The Troubled Theories Of Magnetic Induction

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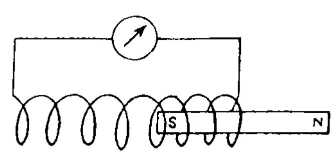
FARADAY'S Law of Magnetic Induction has a special role in fundamental, theoretical physics. This is the law that predicts electricity from magnetism, the law that describes time and process rates, and the law that governs electric motors and most of modern technology. Despite its great importance, fidelity to experimental data, and early quantitative treatment by Neumann[1] in 1845, the law has continually been modified, reformulated, and ignored in favor of inferior hypotheses.

In many situations, especially those where great velocities are involved, assumptions about space and time must be invoked in order to apply Faraday's Law. Electric and magnetic induction both depend upon motion to create an exchange of energy between objects or locations in space. Thus, some assumptions about the nature of space, time, distance and motion must of necessity enter into a law of dynamics to produce a comprehensive theory of dynamics. And because a theory of dynamics should predict the exact force on extended objects of finite-size, the theory cannot be successful if approximations to point-like objects neglect the actual distribution of energy within an object. We will see how erroneous assumptions regarding motion and size of objects have been a major problem for three prominent theories of dynamics.

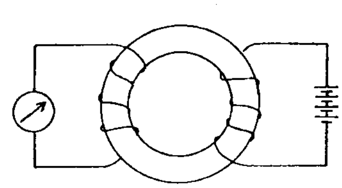
Michael Faraday F.R.S.
of the Royal Institution, 1852.

"A self-educated man, who knew no mathematics, Michael Faraday rose from his humble beginnings as an errand boy to become one of the greatest Englishmen of all time. His single-minded determination and insight led to the discoveries upon which most of the twentieth century technology is based." [2]

Magnetic Induction by a Moving Magnet. Michael Faraday discovered magnetic induction in a series of experiments during the fall of 1831,[2,3] fulfilling a goal to "convert magnetism into electricity" written in his notebook in 1822. The figure shows his simple and direct method of demonstrating magnetic induction. "On 17th October, he produced a current by sliding a cylindrical bar magnet into a long coil or solenoid connected to the galvanometer."[3] The current produced was caused by the *relative motion* between the magnet and the coil, while the magnetic flux produced by the magnet remained constant in *time*.



Magnetic Induction by a Current Loop. Actually, he had demonstrated magnetic induction earlier, on the 29th of August, by the use of two wire coils wound on a soft iron core ring. "He connected the ends of one coil to a galvanometer" and observed that "a current was produced in the second coil only when the current [supplied by a battery] was switched on or off. There was no effect on the second coil when the current in the first was flowing steadily.



Here was the key to it all—a changing current in one coil produced a current in the other." [3]

Both *electric induction* and *magnetic induction* occurred in this experiment:

- Electric induction. A changing current in the primary coil (right side) induced magnetic flux in the iron core—a simple electromagnet.

- Magnetic induction. The changing magnetic flux in the iron core induced a current in the secondary coil—a simple generator.

"Soon after his discovery of electromagnetic induction, Faraday began to hypothesize upon the mechanism of the phenomenon. He abhorred the idea of action-at-a-distance implied in the operation of [the] inverse square law between electrical charges and magnetic poles.

He also disliked the notion that there was no role for the space in the 'vacuum' separating surrounding a magnet and a wire carrying an electric current. With the aid of iron powder sprinkled on a thin sheet of paper under which a bar magnet was placed, Faraday demonstrated the existence of his conceived **lines of force.**" [2]

Two Ways to Change Magnetic Flux. As the reader may understand from the two demonstration described above, an electrical current is induced by the *change* of magnetic flux. The change in flux can be the result of *motion* (moving the magnet) or *time* (an increase or decrease of current over time).

Faraday's Law of Magnetic Induction. The Law of Magnetic Induction is known as Faraday's Law, although it was formulated by others who knew of Faraday's research. The mathematical formulation gives the amount of force (in electrical terms) caused by the rate of change of magnetic flux:

$$emf = \frac{d\phi}{dt} \tag{1}$$

where *emf* is the electromotive force given in the familiar form as voltage around an electrical circuit, ϕ is the magnetic flux that the circuit encloses, and t is time in seconds. The d operator is the *derivative,* which indicates how much the flux changes in some period of time.

In order to develop a theory of dynamic forces, Faraday's Law should be used in ways that include all the effects of motion and size. Motional effects must be included by use of the Galilean Transform based on three-dimensional geometry and absolute time.[4] The effects of size in real particles are included by the finite-size cross sectional area of the circuit detecting the change of magnetic flux. Radio and television antennas are examples of electrical circuits of finite size used to capture income magnetic and electric fields of energy.

Dynamics I. Maxwell's Equations. The next chapter of the history of electrodynamics might have been different if Faraday had formulated the mathematical expression of the law that bears his name. But Faraday "knew no mathematics" and others cast the Law of Magnetic Induction into its familiar form *and into a new form that was supposed to be mathematically equivalent—though in fact was not.*

Faraday worked with a "closed-loop" electric circuit, and equation (1) is easily solved in this case. Maxwell's equation for magnetic induction even begins with a closed-loop circuit, but it ends with a differential equation that can be applied to moving charge elements—an impressive achievement that is taught in every advanced course on electricity and magnetism; but sadly is wrong, containing two errors in logic.

Modern texts on electrodynamics show how to obtain Maxwell's equation in differential form from Faraday's Law, equation (1), by *assuming a closed-loop circuit* (which limits its application) to get expressions for both sides of an equation. According to Jackson [5, p. 213], "Faraday's law therefore reads

$$\int_C \mathbf{E}' \cdot d\mathbf{l} = -\frac{1}{c}\frac{d}{dt}\int_S \mathbf{B} \cdot \mathbf{n}\, da \tag{6.9}$$

where $\mathbf{E}'$ is the electric field at $d\mathbf{l}$ in its rest frame of coordinates." Notice that the prime sign (**'**) is applied to the electric field vector **E** but not to the magnetic field vector **B**, indicating the relative velocity between the two fields. In the final equation (6.11) the notation changes (the prime is dropped) arbitrarily, so that the relative motion between the electric field and magnetic field is lost—in contradiction to the observations of Faraday (and many others). Neither the Galilean Transformation nor any other transformation was applied to Faraday's Law to retain the relative motion that is essential for magnetic induction. Jackson comments that "Faraday's Law (6.9) can be put in differential form by use of Stokes's theorem, provided the circuit is held fixed in the chosen reference frame (in order to have **E** and **B** defined in the *same* frame)." [5, p. 213] But constraining **E** and **B** to be in the same reference frame means that no induction from *motion* is included in Maxwell's equation for magnetic induction—a grave omission in consideration of Faraday's observation.

Still another error is made in this same derivation of the differential form of Faraday's Law. In order to solve equation (6.9), Stokes's theorem is used, as noted above. However, Stokes's theorem—for transforming a line integral of a vector (as in $\mathbf{E}'$ of equation (6.9)) to a surface integral—applies only to a point-particle or, at best, a small particle with spherical symmetry. Jackson seems to be aware of this when he states that the field must be "a well-behaved vector field." [5, p. 35] Since all objects observed in nature are of finite, non-zero size, and few of these have spherical symmetry, the limitation of Maxwell's Equation for Magnetic Induction is obvious.

Dynamics II. Special Relativity Theory. The failures listed above for Maxwell Electrodynamics become quite obvious when objects move with high velocity (approaching to the speed of light). Without including all the energy fields that are induced and act upon charged particles moving with high velocity, one cannot expect to accurately predict the motion and forces on objects. So, when Einstein contrived a set of equations that predicted effects that should be observed for any velocity up to the speed of light, physicists were only too happy to find examples that "proved" SRT is valid.

But nagging doubts remained, and opposition to SRT intensified to a considerable level by the end of the same century that witnessed the birth of SRT. Even Einstein expressed doubts and disappointment with failure of all attempts to achieve a "unified field theory" to integrate the many force laws selectively used in the twentieth century. Even his own General Theory of Relativity rests upon different assumptions with respect to the nature of space and time. Other problems with SRT are described in previous issues of **Foundations of Science**.[6,7]

SRT fails as a scientific theory of dynamics as a result of erroneous and shifting assumptions about the nature of matter and motion. In SRT, all material objects are treated as "point-like"—this point is established [pun intended] by the number of times this phrase and similar terms are used in his 1905 paper.[8]

In SRT, use of assumed *time dilation* makes the actual quantitative descriptions of motion and velocity impossible, thus ensuring the failure of this theory of dynamics.[6]

Dynamics III. Quantum Theory and Bosons. Quantum Theory is fundamentally atomistic, meaning that explanations of natural phenomena permit only *particles* to account for the exchange of energy and the forces this entails. QT dynamics, therefore, ignores Faraday's Law and its underlying assumption of an energetic magnetic field. The popularity of Quantum Theory and confusion caused by QT require us to include a discussion of QT dynamics, even though this hypothesis has no relationship to *magnetic induction,* which is the subject at hand.

Now, to avoid charges of misrepresentation, the reader must be informed that the following portrayal of Quantum Theory was presented in a report[9] by leading Quantum Theorists with impeccable credentials. And the project that created this report was sponsored by the U.S. Department of Energy, the National Science Foundation, and the National Research Council. To assure readers that QT is not being misrepresented, we will quote at length from this official report in order to describe and analyze the latest Quantum Theory of Dynamics. The report states:

> "A century ago, the first elementary particle—the electron—was identified. A revolutionary view of the way matter in the universe is put together was provided by experimental evidence that electrons were basic constituents of all atoms and that they carried electricity. The theory of quantum mechanics explained the paradoxical motion of electrons in the atom and the formation of molecules….
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> "Particle physicists further zoomed in on the subatomic realm with increasingly powerful instruments. Forces were revealed on the subatomic level that no one had predicted, the best example being the strong nuclear force that holds the atomic nucleus together. Experiments revealed the existence of hundred of different

particles. Eventually patterns emerged and theories were put together and tested; today, elementary-particle physics provides the basis for understanding an astonishing variety of phenomena—including those in our daily lives—in terms of just a few truly elementary particles and the forces between them….

"The matter particles exert forces on one another that are understood as resulting from the exchange of the force-carrying particles [called *bosons*]. **Electric and magnetic forces arise when particles exchange photons (the familiar repulsion or attraction of two magnets results from one of them emitting photons that the other receives).** The strong force that holds quarks together to form protons and neutrons comes from the exchange of gluons. The weak forces that cause radioactive decay are created by massive *W* and *Z* particles **(the photon and gluon have no mass)**. These three forces have been successfully described by quantum theories that have remarkably similar structures…. [bold emphasis added]

"Traditionally, elementary particles have been modeled as points that take up no space at all. This approach leads to some theoretical problems because two particles could (in principle) get extremely close and exert arbitrarily large forces on each other. String theory solves this problem by picturing particles as extremely tiny vibrating loops, with the details of their vibrations determining their properties and interactions. This simple idea, with the aid of recent theoretical developments, leads to a theory that is able to encompass *all* of the forces of nature in a unified and self-consistent manner, including—for the first time—gravity." [9]

Our evaluation of QT dynamics will focus on the alleged process that attracts and repels permanent magnets (see bold type above). A claim is made that photons (particles of light) are emitted from one magnetic pole and travel to a second magnetic pole where they either attract or repel. Other literature[10] explains that this is analogous to carrying momentum from one magnet to another by a direct path producing repulsion or an indirect path that produces attraction, because the indirect path taken is such that the photon leaves the emitting pole from behind and hits the attracted magnet from behind. Several problems for this mechanism of energy exchange come to mind:

1. The *law of conservation of energy* would have to be violated by the emission of a photon. (For this reason, such photons have been referred to as "virtual photons.")
2. This process of particles jumping out of the magnet is none other than the "quantum tunneling effect" that has now been shown to be the result of magnetic field energy instead of a spontaneous event initiated by atoms in matter.[11] (Quantum tunneling and the infamous "wave collapse" are the only natural processes proposed by atomists; other predictions are based on equations generated for this purpose.)

3. The concept behind the "familiar repulsion or attraction" is credible only because we are familiar with particles that have mass with ability to transfer momentum upon contact. But the same paragraph quoted here states that photons have no mass.

4. I have looked, and there is no visible evidence for photons (particles of light) surrounding a magnet.

5. A thick sheet of copper or zinc inserted between magnet poles has no change of the strength of the force between them. This is exactly what is predicted by Potential Theory applied to magnetic fields. But this observation is devastating to the hypothesis that photons of light are traveling between magnets, since it is well-known that thick pieces of copper and zinc always stop light.

The simple experiment with magnets described above demonstrates the inability of QT dynamics to predict a force between two stationary magnets. This means, of course, that the QT explanation fails even for *statics*, where no motion is occurring.

Dynamics IV. Weber Electrodynamics. The failures of prevailing theories of dynamics have prompted other theories of electrodynamics. A recent refinement to Weber's original theory, in particular one proposed by Charles W. Lucas, Jr., and Joseph C. Lucas,[12] appears to be a correct and true theory of dynamics.

While previous versions of Weber Electrodynamics started with an assumed expression for potential energy or force between two moving charge elements, the new version proceeds from first principles by using the definition of magnetic flux and applying the Galilean Transformation. The abstract describes this latest version of Weber electrodynamics:

> **Abstract.** Weber's force law for real finite-size elastic particles is here derived from the fundamental empirical laws of classical electrodynamics, *i.e.,* Gauss's laws, Ampère's law, Faraday's law, and Lenz's law assuming Galilean invariance.
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> The rearrangement of the elastic charge density within the finite-size moving particle to produce a minimum in potential energy under the stress of induction forces is seen to be the origin of so-called "relativistic effects." The derived version of Weber's force law appears to be fully "relativistic" without any reference to Einstein's Theory of Special Relativity. It satisfies Newton's Third Law, Conservation of Energy, and Mach's Principle.
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> Furthermore, it incorporates finite-sized particle effects, such as self-induced fields, which are missing from point-particle theories such as Maxwell's Equations, Einstein's Special Theory of Relativity, and Quantum Mechanics. The most general form of the force law appears to properly describe fully "relativistic" radiation and radiation-reaction effects as well as many other higher order time derivative effects.
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> From this derivation it appears that Einstein's Theory of Special Relativity as well as the use of retardation for non-radiation fields in electrodynamics are not proper physical theories but rather mathematical theories cleverly contrived to

imitate the self-field effects of real finite-size elastic particles to order **v** in the Galilean Transformation.

Summary. Two of the four theories of dynamics reviewed here, SRT and QT, cannot be validated as scientific theories but may find a role in predicting phenomena already measured.

Maxwell's Theory of Electrodynamics continues to perform well if certain precautions are taken with its application: high velocity dynamics forces can be correctly predicted

1. when the point particle assumption is unimportant (as for the case of spherical symmetry),[13] and

2. when a Galilean Transformation is applied sufficiently early in the use of Maxwell's Equation for magnetic induction [ref. 4, p. 13 and ref. 13], and

3. when *closed-loop circuits* are evaluated rather than moving charge elements.

Weber Electrodynamics is particularly well-suited to solve problems involving moving charge elements with any velocity. The only limitation in this case appears to be that the Lucas refinement has not yet included the effects of *acceleration* between charge elements.

Conclusions. Consistent application of Faraday's Law of Magnetic Induction and the Galilean Transformation to finite-size particles leads to an true understanding of the fundamental nature and processes that operate in the universe. ◆

References.

1. Peter Graneau, "The Pivoted Current Element and Diamagnetism," **Progress in Space-Time Physics, 1987,** J. P. Wesley, editor, p. 253, Benjamin Wesley, Publisher (1987).

2. John Meurig Thomas, **Michael Faraday and the Royal Institute,** Adam Hilger, Bristol, Philadelphia, NY (1991).

3. Ronald King, **Michael Faraday of the Royal Institute,** The Royal Institution of Great Britain, London (1973).

4. David L. Bergman, "Forces on Moving Objects," CSS website, http://CommonSenseScience.org (1998).

5. John David Jackson, **Classical Electrodynamics,** second edition, John Wiley & Sons, NY (1975).

6. David L. Bergman, "Time, Motion and Relativity," **Foundations of Science,** Vol. 3, No. 1 (Feb., 2000).

7. Curt Renshaw, "Light-Speed and Aether," **Foundations of Science,** Vol. 3, No. 2 (May, 2000).

8. Albert Einstein, "On the Electrodynamics of Moving Bodies," **The Principle of Relativity,** pp. 37-65, Dover (1952).

9. Bruce Winstein (Enrico Fermi Institute, Chair of the Committee on Elementary-Particle Physics) *et al.,* internet address http://www.nap.edu/readingroom/books/particles, National Academy Press, Washington D.C. (1998).

10. Robert Walgate, "Elementary Particles," **Colliers Encyclopedia,** on 3 compact discs for computer (1998).

11. ________, "'Spintronics' Hold Potential for Future Electronic Devices," **APS News,** Vol. 7, No. 4, p. 4 (June 1998).

12. Charles W. Lucas, Jr. and Joseph C. Lucas, "Weber's Force Law for Finite-Size Elastic Particles," accepted for publication in **Galilean Electrodynamics.**

13. Thomas G. Barnes, *et al.,* "A Classical Foundation for Electrodynamics," **Creation Research Society Quarterly,** Vol. 14, pp. 38-45 (June, 1977).