The Marinov motor: A skeleton in the closet of physics

Thomas E. Phipps, Jr.[a)]
908 S. Busey Avenue, Urbana, Illinois 61801, USA

(Received 22 December 2013; accepted 2 March 2014; published online 26 March 2014)

Abstract: The Marinov motor (MM) is a device whose operation has been verified by several independent investigators. This fact is an embarrassment to physicists, since their accepted Lorentz force law is unable to account for it. Full understanding of the MM seems to require (1) a more robust interpretation of the relativity principle, (2) recognition that first-order physics has never been right (in view of the Galilean noninvariance of Maxwell's equations), (3) acceptance of force action by vector potential **A**, and (4) willingness to abandon covariance in favor of invariance. © *2014 Physics Essays Publication*. [http://dx.doi.org/10.4006/0836-1398-27.2.183]

Résumé: Le moteur Marinov (MM) est un dispositif dont le fonctionnement est confirmé par nombre d'investigateurs indépendants. Ce fait est un embarras pour les physiciens, puisque la loi de force de Lorentz qu'ils acceptent n'a pas moyen de le justifier. Il semble que, pour une compréhension totale du MM, il faudrait: (1) une interprétation plus développée du principe de la relativité, (2) une reconnaissance que, en considération de la noninvariabilité Galiléenne des équations de Maxwell, la physique du premier ordre n'a jamais été juste, (3) une acceptation de l'action de la force par le vecteur potential **A**, et (4) un consentement d'abandonner la covariance pour accepter l'invariance.

Key words: Marinov Motor; Electrodynamic Force; Galilean Invariance; First-order Physics; Relativity Principle; Invariance Versus Covariance.

I. INTRODUCTION

One of the many frustrations of Stefan Marinov's life was that he never could account theoretically for the working of the motor he had invented[1] (which he called "Siberian coliu"). All he knew was that it did work. One of the many associated ironies was that within weeks of Marinov's (possibly unrelated) suicide, James P. Wesley, in Germany, came up with an answer.[2] That answer proves important for a number of aspects of physics, particularly for our understanding of relativity.

A typical demonstration form of the Marinov motor (MM) is shown in Fig. 1. A toroidal solenoid or permanent magnet is held fixed, and a direct current $2i$ from an external source is led into a surrounding horizontal conductive ring (supported in bearings not shown) through brushes on opposite sides that permit the ring to rotate freely in place. The current divides, so that i flows in each half of the ring. If the angle ϕ between the two vertical planes containing the magnet and the ring-current entry–exit points vanishes, $\phi = 0$, as shown, a torque is observed to be exerted on the ring, which causes it to turn azimuthally. Alternatively, the ring may be fixed (brushes replaced by solid contacts) and the magnet suspended so that it can turn. In that case, when ϕ lies in the interval $\pm 90°$, torque of a given sense is exerted. If the magnet's turning then continues past those angular limits, the torque sense reverses, so that, to get continuous rotation (motor action), commutation of the current (direction reversal each half-turn) is necessary. There are many variants of these designs. For instance, the vertical members of the toroid may be either inside or outside the ring,[3] torque may be multiplied by use of multiple rings in series,[4] each split at the current entry and exit points and wired so that full current flows in each half-ring, etc.

II. FAILURE OF THE LORENTZ FORCE LAW

What was it, then, that puzzled Marinov about the operation of his motor? In brief, it seems quite impossible that the motor work according to the "known" laws of physics. The accepted Maxwell theory of electromagnetism, which should govern, recognizes only one way in which ponderomotive electrodynamic force can be exerted, and this is in accordance with a semi-empirical supplement to the field equations known as the Lorentz force law, namely,

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v}_d \times \mathbf{B}). \tag{1}$$

Equation (1) expresses the only known linkage of the fields to observability. In the MM, there are equal amounts of plus and minus charge present; hence, $\mathbf{E} \approx 0$. Only the "magnetic" part of the force law, $q\mathbf{v}_d \times \mathbf{B}$, can be effective. The *detector* or field-sensor charge velocity $q\mathbf{v}_d$ refers to current in the ring. Leaving aside all questions of magnitude of the leakage **B**-field outside the toroid, we see from the *cross product* nature of the Lorentz magnetic force term that the force exerted by any stray magnetic field external to the toroid acts in the radial or vertical direction, transverse to the ring current, i.e., in the plane normal to $\mathbf{v}_d$. [Identically, $\mathbf{v}_d \bullet (\mathbf{v}_d \times \mathbf{B}) = 0$ for all **B**.] So there is no predicted

a)tephipps@sbcglobal.net

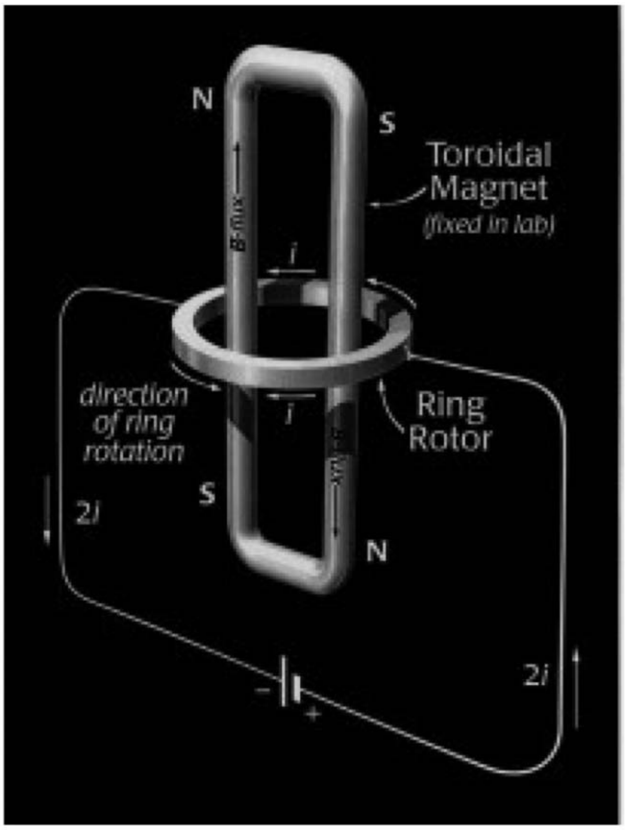

FIG. 1. Schematic of a typical form of the MM.

azimuthal driving force action or reaction (no motor force parallel or antiparallel to $\mathbf{v}_d$ acting on either the ring or the toroid). Like the bumblebee, the MM cannot work; yet it does. I shall discuss the empirical evidence for that in Section V.

III. THE INVARIANT TOTAL TIME DERIVATIVE OF VECTOR POTENTIAL

So, what is wrong with the Lorentz force law? That is the puzzle confronted and solved by Wesley. The key recognition is that whereas **B**-flux is largely contained within the permanent magnet or closed toroidal solenoid, there is also an "**A**-field" of the vector potential **A**, which, owing to proximity, is of appreciable magnitude at the ring. Conventional electromagnetic theory concedes to this **A**-field no ability to exert ponderomotive force. But conventional theory could be wrong! It is worth entertaining that possibility, which will require thinking outside the relativity box. In such willingness to look beyond orthodoxy lay Wesley's genius. Among 10 000 physicists, there is bound to be one like him who is able to question what he was taught. The scientific and technological progress of our species depends on that one in ten thousand. Wesley's challenge was to quantify what Marinov had discovered. His reasoning may have gone somewhat as follows.

First let us review what we know about the electromagnetic potentials $(\Phi, \mathbf{A})$. They are conventionally thought to be related to the magnetic field by $\mathbf{B} = \nabla \times \mathbf{A}$ and to the electric field by

$$\mathbf{E} = -\nabla\Phi - \frac{\partial \mathbf{A}}{\partial t}. \tag{2}$$

However, there is a serious flaw in the latter expression. We note that motors in general are first-order devices (that is, they depend on **v**/c, not on higher powers), so we need to focus attention only on first-order physics, which means that it will suffice to treat inertial transformations by the Galilean transformation (GT), $\mathbf{r}' = \mathbf{r} - \mathbf{v}t$, $t' = t$, under which, if the relativity principle holds in its strictest interpretation, we must demand genuine formal *invariance* of observables such as field quantities. In fact, there is reason to consider each order of approximation as defining its own "physics," because effects at each order are independently observable. We suppose that no observation ever violates the relativity principle. (It would be big news if it did.) That being the case, we are justified in demanding separate invariance of field-related quantities at each order of approximation, beginning with the first, where covariance is not an option. [For field quantities under the GT, $\mathbf{E}' = \mathbf{E}, \mathbf{B}' = \mathbf{B}$ (proven in Ref. 7 for first-order invariant field equations, wherein $\partial/\partial t$ is everywhere replaced by d/dt and also at higher orders for replacement by $d/d\tau$), which express unqualified invariance.]

At low speeds, we have first-order validity of the Galilean velocity addition law,

$$\mathbf{v}'_d = \mathbf{v}_d - \mathbf{v}, \tag{3}$$

v being the constant velocity of the primed with respect to the unprimed inertial frame (and *d*-subscripted velocities being arbitrary detector velocity relative to the indicated frame).

Why do I emphasize literal invariance of field quantities, when all the world accepts covariance[5] as a perfectly good substitute? *Simply because true invariance is an attainable expression of* ***form preservation****, and I can see no reason to settle for less*. Even the wisest of us is in no position to *know* (although conventional wisdom asserts) that nature settles for less. Covariance does not leave unchanged the field quantities whose form it "preserves." It *redefines* those quantities as linear combinations of the old quantities. Does redefinition sound to you like honest form preservation? That, to be sure, is what you have been taught, but would you have thought it without the teaching? The *universal covariance* dodge is both **sly** and **clever**. It beautifully illustrates the principle that the best way to hide an error is to universalize it. A real physicist should be able to sense the impermanence of a physics built on such tricks. Physics is going to need real physicists if progress is to be more than a catch-word.

Now, what we observe about Eq. (2) is that the vector **E** it defines is ***not*** Galilean invariant. The reason is that the partial time derivative operator $\partial/\partial t$ spoils invariance. Thus, under the GT, we have $(\partial/\partial t') = (\partial/\partial t) + \mathbf{v}\cdot\nabla \neq (\partial/\partial t)$. This could be a point of weakness in the whole established conceptual structure, so let us direct our attack there. How to fix it? Well, with little effort, we find that the *total time derivative* **is** Galilean invariant. That is, given the commonly accepted definition of the total time derivative,

$$\frac{d}{dt} = \frac{\partial}{\partial t} + \mathbf{v}_d \cdot \nabla, \tag{4}$$

where $\mathbf{v}_d$ is the arbitrary velocity of a charge that acts as "field detector" or field sensor (the same parameter as in the Lorentz force law, not to be confused with the constant relative velocity $\mathbf{v}$ of two inertial frames). Observe that there is much physics in Eq. (4); e.g., it destroys spacetime symmetry and all the ratiocinations that go with it. Using Eqs. (3) and (4) and the fact that under the GT $\nabla' = \nabla$, we verify first-order formal invariance

$$\begin{aligned}\left(\frac{d}{dt}\right)' &= \left(\frac{\partial}{\partial t} + \mathbf{v}_d \cdot \nabla\right)' = \frac{\partial}{\partial t'} + \mathbf{v}'_d \cdot \nabla' \\ &= \left(\frac{\partial}{\partial t} + \mathbf{v} \cdot \nabla\right) + (\mathbf{v}_d - \mathbf{v}) \cdot \nabla \\ &= \frac{\partial}{\partial t} + \mathbf{v}_d \cdot \nabla = \frac{d}{dt}.\end{aligned} \tag{5}$$

Therefore, we boldly propose to make all electromagnetic theory first-order invariant by *replacing* the invariance-spoiling $\partial/\partial t$ wherever it appears in the field equations or elsewhere by the invariant d/dt. Thus, Eq. (2) yields a modified (Galilean invariant) force law,[6]

$$\mathbf{F} = q\mathbf{E} = -q\left(\nabla\Phi + \frac{d\mathbf{A}}{dt}\right). \tag{6}$$

This law, $\mathbf{F} = q\mathbf{E}$, being formally of an "electric" character, is simpler in structure than Eq. (1), inasmuch as it lacks an overtly magnetic **B**-field part. Observe, moreover, by virtue of Eq. (4), that something exciting has happened to the magnetic part of this electric $q\mathbf{E}$ force law. Suddenly, we have acquired a new force term of motional induction. From Eqs. (4) and (6), the new term is

$$\mathbf{F}_{\substack{\text{motional}\\ \text{induction}}} = -(q/c)(\mathbf{v}_d \cdot \nabla)\mathbf{A}, \tag{7}$$

where I have thrown in a power of c, the light speed, to conform to conventional units. (Elsewhere c is understood to be unity.) Recall that we said the **A**-field extends outside the magnetic toroid and thus impinges on the near-by current-carrying ring. So, in Eq. (7), we have the means of describing a ponderomotive force action on the ring or a reactive-force action on the toroid. This was Wesley's resolution of the puzzle. To be sure, the whole discussion has been limited to the first order, but that is the order needed to describe motor action. Further, it is more or less apparent that higher order physics cannot be right unless the first order is right.

That there could be a first-order mistake or omission in the Maxwellian formulation of electromagnetic physics will strike orthodox physicists as ludicrous. But the MM speaks for itself. When an observed violation of the laws of physics occurs, what gives ground? The laws or the facts? Or do we just hide our heads and hope the whole thing will go away? To be true to history, the latter course has marked the reaction of the physics community so far. This suggests that physics as a science is at an end. From here on, it will be just a taught doctrine. Trust to the academies for that. It is what they do.

How is Eq. (4) to be generalized to higher orders, consistently with our theme of invariance instead of covariance? This remains a topic for research. One plausible suggestion[7] is to replace the noninvariant t wherever it occurs in such relations as Eq. (4) and the electromagnetic field equations (wherein $\partial/\partial t$ has already been replaced everywhere by d/dt) with the higher-order invariant proper-time parameter τ associated with the field detector; whence $\partial/\partial t \to d/dt \to d/d\tau$. This, by the accepted definition of proper time, ensures time dilation at second order, via the famous $\sqrt{1-(v/c)^2}$ factor, but not Lorentz contraction; spacetime symmetry having already been renounced in view of its violation by Eq. (4). [That is, $(\partial/\partial x, \partial/\partial y, \partial/\partial z, \partial/\partial t)$ is spacetime symmetrical; whereas, by Eq. (4), $(\partial/\partial x, \partial/\partial y, \partial/\partial z, d/dt)$ is not. From this, we see that the *homogeneous spacetime manifold* concept underlying both the special and general theories of relativity is falsified by the empirical evidence of the MM.] Clearly, true invariance is an attainable ideal at all orders. It is a myth that covariance is the best we can hope for. Further study is evidently needed, but it does not concern our present first-order considerations on motor action.

There are several other ways of arriving at something resembling the basic force law of Eq. (6). For instance, starting from the vector identity[8]

$$\begin{aligned}\nabla(\mathbf{a}\cdot\mathbf{b}) = (\mathbf{a}\cdot\nabla)\mathbf{b} + (\mathbf{b}\cdot\nabla)\mathbf{a} + \mathbf{a}\times(\nabla\times\mathbf{b}) \\ + \mathbf{b}\times(\nabla\times\mathbf{a}),\end{aligned} \tag{8}$$

if we take **b** to be our vector potential **A**, and **a** to be a velocity $\mathbf{v}_d$ that is constant or at any rate not explicitly dependent on spatial coordinates, this simplifies to

$$\mathbf{v}_d \times (\nabla\times\mathbf{A}) = \nabla(\mathbf{v}_d\cdot\mathbf{A}) - (\mathbf{v}_d\cdot\nabla)\mathbf{A}. \tag{9}$$

Then, since $\mathbf{B} = \nabla\times\mathbf{A}$, the Lorentz force law, Eq. (1), with Eqs. (2), (4), and (9), yields

$$\begin{aligned}\mathbf{F}_{\text{Lorentz}} &= q(\mathbf{E} + \mathbf{v}_d \times (\nabla\times\mathbf{A})) \\ &= q\left(-\nabla\Phi - \frac{\partial\mathbf{A}}{\partial t} + \nabla(\mathbf{v}_d\cdot\mathbf{A}) - (\mathbf{v}_d\cdot\nabla)\mathbf{A}\right) \\ &= q\left(-\nabla(\Phi - \mathbf{v}_d\cdot\mathbf{A}) - \frac{d\mathbf{A}}{dt}\right).\end{aligned} \tag{10}$$

Superficially, this resembles a gauge transformation of the scalar potential Φ in Eq. (6), the transformation function being $\int \mathbf{v}_d \cdot \mathbf{A}dt$. But since there is no matching transformation of **A**, it is not a true gauge transformation, hence does not leave the force gauge-invariant. This unfamiliar form of the Lorentz force law, Eq. (10), is equivalent to what we are assuming to be the valid force law, Eq. (6), provided we are willing to modify Eq. (10) by subtracting from it the term $q\nabla(\mathbf{v}_d\cdot\mathbf{A})$. This simple result holds rigorously, however, only under the stipulated conditions on $\mathbf{v}_d$. In any case, our claim is confirmed that the unmodified Lorentz force law is not equivalent to the presumably correct Eq. (6). It should be remarked, though, for purposes of possible experimental inquiry that the discrepancy is a gradient term that integrates to zero around any closed curve.

Since experiments involving current require closed circuits, the physical effect (presence or absence) of this extra gradient term is not easily demonstrated experimentally. However, in general, when two rival candidate laws of nature differ in their predictions only by an exact differential quantity, so that their difference vanishes when integrated around any closed curve, an experimental method[7,9,10] which I have termed "inertial modulation" allows them to be distinguished. (The basic idea is to spoil the exactness of the differential by a suitably varied distribution of mass around the circuit. Such a mass distribution can serve formally as a Green's function in the integrand, thereby altering the dynamics enough to reveal the desired distinction of laws.[9]) Thus, there is an empirical way to distinguish the candidate laws of Eqs. (1) and (6). The method has not been applied to that particular problem; but it has been applied[11] to the related rivalry between the Lorentz force law and the original Ampère law of force between *current elements*, with the empirical decision in favor of the latter. This experiment,[11] like the MM, rates as one of the turning points of modern physics that is completely ignored by modern physics.

IV. SO, WHAT'S NEW?

If there is anything fundamentally new in the above, it is that the relativity principle must be more broadly and insightfully interpreted than has been the custom among physicists. Thus, the principle must be seen as implying *true invariance at each order of approximation*, independently of the other orders, because, if the principle is about anything, it is about what can be *observed*, and each order of approximation can offer physical effects that are independently observable.

In contrast, Einstein's procedure implies that the first order will take care of itself. Whatever may be wrong there is magically corrected by second-order applications of the relativity principle. Further, to clinch this, he substituted Lorentz covariance (second-order mathematics differing intrinsically from true invariance) for genuine invariance, as his means of expressing form preservation at all orders. By this stratagem, he took the whole world of physics with him, trembling in a stunned ecstasy of admiration. On two counts he was wrong: (1) Covariance is no substitute for invariance. (2) First-order physics demands first-order (low speed) invariance, regardless of what is happening at higher orders. The first order constitutes a physics of its own, divorced from all higher-order considerations and entitled to its own (first-order) relativity principle. The first order will not take care of itself; it needs to be analyzed like any other physics. That is what a full understanding and application of the relativity principle implies. Anything less is a swindle. Evidence of the MM shows that for a century, physicists have been easily swindled. No wonder they prefer to ignore the testimony of fact. Continuing ignoration of the MM will demonstrate that they like things the way they are and mean to keep them that way—to keep the "relativity" ecstasy rolling. In our youth, indeed, we all rolled in the sheer ingenuity of its contrivance. The trouble is (a) most of us never had the second thoughts that are supposed to come with maturity, (b) from among external nature's many attributes, ingenuity was conspicuously left out. Successful description of nature we know must be beautiful; that means it cannot be contrived.

In connection with first-order questions, it may be worth noting the remarkable first-order limiting form of the Lorentz time transformation, namely, $t' = t - vx/c^2$. Although the difference between this and the GT appears subject to empirical testing over either very long distances or very short time intervals, I am not aware that any such tests have been made.

The fact is that none of Einstein's theories cleared up or even addressed the manifest problems of electromagnetism at first order. From start to finish, there was no first-order (Galilean) invariance of Maxwell's equations or of the equations that defined the electromagnetic potentials. One was left to infer, if one chose, that the relativity principle did not hold at first order. Indeed, strictly construed as a true *invariance* principle, the relativity principle did not hold at any order. From that standpoint, the second-order swindle was an all-order swindle. The relativity principle, in its debilitated Einsteinian form, was a delicate conception that originated and lived only at second order, where spirits refined in subtlety could best appreciate it. And the resulting covariance (*ersatz* invariance) was a parallel test of the physicist's capacity to appreciate the subtlety of the almost-as-good, this time on the side of mathematics.

V. WESLEY'S TORQUE FORMULA AND THE EMPIRICAL EVIDENCE

Let us first see qualitatively why the motional induction force specified by Eq. (7) must produce an azimuthal torque that turns the magnet or the ring, whichever is free to rotate. We may begin by recalling Ampère's model of a permanent magnet. This pictures the bulk material as filled with tiny current loops lying in planes transverse to the magnetic flux lines, each loop enclosing a flux line. In the interior of the material, adjacent coplanar current loops cancel each other, but around the periphery of the magnet, there is no cancellation, so a closed loop of virtual current flows around the magnet's outer surface. Alternatively, if the magnet is replaced by a solenoid, a real (electronic) current flows around the outer surface, producing a similarly contained bundle of magnetic flux lines that constitutes the internal **B**-field. In the case of either the magnet or the solenoid, the important thing to note is that the surface "magnetic current" flows azimuthally.

The vector potential **A** is produced by current and is directed *in the same way as the current that produces it*. This turns out to be just as true for the virtual current responsible for permanent magnetism as for the real current in a solenoid. So, the **A**-vector circulates azimuthally, just as the ring current does, and we see that the force predicted by Eq. (7) is indeed such as can exert ponderomotive torque on the mobile portion ("armature") of the motor. Wesley performed the necessary integration[2] and given that (a) the ring is free to rotate and (b) the vertical planes containing the magnetic toroid and the ring-current exit–entry points coincide ($\phi = 0$, as in Fig. 1) obtained an approximation for the ring torque[2,3] as

$$\delta T_{b<r} = \frac{4B_0 \delta A i_{amp} br}{10\pi(r^2 - b^2)}, \quad (11)$$

where δA is the infinitesimal cross-sectional area (square cm) of the magnet's vertical member or solenoid, B_0 is its contained magnetic field (gauss), i_{amp} is the ring current in amperes (the current in the external circuit being $2i_{amp}$), b is the radial distance (cm) between ring center and magnet vertical member center, r is ring radius (cm), and $\delta T_{b<r}$ is ring torque in dyne centimeter for the case in which the ring encloses the toroid. (The factor of 10 converts amps to abamps.) The torque of Eq. (11) is a maximum value, lesser values being obtained when the two vertical planes mentioned do not coincide. [Zero torque occurs when the planes are at right angles ($\phi = 90°$).] In case the ring is fixed to prevent rotation, the counter-torque on the magnet is obtained by multiplying Eq. (11) by b/r. To convert these cgs torque values to practical U.S. units (foot-pounds), multiply by 7.3757×10^{-8}. Equation (11) is at best a rough approximation. Wesley[12] obtained an additional logarithmic term, neglected here and elsewhere in his work,[2] and also a further term in the definition of $d\mathbf{A}/dt$, to be discussed in Section VIII. Still, experience suggests that Eq. (11) describes most of the observable torque.

What about empirical tests of the MM? Tom Ligon, Jeff Kooistra, and I have each independently built working models of the MM. As far as I know, the only reported failure to make the MM work is that of Alexander Kholmetskii and his coworkers, about whom I shall say more in Section VI. Kooistra has adequately reported his work,[13] and I have carefully written up mine.[3] An independent demonstration of the MM principle has been given by Driscoll.[14] Of course, none of this is available in the mainline physics literature, owing to the widespread editorial paternalism that protects modern physicists from anything that might upset them.

I shall limit myself to summarizing my own investigations. I wanted to verify that the magnitude of observed torque approximated the prediction of Wesley's theory, Eq. (11) [multiplied by b/r]. The device I used for this purpose[3] resembled that of Fig. 1, except that the ring was fixed (no brushes) and the toroidal permanent magnet was suspended so it could rotate. Suspension was by a calibrated tungsten torsion fiber of 0.005-in. diameter and 5-in. length. Ring currents up to $i_{amp} = 10$ A were used. The resulting torques were observed to produce maximum magnet turns proportional to the current. In each case, these turns were restored by measured counter-rotations of the fiber (null method, the null being verified by the fiducial position of a reflected laser spot). The observed turning of the magnet was 10.5 ± 0.1 deg/A. Calibration of the torsion fiber[3] yielded 0.08794 deg/(dyn-cm of torque). Consequently, the observed torque for the configuration shown in Fig. 1 ($\phi = 0$ for the angle defined in Section I) was roughly 10.5/0.08794 = 119.4 dyn-cm/A. The simple theory based on Eq. (11) [treating the "infinitesimal" area δA as the actual cross-sectional area of the 3/8-in. diameter cylinder magnets employed] predicted[3] 96.26 dyn-cm/A. The approximate theory is thus in the "right ballpark" for magnitude but is not quantitatively accurate. Further departures of experiment from theory were observed with regard to variation of the angle ϕ. In all cases, the observed torques exceeded the predictions of the simple theory by at least 20%. This has all been reported in Ref. 3. The data provide an undeniable confirmation of the *fact* of the working of the MM. Better theory can certainly be devised, as will be discussed below.

In addition to this fiber-suspended version of the MM, I built also a working (continuously rotating magnet) motor, which required commutation of the current (reversal each half-turn). As I recall, this spun quite vigorously but was not self-starting in every configuration. [That is, it sometimes stopped with the magnet at an azimuth (ϕ near $\pm 90°$) such that it would not restart without help.] I have absolutely no doubt that the MM works, as a fact of nature, theory or no theory.

VI. WHY DID KHOLMETSKII FAIL?

Skeptics will have perked up their ears when they heard that Kholmetskii and his collaborators, Missevich and Evdokimov at the Belarus State University, tried to build a MM and failed to get it to turn.[15] After all, the only people that academicians listen to are other academicians, and these Russians are the only academicians who have spoken.

First, let me say that I know Kholmetskii to be a competent scientist and an honest man. He is also exceptional in being willing to entertain and test unorthodox ideas. That makes him perilously close to being a traitor to his class. The accepted behavior for academicians is to lean back in the old armchair and scoff at anything unorthodox. (Case in point: Cold fusion.) So, how did he happen to fail?

Kholmetskii's own hypothesis on that subject was that the brushes he employed to introduce current into the ring (he used the fixed-magnet, mobile ring embodiment of the MM concept similar to that of Fig. 1, but with the magnet toroid outside, enclosing the ring, rather than enclosed by it) exerted a counter-torque that cancelled the Wesley motor torque. This *brush torque* idea seems to me highly dubious. Brushes are not designed to exert torque of any kind. Moreover, if the brushes he used did produce a counter-torque, its only effect would have been to hide the motor torque that was there, not to disprove its existence.

A much simpler explanation for the absence of motor action occurs to me, provided the figure Kholmetskii gives shows the actual way he did the experiment. In that figure, the toroid members lie just outside the ring, adjacent to it, and with their vertical plane at the same azimuth as the brushes that introduce current into the ring ($\phi = 0$). Thus, the toroid members are so positioned as to prevent the current leads external to the ring from being brought in radially in the plane of the ring, as shown in Fig. 1. Instead, there was a choice to bring them in either normally (vertically) or tangentially in the plane of the ring. Unfortunately, to judge from their figure, the experimenters elected the latter method, i.e., tangentially to the ring in its plane. These leads, fixed in the lab, carry double current $2i_{\text{amp}}$ and thus count double compared with the adjacent ring current itself. In its vicinity, this strong lead-current creates an **A**-field that cannot be neglected. It is therefore essential to be cautious about the "dressing" of the leads.

Observe, then, that if the leads had been dressed so as to bring current in from either above or below, normally to the plane of the ring, they would have had very little effect on the running of the motor, and success should have attended the experiment. But, bringing them in tangentially in the plane of the ring, as it was apparently done, the leads frustrate all possibility of motor operation. Thus, of the $2i_{\text{amp}}$ carried by one of these leads, half of it frustrates the oppositely flowing current i_{amp} in the closely adjacent near half of the ring, and the other half of it frustrates the current i_{amp} flowing in the far half of the ring, by flowing (adjacent to the near half) in the *wrong direction* to reinforce torque (that is, in the right direction to produce a roughly equal counter-torque). The easiest way to recognize the nature of these frustrations is to consider the force actions of the various currents upon the nearby magnets. These actions practically cancel, so no appreciable net force is exerted upon the magnets; hence, by action-reaction equality, none is exerted upon the ring. These frustrations are not total, of course, but are probably sufficient to explain the observed failure of the ring to turn. The moral is that the near-tangency of the current lead-ins to the ring results in near-cancellation of all torques. I find that to be by far the simplest explanation of the experiment's failure. What a pity, the leads were not brought in normally to the ring!

I am certain Kholmetskii did not deliberately design for a publishable failure rather than an unpublishable success. So, let us put the whole matter down to bad luck. Science's bad luck. There will probably never be another academician who will give it a try, so the MM will never become a recognized part of "science," given the political reality that academia grips science in an iron stranglehold. Outside academia, there is no such thing as science. Ask any academician… or any science editor… or any citizen. The taxpayer is sold: Research is what is done in research universities.

Wouldst do science? Hence, vamoose, scram, begone, aroint thee! Get thee to thy research university.

VII. TORQUE SENSE AND THE AMPÈRE FORCE LAW

I have not said a word about which way the MM turns. That should be mentioned for completeness. Ampère, who did so amazingly much for the science of electricity, did a series of highly ingenious null experiments that enabled him to discover a law[16] of force action between "current elements." This law has been largely forgotten or falsely subsumed under the Lorentz force law. I shall not reproduce Ampère's result. The interested reader can look it up (e.g., see Ref. 10, Part I, or Ref. 16). For present purposes, all we need is a few rules of thumb, derived from the Ampère law, a law which has never been violated by any observation. The fact that it has been by-passed and forgotten (not taught to generations of physics students) should tell you something about the true status of a science that has its head in the mathematical clouds and its feet, so its flaks tell us, teetering on the crumbling verge of a Theory of Everything.

The Ampère rules, reduced to simplest form, are as follows:

(1) Parallel current elements attract.
(2) Antiparallel current elements repel.
(3) Proximity rules as to which force dominates.
(4) Current elements are considered fixed in their conductors.

From this, we can easily work out the turning sense of the MM. We suppose current to flow in the conventional or Ben Franklin direction (opposite to electron flow). Then, referring to Fig. 1, in which the magnetic toroid is fixed and the ring free to turn, we see that the **B**-flux points downward in the near (right-hand) vertical member of the suspended magnet, shown with "S" (south magnetic pole) at the top. This means that the Ampère surface current on this part of the magnet circulates clockwise when seen from above. Therefore, for the ring current circulating as shown, the current elements in the near half of the ring and in the adjacent portion of the magnet are roughly parallel, so their force is attractive [rule (1)]. This attraction of current elements fixed in the ring acts to turn the ring counter-clockwise [rule (4)], as seen from above. [Rule (4) apparently implies that the force on the electrons of the ring current is transmitted to the bulk material of the ring through internal charge separations.] Similarly the current elements in the back half of the ring are roughly antiparallel to the nearest magnet surface current elements, so they act repulsively [rule (2)]; hence, the counter-clockwise turning force on the ring is doubled. In summary of Fig. 1 configuration, when seen from above, by action-reaction the ring seeks to turn counter-clockwise and the magnet to turn clockwise. These turning senses are reversed when the adjacent magnetic toroid lies outside the ring instead of inside it.

VIII. ALTERNATIVE FORMS OF THE GENERALIZED TOTAL TIME DERIVATIVE

Wesley claimed[17] that the accepted form of the total time derivative, Eq. (4), is valid only if the operand on which the operator acts is a scalar. If it is a vector **X**, he asserted as a theorem that the proper form is

$$\frac{d\mathbf{X}}{dt} = \frac{\partial \mathbf{X}}{\partial t} + (\mathbf{v}_d \cdot \nabla)\mathbf{X} + (\mathbf{X} \cdot \nabla)\mathbf{v}_d. \tag{12}$$

In other words, he insisted on spatial symmetry between the vectors $\mathbf{v}_d$ and **X**. This amounts (when $\mathbf{X} = \mathbf{A}$) to a symmetry under interchange of source current and sink current. I will not reproduce his proof of this theorem but leave that for the interested reader. Wesley's torque formula (11) ignores the last term of Eq. (12). Since the ring current changes direction (if slowly), the last term in Eq. (12) cannot quite vanish (when $\mathbf{X} = \mathbf{A}$), so it is clear that if Wesley is right about Eq. (12), his torque formula (11) cannot tell the whole story. This may account for some of the discrepancy between observed data and the calculated torque, as discussed in Section V, above.

However, the story does not end here. Mocanu[18] has proposed a different form

$$\frac{d\mathbf{X}}{dt} = \frac{\partial \mathbf{X}}{\partial t} + \nabla(\mathbf{X}\cdot\mathbf{v}_d) - \mathbf{v}_d \times (\nabla \times \mathbf{X}), \tag{13}$$

for the generalized total time derivative, which he traces back to Helmholtz. We note that if Mocanu is right, the Lorentz force law (when $\mathbf{X} = \mathbf{A}$) is in fact recovered in exactly the form (10). This, of course, does not settle the physics of the force law, e.g., as between Eqs. (10) and (6). In the special case that the detector's motion is rectilinear, its velocity can be constant or any explicit function $\mathbf{v}_d(t)$ of time t; then (12) and (13) agree and both are equivalent to Eq. (4). When the detector motion curves, there is no agreement. In that case, application of the full identity (8) shows that Eq. (13) resembles Eq. (12) but with the addition to Eq. (12) of an extra term $\mathbf{X} \times (\nabla \times \mathbf{v}_d)$, which spoils the $(\mathbf{X}, \mathbf{v}_d)$ symmetry.

Still another form attributed to Helmholtz[19] has been given by Miller,[20] namely,

$$\frac{d\mathbf{X}}{dt} = \frac{\partial \mathbf{X}}{\partial t} + \mathbf{v}_d(\nabla\cdot\mathbf{X}) - \nabla \times (\mathbf{v}_d \times \mathbf{X}). \tag{14}$$

I tried my hand at resolving these problems[21] theoretically, but without what could be called success. More empirical evidence is needed. For practical purposes, I shall consider that the traditional Eq. (4), used in Eq. (6), tells enough of the force story to provide a working approximation.

In view of such uncertainties, I have not tried to derive a complete theory. What is the use of refining MM theory if nobody (in academia, where the only true science moils and boils) believes that the device exists? Or cares? The reader has doubtless sensed my personal frustration in this matter. It is maddening to go to the trouble of building working motors and making quantitative torque measurements, only in effect to be ignored as a liar about the whole thing by armchair experts. Try it if you doubt it. But take care. It appears to have played a part in maddening Marinov one notch past the ultimate degree.

IX. SUMMATION

The MM has been shown to work in violation of the accepted Lorentz force law and in accordance with an unorthodox theory due to J. P. Wesley. The latter attributes magnetic force not directly to the **B**-field but to the total time derivative of the vector potential, $d\mathbf{A}/dt$. This total time derivative, in turn, introduces a new force of motional induction proportional to $(\mathbf{v}_d \cdot \nabla)\mathbf{A}$, where $\mathbf{v}_d$ is the same velocity parameter that traditionally appears in the Lorentz force law (and not in Maxwell's field equations). The conceptual justification for such a change in the force law is that established electromagnetic theory is not invariant at first order but needs to be made Galilean invariant in obedience to a first-order relativity principle. The importance of true formal *invariance*, resulting from a strengthened interpretation of the relativity principle, was not known to Maxwell himself and was initially recognized in the work of Hertz,[22] who first introduced the total time derivative into field theory [via velocity parameters (α, β, γ) equivalent to our (v_{dx}, v_{dy}, v_{dz})]. It entirely escaped Lorentz, Einstein, and their followers, who settled for the next best thing, Lorentz covariance.

On the side of theory, several points emerge. First, the relativity principle is a more powerful and also a more demanding one than is recognized by advocates of established "relativity theory." The principle should be viewed as valid at every order of approximation, none being exempt. Covariance is widely thought to be just as good an expression of form preservation as invariance. That is a swindle. Covariance does not even begin to preserve the form of what needs to be, or is alleged to be, preserved. Any mathematician should agree that putting a prime on a collection of symbols is no way to *preserve* a symbol. To restore rectitude, or simple truthfulness, to physics, universal covariance needs to be upgraded to universal invariance.[7] This would define a suitable agenda for physical theorists of the 21st century if they were a trifle more intelligent, sentient, or honest than those of the twentieth… or just a tad less clever.

Apart from demonstrating the inadequacy of standard electromagnetic theory as well as suggesting the need to rethink relativity theory with regard to the literal meaning of "invariance," can the MM be of any practical use? In its simplest embodiments, discussed here, it has rather weak torque and is not directly competitive with conventional motor designs, which have had many years in which to mature. However, the MM is readily capable of design improvement,[4] by suitable reshaping of the magnet, by multiplying the number of current-carrying rings, by splitting the rings so as to allow full current to flow in each half-ring, etc. I have calculated[4] that its torque could thereby be boosted enough to make feasible a "motor-in-a-wheel" design[4] suitable for automotive applications, where electric four-wheel drive is appropriate. Like any motor, the MM can also act as an electric generator if motive power is supplied to turn it (as in regenerative braking). A back emf is produced[4] proportional to torque per ampere. This tells us the MM is not a perpetual motion machine.

In the time of Tesla, the advent of anything new in the realm of electromagnetism would have challenged *Yankee ingenuity* and stimulated a flowering of exciting applications. But that is all in the past. In the 21st century, we know it all. Yankee insouciance has replaced Yankee ingenuity. Except in the digital world, the technical innovator is no longer to be envied. His life, like Marinov's, is apt to be one of frustration. I see this as the indirect result of our allowing the teaching profession (dedicated to stasis) to dominate the science and research professions (the well-springs of innovation). This is reinforced by our tendency to desiccate those well-springs through universal institutionalization, which entails "planning" and "organizing" everything to eliminate surprise. If there is anything an institution dreads, it is surprise. (Try picturing tesla as part of an institution, complete with serried ranks of administrators.) Teaching and research are thought to be two sides of the *same thing*. That is an infallible guide to policy if you like the same thing.

It seems advisable to restate the central message of this paper: ***The Lorentz force law has been shown by empirical***

evidence to be qualitatively wrong at first order. That is about as wrong as wrongness gets. This knocks spacetime symmetry and established ("covariant") relativity theory into a cocked hat. There is no "magnetic force," as such; only its equivalent electric force expressed in terms of the invariant total time derivative of vector potential. This puts it bluntly and will not be believed. I, therefore, ask of the reader only that he keep in mind that somewhere someone raised a doubt about the Lorentz force law—just a shadow of doubt, to taint the professorial certainties. With that, the progress of theoretical physics will cease to be excluded as a logical possibility. Without it, those blind to the facts will continue to educate the blind, and physics will stay jammed into a dead end.

ACKNOWLEDGMENTS

I thank Ruth Rains for the French abstract. Graphic art credit for Fig. 1: R. J. Benish. After this manuscript was completed, a referee called my attention to the work by Pinheiro in 2007 (Refs. 23 and 24) that confirms the present recognition of the need to modify Maxwell's equations so as to get them right at first order and to incorporate in them a force law that accounts for MM operation. I agree entirely with Pinheiro, except that he seems to avoid a clean break with covariance. To me, that is necessary for the sake of clear thinking.

[1] S. Marinov, Deutsch. Phys. **6**, 5 (1997).
[2] J. P. Wesley, Apeiron **5**, 219 (1998). [For a complete Apeiron archive, put "redshift.vif" into Google Search.]
[3] T. E. Phipps, Apeiron **5**, 193 (1998).
[4] T. E. Phipps, Infinite Energy **4**, 62 (1998).
[5] T. E. Phipps, Galilean Electrodyn. **20**, 3 (2009).
[6] T. E. Phipps, Infinite Energy **3**, 43 (1997).
[7] T. E. Phipps, *Old Physics for New*, 2nd ed. (Apeiron, Montreal, 2012).
[8] J. A. Stratton, *Electromagnetic Theory* (McGraw-Hill, New York, 1941), Appendix II.
[9] T. E. Phipps, Phys. Essays **10**, 615 (1997).
[10] T. E. Phipps, "Electric space craft," Part I: 5 August 2005, Issue 39, 6; Part II: 30 January 2006, Issue 40, 6; Part III: 28 August 2006, Issue 41, 6.
[11] N. Graneau, T. Phipps, Jr., and D. Roscoe, Eur. Phys. J. D **15**, 87 (2001).
[12] J. P. Wesley, *Selected Topics in Scientific Physics* (Benjamin Wesley, Bloomberg, Germany, 2002), p. 155.
[13] J. D. Kooistra, Infinite Energy **3**, 40 (1997).
[14] R. B. Driscoll, in American Physical Society, California Section Spring Meeting, Davis, CA, 29–30 March 2002, Meeting ID: CSS02, abstract #B1.011.
[15] A. Kholmetskii, O. Missevich, and V. Evdokimov, Proceedings of the Physical Interpretation of Relativity Theory, Imperial College, London, 15–18 September 2000; also available at http://exvacuo.free.fr/div/Sciences/Exp%E9riences/Em/A%20Kholmetskii%20%20Experimental%20proof%20of%20an%20absence%20of%20Marinov%20Motor%20effect.pdf.
[16] P. Graneau, *Ampere-Neumann Electrodynamics of Metals* (Hadronic Press, Nonantum, MA, 1985).
[17] J. P. Wesley, Apeiron **6**, 237 (1999).
[18] C. I. Mocanu, *Hertzian Relativistic Electrodynamics and Its Associated Mechanics* (Hadronic Press, Palm Harbor, FL, 1991), Vol. I, p. 34.
[19] H. von Helmholtz, Borchart's J. Math. **78**, 273 (1874).
[20] A. I. Miller, *Albert Einstein's Special Theory of Relativity Emergence (1905) and Early Interpretation (1905–1911)* (Addison-Wesley, Reading, MA, 1981).
[21] T. E. Phipps, Apeiron **7**, 107 (2000).
[22] H. R. Hertz, *Electric Waves* (Teubner, Leipzig, 1892; Dover, NY, 1962), Chap. 14.
[23] M. J. Pinheiro, Phys. Essays **20**, 267 (2007).
[24] M. J. Pinheiro, Sci. Rep. **3**, article no. 3454 (2013).