The Electrodynamic Origin of the Force of Inertia ($F = m_i a$)—Part 2

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Abstract. A review of Newton's *Principia* [3] shows his dependence on his Existence Theorem for absolute space and time in order to explain the force of inertia and the centrifugal force in terms of absolute coordinates. A review of the history of Einstein's General Theory of Relativity reveals his failure to establish the basis of inertia and the centrifugal force in terms of relative coordinates as Mach [5] had envisioned. In this work the force of inertia, including the centrifugal force, is derived from the universal electrodynamic force law based on relative coordinates. From the electrodynamic perspective the inertial force is an average residual force between vibrating neutral electric dipoles consisting of atomic electrons vibrating with respect to protons in the nucleus of atoms. The inertial mass is derived and shown to be equal to the derived gravitational mass resulting from the same universal force law. The vibrational mechanism for both gravitational and inertial mass causes the magnitude of both masses to decay over time. The derived electrodynamic inertial force has a second term, a non-radial $\mathbf{R} \times (\mathbf{R} \times \mathbf{A})$ term, which describes certain observed non-Newtonian inertial gyroscopic motions. Arguments are made that this derived law of inertia is superior to both Newton's Law of Inertia ($\mathbf{F} = m\mathbf{a}$) and Einstein's field equations of General Relativity Theory, because (1) it is properly based on local contact forces instead of unphysical action-at-a-distance forces, (2) it is based on forces between finite-size particles instead of imaginary point particles, (3) it is based on relative coordinates instead of fictitious absolute space coordinates, (4) it is derived from a universal force law, (5) it explains the centrifugal force as a piece of the inertial force, (6) it is simpler and does not need mass as a fundamental quantity, (7) it explains the apparent equivalence of gravitational and inertial mass, (8) it contains a new non-radial $\mathbf{R} \times (\mathbf{R} \times \mathbf{A})$ term that describes additional observed phenomena not previously explained by any theory of inertia, and (9) it contains relativistic type v/c corrections for high velocity.

Derivation of Force of Inertia from the Universal Electrodynamic Force Law. In this section the origin of the inertial forces will be shown to be due to the acceleration terms of the universal electrodynamic force which is based on relative coordinates. The coefficient of the acceleration term defines the inertial mass in the same way as a previous paper defined the gravitational mass. In this way the equivalence of the gravitational and inertial mass will be demonstrated to be valid under certain conditions. In general the concept of a fundamental physical quantity called *mass* [4] will be shown to be invalid. The physical quantity previously identified as mass is found to be an approximately constant grouping of electrodynamic vibrating neutral dipole terms under certain conditions.

Equation (8) for the universal electrodynamic force [1, 2] was derived assuming that the electrodynamic potential is a regular well-behaved continuous function of the relative coordinates $\mathbf{R} = \mathbf{r}_1 - \mathbf{r}_2$, $\mathbf{V} = \mathbf{v}_1 - \mathbf{v}_2$, $\mathbf{A} = \mathbf{a}_1 - \mathbf{a}_2$. Consider the possibility that the first acceleration term of equation (8) is the origin of Newton's second law $\mathbf{F} = m_i\,\mathbf{a}$.

$$\vec F(\vec R,\vec V,\vec A)=\frac{qq'\frac{2}{c^2}\vec A}{\left(1-\beta^2\sin^2\theta\right)^{1/2}}-\frac{qq'\left(1-\beta^2\right)\vec R\times\left(\vec R\times\frac{\vec A}{c^2}\right)}{\left[\vec R^2-\frac{\left\{\vec R\times\left(\vec R\times\beta\right)\right\}^2}{\vec R^2}\right]^{3/2}} \qquad (8)$$

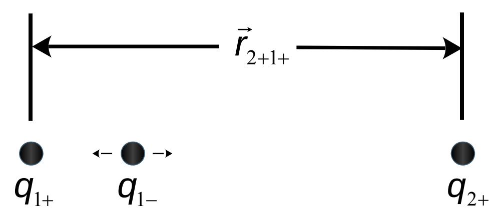
$$=qq'\frac{2}{c^2}\vec A\left[1+\frac{\beta^2\sin^2\theta}{2}+\ldots\right]-\frac{q\vec q}{\vec R}\hat R\times\left(\hat R\times\frac{\vec A}{c^2}\right)\left(1-\beta^2\right)\left[1+\frac{3}{2}\beta^2\sin^2\theta+\frac{\left(\frac{3}{2}\right)\left(\frac{5}{2}\right)}{2}\beta^4\sin^4\theta\ldots\right]$$

$$=qq'\frac{2}{c^2}\vec A\left[1+\frac{\beta^2}{2}-\frac{\beta^2}{2}\cos^2\theta+\ldots\right]$$

$$-\frac{qq'}{R}\hat R\times\left(\hat R\times\frac{\vec A}{c^2}\right)\left[1+\frac{\beta^2}{2}-\frac{3}{2}\beta^2\cos^2\theta-\frac{3}{8}\beta^4-\frac{9}{4}\cos^2\theta+\frac{15}{8}\beta^4\cos^4\theta+\ldots\right]$$

Assume that the force of Newton's second law is between a charge and some vibrating neutral dipoles consisting of positive protons and negative electrons where the dipole is defined by $\vec r_{2+1+}=\vec r_{2+}-\vec r_{1+}$ and $A_1\ f_1 = \nu_1$ and $\vec r_{2+1-}=\vec r_{2+}-\vec r_{1-}-A_1\cos\left(\omega_1 t+\varphi_1\right)$.

Figure 2.
Oscillations of Electon in Neutral Dipole.



The amplitude of the oscillation A_1 is of the order of the size of the atom $\approx 10^{-10}$ meter. The frequency of oscillation ω_1 is in the microwave range $\approx 10^{10}$ per second. At time $t = 0$ the amplitude of the vibration is maximum as represented by $\cos(\omega t + \varphi)$.

In order to simplify the calculations assume that the positively charged proton is much more massive than the negatively charged electron such that the vibratory motion of the dipole can be considered as due primarily to the motion of the electron. Since the mass of the proton is 1836 times the mass of the electron, this is a reasonable approximation.

In order to calculate a quantity comparable to Newton's second law $\mathbf{F} = m_i\,\mathbf{a}$ [3], it will be necessary to perform a number of averages. Each oscillating dipole has a different phase φ that must be averaged over. Each oscillating dipole may have a different physical orientation that needs to be averaged over for all the dipoles in the material body. In order to obtain a time independent value, it will be necessary to perform a time average on the oscillating dipoles. Thus the force to be compared with Newton's second law is

$$\vec{F} = \frac{1}{T_1}\int_0^{T_1} dt \, \frac{1}{2\pi}\int_0^{2\pi} d\varphi_1 \, \frac{1}{\pi}\int_0^{\pi} \sin\theta \, d\theta \, \frac{1}{2\pi}\int_0^{2\pi} d\varphi \, \vec{F}\left(R,\theta,\varphi,A_1,\omega_1,\varphi_1,t\right) \tag{9}$$

For simplicity assume that the collection of dipoles has spherical symmetry. In this case the integral over φ becomes just 2π giving

$$\vec{F} = \frac{1}{T_1}\int_0^{T_1} dt \, \frac{1}{2\pi}\int_0^{2\pi} d\varphi_1 \, \frac{1}{\pi}\int_0^{\pi} \sin\theta \, d\theta \;\; \vec{F}\left(R,\theta,\varphi,A_1,\omega_1,\varphi_1,t\right) \tag{10}$$

Note that there are two fundamental type terms in the force given in equation (8). The first term is proportional to the acceleration **A**. The second term is perpendicular to the acceleration **A** and **R**. This term will lead to a new (previously unknown?) inertial force which causes corkscrew spiraling motion perpendicular to the acceleration.

Computation of the Acceleration Term for Newton's Second Law (F = *m*a).
The force terms for the first acceleration term to order β^4 in equation (8) are given below

$$\vec{F}_{2+1-} = -\frac{2e^2\vec{A}}{c^2}\left[1+\left(\beta_2-\beta_1\right)^2\frac{\left(1-\cos^2\theta\right)}{2}-\left(\beta_2-\beta_1\right)^4\left(\frac{3}{8}+\frac{9}{4}\cos^2\theta-\frac{15}{8}\cos^4\theta\right)+\ldots\right]$$

$$\vec{F}_{2+1+} = \frac{2e^2\vec{A}}{c^2}\left[1\right] \tag{11}$$

For the velocity terms in the [ ] of the expressions for the force above, consider the case $\beta_2 = \beta_1$ corresponding to typical lab force table experiments. In this case only the $A_1\omega_1$ terms are left giving

$$\vec{F}_{2+1-} = -\frac{2e^2\vec{A}}{c^2}\left[1+\left(A_1\omega_1\sin\left(\omega_1 t+\varphi_1\right)\right)^2\frac{2\left(1-\cos^2\theta\right)}{2}+\ldots\right] \tag{12}$$

$$\vec{F}_{2+1+} = \frac{2e^2\vec{A}}{c^2}\left[1\right]$$

One can see that the sum of the first terms in the [ ] of the two forces is just 0. Thus the total force is

$$\vec{F}\left(R,\theta,\varphi,A_1,\omega_1,\varphi_1,t\right) = \vec{F}_{2+1+}+\vec{F}_{2+1-} = -\frac{2e^2\vec{A}}{c^2}\left(A_1\omega_1\sin\left(\omega_1 t+\varphi_1\right)\right)^2\frac{2\left(1-\cos^2\theta\right)}{2} \tag{13}$$

Now the integrals of equation (10) can be evaluated

$$\vec{F} = \frac{1}{T_1}\int_0^{T_1} dt\, \frac{1}{2\pi}\int_0^{\pi} d\varphi_1\, \frac{1}{\pi}\int_0^{\pi} \sin\theta\, d\theta\, \vec{F}\left(R,\theta,\varphi,A_1,\omega_1,\varphi_1,t\right) \tag{14}$$

$$= \frac{1}{T_1}\int_0^{T_1} dt\, \frac{1}{2\pi}\int_0^{\pi} d\varphi_1\, \frac{1}{\pi}\int_0^{\pi} \sin\theta\, d\theta\, \left(\frac{-2e^2\vec{A}}{c^2}\right)\left(\frac{A_1^{\,2}\omega_1^{\,2}}{c^2}\right)\sin^2\left(\omega_1 t+\varphi_1\right)\frac{1-\cos^2\theta}{2}$$

$$= \frac{1}{T_1}\int_0^{T_1} dt\, \frac{1}{2\pi}\int_0^{\pi} d\varphi_1 \left(\frac{-2e^2\vec{A}}{c^2}\right)\frac{A_1^2\,\omega_1}{c^2}\sin^2\left(\omega_1\, t+\varphi_1\right)\left(\frac{-4}{3\pi}\right)$$

$$= \frac{\omega_1}{2\pi}\int_0^{\frac{2\pi}{\omega_1}} dt \left(\frac{2e^2\vec{A}}{c^2}\right)\left(\frac{1}{2}\right)\frac{A_1^2\,\omega_1^2}{c^2}\left(\frac{4}{3\pi}\right)$$

$$= \left(\frac{4e^2}{3\pi c^2}\right)\frac{A_1^2\,\omega_1^2}{c^2}\vec{A} \equiv m_{i1}\,\vec{A}$$

where

$$\frac{1}{2\pi}\int_0^{2\pi}\sin^2(\omega t+\varphi)\,d\varphi = \frac{1}{2\pi}\int_0^{2\pi}\left(\sin^2\omega t\,\cos^2\varphi + 2\cos\omega t\,\sin\omega t\,\sin\varphi\,\cos\varphi + \cos^2\omega t\,\sin^2\varphi\right)d\varphi$$

$$= \left(\frac{1}{2\pi}\right)\left(\pi\cos^2\omega t + 0 + \pi\sin^2\omega t\right) = \frac{1}{2}\left(\cos^2\omega t + \sin^2\omega t\right) = \frac{1}{2} \tag{15}$$

Thus we have derived an electrodynamic formula for the inertial mass m_{i1}. Using this definition we can evaluate equation (6), *i.e.*

$$\frac{F_{i1}}{F_{i2}} = \frac{m_{i1}\,A_1}{m_{i2}\,A_2} = \frac{m_{i1}\,g}{m_{i2}\,g} = \frac{A_1^2\,\omega_1^2}{A_2^2\,\omega_2^2} \tag{16}$$

From the derivation of the force of gravity from the universal electrodynamic force law [4].

$$\vec{F}_G = \frac{-e^2}{\left|\vec{r}_2-\vec{r}_1\right|^2}\hat{r}_{12}\,\frac{A_2^2\,\omega_2^2}{c^2}\,\frac{A_1^2\,\omega_1^2}{c^2}\,\frac{2}{5\pi} = -G\,\frac{m_1\,m_2}{\left|\vec{r}_2-\vec{r}_1\right|^2}\hat{r}_{12} \tag{17}$$

and equation (3) we may write the ratio of the force of gravity on two different bodies at the surface of the earth of radius R_E and mass m_E as equal to the ratio of the inertial forces for the case of the body at rest on the surface

$$\frac{F_{g1}}{F_{g2}} = \frac{G\,m_{g1}\,m_E/R_E^2}{G\,m_{g2}\,m_E/R_E^2} = \frac{m_{g1}}{m_{g2}} = \frac{A_1^2\,\omega_1^2}{A_2^2\,\omega_2^2} = \frac{m_{i1}}{m_{i2}} \tag{18}$$

In summary, we have derived Newton's second law from electrodynamics and defined the inertial mass m_i. Then we showed that the ratio of two inertial masses is exactly the same as the ratio of the previously derived gravitational masses [4]. Thus we have a classical electrodynamic explanation of why the gravitational and inertial masses are identical. This is also a further indication that the electrodynamic force law is the "universal" force law.

Summary of Part 2. A new classical electrodynamic inertial force law was derived from a local contact type universal electrodynamic force law for finite size particles. In this force law mass is not a fundamental quantity of nature, but merely a common grouping of electromagnetic factors. The first acceleration term of the electrodynamic force, of order β^2, gives rise to Newton's second law for non-relativistic velocities.

This derived law of inertia appears to be superior to both Newton's Law of Inertia ($\mathbf{F} = m\mathbf{a}$) and Einstein's field equations of General Relativity Theory, because (1) it is properly based on local contact forces instead of unphysical action-at-a-distance forces, (2) it is based on forces between finite-size particles instead of imaginary point particles, (3) it is based on relative coordinates instead of fictitious absolute space coordinates, (4) it is derived from a universal force law, (5) it explains the centrifugal force as a piece of the inertial force, and (6) it explains the apparent equivalence of gravitational and inertial mass.

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