such experiments showed that the velocity of light is not affected by the relative motion of the emitter and the observer.

In other words, the velocity of light is the same in all inertial systems no matter from where the light comes, i.e., the velocity of light is invariant to transformation from one system (S) to another system (S′) in relative motion. Their relative velocity has no effect on the velocity of light, much against our physical perception of the composition of velocities.

It will be instructive to see what various writers have said about the M-M experiment from the technical, historical and pedagogic angles.

Ugarov[11] of Russia quotes a detailed letter of 2 Feb. 1954, perhaps the last comment of Einstein on the M-M experiment in reply to one American, Davenport, who wrote to Einstein apparently from a patriotic impulse saying that he was looking for evidence that Michelson had "influenced your thinking and perhaps helped you to work out your theory of relativity….indicating how Michelson helped to pave the way, if he did for your theory."

11. V.A. Ugarov, Special Theory of Relativity, trans. into Eng. By Yuri Atanov, Mir Pub., Moscow, 1979,pp. 348-49.

Einstein's reply:

QUOTE: Before Michelson's work it was already known that within the limits of the experiments there was no influence of the state of motion of the coordinate system on the phenomena, resp. their laws…….The work of Michelson, equally great through the bold and clear formulation of the problem as through the ingenious way by which he reached the very great required precision of measurement, in his immortal contribution to scientific knowledge. This contribution was a new strong argument for the non-existence of absolute motion, resp. the principle of special relativity which, since Newton, was never doubted in mechanics but seemed incompatible in electrodynamics.

In my own development Michelson's result has not had considerable influence. I do not even remember if I knew of it at all, when I wrote my first paper on the subject (1905). The explanation is that I was, for general reasons, firmly convinced how this could be reconciled with our knowledge of electrodynamics. One can therefore understand why in my personal struggle Michelson's experiments played no role or at least decisive role. **UNQUOTE**

We must also quote Hermann Bondi[12] in these connections.

QUOTE: What has bedeviled this issue in textbooks is the undue prominence given to the Michelson-Morley experiment ……..Later on when it was decided to reprint various essays on relativity….the first part that was included happened to be the Michelson-Morley experiment. For the reason since then everybody, was left obliged to start in the same way. And what a complicated start it is! **UNQUOTE**

The reprints mentioned above by Bondi, comprised the collection of essays published in 1923 by Methuen and Co., in English translation was made by W. Perrett and G.B. Jeffery. The collection had been published in Germany earlier by Teubner. The first essay is on an extract from Lorentz's famous paper of 1895, with the title : Michelsons's Interference Experiment.

12. H. Bondi, Assumption and Myth in Physical Theory, Cambridge, 1967.

We briefly mention how this matter was seen by some leading writers.

MAX BORN[13]

QUOTE: After describing the M-M experiment he writes: "The result of the experiment was negative: the aether wind is not really there. To explain this fact Einstein developed his theory of relativity." **UNQUOTE.**

G. JOOS[14]

QUOTE: Experiment has thus decided against our acoustic analogy and against the existence of a stationary medium carrying light, i.e., the existence of a cosmic ether or absolute space is disapproved.

Further:

The result of the Michelson-Morley…shows that the velocity of light is same in all directions on the moving earth. **UNQUOTE.**

ISAAC ASIMOV[15]

The honour of writing the one-page article in Encyclopedia Britannica on Michelson, fell on Late Mr. Isaac Asimov, a profile popular science-writer who concluded:

QUOTE: "To explain the result of the Michelson-Morley experiment, physics had to be recast on a new and more refined foundation, something that resulted, eventually, in Albert Einstein's formulation of the theory of relativity in 1905." **UNQUOTE.**

13. Max Born, Atomic Physics, trans. by J. Dougall, Blackie & Sons, 4th ed. of 1946, p. 283.
14. G. Joos, Theoretical Physics, trans. by Ira M. Freeman, Blackie & Sons, 1947 reprint of 1934, p. 227-28.
15. Encyclopedia Britannica, Macropaedia, 1979, volume 12, p. 104 (Note: Not in the smaller Micropaedia).

What are the poor students and the public to make of all this, about the connection between the M-M experiment and relativity, as to the import of the experiment?

It will surprise many that there has been no settled opinion as to what is to be expected theoretically of the M-M experiment. A conference[16] on this subject was held at Mt. Wilson in 1927 where experts in optics, Lorentz and the experimental physicists involved in the experiment (Michelson, Miller and Kennedy) were present. There was no unanimity as to what was to be expected but they agreed that the result was consistent with relativity!

It is a pity that the two adjectives "constant" and "invariant" for the velocity of light are often mixed up in literature, much to the confusion of students.

The first means velocity in any direction within one system, in which both the emitter and observer are at rest, is the same.

The second refers to more than one inertial systems, with the emitter at rest in S and the observer in any other system S', when too, no variation in the velocity of light is observed. As we shall see in this book invariance of light velocity is the invariant physical property of the medium of transmission, viz. "space", upto this day (2005).

It is interesting to know what Einstein[17] had to say about the Michelson-Morley experiment in his two extensive expositions of 1907 and 1909, respectively, soon after his first paper of 1905.

QUOTE: "It is well known that this contradiction between theory and experiment was formally removed by the postulate of H.A. Lorentz and Fitzgerald, according to which moving bodies experience a certain contraction in the direction of their motion. However, this ad hoc postulate seemed to be an artificial means of saving the theory: Michelson and Morley's experiment had actually shown the phenomena agree with the principle of relativity even where this was not to be expected from the Lorentz theory. It seemed therefore, as if Lorentzs' should be abandoned and replaced by a theory where foundations correspond to the principle of relativity, because such a theory would readily predict the negative result of the Michelson and Morley experiment." **UNQUOTE**

16. Astrophys. J. 1928, 68, 385-388 (1928).
17. The Collected Works of Albert Einstein. Vol. 2, trans. by Anna Beck, Princeton Univ. Press, 1989, p.253 & 383.

This is perhaps the exact situation.

Some levity may be permitted at the end in this note on a serious matter. Shankland[18] has recorded the wry reaction of some of the young contemporaries of Michelson including Shankland's father. They were disappointed. They regarded it as a failure, since it gives a null result! Well, there was this massive stone floating on mercury, carrying the emitting and observing equipment, all relatively at rest on the earth although it could be rotated around to observe in different directions. Only light rays criss-crossed in quiet and geometrical perfection. The earth moved at about 30 km per sec. in its orbit around this Sun but the rays moved as if the earth was at rest. Common sense demanded something to come out, from this mountain of experimental ingenuity.

PAULI[19]:

Pauli refers to the Michelson experiment noting that it was repeated by Tomascheck in 1924 with extra-terrestrial light (Sun and Stars) with no change of velocity of light rays.

The null result was necessary, but not sufficient to assert that only relative motion can possibly be detected for electromagnetic, as for mechanical, phenomena. The experiment with the null result does not show that the Maxwell's equations remain invariant in form when going over from one inertial system to another, because only one system was in the picture. It needs to be emphasized that the shift in the interference fringes was expected, if there was an independent medium between the two, i.e., the source and the observer but the shift did not occur.

18. R.S. Shankland, ibid., Part I, footnote (No. 9), p. 49.

19. W. Pauli, Theory of Relativity, Pergamon Press, 1921, with Supplementary Notes, in 1958, pp. 19 &207.

After 1905, the sun and the stars were used as “emitters” of light, with a large motion in between the emitters and the observer. These related experiments of D.C. Miller (in 1925) and R. Tomaschk (in 1924) came up in the conversations between Einstein and Shankland[20]. Such experiments showed that the velocity of light is not affected by the relative motion of the inertial systems no matter from where the light comes, i.e., the velocity of light is invariant to transformation from one system (S) to another system (S`) in relative motion. Their relative velocity has no effect on the velocity of light, much against our physical perception of the composition of velocities.

20. R. S. Shankland, ibid, p. 49.

IS THE SPACE NON-EUCLIDEAN IN GENERAL RELATIVITY?

Abstract

We show that if the 3-space is non-Euclidean according to Einstein[1], $g_{ij}\, dx_i\, dx_j$ defining the metric of space-time, the perihelionic advance of Mercury in its orbit in one terrestrial century will not be 43 arc-sec.

Two elements are involved in their effect on the perihelion:

i) The change in the geometry of space transversed by the planets
ii) The dynamics of motion in the orbit of the planet.

When the prevailing geometry is taken as non-Euclidean, the ratio circumference/radius is not 2π, which is taken in the calculation of the figure of 43 arc-sec. It is in fact a trifle less than 2π per revolution, the cumulative effect being 65 arc-sec in the same period of hundred earth-years. It is not the measure of the circumference of the orbit, which is affected sensibly, but the radial measure i.e. the related angular measure directly.

The equation of the orbit of Mercury is obtained from the exterior Schwarzschild metric:

$$ds^2 = (1-2m/r)dt^2-[(1-2m/r)^{-1}\, dr^2+r^2(d\theta^2 +\sin^2\theta\, d\varnothing^{\,2})]/c^2, \qquad \textbf{(1)}$$

regarding the Sun as a point-mass.

Various symbols have the usual meaning, r being the curvature coordinate, so that $4\pi r^2$ is the invariant surface area of the spherical surface centred on the spherical mass. r is not the geodetic radial distance which is $\int dr/(1-2m/r)^{1/2}$ exterior to the Sun, and $\int dr/(1-2m^2/R^3)^{1/2}$ inside the Sun[2]. As usual, the constant radius, $R_\odot$ of the sun and the average radius, R, of the orbit of Mercury are assumed. The numerical values of these two are approximations in a Euclidean space but this will have little effect on the accuracy necessary to the present purpose.

Schutz[3] has given an elegant analysis to get the usual figure of advance of the perihelion per revolution, assuming Schwarzschild exterior metric throughout, i.e., for a point-mass which is,

$$\Delta\varnothing = 2\pi(1-6m^2/L^2)^{-1/2},$$

where, the angular momentum, L, is given by the equation:

$$L^2 = mr / (1-3m/R).$$

To a good approximation, the advance from one perihelion to the next is then:

$$\Delta\varnothing \sim 6\pi\, m/R \text{ radian.}$$

R the average distance of Mercury from the Sun is taken by Schutz as 5.55×10^7 km, which is more correctly, 5.79×10^7 km. Likewise, Schutz takes m= Sun's mass x G/c^2 = 1.47 km, which is more nearly equal to 1.4767 or 1.48 km. $R_\odot = 6.96 \times 10^6$ km. $M_\odot = 1.9891 \times 10^{30}$ kg.

Thus, Schutz gets the famous figure of advance of Mercury's perihelion per terrestrial century, of 43 arc-sec.
It is well-established that the observed advance of the perihelion of Mercury, not explicable by Newtonian theories, is ~ 43 arc-sec in one terrestrial century. This is equal to 4.99 x 10^{-7} radian per orbit. This has been verified from reliable astronomical observations now over very long periods of time since the 19th century. The question I raise is: What does the General Theory say?

Geometry of Orbital Space

The theory of General Relativity is involved in two ways: (i) in the equation of the orbital motion, and (ii) in the geometry of Mercury's orbital space, also, according to the same theory.

In literature the second factor is not considered as significant and is omitted altogether. The ratio, circumference/radius, in a non-Euclidean space will not be 2π. Indeed R.C. Tolman[4] and G.C. McVittie[5], both considered the fact of non-Euclidean geometry but concluded that no significant error is introduced by ignoring this fact. They argued that whether one takes (i) r, or $\int dr/(1-2m/r)^{1/2}$, or (ii) s, as the proper time at Mercury, or (iii) t as coordinate time at the origin (or, for that matter the proper time measured by an astronomer on the earth) in the calculation, the end result is not sensibly affected. L.D.Landau and E.M.Lifshitz[6] said, that following the GR (Schwarzschild metric), the ratio of the circumference ($2\pi r$) to the radius $_0\int^r \sqrt{g_{11}}.\, dr$, is less than 2π. But they did not numerically calculate the cumulative difference in the angle, in one terrestrial century. The fly in the ointment is $\varnothing$, the angle swept out in the orbit of Mercury. Also one should consider the interior metric within the Sun for a more accurate result. McVittie integrates from $R_\odot$ to R, not zero to R.

Quantitatively, as a result of the small change (increase) in the radial distance, per se (there is no circumferential change as can be seen from the metric), in non-Euclidean space there will be a small reduction (in the angle swept by Mercury) of –7.618 x 10^{-7} radian, in one revolution of Mercury. (Calculation given in the sequel.)

The change gets enhanced by a multiplier of 100 (terrestrial years), in which the faster Mercury with an orbital period of 87.97 Mercury-days, compared to 365.26 earth-days in one terrestrial year results in a multiplier equal to 100 years x 365.26 / 87.97 = 415.2 Mercury-years, i.e., its orbital revolutions, counted from perihelion to the next successive perihelion.

Therefore, in one terrestrial century, Mercury makes 415.21 revolutions – more than 4-times faster than the earth's - and a noticeable reduction (not advance) in the angle, cumulatively takes place as given by the following calculation:

Reduction from 2π in one revolution of Mercury due to non-Euclidean space:

-7.618 x 10^{-7} radian x $(180/\pi)$ [Conversion from radian to degree]
x 3600 [Conversion from degree to arc-sec, 60min. x 60sec.]
x 415.2 [Number of revolutions of Mercury in 100 earth-years]
= **- 65.24 arc-sec,** which is the angular reduction in the position of the perihelion of the planet Mercury per terrestrial century, due to non-Euclidean geometry of space where the ratio

(circumference / radius is less than 2π), the angle from perihelion to the next perihelion being 2π radians – 65.24 arc-sec. Identical calculations are done for the advance of the perihelion except that the advance is + 4.99 (~5) x 10^{-7} radian in one revolution of Mercury, as against –7.618 x 10^{-7} radian per orbit for the non-Euclidean space.

The Main Issue

The question that now arises is: What is the solution? Answer: It is possible to maintain the figure of advance of 43 arc-sec per terrestrial century, if $g_{ij's}$ are regarded like potentials, physically, but not affecting space geometry which remains Euclidean. We have to come to grips with the matter.

Indeed, years ago in 1939-1940, in a general context (perihelionic advance of Mercury was not in his picture), Prof.N.Rosen (of MIT) had made an identical proposal .

Calculation of deficit in angular measure due to non-Euclidean Space

We now calculate the ratio circumference/radius. In principle, we only carry McVittie's and Landau's calculation forward. G.C.McVittie correctly worked out the difference as $(8 \times 10^{+6})^{-1}$ in the radius for a much closer distance $R = 2.48R_{\odot}$, very close to the Sun (actually, $R= 8.3R_{\odot}$) but observed that "identification of r with the heliocentric distances computed by astronomers on the hypothesis of Euclidean geometry introduces an error no larger than one part in eight millions," and just neglected it. Actually, the change in the angle, which accumulates with time, and not in the radius, which is significant. A large multiplier over a century applies, yielding a substantial cumulative figure. Not only the exterior metric but also the interior metric for the Sun, will be considered, although this makes a smaller contribution of about 7% of the total of both.

Using the interior and exterior Schwarzschild metrics[2], we have the radial geodesic distance:

$$\rho=\int_0^{R_{\odot}} (1-2mr^2/R_{\odot}^3)^{-1/2}dr+\int_{R_{\odot}}^{R}(1-2m/r)^{-1/2}dr, \qquad \textbf{(2)}$$

where, $R_{\odot}$ = radius of curvature at the surface of the Sun (taken as bounded), equal to 0.696 x 10^6 km and, R= radius of curvature at the mean position of Mercury with reference to the origin (centre of the Sun) equal to 5.79 x 10^7 km, quoted earlier.

$R_{\odot}$ and R can, without sacrifice of the necessary accuracy, be identified with the astronomer's measures of the radius of the Sun (its surface is fuzzy) and the average distance of the centre of Mercury (its orbit is elliptical) from the centre of the Sun, respectively.
Expanding (2) we get

$$\rho= \int_0^{R_{\odot}} (1+mr^2/R_{\odot}^3 +\ldots)\,dr + \int_{R_{\odot}}^{R} (1+ m/r +\ldots)\,dr \sim [R+ m(1/3^{*}+\log_e{}^{**}R/R_{\odot})] \qquad (3)$$

to first order which suffices.

* m/3 in the interior field.

** m $\log_e R/R_{\odot}$ in the exterior field.

Then, the angle swept per revolution would be less than 2π and would be equal to:

$$2\pi\, R/\rho = 2\pi R / [R+m\,(1/3 + \log_e R / R_{\odot})] \sim 2\,\pi - 7.618 \times 10^{-7} \text{ radian.}$$

The second term represents departure from Euclidean geometry. And in one terrestrial century, the deficit of 7.618×10^{-7} radian per revolution, amounts to ~65 arc-sec.
See the calculation at the end.

The matter is important, and needs discussion in a Journal or Academy. I should say, all the more, because the shifts of the periastron in the binary pulsars are very large, by many orders of magnitudes, above Mercury's advance. Is the dynamics of motion of these pulsars being played out in a Euclidean space? We shall deal with this matter separately. The dynamics of the binary pulsars are rather complex, involving gravitational radiation, etc.

My purpose was to bring these fundamental matters into focus.

CALCULATION:

$2\pi R/[R + m\,(1/3 + \log_e R/R_\odot)]$** $\qquad R/R_\odot = \frac{5.79 \times 10^7}{0.696 \times 10^6} = 83.19$

$= 2\pi/[1+m(1/3 + 4.4212)/R]$

$\sim 2\pi[1-(1.4767 \times 4.754)/5.79 \times 10^7]$

$\sim 2\pi - 2\pi \times 7.020/5.79 \times 10^7$

$\sim 2\pi - 7.618 \times 10^{-7}$ radian in one revolution.

In one terrestrial century, Mercury makes 365.26 x 100/87.97 = 415.21 revolutions. Then the deficit in the angle swept in one revolution would be $415.2 \times (180/\pi) \times 3600 \times 7.618 \times 10^{-7}$, which works out at 65.24 or ~65 arc-sec per terrestrial century.

NOTE: We have not considered here the effect of the interior metric on the dynamics of the orbital motion, only exterior metric of empty space for a point-mass, is assumed to prevail in the usual calculation of the trajectories of Mercury.

** The contribution by the interior metric, (1/3), compared to the exterior one, ($\log_e R/R_\odot$) , is (1/3) : (4.212) = 1/12.636, i.e., 7.3% of the total.44

1. A.Einstein, The books: The Principle of Relativity, Dover, p.161; The Meaning of Relativity, Methuen, 1950 p.59. In the first, Einstein said, "Euclidean geometry does not hold even to a first approximation," and in the second, "In the presence of a gravitational field, the geometry is not Euclidean."
2. See: J.L.Synge, Relativity: The General Theory, North-Holland Pub. Co., 1965, pp.275-289.
3. B.F.Schutz, A First Course in General Relativity, Cambridge Univ. Pr., 1992, pp.283-84. The more accurate figures are: the average distance of Mercury from the Sun, $R = 5.79 \times 10^7$km, m=1.4767 km and $R_\odot = 0.696 \times 10^6$km. These latter figures have been used in the calculations below. Schutz gives the figure of Mercury's advance 4.99×10^{-7} radians per orbit, and of the period 0.24 earth years.
4. R.C.Tolman, Relativity Thermodynamics and Cosmology, Oxford, 1949 p.208, footnote.
5. G.C.Mc Vittie, General Relativity and Cosmology, Chapman&Hall, 1956, pp.87-88.
6. L.D.Landau and E.M.Lifshitz, The Classical Theory of Fields, Pergamon, 1959,p.307.
7. N.Rosen, General Relativity and Flat Space, Physical Review, Vol. 57, p. 150, 1939.

WHAT IS SPACE?

At the foundations of physics lie two fundamental entities, space and time. Even life, is played out in the framework of space and time. Although we cannot experience space and time with our senses there is an inner awareness of both. In the case of time the humans have an approximate physiological clock and eyes which have some rough measure of space.

One may sample the classical understanding. Leibnitz, one of the greatest of thinkers of all times and Hobbs, one of the sharpest philosophers, denied that space is a real entity. It is rather something we construct in our imagination in order to represent the position of bodies. Newton's is mathematical space, something we construct mathematically in order to describe continuous motion.[1]

Let us see how far the physics can carry our understanding of space. My introspections have led me to believe that space has definite physical properties which really go to the core and construction of the special theory of relativity, viz., the constancy of velocity of light in vacuum or free-space, which is commonly supposed to be empty.

This constancy was noticed by Poincaré[2], in 1898 in his paper entitled "la mesure du temps".

He observed that astronomers have assumed that the velocity of light received from the celestial bodies had the same velocity, and this assumption led to consistent results. He, therefore, postulated that "light has a constant velocity". Poincaré likened this postulate, which he also called a 'Rule', to the Principle of Sufficient Reason, with respect to reliability and importance.

The questions why it is constant and impassable have not been addressed. But it is also true that there are other constants of physics such as the Planck's constant, h, for which we do not know why it is exactly, what it is.

We shall examine the proposition that space is not free and that light interacts with it; that space has the properties, which are connected physically with the speed of light.

I will put first together the facts which are already known.

To this purpose we go to Maxwell's Treatise on Electricity and Magnetism written well before Poincaré's essay.

What he found, was that the ratio of the induced electric field (his displacement current) to the applied electric field, and the ratio of the induced magnetic field to the applied field, in both the cases, have specific constant values for different media. The two ratios are named permittivity (electrical constant) and permeability (magnetic constant). When the medium is "vacuum" or "empty" space, the ratios are called absolute permittivity and absolute permeability, with symbols ε_0 and μ_0, respectively and both have specific and constant non-zero values.

Strangely enough, the product of these ratios ($\mu_0 \times \varepsilon_0$) turns out to be, perhaps the most important constant of Physics as Maxwell anticipated. And more strangely this product was always the same, and exactly equal to $1/c^2$, i.e. $c = \sqrt{(1/\mu_0\varepsilon_0)}$, where c is the velocity of light!
The dimensions and values of μ_0 and ε_0 for "empty" space[3] are given below.

Permittivity of free space, or electric constant, ε_0 $L^{-3} M^{-1} T^4 I^2$
Permeability of free space, or magnetic constant, μ_0 $L M T^{-2} I^{-2}$
} The fourth dimension is the current I.

Product $\varepsilon_0 \times \mu_0$ has dimensions $L^{-2} \times T^{+2}$

$= T^2/L^2$, i.e,. 1/velocity ^{2}, dimensionally.

This leads to :

$\mu_0 = 12.566,370,6144 \times 10^{-7}$ H/m

$\varepsilon_0 = 8.854,187,818 \times 10^{-12}$ F/m

$1/ \mu_0 \varepsilon_0 = c^2 = (2.997,924,58)^2$ m/s.

It is hardly to be believed that the velocity of light was therefore measured from 1856 to 1878 on the basis of the ratio of the electric and magnetic units, as it was called, based on experiments in the laboratory. This method was then the most accurate. It was only in 1878 that the velocity of light was first measured in air by time-of-flight techniques. Maxwell himself was the second person who measured the velocity of light on the basis of the ratios of the units.

Now comes the wonder. Doesn't then, this so-called free space, has physical properties, (permeability and permittivity), which are measurable, and also permit electromagnetic waves to go through itself (space) with velocity determined by these two properties of space, constant, finite though small, and specific? The cosmic space permits this, and only this velocity for the propagation of electromagnetic waves, which has a simple mathematical relationship with its properties, which is a physical fact. The constants μ_0 and ε_0 are a kind of resistance, limiting or better regulating the passage of electromagnetic waves (or photons) searing through space in all directions, and from all distances, and on all times.

Therefore, SPACE is, in full sense of the word, a real physical entity, and is linked inexorably with the velocity of light.

Question: Why does space not interact with other fields and matter?
Answer: In fact, space does contract, as time also does, when motion is given to a body, on which the measurements of space or time are made. Cosmology assumes that space expands, but time remains the same, flowing evenly.

However, at present the product ε_0 and μ_0 remains invariant, in the whole universe judging by the astronomical data, and the velocity of light as well remains constant even for light coming from great distances billions of light-years away.

However, it is possible that there could be conditions of matter and radiation in the extreme in which the product $\varepsilon_0 \times \mu_0$ changes, locally.

But my main idea here was to show that the constancy of the velocity of light arises from the fact that space has discrete and measurable properties, fixed ε_0 and μ_0, which determine the velocity of electromagnetic waves through space and these discrete values prevail throughout the Cosmos, the largest laboratory, as confirmed by astronomical observations. The mystery of the constancy of the velocity of light, that no matter how it is ejected into "free" space (including such space within matter), is solved. There is an omnipresent medium, as Maxwell thought some times. It is a new type of medium and it has interaction, with the emitted light travelling through it, even in scattering. Although there may be interchange of energy on the way, light has the same velocity in the selfsame "free" space, everywhere so long as ε_0 and μ_0 of space remain constant. There could be pockets in the universe where ε_0 and μ_0 are different due to abnormal gravitational and electromagnetic conditions, but that is a different matter.

I have discussed the "matter" of space at the terrestrial and cosmological level, but not at the quantum level of, say, "Dirac's Sea", spontaneous decay of vacuum, virtual particles, and violation of conservation of mass/ energy to the extent $\pm \Delta E$ and for time Δt, if $\Delta E \times \Delta t$ is less than $h/4\pi$, in which, much could be conjured up, and mathematics found to fit, hand in glove, with the new experimental results. The mathematics is bounteous.

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PHYSICAL TIME

Time travels in diverse paces with diverse persons.
I'll tell you who time ambles withal,
Who time trots withal, who time gallops withal,
And who stands still withal.

Shakespeare, As You Like it (III. ii.328)

Liebnitz[1] said that time is not itself a physical entity, and it has no existence apart from the things it relates.

The best definition of time the author knows is the one given by Einstein in his 1905 – paper as: "the position of the small hand of my watch".

Time is not something existing everywhere, flowing (into what?) irreversibly, such as our physiological awareness of the passage of time, which is probably a learned experience.

It is simply a physical entity that is measurable expression of the rhythm within every material body or radiation. Immanuel Kant said it is like counting, as in arithmetic.

There are numerous repetitive processes, such as, spontaneous decay of atoms, vibrations (e.g., of cesium or quartz), an oscillating spiral spring with an escapement as in Einstein's watch, pendulum clocks worked by gravity, a tuning fork, frictionless rotating objects like the earth, the earth in orbital motion, pulsating pulsars, the motion of binary starts, light reflected between parallel mirrors, the frequency of a laser beam, and so on.

It is experimentally established but it is a strange fact that these disparate and independent recorders or, more correctly, time-makers, are all concordant. Some are more accurate or stable, but their physics is, generally speaking well- known. Indeed, it is possible to assign the degree of accuracy of the time-makers, using experimental and statistical methods, down to 10^{-16} sec.

One is thus forced to grant that time has an objective existence, but it is there, where matter and radiation fields are. It is an accompaniment of physically existential "things". Does time exist in some other manner in all space? It appears to me that it does, implicitly, because, as I showed in my reflections on space, its two physical properties, viz., permitivity (ε_0) and permeability (μ_0) related to electrical and magnetic properties are so to speak, genetically connected to the velocity of light(c), thus:

$1/c^2$ (T^2 / L^2 dimensionally) is connected germinally to $\mu_0\varepsilon_0$ (T^2 / L^2). There is an elemental web of distance (L) and (T), in space.

[1]T.W. Arthur, Liebnitz's Theory of Time, in "The Natural Philosophy of Time", D. Reidel. Pub. Co., 1985, p.263.

Experimental evidence shows conclusively that when a clock is set into motion relative to the earth it goes slower. I have discussed why it does so. Simply because motion given to

anybody means infusion of energy into the body and its inertial mass increases. Clock has history of its rhythm locked up within it cummulatively. Experiments show that the clocks have their original rhythm restored when brought to their earlier state of rest. We are thus led to believe (it is highly probable) that all the matter on earth has the same history from birth. That points to the birth of time itself when first creation took place! When probably time stood still!!

Is evolution of the universe from the elements ($h\nu$) ranging from $0 = \nu < \infty$