

ON LORENTZ'S CRITICISM OF STOKES' FLUID AETHER

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Our original intention had been a review of Stokes' theory of light; however, this issue of the **Journal** is so overfull that it will be necessary to adjourn that undertaking until another time.

Interest in Stokes' theory has revived with Durie's [1] and Zapffe's [2] papers on aberration, and now our own [3]. Though all four of these theories are based on entirely different principles, they all have areas of common agreement and this intersection is that the carrier for light, whatever it is, is not a rigid, static, incompressible sea at rest, but is, rather, a very labile, fluid vehicle that is essentially inviscid and which locally accompanies gravitating bodies in their spatial motions. Since this model, to which we are almost compelled in the development of our own transmission theory by consideration of aberration, so closely relates to Stokes' aether, we find it rather essential to go back and see what Stokes actually had to say in his original papers.

Stokes' fluid, dynamical aether has been discredited and rejected; it is no longer considered seriously and if it is mentioned at all in modern textbooks, it is as a curiosity that merits only passing comment from an historical point of view. The objections to it are never presented and we had to ask about to find out what they might have been. We were informed that it was Lorentz that did it in some time at about the turn of the century, prior even to the relativistic fad. Our opinion of Lorentz's scientific abilities was already low so we had cause to ask if his objections were validly taken.

Going first to the criticism of Stokes' ideas and considering it carefully may be a time-saver, for if the criticism is compelling, as it was, for instance, in De Sitter's criticism of Ritz's theory of light propagation, we need not then dig very deeply into Stokes' work and may content ourselves with the general outline of what his ideas were. After all, there is not much advantage gained in studying something that is false. On the other hand, if Lorentz's criticism turns out to be superficial and his objections ill-founded, then we shall wish to be a bit more particular in our own critique of Stokes to discover any other flaws that Lorentz might have passed over.

We add that the last is unlikely, for it is rather evident that Lorentz was motivated by an effort not necessarily to arrive at truth but rather to squeeze Stokes' theory out of the nest so as to give total room for his own. Though the objections taken are not altogether superficial they are but plausible ones, a fact of which we are sure Lorentz was probably secretly well enough aware. Had he been able to find something more substantial to find fault with, undoubtedly he would have made use of that, rather than what he has.

Lorentz's objections to Stokes' theory are apparently contained in three separate papers by him [4, 5, 6] and must have been included in his lecture courses delivered before the rising generation of young German physicists who attended them. We have been successful in obtaining reprints of only [4] and [6]. Though these two papers are quite different from one another, the first discussing the Stokesian theory on a logical basis, the second mathematically, we doubt that reference [5] contains anything more than what is covered in [4] and [6] together; indeed, it is likely that [5] is just the original German version of [4]. Thus, we are fairly confident that all his objections are being included in this review. They turn out to be that the Stokesian aether circulates in a global sense, is not irrotational and therefore could not have a global velocity potential everywhere throughout space.

In [6], Lorentz also goes to work on other theories as well, mentioning some we have not heard of before. But it is Stokes' that bothers him the most. This is indicated by the fact that he fronted his attacks on other theories against Stokes' and does so in the first two sections of his book of lectures even before introducing his own ideas to his students. The same treatment of other theories is adjourned until much later on. This includes De Fresnel's fixed aether, Planck's compressible aether, Graetz's theory, Mc Cullagh's aether, Kelvin's aether and some other models. We suggest, in passing, that Zapffe might find Planck's aether even more closely akin to his magnetospheric model than is Stokes'; there are many ways that a fluid may circulate around objects and Planck's is based on such a different mode.

Certain characteristics of Lorentz's personality are betrayed to the reviewer in these papers. He exhibits a retentive memory, a wide acquaintance with the literature relative to his topic and a facile recall of the information gleaned from it, including the ability to regurgitate mathematical formalism at will, without having to go back and look it up in the original sources of it. We can imagine that on the lecture podium this could be impressive to an audience, and that if combined with an imposing stage presence, it would pass for what is commonly taken to be erudition. However, a good tape recorder with fast playback would be even more effective. On close examination, we find an overreliance on this memory capability, and that Lorentz's basic understanding of the formulations he cites so readily, is not deep; indeed, it is quite superficial and by and large erroneous. There would not appear to be much there but confusion of mind concerning what are rather rudimentary mathematical principles, misconceptions concerning them, all betraying a woeful lack of comprehension of fundamentals. This descends to such a level as to bring smiles of amusement to the face of anyone better aware, moving to outright mirth in some instances. It is the same difficulty that he experiences when proposing his contraction theory. Was the man unable to realize that if all matter 'contracted' with its motion through an hypothesized rigid aether, then so did the very rods with which the measurements were made, so that one is, in the

final analysis, achieving nothing but to chase his tail around? The metric properties of the 'contracted' and 'uncontracted' physical universe remain unaltered. It is only by comparison of the physical world with the presumed rigid aether universe, in which there are no tangible measuring rods available other than the assumed constancy of the velocity of light as such - and even the term velocity has no meaning without time and rods - that it would be possible to detect any such effect. If it occurred, a mathematically equivalent hypothesis, even then, would be that the real world remained put, but it was the aether that 'expanded' instead. The two are equivalent and indistinguishable mathematically; physically, the latter is more realistic than the former, too. The incapability of understanding this and his clinging to a false understanding of what are metric standards, as some sort of scale-in-the-sky fixed there already somewhere, is indicative of something lacking in Lorentz's scientific training.

In establishing the relationship between the real world and the mathematical abstraction of Euclidean space and arithmetic, the correspondence is not made in the way Lorentz imagines; it is done by establishing first what are spherical neighborhoods of the topological base. There is no scale-in-the-sky; Newton might have thought that, but that was two centuries ago and better mathematical understanding has developed since and was achieved before Lorentz was born. We do not live in the primitive period of the dinosaurs, still. Establishing the metric base is accomplished practically by extending what are deemed to be rigid rods in all directions so as to make a determination. Whatever comes out of the process constitutes the spherical neighborhoods of the base of the topology and 'contraction' or 'non-contraction' plays no part and cannot. There are many infinitudes of ways to select the metric base but once it is done, it is fixed and it is an error to change from one base to a different one, as Lorentz does, in midstream, between observing data and comparing conclusions of mathematical analyses based on that data, according to an altogether different base imposed, ad hoc, on the physical world. There are no double standards of units, one 'contracted', the other 'uncontracted'; between which one is permitted to juggle. Pretending that there are is praetereo principia of what constitutes distance and the meaning of the term measurement. That is established at the outset, and, once established, cannot be covertly departed from.

Our initial comment on Lorentz's papers under review is that it is amazing to us how literal was his interpretation of the aether concept. Perhaps this was the view generally held in 1897, but if so, it brings one up short today. Aether was not just some postulated carrier for electromagnetic waves as we believe Huyghens had it in mind, but, to Lorentz, it was a veritable substance probably chemically analysable. In this, the impression given is similar to that on encountering an extreme religious fundamentalist. To him aether was a veritable substance that did permeate all other matter as we know it, to any depth, right to the very core of the Earth's center, in fact; which streamed freely through all matter; it was, however, convected by the motion of the latter in just the way De Fresnel said. Lorentz's literal mindedness is something to be reckoned upon. We may be well assured that he believed that all matter actually did contract in his imagery, just as does an ordinary piece of latex rubber when compressed by a fat woman sitting on it. This is well borne out in his statement, designated in [4] as:

Hypothesis (E): The dimensions of the rigid body (metal or stone) that served as support to the optical apparatus during these experiments [of Michelson & Morley] will undergo an alteration as soon as it moves with a given velocity v , relative to the ether in the immediate neighborhood.

We comment that the last two words are deceptively lacking in clarity of meaning. Lodge's experiment disproves what Lorentz is hypothesizing. That experiment had been performed five years prior to the publication of [4] and the results of it would certainly be known to Lorentz. Experimental facts be disregarded in making hypotheses! It is possible to outface reality if one has sufficient stage presence and influence in high places!

Our negative pre-impression of Lorentz's abilities, however, came up a notch - though not above zero - when we read his papers. We had expected them to be a confusion of concepts stirred into a potpourri of mishmash, not atypical of others we have had the misfortune to undertake reading on this subject of light propagation. They are not; and [4], in particular, is clearly enough written to be understood by almost anyone interested enough to read it. There is even an attempt on Lorentz's part to state axioms properly and to argue according to them. For this attempt we gratefully give him credit, but he fails miserably at it, nonetheless. Even a very junior, but trained, mathematician would recognize how many loopholes he leaves behind in his discussions; the effect is like looking over a code of a beginning programmer who is sloppy and careless about leaving behind one unclosed logical branch after another, inevitable sources of future trouble and errors. In the reviewer's estimate clear reasoning ability is not Lorentz's forte. These personality traits are to be considered in reading these papers, to which we can now proceed.

Since [4] is the easier of the two papers and does not involve mathematical discussion, we shall begin with it. Here its author summarizes in concise statements certain propositions called hypotheses (A), (B), (C), (D) and (E), of which the last has already been given above. The others are:

(A) *Transparent ponderable bodies are filled with ether which can move freely. When two transparent bodies are in contact (or a body of this kind with a vacuum) the components of velocity of the ether are continuous at the boundary surface.*

(B) *The movement of the ether is irrotational; therefore a velocity potential exists.*

(C) *The convection of light waves in transparent isotropic matter is established by the well known coefficient of Fresnel.*

(D) *The velocity of the ether is everywhere on the surface of the earth equal to that of the earth.*

Insofar as postulate (B) is concerned, it is a subtle misstatement of Stokes' actual statements. Stokes predicated postulate (D), as well as (C), and, as Lorentz points out, (A) is a fairly manifest conclusion insofar as the behaviour of light is concerned in the Earth's aether atmosphere in relation to the Michelson & Morley experiment, at least. Stokes did not treat (B) as an hypothesis of his theory. He set up the differential equations descriptive of his model, and discovered they were exact.

Tickled with this consequence, he tried to make something out of it that was important and a sales feature for his wares. He claimed there was a potential, which is to say that some function can be found, the partial derivatives of which give the velocity components of the velocity vector of propagation of light rays. Any Pfaffian system of differential equations that has a solution is exact, by the very meaning of the term, and that solution forms a potential function. The term 'potential' is borrowed from mechanics where the solution does have physical meaning as representing 'potential energy'. Lorentz is confused by the extension of the term to a broader meaning. We comment that it is a very bad habit on the part of mathematicians to do this sort of thing, using terminology in a manner that is sometimes in totally irrelevant association with the original meaning of a word. Covariance is such a word, which has a meaning in statistics, for instance, unrelated to that in tensor analysis, while that of tensor analysis is almost unrelated to its original sense in invariance theory. Potential is one of these words and covariance has come to mean: co-variance, or to vary along with, which has about as broad a significance as one could attribute to a word. It must be quite confusing to physicists like Lorentz who rely on memory rather than understanding, to encounter the word 'potential' both as referring to energy and as the function which comes out of any exact Pfaffian system of differential equations. However, there are a lot of the latter class of potentials around, particularly in the theory of elasticity, to which some physical significance or other could probably be attributed, but which are merely functions, the partial derivatives of which give the components of a vector field - handy affairs as they compress a lot of junky mathematical symbolism that it would otherwise be necessary to print. Thus, really Stokes' velocity potential is nothing but a function $f(x,y,z)$ such that $\partial f/\partial x = v_x$, $\partial f/\partial y = v_y$, $\partial f/\partial z = v_z$ where $\mathbf{v} = (v_x, v_y, v_z)$ describes the motion of what the reviewer calls a light-point - an identifiable infinitesimal volume of electromagnetic radiation - through space. We shall return to this discussion again when we get to the review of Stokes' original papers.

It is true that in fluid dynamics, by which discipline, well known to Stokes as a leading fluid dynamicist, Stokes was treating his theory of the aether as a fluid substance, the vortical character of flow is characterized mathematically by the curl of the vector field. Indeed, that is the significance of the word curl and what is today designated as curl \mathbf{v} was formerly written $\text{rot } \mathbf{v}$ or the rotation of the field, and still is occasionally. For, in fact, the curl quantifies how fast the fluid is turning or swirling around a given point. In simplified fluid dynamics one generally insists that curl $\mathbf{v} = 0$, for when a fluid is circulating about a point, as in a whirlpool or eddy, the mathematical complications become formidable: the cross partial derivatives of the velocity potential $\partial^2 f/\partial x \partial y$, $\partial^2 f/\partial y \partial x$ are not equal and the velocity potential has pathological properties no longer amenable to treatment by the standard methods of the calculus. Thus, it was a very desirable attribute of the Stokesian aether that it would be without whirlpools or eddies, and so Stokes presented it.

Lorentz's objection, and there is but one, is that hypotheses (D) and (B) are incompatible. One may not at once see why Stokes' aether is supposed to have whirlpools or eddies - Stokes not having really ruled them out of existence to begin with; merely pointing out, in fact, that the solution of his Pfaffian system of differential equations did not lead to them. Why is there a vortex in the aether? Well, one must realize that the Earth is rotating once a day and if the aether fluid is

concomitant with it in a way similar to the atmosphere, then a vortex ring is formed with a vortex center existing at the center of the Earth or along its axis. There is an especially disastrous situation occurring precisely at the North and South geographic poles, where the inescapable conclusion confronts Lorentz that some, we cannot say molecule or even electron, some ultrafine particle of aether is turning on itself on a twenty-four hour basis. Therefore, as the reader may see, Stokes theory does not hold water and must be abandoned - in favor of the Lorentzian hypothesis of contraction of all matter in the direction of motion of the Earth through the aether-sea-at-rest, of course. There you have it: why Stokes' theory was abandoned by the herd of physicists bowing in adoration of the prognosticative tail switchings of one of its golden calves.

We digress briefly from the foregoing line of discussion before returning to the problem of circulating vector fields again further below, after bringing out an intermediate point or so. The first of these relates to hypothesis (A) which Lorentz incorporates as such into his aetheric theory. Today, we recognize that almost all substances are transparent to electromagnetic vibrations at some frequency or another, while they are opaque at others. Whether light waves can propagate through so large a body as Earth or not, is yet to be seen, but certainly X-rays will penetrate a rock several feet thick. Therefore, the Lorentzian aether moves freely through such 'transparent' substances, and since, presumably the Earth is made up of individual rocks, or volcanic magma, which can be subdivided into volumes of such dimensions that they are each 'transparent', we conclude that the Lorentzian aether penetrates freely everywhere, even to the center of the Earth where the disastrous situation of vorticity certainly prevails. We ask: why does the objection of circulation not then apply to the Lorentzian aether theory? Lorentz is less than explicit about the nature of his aether in non-transparent bodies, if there be any such in reality. Let us, for the sake of being totally agreeable, consider what he would certainly admit was transparent material to visible light, e.g., a goldfish bowl full of water, placed on a revolving stand. Here is transparent matter in rotational condition. Through the very center of this rotating body of transparent matter we shine a light ray. Physically, nothing of significance occurs. In other words, on a realistic basis, irrelevant to either Stokes' or Lorentz's ideas, mild rotational characteristics of transmitting media have, at most, a negligible effect on light propagation. Consequently, Lorentz's objection is physically irrelevant; it is based on mathematical crankturning hitches leading to singularities in equations never designed to cope with the conditions to which they are now being subjected.

Next, let us send Lorentz hoisting with his own petard. His theory, as does Stokes', accepts the De Fresnel drag coefficient. De Fresnel considered only the drag effect in the line of propagation of the light ray, backwards or forwards. He said nothing of the effect of the motion of the medium when this is transverse to the direction of light propagation. Kantor, and we ourselves, have pointed out this complete lack of full description. Marinov has supplied it, ascribing a quantifying formula for it that is dependent on the angular difference between the directions of motion of the light in the beam and that of the transmitting medium; the reviewer has no idea what the source is for his formula, other than Marinov's own skull bone. The related experimental facts we intend to review in considerable detail in a future issue of this **Journal**, when time and space permit it, and so adjourn a discussion until then, as the

facts are rather complex:- it seems that the experimental evidence is that in solid materials lateral convection is total, but in fluids and gases it is partial, ranging to a nil effect. Let us represent this uncertain convection by an (unknown) functional relationship: $f(\theta)$, where θ is the angle between ray and the velocity vector of the moving medium; then, according to De Fresnel: $f(0) = -f(\pi) = (1 - n^{-2}) v \neq 0$, if $|v| \neq 0$. Now, the motion of a light ray, c , on traversing a transmitting medium with motion described by v , is given by C according to the generalized De Fresnel drag formula:

$$C = \frac{c}{n} + f(\theta)v, \quad f(0), f(\pi) \neq 0 \quad (1)$$

for every velocity distribution of the medium. At the point of rotational singularity we must revert to the primitive definition of the curl as

$$\text{curl } [v] = \lim_{V \rightarrow 0} \int (S) n \times v \, dS \quad (2)$$

where V denotes a small volume in the vector field containing the rotational point and for which its largest dimension tends to zero; S is its surface; and n is the normal to S directed outwards. We now curl both sides of (1) and since $\text{curl } [c] = 0$, we have:

$$\text{curl } [C] = \text{curl } [f(\theta)v] \quad (3)$$

No matter what the function $f(\theta)$ may be, since it is non-zero somewhere, and nature demands continuity of it, there is some vector v -field for which $\text{curl } [C]$ does not vanish. In other words, Lorentz's objection applies to his own theory. If relevant to Stokes' aether, it is relevant to the Lorentz aether. Lorentz has been at pains to see the mote in Stokes' eye but has been oblivious to the beam in his own. This is not a case of talking out of two corners of the same mouth, so typical of relativists generally, it is simply blindness to implication, and as such is a low measure of scientific competence.

From this point on, particularly throughout [6], there is a repeated clarioning of the extreme necessity of having an aether which is irrotational.

We note in passing that even if the drag coefficient is replaced with unity, i.e., the drag is total, as in rotating solids (Zeeman's experiment with quartz rods, notwithstanding) the same conclusion applies.

Light gives no significant indication of a change of properties when it traverses a rotating goldfish bowl full of water. Thus, from a physical point of view, irrespective of the mathematical equations, nature does not seem to care much whether the medium, and therefore the convected aether that is, presumably, carried with it, is rotational or not.

Mathematics, though queen in her mansion, is but a servant in the houses of the applied disciplines that employ her. She must conform to the will of nature. It is a mistake to suppose that having written down some equations, they totally describe what is nature and physics. In this instance, we see that dully extending mathematical expressions into the vicinity of a singularity has led to some difficulty in their use; under such circumstances it is a commonplace mathematical procedure to remove the singularity and a small open region containing it from the domain of definition of those expressions. This is what it was necessary for Stokes to have done and Lorentz's objection is met - though an additional step has to be taken, also, to do this properly, as we shall discuss further below.

Continuing our study of the physical situation, let us consider a tidal wave racing across the Pacific Ocean. An oceanside dweller, getting advance warning of it flees inland, leaving his garden hose running. The water from it trickles to the beach and the streamlet encounters a couple of pebbles and forms into an eddy. When the tidal wave arrives, do we suppose this whirlpool significantly alters its course? On the other hand, suppose the Pacific Ocean were a gigantic and fast rotating whirlpool, and the tidal wave were propagating over it. Certainly then that whirlpool would alter the course and direction of the advancing tidal wave; indeed, even the weak Coriolis forces of the Earth's rotation are known to change the paths of tidal waves. The analogy may be applied to a light wave propagating through a goldfish bowl of rotating water, or to the slow rotation of the Earth, presumably causing a circulating effect on either Lorentz's own or Stokes' aethers. Whirlpools and eddies in propagating transparent media, particularly gases, must be presumed to exist in abundance everywhere in the path of an electromagnetic vibration.

One must accompany the application of equations with a degree of common sense and physical understanding as to when their relevance applies. Physics is not just a degenerate form of mathematics, and this Lorentz, with his remarkable recall of formulations at his disposal, did not seem to understand. His objection to Stokes' theory, though technically correct in a nit-picking way, is a removable singularity, somewhat irrelevant to reality. He has a point, but it is a point without either breadth or depth.

As a further aside, let us examine hypothesis (A), and its consequent implications, as Lorentz should have done were he a competent scientist. Suppose we have a transparent body, a block of glass of refractive index n . If at rest in the aether, the velocity of light through the aether filling the block is c/n . We put the glass block in a vacuum so that the aether of the vacuum surrounds it, presumably filtering its way through the containing walls of the vacuum chamber. We now set the glass block in motion at velocity v relative to the aether rest frame (it may already possess such motion, but we can guarantee it by moving it alternately back and forth in the same direction as the light ray). We quote directly from an authoritative text of 1901: Thomas Preston, *The Theory of Light*, Macmillan, Third Edition, p. 522, as to what the accepted meaning was then of the De Fresnel hypothesis which Lorentz mentions in his Hypothesis (C):

The law of drift consequently is that the ether waves must be carried by the moving matter with a velocity v' in the direction of motion and this velocity is less than the full velocity of the matter in the ratio $(n^2 - 1)/n^2$.

This is equivalent to saying that the whole ether within the body is not carried forward with the velocity of the body, but with a velocity v' less than v , and determined by the equation ...

$$v' = \left(1 - \frac{1}{n^2}\right) v$$

In Lorentz's reference to De Fresnel in (C) this is what was intended. Now, the aether in the block is moving at velocity $v' \neq 0$ relative to the aether at rest just outside the block in the vacuum chamber. There is, therefore, a discontinuity of

velocity in the aether at the lateral boundaries of the block as they are crossed from outside to inside. This is a patent contradiction of Lorentz's hypothesis (A):

... the components of velocity of the aether are continuous at the boundary surface.

This is genius? The ravings of such a mentality are worthy of so much as three minutes' consideration? But physicists devote whole books to endeavours to make sense out of what is nonsense, like trying to divine the future out of the random markings on the liver of an ox, as did the diviners of old, believing devoutly that they had to be the words of the gods. Thank goodness mankind in two thousand years got over that syndrome, but it has only been to suffer from this disease instead! Better would it be to gaze with hypnotic fixation and read the portents of science in a puddle of mud than try to make scientific sense out of anything so weak an intellect has to expound! We must comment that it is amazing that the rank and file among physicists seem unable to discern for themselves such elementary and evident self-contradictory errors in the work of the figures of their discipline to whom they pay abject homage. It seems that whenever a Bull of their Establishment but moos, ears are pricked up and the herd runs after the leader, tails high, no matter through what depths of stinking manure they are taken. Even this **Journal**, to which the more enlightened and free thinking minority of the scientific dissidents contributes, is filled with analyses, reanalyses, historical reviews, logical discussions, dwelling on whatever word of pure nonsense is moored by these false deities. This is to the total exclusion of remark or comment on the sincere efforts of far more intelligent scientists made during the past century which are ignored, left on the vine and, in many instances have not even been allowed into print. We wonder how many better theories have died in this way because they are not the moosings of the gods. No matter how imperfect, ill founded, far fetched or poorly developed the ideas of these lesser lights might ever have been, they could in no wise be worse than the gibberish put forth by Lorentz, Einstein, Von Laue, Sommerfeld, Eddington and the rest of the relativistic faction. We are just about fed up with any serious consideration being given to space contractions, time dilations, aging twin paradoxes, relativistic momenta, mass equivalences to energy, black holes and the rest of such preposterous rubbish concocted by these errant non-minds.

It is difficult to bother continuing further reading these papers, as they are, in our opinion, expressions of a feeble and ignorant intellect, not worth spending valuable time on. However, we persist with grit and stubborn determination and find ourselves rewarded by Lorentz mentioning a little known experiment of Michelson's in which Michelson seems to have done what would today be called a ring experiment around a vertical rectangle extending 100 ft in the air on the upward sides BC, AD and 50 ft on the horizontal AB, CD. The horizontal sides faced East and West, and the usual interferometric arrangement was set up with one ray traversing the rectangle in the orientation ABCD, the other in the direction ADCB. The objective was to determine if the aether in the arm AB, when compared with that in BC at the greater distance of 100 ft from the Earth's center, was convected at a faster rate because of the faster motion at that altitude than at the lower altitude. A negative result was obtained: i.e.

that the aether was not convected at greater velocity at the higher altitude than at the lower. It is strange that this experiment has not received greater publicity. It is the first time the reviewer has encountered anything in the literature concerning it; even Kantor seems to be unaware of it. There must be some implication in it contrary to relativism and it has, therefore, been quashed; that something being that it experimentally disproves the partial drag coefficient of De Fresnel.

Lorentz makes some basically incomprehensible remarks about it and, in some way or another we cannot follow, seems to satisfy himself that this result is not incompatible with his theory. We do not see why, but could care less, having no respect left for anything the man has to say.

In the final section of this paper [4] Lorentz speculates on an aether without velocity potential. There may be a point to what he is saying, but the reviewer cannot discover it and has more to do than have the patience to dig out what may not be there. One must realize that refereeing standards are different for Bulls than for common kine. To us, these three pages seem to be made up of pointless mathematical doodlings that have been allowed into print. Since they do not relate to any further objections to Stokes' theory we leave them out of review.

Let us devote a moment or so, however, to this question of the existence of a velocity potential function and how essential it is from a physical point of view, as that does relate to what is under study. Suppose we have some object, say our intelligent tuna fish, Charlie, moving through space, with reference to some coordinate system, say, the hypothesized aether-sea-at-rest, for lack of anything better. For Charlie's well-being, we may consider him to be in the aforementioned goldfish bowl, rotating around an axis through the center of the bowl, perpendicular to the surface of the water. Not knowing what the velocity of the goldfish bowl, water and Charlie is with respect to the aether-sea-at-rest, let us presume it is zero and the axis of rotation coincides with the z-axis of the aether, the origin being in the same plane as Charlie and Charlie does not dive or sault. Thus, all motion is two-dimensional, confined to the x-y plane. Charlie is supremely lazy. He is simply there basking in the plane, being carried round and round with the revolving goldfish bowl in a circle of radius r:

$$\sqrt{x^2 + y^2} - r = 0 \quad (4)$$

Let us describe his motion in the Cartesian coordinate system; it is:

$$x = r \cos(\theta - \theta_0) = r \cos \omega(t - t_0) \quad (5)$$

$$y = r \sin(\theta - \theta_0) = r \sin \omega(t - t_0)$$

where ω is the uniform angular rate of rotation of both the water and the element of it that Charlie displaces, and (θ_0, t_0) is the angular displacement at some initial time. The velocity of Charlie and of the water is:

$$v_x = \frac{d}{dt} r \cos \omega(t - t_0) = -\omega r \sin \omega(t - t_0) = -\omega y \quad (6)$$

$$v_y = \frac{d}{dt} r \sin \omega(t - t_0) = \omega r \cos \omega(t - t_0) = \omega x$$

Now, Charlie's position and velocity, and that of every element of water, is completely described by equations (5) and (6) for some r and t_0, θ_0 . Is there any evidence of a velocity potential? Is there any real need for it? The water is circulating but is the situation physically unreal?

What is velocity potential? It is a function $\varphi \equiv \varphi(x,y)$ with the property:

$$\frac{\partial \varphi}{\partial x} = v_x, \quad \frac{\partial \varphi}{\partial y} = v_y. \quad (7)$$

In this simple instance, which entirely corresponds to Lorentz's objection, there is no velocity potential function definable, since partial integration of each of (6) leads independently to:

$$\begin{aligned} \varphi(x,y) &= \int -\omega y \partial x = -\omega x y + f(y), \\ &= \int \omega x \partial y = +\omega x y + g(x) \end{aligned} \quad (8)$$

where f, g are arbitrary differentiable functions of the indicated variables. It is quite clear that no choice of f and g is possible to make the two expressions equal. The example is quite commonplace. The requirement of a velocity potential is needless.

In other words, these paragraphs are painful self-flagellations by Lorentz intended to impress us with how much deep and serious consideration he has given Stokes' ideas before proceeding to cut them down on some flimsy pretext, in favor of his own - all to the oft-repeated, propagandistic refrain: Lacking velocity potential.

We now turn to [6]. This makes up the first two lectures of a compilation of lectures given in 1922 in the United States by Lorentz on what we presume was a visiting lecturer tour.

The objection raised is the same as in [4], now backed with mathematical arguments. It is the non-existence of a velocity potential function $\varphi \equiv \varphi(x,y,z)$ such that the components (u, v, w) of velocity in a Cartesian coordinate system (x, y, z) are given by the relations, already given by ourself in two-dimensions, in 3-space:

$$u = \frac{\partial \varphi}{\partial x}, \quad v = \frac{\partial \varphi}{\partial y}, \quad w = \frac{\partial \varphi}{\partial z}. \quad (9)$$

We have already seen above how needless this requirement is and need not dwell on it further, but we go on to other related matters.

Lorentz states:

Now, it is actually possible to account for aberration by means of this rotation of the wave-front provided that the motion of the aether is assumed irrotational.

This is precisely why we are going back to discover what Stokes has really said. The rotation referred to is proper to Stokes' theory and will be taken up in our review of it in due course; suffice it to say that it is the change in direction of the wavefront caused by the flow of aether according to what is Stokes' theory.

The condition of irrotationality, however, is one imposed by Lorentz and is his own construction. It is certainly true that the condition is sufficient for the existence of the desideratum of a velocity potential in hydrodynamical flows, but even

there, there are plenty of such flows where rotationality exists at certain points in the flow field. These are very adequately described without a velocity potential function existing in the large. The man does not seem to have the ability to distinguish between the sometimes subtle difference between what is sufficient and what is necessary; though in this instance it is not a fine distinction.

We may ask where the implication is that the Stokesian aether is one of fluid dynamics of incompressible and irrotational fluids? It is very clear, even according to Lorentz's own presentations of the equations descriptive of Stokes' aether that there is no such direct implication in them. Lorentz considers a plane aether wave in the x-y plane with motion of the carrying aether being directed into x, y, z-space with velocity u_0, v_0, w_0 at $x, y, z = 0$ and u, v, w of the same aether element an instant dt later. The equations are technically erroneous for he has projected the effect of this motion on the x-y plane and one should be on his guard against ever using his relations without proper rederivation to the correct form; in writing a book, one should exert a few watts to make sure the presentation is mathematically correct. However, the equations are 'good enough' to illustrate Lorentz's arguments and the error introduces some mathematical simplifications. The new position of the aether element is:

$$\begin{aligned} x + (u_0 + \frac{\partial u}{\partial x} x + \frac{\partial u}{\partial y} y), \\ y + (v_0 + \frac{\partial v}{\partial x} x + \frac{\partial v}{\partial y} y), \\ z + (w_0 + \frac{\partial w}{\partial x} x + \frac{\partial w}{\partial y} y). \end{aligned} \tag{10}$$

He then assumes that the aether wave is slewed in the direction of motion of the aether element, in proportion to its progress over the moving aether carrier at velocity $c (= V)$. The end result is that the light ray, or normal to the wave front, is changed in direction incrementally by the amount:

$$- \frac{1}{c} \frac{\partial w}{\partial x}, \quad - \frac{1}{c} \frac{\partial w}{\partial y}. \tag{11}$$

The errors in his faulty treatment are manifest on checking the final result:- this depends on the components of acceleration of the aether's motion solely in the z-direction of that motion. Slewing, according to the principles of Stokes, occurs even if $w = 0$ and manifestly depends on not only the velocity of the aether's motion in the z-direction but in the other x- and y- directions as well. In fact, it occurs even if all the partial derivatives of the velocity vanish. Thus his mathematics does not correspond to the mechanics of the system. It is really atrocious.

There is nothing in (11) that relates to rotationality; it is merely assumed by Stokes that the region where the analysis applies is one of irrotationality.

W

e may make some comments:

(i) the drag or partial convection effect of De Fresnel is not included anywhere in this treatment, though in [4] Lorentz would lead us to believe - though he does not so expressly state when we read

the fine print carefully - that hypothesis (C) is part of Stokes' theory. Here, the convective drift is total according to the presumed motion of the aether, though the effect on that motion by 'transparent' objects moving through it is something else, not included anywhere in the equations given;

(ii) the direction of aberrational change is assumed by him to be that of the normal to the wave front, which may or may not be in any way related to what is observed as aberration [vide brief comment on this by ourselves p. 1336, ¶ 3, this J.].

After deriving the above formulae and agreeing that aberration is satisfactorily described by them, if only the needless and irrelevant global velocity potential function φ were present, we are suddenly switched over to something new: a requirement that φ be harmonic, satisfying Laplace's differential equation:

$$\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} + \frac{\partial^2 \varphi}{\partial z^2} = 0 \quad (12)$$

We need only remark that $\varphi = x^3 - y^3$ does not satisfy Laplace's equation but defines a velocity field $u = 3x^2$, $v = -3y^2$, $w = 0$, rather nicely.

The final unforgivable sin is that, drawing on some unrelated material in Stokes' papers, he first punctures the domain of definition of the equations so as to leave the center of the Earth out of it and then writes down the harmonic potential for that punctured region as:

$$\varphi = Cx/r^3 \quad (13)$$

which, we note, as $r \rightarrow 0$, is singular at the origin of the chosen coordinate system. He then states this is the unique potential *and according to the theory of Laplace's equation this is the only possible solution*, which it is, if that particular puncturing is considered and the word 'harmonic' is included. However, there is no basis for this particular choice of the position of the permitted singularity. If it is moved to any other spot, another harmonic potential function exists around that point that agrees with the presumed potential at the Earth's surface as much as the cited one does. The sum of the two is another potential, too, as are all sorts of others in linear combination. Indeed, if there is any open region included in the domain of exclusion at all, then any number of harmonic potential functions can be found. The boundary value problem has to be changed over to one of different character to secure uniqueness; for example, to an annular region with an additional specification of conditions given everywhere on the added boundary.

The discussions of this entire section of Lorentz's paper are, as we see, mathematical rubbish, misleading in their critical implications. In this, one wonders regarding whether Lorentz could be regarded as ever having achieved senior scientific competence in his training or ability. He should, somewhere along the line, have acquired some basic awareness of potential theory from standard textbooks on the subject if not from some very famous papers in the literature, before opening his mouth and displaying ignorance at this low level.

Lorentz is dead and it is generally deemed disrespectful of the departed to castigate them when they are unable to defend themselves here on Earth. However, the harm that has been done by him to science goes marching on. His intellectual confusion, even more than that of Einstein, is probably the factor most responsible for the

present deplorable state of physical science. Had he not already had a hobby to ride of his own infantile theories of electromagnetism, with warpings of time and space which they unrealistically demand, it is unlikely Einstein would have received sufficient support from the politically 'in' of the ranking establishment of physics at the turn of this century, to allow his theory of relativity ever to have been seriously considered. It would have washed out along with many another harebrained scheme, on the tides of time.

Phipps has characterized the leading contraversialists of the turn of the century as a set of solemn clowns. In the interests of semantic accuracy, let us use a less euphemistic word, replacing 'solemn' with 'ignorant'.

In sum, Lorentz's objection is nothing worth. Stokes' theory may be open to serious criticism on other counts but it remains viable despite Lorentz. This stuff of Lorentz's is simply invalid.

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