Faraday's Paradox – Some Modern Mistakes

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Abstract

Einstein's 1905 paper described at the outset a puzzling failure of Faraday's law of induction, one of the four Maxwellian EM equations. The application of Faraday's law of dynamics to relative motion of a magnet and metal conductor in the laboratory setting did NOT produce the same induced effect.
Two modern references, Andre Assis and Wikipedia, attempt to resolve this issue, but end up confusing the issue even more by citing the wrong experimental result for the moving magnet!
One wonders , then, what other mainstream beliefs are based on test data misrepresentation. Is it as many as their errors of mis-interpretation of test results?
The required epistemology here is the scientific method and philo-realism.

A Review of Kinematics and Dynamics

Kinematics: The measurement and interpretation of motion by use of abstract mathematical models to describe point motion via kinetic variables. Kinematic laws include the law of Relativity of Motion, Xa,b(t) = -Xb,a(t), where X is a kinematic variable - distance, velocity, acceleration.

Dynamics: The prediction of motion using the Lagrangian method of functional variation. Note that Lagrange assumed that generalized coordinates were valid for any observer's state of motion, an assumption whose validity seems to have escaped testing by all physicists since the mid-18th century.
Here is the way the two concepts support the scientific method.

- kinematic data analysis of a system establishes a reason for forming a hypothesis;
- theoretical predictions are made via the dynamic Euler-Lagrange equations;
- new kinematic test data then either supports or refutes the dynamic theory.

In brief:
kinematics uses measurements to **describe** current motion;
dynamics uses the Euler-Lagrange equations to **predict** future motion.

First for examination is the
'**Moving_magnet_and_conductor_problem'** on Wikipedia
https://en.wikipedia.org/wiki/Moving_magnet_and_conductor_problem
(quotes indented; kinematic terms in bold, dynamic in red)

> The moving magnet and conductor problem, or Faraday's paradox, is a famous thought experiment concerning the intersection of classical electromagnetism and **special relativity**. In it, the current in a conductor moving with constant velocity, v, with respect to a magnet is calculated in the frame of reference of the magnet and in the frame of reference of the conductor. The **observable quantity** in the experiment, the current, is the same in either case, in accordance with the basic principle of **relativity**, which states: "Only relative motion is observable; there is no absolute standard of rest".

In kinematics, only!

> However, according to Maxwell's equations, the charges in the conductor **experience**....

No.... '**experience** is kinematics'; dynamical insertion is ' are predicted to produce'

a magnetic force in the frame of the magnet and an electric force in the frame of the conductor. The same phenomenon would seem to have two different descriptions
depending on the frame of reference of the observer.

Einstein's 1905 paper that introduced the world to relativity opens with a description of the magnet/conductor problem.

*It is known that Maxwell's electrodynamics – as usually understood at the present time – when applied to moving bodies, leads to asymmetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The **observable phenomenon** here depends only on the **relative motion** of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either the one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighborhood of the magnet an electric field with a certain definite energy, producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighborhood of the magnet. In the conductor, however, we find an electromotive force, to which in itself there is no corresponding energy, but which gives rise – assuming equality of relative motion in the two cases discussed – to electric currents of the same path and intensity as those produced by the electric forces in the former case.*

A. Einstein, On the electrodynamics of moving bodies (1905)

Except for the mention of measuring relative motion, the issue here is clearly dynamics.

Consistency is an issue because Newtonian mechanics predicts one transformation (so-called Galilean invariance) for the forces that drive the charges and cause the current, while electrodynamics as expressed by Maxwell's equations predicts that the fields that give rise to these forces transform differently (according to Lorentz invariance).

Consistency is restored by using an aether fluid model that includes entrainment by moving matter(ALFA). Aether is then used as the reference frame for EM effects, by which Maxwell's laws become the Hertz EM laws which use total time derivatives to include convection of the fields and Vq,ae in the Lorentz force equation, replacing Vq,lab.
The inclusion of these aether modifications to Maxwell's EM laws makes the <u>Hertz laws Galilean invariant, just like the laws of mechanics</u>.

Observations of the aberration of light, culminating in the Michelson–Morley experiment, established the validity of Lorentz invariance, and the development of special relativity resolved the resulting disagreement with Newtonian mechanics.

This is a red herring - MMX has nothing relevant to understanding aberration…
Hertz EM made Newton's laws compatible via Galilean transforms, and the aether model explained the MMX.

In addition to consistency, it would be nice to consolidate the descriptions so they appear to be frame-independent.

Kinematics is frame-independent, because motion is relative.
Dynamics is frame- dependent…on the Earth/lab frame.
Kinematics is thus covariant; dynamics is NOT.

A Lorentz-invariant four vector (f/c, Ax,Ay,Az) replaces E and B and provides a frame-independent description…..

The addition of the aether A (aka magnetic vector potential)makes the 4-vector Galilean invariant.

Electromagnetic fields are not directly observable.

Neither is aether….yet E and B are considered real by the physics establishment, aether isn't.

Electromagnetic fields do explain the observed motions of classical charged particles.
….with the addition of the aether field.

A strong requirement in physics is that all observers of the motion of a particle agree on the trajectory of the particle. For instance, if one observer notes that a particle collides with the center of a bullseye, then all observers must reach the same conclusion. This requirement places constraints on the nature of electromagnetic fields and on their transformation from one reference frame to another.

The E and B fields transform as scalars…. That is, $E'(r',t') = E(r,t)$ …same for B'
This yields the Hertz equations which are Galilean covariant
See HereticaL Verities, T. Phipps,Jr P. 128

Perhaps the simplest example, and one that Einstein referenced in his 1905 paper introducing special relativity, is the problem of a conductor moving in the field of a magnet. In the frame of the magnet, a conductor experiences a *magnetic* force. In the frame of a conductor moving relative to the magnet, the conductor experiences a force due to an *electric* field.
For the problem of a conductor moving in the field of a magnet,
the magnetic field in the magnet frame and the electric field in the conductor frame must generate consistent results in the conductor.

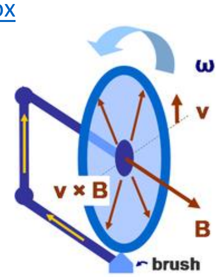
Dynamic tests must be done in the lab frame…which is usually the case.

Faraday's law of induction predicts an induced force when free charges (in a conductor) move across B lines, or when B lines move across free charges. This is frame independence or covariance.

For the magnetic force $F= qvB$, the magnet is at rest in the lab frame and the conductor moves at v.
Experiments confirm this.

For the electric force $F= qE$, the conductor is at rest in the lab frame and the magnet moves at v.
Experiments DO NOT confirm this…. The induced force and current is measured as zero; $F= i = 0$.

An interesting conflict, between this Moving_magnet_and_conductor_problem in Wiki
and "Faraday's paradox" , also in Wiki.
https://en.wikipedia.org/wiki/Faraday_paradox



1. The magnet is held to prevent it from rotating, while the disc is spun on its axis. The result is that the galvanometer registers a direct current. The apparatus therefore acts as a generator, variously called the Faraday generator, the Faraday disc, or the homopolar (or unipolar) generator.
2. The disc is held stationary while the magnet is spun on its axis. The result is that the galvanometer registers no current.

This is the correct statement for a conductor at rest and magnet in motion in the lab frame. Wacky Wiki Wacky is well-named; the two links are in contradiction. How many other Wiki topics fail fact-checking?
The laws of Hertz and Newton are consistent. Transformation of fields, assuming Galilean transformations, will demonstrate that the induced Force = qvB for the moving conductor but zero for the moving magnet.

The sections on Magnet frame and Conductor frame and field transformation are irrelevant …and incorrect. Maxwell's laws predict that there will be an induced current whether the magnet or the conductor moves; the Lorentz force will be the same for either one's relative motion.
$Fq = q(v \times B)$
But experiments show that when magnet moves and conductor is at rest in the lab frame, there is no induced effect,
$Fq = 0$
The reason for the asymmetry: there is no inclusion of aether motion (Hertz laws) in Maxwell's laws.
It's the dragged aether that explains the true observations.

Next for analysis is ….
Relational Mechanics Andre Assis
https://www.ifi.unicamp.br/~assis/Relational-Mechanics-Mach-Weber.pdf P257 & P273

P257 The asymmetry of electromagnetic induction pointed out by Einstein does not appear in Maxwell's original formulation of electrodynamics, contrary to what Einstein wrote. ….
This asymmetry did not exist as well for Faraday ….

Einstein seems to be referring to the asymmetry in Faraday's law. The Maxwell predictions for the Lorentz force, $F = qvB$, are true for the moving magnet but not for the moving conductor ($F=0$). Unlike Wiki, Einstein was aware of the correct test results for the Faraday paradox!

….
Figure 15.1: Magnet M with its axis orthogonal to a plane circuit C.
(a) Magnet moving relative to the ground with velocity $Vm = Vx$, with $V > 0$, while the circuit is at rest.
(b) Magnet at rest, while the circuit moves relative to the ground with velocity $Vc = Vx$. In both cases the same current i flows in the circuit.

The induced current is predicted to be the same, but tests prove the moving magnet (a) causes no current flow, repeating the test result error in the Moving Conductor and Magnet problem, analyzed above. The belief that Faraday and Maxwell and Weber had that the motion was symmetric has been disproven many times since their theory of equal results for relative motion was published.
The error here is enormous, as it misstates test results that are not in question. This brings all of the analysis of Assis into question.

To Lorentz only velocities relative to the ether were important. …..

Only velocities <u>OF CHARGES</u> relative to aether are important, since charges are the source of EM interactions.

Einstein then began to interpret the velocity which appears in the magnetic force of classical electromagnetism, namely, $qv \times B$, as being the velocity of the test charge <u>relative to the observer</u> in this analysis.

This is the error of ignoring inertial frames. The Earth/lab frame is the inertial frame in which the laws of physics, including electromagnetism, are valid. The observer must be in the lab frame. The laws of physics are invalid in any other frame.

…The problems introduced by Einstein with his interpretation of this phenomenon might also have been avoided if he had been guided only by the experiments of induction, which do not suggest any asymmetry. …..

The error continues….

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15.5 Origins and Meanings of the Velocity v which Appears in the Magnetic Force $qv \times B$
Our goal is to discuss the meaning of this velocity v which appears in equations (15.14) or (15.15) for the Lorentz force law. …. In particular, relative to what object, body or entity is to be understood the velocity v of the charge q which appears in equations (15.14) or (15.15)? ….
Some possible answers to this fundamental question:

- Relative to Newton's absolute space.
- Relative to the laboratory or relative to the Earth.
- Relative to the frame of fixed stars.
- Relative to the universal frame of distant galaxies.
- Relative to the macroscopic source of the magnetic field (that is, relative to the magnet or relative to the current carrying wire).
- Relative to the average velocity of the microscopic charges (normally electrons) which generate the magnetic field.
- Relative to the magnetic field itself.
- Relative to the detector of the magnetic field.
- Relative to any inertial frame of reference.
- Relative to an arbitrary frame of reference, which does not need to be inertial.
- Relative to the aether.

Finally, the last choice, #11, is correct. Remember aether is a fluid in the ALFA model, not the rigid Lorentz model.

….Maxwell interpreted this velocity as being the velocity of the test body relative to the magnetic field. This wrong choice explains several anomalies/paradoxes.

> ….. for Lorentz the velocity v meant originally the velocity of the charge relative to the aether and not, for instance, relative to the observer or frame of reference. …. In Lorentz's theory the ether was in a state of absolute rest relative to the frame of fixed stars.

So Lorentz was right in choice of an aether reference frame in EM, but wrong in rejecting a fluid aether model and in picking the 'fixed'? stars as frame of reference.

> ….What Einstein proposed was that the velocity v which appears in Maxwell-Lorentz's force, equation (15.14), should be interpreted as the velocity of the charge relative to the observer. He initially obtained Lorentz's transformations for the spatial coordinates and for time. These transformations relate the magnitudes in one inertial frame to another inertial frame moving relative to the first frame with a constant linear velocity.

There's only one inertial frame. The lab frame cannot be in motion relative to itself!
There's no need for Lorentz transformations; all physical laws are Galilean covariant.

> Einstein presented a completely new meaning for the velocity v which appears in Maxwell-Lorentz's force, equation (15.14), namely, velocity of the charge relative to the observer or relative to the frame of reference. The introduction of physical forces which depend on the state of motion of the observer has created many problems and paradoxes for the explanation of several simple phenomena of nature. Unfortunately it has been part of theoretical physics ever since that time.
> No experiment has suggested or forced this new interpretation. This whole interpretation arose from Einstein's mind. … He created an enormous confusion with this new interpretation which has plagued theoretical physics ever since 1905.

Agreed.

Summary
The documents by Wiki and Assis show amazing disregard for the scientific method; correct data analysis is the basic starting point of testing a hypothesis. Both articles failed this crucial requirement.

Both sources ignored critical distinction between kinematics and dynamics, Aether motion, the Hertz laws, choice of inertial frame and Galilean transforms.