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WEBER POTENTIAL FROM FINITE VELOCITY OF ACTION ?

J. P. Wesley

Weiherdammstrasse 24
W-7712 Blumberg
Germany

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The Weber potential energy U for charges q and q' separated by the distance R is $U = (qq'/R)[1 - (dR/dt)^2/2c^2]$. If this potential arises from a finite velocity c of energy transfer Q', where the retarded rate of transfer from q' to q is $dQ(t-R/c)/dt = Q'[1 - (dR/dt)/c]$ and where the advanced rate from q to q' is $dQ(t+R/c)/dt = Q'[1 + (dR/dt)/c]$, then the resultant time-average root-mean-square action is given by $Q'\sqrt{1 - (dR/dt)^2/c^2} \approx Q'[1 - (dR/dt)^2/2c^2]$. Identifying Q' with the Coulomb potential energy qq'/R, the Weber potential is obtained. Using the same argument, Newtonian gravitation yields a corresponding Weber potential energy, qq'/R being replaced by (- Gmm'/R).

Key words: electrodynamics, Weber potential, action velocity finite.

1. SUCCESS OF THE WEBER THEORY

The original electrodynamic theory of Wilhelm Weber [1] is based upon a simple potential energy function U for two charges, q' at **r**' and q at **r**; thus,

$$U = (qq'/R)[1 - (dR/dt)^2/2c^2], \tag{1}$$

where $R = |\mathbf{r} - \mathbf{r}'|$. Taking the time derivative of (1), the Weber force **F** on q due to q' is prescribed by

$$dU/dt = -\mathbf{V}\cdot\mathbf{F}, \qquad (2)$$

where $\mathbf{V} = \mathbf{v} - \mathbf{v}'$ is the relative velocity between q and q'. The Weber theory, being derived from a potential, agrees with Newton's third law; and energy and momentum are conserved [2].

The original Weber theory agrees with *all* experimental results for slowly varying effects. It yields Ampere's [3] original empirical law for the force between current elements. It predicts the force on Ampere's bridge as measured by Moyssides and Pappas [4,2]. It yields the tension to rupture Graneau's [5] current carrying wires and fluid. It predicts the force to drive the Graneau [6] - Hering [7] submarine. It yields the force to drive the mercury in Hering's [7] pump. It predicts the force to drive the oscillations in Phipp's [8] current carrying mercury wedge. In contrast, the Maxwell theory [9], being based upon the Biot-Savart law or Lorentz force, does not obey Newton's third law; and energy and momentum need not be conserved. The Maxwell theory predicts none of the above experimental results; since the Ampere repulsion between colinear current elements is suppose to be zero. Moreover, it can be shown [10] that the Biot-Savart law, predicting any value what-so-ever (within limits) of the force on Ampere's bridge, is *absurd*.

The Weber theory predicts all of the electromagetic induction experiments, including those of Faraday and the unipolar induction experiments of Kennard [11] and Müller [12]. In contrast, Maxwell theory, limited to induction effects in entire closed current loops, cannot predict the Kennard and Müller results [2]. Lenz's law, which is an empirical rule based essentially upon Newton's third law for electromagnetic induction processes, is an integral part of Weber electrodynamics. In contrast, Lenz's law cannot be derived from Maxwell theory; because Maxwell theory does not satisfy Newton's third law. For example, the force on a time changing current element produced by a static charge distribution is lacking in the Maxwell theory.

Since the Weber theory conserves energy for an isolated system of two moving charges; an isolated system of two moving charges need not radiate. For example, the Bohr hydrogen atom, according to the Weber theory, is stable and need not radiate. In contrast, the Maxwell theory does not satisfy Newton's third law and, thus, does not conserve energy for an isolated system of two moving charges. The Bohr hydrogen atom, according to the Maxwell theory, is not stable; the electron is suppose to spiral into the proton while radiating its energy.

The Maxwell theory satisfies Newton's third law only for extended closed current loop sources. To be physically correct the Maxwell theory is, thus, limited to closed current loop sources. But in this case the force between two moving point charges cannot be prescribed by the theory; and the Maxwell theory cannot be a *fundamental* theory.

The Weber theory has been extended to fields by Wesley [2]. By introducing retarded (or advanced) time rapidly varying effects, including radiation, are predicted. This Weber-Wesley field theory predicts the observed zero self-torque on the Pappas-Vaughan [13,2] Z-shaped antenna. In contrast, the Maxwell theory predicts a large nonzero self-torque in violation of Newton's third law and the observations.

The Weber potential for gravitation, where $(-Gmm'/R)$ replaces (qq'/R) in Eq.(1), has been successfully used by Assis [14,15] to yield Mach's principle.

Considering the success and the importance of the Weber potential in electrodynamics and in gravitation, one is justified in speculating about possible origins of the factor

$$[1 - (dR/dt)^2/2c^2] \tag{3}$$

which converts the Coulomb or gravitational potential energy into the Weber potential (1).

2. DIRECT ACTION VERSUS ACTION AT A DISTANCE

It is important to stress the fact that the Weber potential (1) is an action-at-a-distance approximation valid only for slowly varying effects, where the two charges involved are strongly symmetrically coupled together. Only the relative position, relative velocity, and relative acceleration are involved. For rapidly varying effects, where electromagnetic radiation, such as light, may be involved, the action of a moving charge can be described *only* in terms of an intermediate electromagneitc field. To satisfy Newton's third law and to conserve momentum and energy the inertia and energy of the electromagnetic field itself must be taken into account. The source q' and the sink charge q are not directly coupled together as for action at a distance. The intermediate field is prescribed in terms of the absolute motion of a single charge, retarded fields being needed for a radiating charge and advanced fields for an absorbing charge [16].

It is clear that rapidly varying effects involve direct action of a single moving charge q at a point **r** on the immediate electromagnetic field. The resulting Poynting's vector then defines a fluid or a flux of photons [17] that transmits (or receives) the action to (or from) a distant independent charge.

It has been speculated from time to time that the static Coulomb's law or Newton's universal law of gravitation do not represent action at a distance, but instead result from some sort of direct action. Newton [18] himself, who seems to have been unhappy with action at a distance, speculated that an ether existed throughout space, whose relative density could account for gravitation. This same ether was suppose to be responsible for the transmission of light waves (which accompanied and determined the phase state of his photons). G. L. Le Sage speculated in about 1762 that space might be filled with tiny particles moving with supraluminal velocities whose direct kinetic action on bodies was responsible for the apparent gravitational action at a distance. Descartes speculated that gravitation could only be caused by the direct action of particle transmission. Ritz [19] speculated that the action between charges was produced by an exchange of particles. In quantum theory it is sometimes claimed that a static "exchange force" can arise between two stationary bodies through the agency of "exchange particles" travelling back and forth between the two bodies, which implies direct action as opposed to action at a distance.

Unfortunately these direct action theories for static forces have remained essentially idle speculation; as the theoretical models proposed have generally involved many more ad hoc assumptions than the empirical facts to be explained.

3. WEBER POTENTIAL FROM DELAYED COULOMB ACTION

Direct action models are seldom concerned with the *velocity* of transmission of the direct action. Since electromagnetic radiation is observed to involve direct action with the velocity of light c; if Coulomb's law does result somehow from direct action, then it may be assumed that this action is transmitted with the velocity c. If energy, particles such as "virtual photons", or a fluid Q is transferred back and forth between charges q and q' at a time rate dQ/dt = Q' such as to account for the Coulomb potential energy, then for static charges

$$Q' = qq'/R. \tag{4}$$

For moving charges the rate that energy arrives at q at time t is a function of the rate that energy leaves q' at an earlier or retarded time t^-, where

$$t^- = t - R/c; \tag{5}$$

thus,

$$dQ(t^-)/dt = Q'[1 - (dR/dt)/c]. \tag{6}$$

It may be noted that for electromagnetic radiation the retarded field represents radiation from a moving charge (q' here); as the Poynting's vector is directed away from the charge [16]. Similarly the rate that energy leaves q is a function of the rate energy arrives at q' at a later or advanced time t^+, where

$$t^+ = t + R/c; \tag{7}$$

thus,

$$dQ(t^+)/dt = Q'[1 + (dR/dt)/c]. \tag{8}$$

It may be noted that for electromagnetic radiation the advanced field always represents absorption of radiation by a moving charge (q' here); as the Poynting's vector is directed toward the charge [16]. Advanced fields do not violate causality as frequently erroneosly claimed. They are necessary to allow for absorption of radiation; otherwise the universe would degenerate into pure radiation.

For slowly varying effects the interaction should be symmetric between the two charges q and q'; so the net time-average action may be taken as the root-mean-square average of the retarded and advanced actions; thus,

$$\begin{aligned}\langle dQ/dt\rangle_{rms} &= Q'\sqrt{1 - (dR/dt)^2/c^2} \\ &\approx (qq'/R)[1 - (dR/dt)^2/2c^2],\end{aligned} \tag{9}$$

which is Weber's potential (1). (The square root form of the potential appearing in Eq.(9) has already been suggested by Phipps [20] for other reasons.)

It should be noted that no distinction has been made here between retarded and advanced separation distances R; since for slowly varying effects time intervals are such that $\Delta t \gg R/c$. Thus, for slowly varying effects the approximation in Eq.(9) is justified.

It may be speculated that the decreased energy represented by the Weber potential energy as compared with the Coulomb potential energy may be energy stored in the agent transmitting the action while in transit between the two charges.

4. HISTORICAL NOTE

Since the early days of electrodynamics there have been attempts to derive Weber's electrodynamics from Coulomb's law using a finite velocity of action. None of these prior attempts has been successful.

First, because W. Weber [1], Gauss [21], Helmholtz [22], C. Neumann [23], and others, attempting to prove the conservation of energy for velocity dependent potentials using Lagrangian formalism and becoming thereby confused and mired down in unnecessary mathematical complications, made frequent errors. Here the proof, indicated by Eqs.(1) and (2) above is trivially obvious. (This proof also indicates the nature of the velocity dependence that will allow energy to be conserved.) In general, Lagrangian formalism (with its Hamiltonian and variation principle) should be avoided; as it can produce more problems than it can solve. The fundamental empirical physics is contained in Newton's laws; and Lagrangian formalism "begs the question" by requiring the solution of the problem to be partially known (an energy integral of the motion) before the problem can even be stated.

Second, the finite velocity of action has been restricted to retarded action alone, which involves the oneway effect of a source charge upon a detector charge. The recoil effect on the detector charge given by the advanced action has been entirely overlooked. The retarded action alone necessarily leads to a first order effect in $(dR/dt)/c$, as indicated by Eq.(5) above; but the Weber potential, Eq.(1), involves a second order effect in $(dR/dt)/c$. C. Neumann's [23] claim of having obtained a second order effect (from a first order effect) arose from an arbitrarily chosen potential and an improper use of the Lagrangian method. Similarly, the claim by Gerber [24] (for gravitation) to having obtained a second order effect (from a first order effect) arose from his improper use of the Lagrangian method. Clausius [25] refuted the claims of C. Neumann [23] (on still other grounds) as well as similar claims by Riemann [26] and Betti [27]. G. B. Brown [28] claims to having obtained a Weber like force from Coulomb's law and retarded action; but he presents no mathematical derivation. Here out-and-back action, advanced as well as retarded effects, are included, which results in a net second order effect, as indicated by Eq.(9). The present theory, although an improvement, is still speculative.

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