Inertial Mass of Charged Elementary Particles

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Inertial mass and its property of momentum are derived from electrodynamic effects on the spinning charged ring model of elementary particles. By this result, a foundation is laid for Newton's laws of mechanics—without assuming intrinsic mass or non-causal actions at a distance. Internal structure of elementary particles is deduced, and the measured mass values for elementary particles require the charge distributed near the surface to have a finite thickness approximately equal to 0.174 percent of the particle's thickness dimension.

INERTIAL MASS

An important property of matter is its tendency to maintain momentum, and a body in motion maintains its velocity unless an external force is applied. External forces can accelerate or decelerate matter in accordance with Newton's second law of motion:

$$F = ma \qquad (1)$$

where *m* represents inertial mass.

Gravitational mass and inertial mass are distinct properties of matter that originate by fundamentally different mechanisms and relate to different forces. The force of gravity is an attraction of two bodies for each other. One body with mass exerts an external force upon a second body in proportion to the product of the two masses. This paper is concerned with inertial mass only and does not deal with gravitational mass.

Inertial mass is not an intrinsic property of matter but arises from electrostatic charge and current that exist in the elementary particles. All matter is composed of elementary particles and receives its property of momentum from the charges and currents of its elementary particles.

The external structure of the elementary particles has been specified by the spinning, charged ring model where electrostatic charge of one quantum rotates with rim velocity equal to the speed of light. Earlier papers[1,2] showed that electromagnetic effects account for the fundamental properties of the charged elementary particles, including size, magnetic moment, spin, and mass-equivalent energy. All these properties are related to external electrostatic and magnetostatic fields. The effect of inertia, however, depends upon the interior charge distribution and corresponding fields *inside* the toroid.

Inertial mass is the result of a reaction force between charge (including currents, or moving charge) and the electromagnetic fields induced by the motion of acceleration. This means that the inertial reaction takes place where the charge is located, *i.e,* within the toroid. Thus, inertial mass of an elementary particle is directly related to its internal structure (specifically, the distribution of its charge).

INTERNAL STRUCTURE OF CHARGED PARTICLES

Due to the Coulomb force of repulsion, charge in the ring is pushed outward to the surface of the ring, leaving the interior hollow. The exact distribution of charge is unknown, but to a first approximation, the charge resides in a thin shell of finite thickness t just below the surface of a toroid, as illustrated in figure 1. For purposes of calculations, the charge within the thin shell is considered to be uniformly distributed. At every point where charge resides, the outwardly directed Coulomb force of the charge is balanced by an inwardly directed magnetic pinch force on the moving charge. The balanced configuration occurs when t/r = 0.174 percent. This concentration of charge produces the measured values of inertial mass of the free electron (and also the measured inertial masses of the other charged elementary particles, *i.e.,* the proton, positron and antiproton).

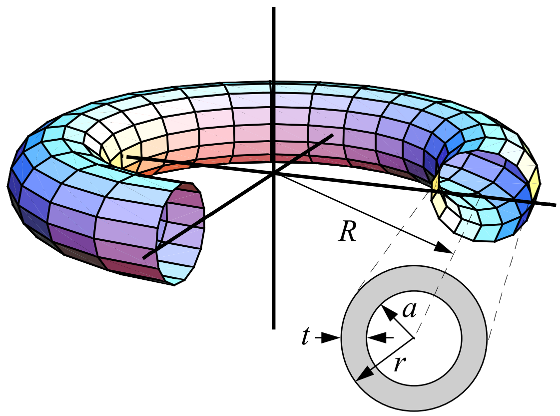

Figure 1.
Thickness of the Surface Charge on a Spinning Ring
Charge is uniformly distributed in a thin shell at the surface of the toroid.

INERTIAL MASS OF CURRENT

Humphreys[3] has shown that a current resists any force attempting to laterally accelerate the moving charge, thus revealing that electric current has inertial mass. His analysis shows that by Maxwell's First Equation, a moving current induces an electric field. Then, from Maxwell's Second Equation, an accelerated electric field produces an induced magnetic field within the region of the flowing current. The induced magnetic field interacts with the moving charge to produce the reaction force of Newton's second law; this force of reaction is, of course, the phenomenon of inertia.

Using this approach, Humphreys found, for the case of uniform current density in a long circular cylinder, that the inertial mass m_{ml} from magnetic effects per unit length is

$$m_{ml} = \frac{3\,\mu_o\,I^2}{16\,\pi\,c^2} \qquad (2)$$

where I is the electric current, c is the speed of light and μ_o is the permeability of free space.

INERTIAL MASS OF CURRENT IN A SPINNING RING

Although Humphreys derived inertial mass from current flowing in a cylinder, his solution can be adapted to a spinning charged ring. For an elementary particle, the ring is very thin $r \ll R$, and the curvature of a toroid is negligible over any short section of the ring. When the calculations involve only the toroid's surface and interior, then the results obtained for an infinitely long cylinder can be applied over a length $2\pi R$ to provide an expression of inertial mass for a thin ring of radius R.

Inertial mass m_m from the magnetic field of the spinning ring is obtained by multiplying the circumference and mass per unit length:

$$m_m = 2\pi R\, m_{ml} = \frac{3\mu_o I^2 R}{8c^2} \qquad (3)$$

For balanced forces at the toroidal surface, charge near the surface of free electrons (and other charged elementary particles) must rotate at a rate $\omega = c/R$.[1] Using $I = \omega e/2\pi$, the magnetic inertial mass of a spinning ring is

$$m_m = \frac{3\mu_o e^2}{32\pi^2 R} \qquad (4)$$

where e is the electron charge.

Equation (4) applies to the case of uniform current density throughout the interior of the ring; but, actually, the current of an elementary particle is flowing near the surface of a ring with no current in the ring's interior (the ring is hollow). The effect of charge concentration in a thin shell beneath the ring surface is a larger inertial mass. In the next section, an appropriate adjustment is determined to account for the hollow interior.

INERTIAL MASS OF CURRENT IN HOLLOW RING

The principle of superposition is used, along with equation (4), to determine the contribution of current to the inertial mass of a hollow, spinning ring. Consider two coplanar and coaxial rings, each with radius R. One ring has a thickness radius r that specifies the outer surface of the toroid; the other ring is slightly thinner, with thickness radius equal to $a = r - t$. Each ring has the same uniform current density j but the currents are in opposite directions. Then, the superposition of these two rings provides the hollow ring illustrated in figure 1. This configuration has a uniform charge and current density in the toroid shell charge layer of thickness t.

Let k represent the ratio of the inner and outer radii of the shell as illustrated by the cross section of the ring illustrated in figure 1.

$$k \equiv a / r \qquad (5)$$

The current density is related to the total ring current I by

$$j = \frac{I}{\pi r^2 \left(1 - k^2\right)} \qquad (6)$$

The components of current in the two rings of thickness radii *a* and *r* are, respectively

$$I_a = \pi a^2 j = \frac{I k^2}{\left(1 - k^2\right)} \qquad (7\,a)$$

$$I_a = \pi r^2 j = \frac{I}{\left(1 - k^2\right)} \qquad (7\,b)$$

Equation (3) is used to obtain the net inertial mass from current by summation of the two current contributions:

$$m_m = m_{ma} + m_{mr} \qquad (8\,a)$$

$$m_m = \frac{3\mu_o R}{8c^2}\left(I_r^2 - I_a^2\right) \qquad (8\,b)$$

Inserting equations (7) into (8b) gives

$$m_m = \frac{3\mu_o I^2 R \left(1 + k^2\right)}{8c^2 \left(1 - k^2\right)} \qquad (9)$$

Comparison of equations (3) and (9) reveals that the inertial mass is greater when the current is concentrated in a shell at the surface of the toroid. This is because potential theory and the law of conservation of energy require more potential energy to accumulate when charge elements of like sign and repulsive force are compressed into smaller volume.

With the condition for a balance of Coulomb and Ampère forces on the moving charge elements of a ring $\omega = c/R$) and the relationship between current and spinning charge ($I = \omega e/2\pi$), equation (9) can be written as

$$m_m = \frac{3\mu_o e^2 \left(1 + k^2\right)}{32\pi^2 \left(1 - k^2\right)} \qquad (10)$$

INERTIAL MASS OF CHARGE

An elementary particle with distributed *electrostatic charge* also possesses inertial mass m_e. Unlike the case for current, the contribution from charge is unrelated to the tangential velocity of the charge. It can be shown that charge and current contribute equal amounts of inertial mass when the current consists of charge moving with velocity equal to the speed of light.

An equation for the inertial mass of accelerated electrostatic charge can be derived, from Maxwell's first and second laws following the same approach used by Humphreys for current.

In the spinning charged ring, where charge rotates with tangential velocity at the speed of light, charge and current contribute equal amounts to the inertial mass of an elementary particle. From equation (10), this inertial mass is

$$m = m_e + m_m \qquad (11a)$$

$$m = \frac{3\mu_o e^2 \left(1+k^2\right)}{16\pi^2 R\left(1-k^2\right)} \qquad (11b)$$

Mass and radius are inversely related in the elementary particles; according to equation (11b), a proton (with mass greater than an electron's mass) will be found to be smaller than an electron. The same relationship was previously demonstrated by equation (6) of reference [2].

THICKNESS OF THE CHARGE LAYER

Equation (11b) can be rewritten to determine *k*, the ratio of shell radii that define the thickness of the charge layer.

$$k = \sqrt{\frac{16\pi^2 Rm - 3\mu_o e^2}{16\pi^2 Rm + 3\mu_o e^2}} \qquad (12)$$

where the product of radius and mass has a constant value (see equation (7) of reference [2]) with *m* given by standard references and *R* is obtained from the measured value of magnetic moment μ, $R = 2\mu/ec$. Substituting this value of *Rm* into equation (12) gives the value of *k* for all the charged elementary particles:

$$k = .998261 \qquad (13)$$

The thickness *t* of the charged layer at the surface of the elementary particles is given by

$$\frac{t}{r} = 100 \times \left(1 - k\right) = 0.174\,\% \qquad (14)$$

Since the thickness ratio *r/R* is identical for all the charged elementary particles,[2] and since the ratio *t/r* is also identical in all the particles, the shapes of the elementary particles are identical in every respect.

SUMMARY

The phenomenon of momentum has been theoretically derived for *lateral* acceleration in the axial direction. Acceleration in other directions is more complicated and not analyzed here.

The ring model specifies the shape and size of charged elementary particles. In addition, the structure of charged elementary particles has been described; an elementary particle consists of its constituent material (electrostatic charge) and its structure (a thin shell at the surface of a toroid). Evidently, the essential features of an elementary particle are its **charge** (one unit of positive or negative sign) and **energy** (small—as in electrons and positrons, or large—as in protons and anti-protons). *This description of matter is useful to distinguish matter from light, which has energy but no charge.*

Charge located in the thin toroidal shell was assumed to be uniformly distributed. Use of this approximation means that the structure described above for an elementary particle is an approximation to the actual structure of an elementary particle.

Another work found in these proceedings[4] shows that Maxwell's First Equation (placing *Faraday's Law of Magnetic Induction* into differential form) is incorrect when a significant induction effect is involved or when high relative velocity between two objects is involved. The approximations made in Maxwell First Equation and its application here to an accelerated charged body produce a corresponding approximation in the result obtained for electrical inertia; the approximation is small for small accelerations. And, the inertial effect is undoubtedly real because the approach taken is fundamentally based on the foundational laws of Coulomb, Ampère, and Faraday.

CONCLUSIONS

The ring model and well established laws of electricity and magnetism predict the physical property of momentum expressed by Newton's second law. Inertial mass is a property of charges and currents. In the elementary particles, charge and current provide equal contributions to the inertial mass of each particle.

No assumption of *inherent* mass is required to account for the property of inertia observed in all material objects. Rather, using fundamental laws of electricity and magnetism, the inertial mass of an object and its property of momentum have been *derived* from first principles. Matter and its property of inertia are found wherever charge is found.

By means of field theory and a few laws of electricity and magnetism, Maxwell was able to unify theories of light, electricity, and magnetism and explain a wide variety of observed natural phenomena—particularly those related to *forces* and *radiant energy*. Other works[1,2] have even demonstrated the electrical character of the fundamental attributes of *matter*. Even inertial mass is shown here to be a derived feature of electrical charges and a “feedback effect” of induced fields that exert a retarding force on any accelerated charge. A fundamental approach based on first principles has produced a significant contribution to the scientific goal of a unified field and force theory.

REFERENCES

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