Inertial Mass of a Charge in a Uniform Electrostatic Potential Field

J. P. WESLEY

Weiherdammstrasse 24, D-78176 Blumberg, Germany

ABSTRACT. To agree with mass energy equivalence and with induction experiments and to generalize Weber electrodynamics to fields the Weber relative acceleration $(\mathbf{R}\bullet\boldsymbol{A})\mathbf{R}/R^2$ is replaced by the acceleration **a** of charge q (or by $-\mathbf{a}'$ of q′) alone. The force **F** on a charge q with acceleration **a** in a uniform electrostatic potential field Φ is then given by $\mathbf{F} = (q\Phi/c^2)\mathbf{a} = -m'\mathbf{a}$ where m′ is the mass equivalent of the electrostatic energy of the charge.

RESUME. Pour être en accord avec l'équivalence masse énergie, avec les expériences d'induction et pour généraliser l'électrodynamique de Weber aux champs, l'accélération relative de Weber $(\mathbf{R}\bullet\boldsymbol{A})\mathbf{R}/R^2$ est remplacée par l'accélération **a** de q (ou par $-\mathbf{a}'$ de q′) seulement. La force sur une charge q avec l'accélération **a** dans un champ uniforme de potentiel électrostatique est donnée par $\mathbf{F} = (q\Phi/c^2)\mathbf{a} = -m'\mathbf{a}$ où m′ est la masse équivalente à l'énergie électrostatique de la charge.

1 Modified Weber Theory for Gravitation

The original Weber (1848, 1893) electrodynamic acceleration force **F** on a charge q at **r** with an acceleration **a** due to a charge q′ at **r′** with an acceleration **a′** is

$$F = (qq'/c^2)\,(\mathbf{R}\bullet\boldsymbol{A})\mathbf{R}/R^3 \qquad (1)$$

where $\mathbf{R} = \mathbf{r} - \mathbf{r}'$ and $\boldsymbol{A} = \mathbf{a} - \mathbf{a}'$. A number of authors (Tisserand 1872, Schrödinger 1925, Assis 1989, and Wesley 1991a) have applied this force to gravitation by replacing qq′ by –Gmm′ to derive Mach's principle. In particular, if the distant masses in the universe are taken to be equivalent to a distant spherical shell of radius b and of surface mass density σ, then Eq. (1) yields :

$$\mathbf{F} = - (2\pi Gm\sigma b/c^2)\mathbf{a}\int_0^\pi d\theta \sin\theta \cos^2\theta = - (4\pi Gm\sigma b/3c^2)\mathbf{a} = - m(\psi/3c^2)\mathbf{a} \qquad (2)$$

where ψ is the gravitational potential chosen negative. This result (2) confirms Mach's principle that the inertial force $-m\mathbf{a}$ experienced by a body is a function of the distant masses in the universe, as given by the potential ψ. The applied force $\mathbf{F}'$ to overcome the force of inertia, Eq. (2), is the negative of Eq. (2): so Newton's second law becomes $\mathbf{F}' = -m(\psi/3c^2)\mathbf{a} = m\mathbf{a}$, where the inertial mass would seem to be $m = -m\psi/3c^2$. Unfortunately, since $m\psi$ is the gravitational potential energy U of the mass m; mass energy equivalence requires

$$m\psi/c^2 = U/c^2 = - m \qquad (3)$$

and not $-3m$.

If the relative acceleration in Weber's original force, Eq. (1), is replaced simply by $\mathbf{a}$,

$$(\mathbf{R}\bullet\boldsymbol{A})\mathbf{R}/R^2 \rightarrow \mathbf{a} \qquad (4)$$

then the distant masses in the universe yield

$$F = m(\psi/c^2)\mathbf{a} \qquad (5)$$

which satisfies mass energy equivalence.

2 Induction Experiments Verify the Modified Weber Force

It may be shown by a straightforward but lengthy analysis that Weber's original force, Eq. (1), yields Faraday's law of electromagnetic induction for transformer induction in a rigid closed loop. But for induction in general the proper empirical law for the force $\mathbf{F}$ of induction on a charge q is given by :

$$- c^2\mathbf{F}/q = d\mathbf{A}/dt = \partial\mathbf{A}/\partial t + (\mathbf{v}\bullet\nabla)\mathbf{A} + (\mathbf{A}\bullet\nabla)\mathbf{v} \qquad (6)$$

where **A** is the magnetic vector potential and where the total time variation as experienced by the charge q moving with the velocity **v** in the vector field **A** is given by the right side of Eq. (6) (as proved in a theorem by Wesley (1999)).

Since the magnetic vector potential **A** is defined in terms of the current density **J**,

$$\mathbf{A} = \int d^3r' \mathbf{J}'/R \tag{7}$$

its time derivative is a function of the acceleration of the source charges, where the replacement of the relative acceleration in the Weber theory by :

$$(\mathbf{R} \bullet \boldsymbol{A})\mathbf{R}/R^2 \rightarrow -\mathbf{a}' \tag{8}$$

is then implied.

The term $\partial\mathbf{A}/\partial t$ in Eq. (6) (as well as Eq. (1)) accounts for Faraday transformer induction. The term $(\mathbf{v}\bullet\nabla)\mathbf{A}$ yields the Aharonov-Bohm effect (Wesley 1998a) as well as the force that drives the Marinov motor (Wesley 1998b). The two terms $(\mathbf{v}\bullet\nabla)\mathbf{A} + (\mathbf{A}\bullet\nabla)\mathbf{v}$ together account for unipolar induction.

3 The Inertial Mass of an Accelerating Charge in a Uniform Electrostatic Field

The force on a charge q with an acceleration **a** at the center inside a hollow charged metal sphere of radius b is given by the modified Weber force (involving the acceleration **a** of the charge q only) as :

$$\mathbf{F} = (q/c^2)\mathbf{a}\int dS'\sigma'/r' = (4\pi\sigma' b/c^2)\mathbf{a} = (q\Phi/c^2)\mathbf{a} \tag{9}$$

where $\sigma' = q'/4\pi b^2$ is the surface charge density on the sphere and dS' is an element of surface. Since Eq. (9) gives the force experienced by charge q due to its acceleration **a**; the applied force **F**′ in Newton's second law must have the opposite sign, $\mathbf{F}' = -\mathbf{F}$. Thus, the inertial mass m′ of an accelerating charge q in a uniform electrostatic field from mass energy equivalence is :

$$m' = - q\Phi/c = - U/c^2 \qquad (10)$$

where U is the potential energy of the charge. Costa de Beauregard (1995) has also proposed this same relationship (10) between inertial mass m′ and the potential energy U. Assis (1993) prefers the inertial mass implied by Weber's original force, Eq. (1), equal to $-q\Phi/3c = - U/3c^2$ (as given by Eq. (2) above for the gravitational case, where it does not agree with mass energy equivalence).

4 The Mikhailov Experiment Measuring the Inertial Mass of an Electron in a Uniform Electrostatic Field

The Mikhailov (1999) experiment verifies directly the existence of an inertial mass equivalent to the electrostatic potential energy of a charge, Eq.(10). He examined electrons moving in a uniform electrostatic potential field, where the total mass M* of an electron is given by :

$$M^* = m_e + m' \qquad (11)$$

where m_e is the material mass of the electron. An oscillating neon glow lamp was placed at the center inside a hollow conducting sphere charged to the potential V to yield the desired uniform potential energy U = eV. The frequency of the glow lamp depends upon the net mass M* of the electron. Varying the electrostatic potential on the conducting sphere from –3000 to + 3000 volts he found a linear decrease in the ratio $(M^* - m_e)/m_e = -U/c^2m_e = -eV/m_e$, as expected from the theory, Eqs. (10) and (11). For 3000 volts he found $(M^* - m_e)/m_e = (-3.0 \pm 0.3)\times10^{-3}$. According to the theory this ratio should have twice this value, or -6×10^{-3}. Costa de Beauregard (1999) has suggested that perhaps the ½ factor found by Mikhailov might be due to an equipartition of the energy between the charge and the charged sphere.

An alternative independent method for measuring the mass of an electron in a uniform electrostatic field should be undertaken as a check on the theory and on Mikhailov's results, and to make it clear whether the inertial mass equivalent is $-U/c^2$, $-U/3c^2$, or $-U/2c^2$.

5 Discussion

The original Weber theory, that gives Eq. (1) for the acceleration force, is an action-at-a-distance theory, where action acts presumably directly instantaneously across any distance. However, if action proceeds with a finite velocity c, then the Weber theory must be altered to include fields, that transmit the action. The inertial force –m**a** on a body is experienced instantaneously upon the application of a force on the body. This inertial force cannot, thus, be due to an *instantaneous* action of the distant masses in the universe (as required by Mach's principle). Instead the inertial force must arise from the interaction of the accelerating body with the local gravitational field, that is produced by the distant masses in the universe over eons of time. This local gravitational field is a *scalar*, a constant; so the relative acceleration of the original Weber theory, that is a function of the direction **R**/R, must be replaced by **a**, Eq. (4).

Similarly the effect of accelerating sources, as occur in induction, cannot be given, in general, by the original Weber theory. Instead the relative acceleration must be replaced by the individual acceleration –**a**′ Eq. (8).

It is interesting to note, as pointed out by Costa de Beauregard, that the value of the local gravitational potential field Ψ produced by the distant masses of the universe is given simply from inertial mass energy equivalence and Mach's principle (Eq. (3) above) as $\Psi = c^2$.

Since an inertial mass can be defined in terms of the potential energy; potentials are physically real. They are not merely mathematical generating functions for the forces. Potential fields, such as Φ, are defined in terms of the *sources*; so they are *causes*. Forces, being defined in terms of potentials, are merely *effects* produced by the potentials.

References

Assis, A.K.T. 1989, *Found. Phys. Lett*. **2**, 301

Assis, A.K.T. 1993, *J. Phys. Soc. Japan*, **62**, 1418

Costa de Beauregard, O. 1995, in *Advanced Electrodynamics*, Eds. Barret, T.W. and Grimes, D.M. (World Scientific, Singapore) pp. 77 – 104

Costa de Beauregard, O. 1999, comments following Mikhailov's paper, *Ann. Fond. Louis de Broglie*, **24**, 161

Mikhailov, V.F. 1999, *Ann. Fond. Louis de Broglie*, **24**, 161

Schrödinger, E. 1925, *Ann. der Phys.* **77**, 325. For his ad hoc ξ factor equal to unity.

Tisserand, M.F. 1872, *Comptes Rendus*, **74**, 750

Weber, W.E. 1848, *Ann. der Phys*. **73**, 229; 1893 (Julius Springer, Berlin) Vols. 1-6

Wesley, J.P. 1998a, *Apeiron*, **5**, 89

Wesley, J.P. 1998b, *Apeiron*, **5**, 219

Wesley, J.P. 1999, *Apeiron*, **6**, 237

(Manuscrit reçu le 2 mai 2000)