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Research Article

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A Cause of Inertia

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Abstract

A charged particle, moving at a constant velocity, carries along its electrostatic field $\mathbf{E}_o$*. But, as a result of finite speed of light, a particle of charge Q and mass m moving at time t with velocity v and acceleration dv/dt, has a resultant of its electrostatic field in the opposite direction of accelerarion. So, a reactive electric field* $\mathbf{E}_a$ *proportional to and in the opposite direction of the acceleration is created. The field* $\mathbf{E}_a$ *acts only on the same charge Q, producing it, to generate an inertial force* $\boldsymbol{f} = Q\boldsymbol{E}_a = -m\,(dv/dt)$*, where m is a constant equal to the rest mass. For a neutral body of mass M, composed of N/2 positive and N/2 negative charges, the inertial forces on the charges add up to* $N\boldsymbol{f} = NQ\boldsymbol{E}_a = -Nm\,(d\mathbf{v}/dt) = -M\,(d\mathbf{v}/dt)$*. This explains the cause of inertia, the tendency of a body to resist acceleration or deceleration, as the result of self-induced reactive forces on the electric charges composing the body, contrary to general relativity. Expressions are deduced for the mass m and energy E of an electric charge Q, in the form of a spherical shell of radius a, in conformity with a mass-energy equivalence law as* $E = \frac{1}{2}mc^2$*, where c is the speed of light in a vacuum, in contrast to special relativity giving* $E = mc^2$*. The total energy of a particle of mass m moving at speed v, relative to an observer, is* $E_v = \frac{1}{2}m\,(c^2 + v^2)$*.*

Keywords: Acceleration, Electric Charge, Electric Field, Force, Inertia, Magnetic Field, Mass, Relativity, Velocity

Introduction

Newton's first law of motion [1], often called the law of inertia, identifies inertia as the force required to accelerate or decelerate the motion of a body. The second law defines force **F** in terms of acceleration $d\mathbf{v}/dt$ imparted toa body or particle of mass m, moving at time t with velocity vand acceleration dv/dt as vector:

$$\mathbf{F} = m\frac{d\mathbf{v}}{dt} \qquad (1)$$

Newton's third law of motion gives the inertial force as a reactionequal to and in the opposite direction of the the impressed force **F**. Mathematically, the second law of motion contains the first and third laws. The significance of Newton's laws of motion may be stated to the effect that '*at any point and time, the vector sum of forces acting on a body is zero*'- the 'zero-sum law of fields and forces'.

Newton's second law of motion, as expressed in equation (1), is one of the most important principles in physics, with m as a constant, equal to the rest mass, contrary to the theory of special relativity [2, 3]. In this case, inertia or inertial force, the tendency of a body to resist being accelerated or decelerated, becomes the reactive force or reverse effective force, equal and opposed to the accelerating force on the body. This paper is another thrust, following other attempts [4, 5], to describe the cause of inertia of a body.

A particle of charge Q, moving at a constant speed, carries along its own electrostatic field $\mathbf{E}_o$ and is associated with a magnetic field of intensity **H** perpendicular and proportional to the velocity **v**, relative to an observer, as given by vector cross product [6, 7]:

$$\mathbf{H} = \varepsilon_o \mathbf{v} \times \mathbf{E}_o \qquad (2)$$

where ε_o is the electric permittivity.

If a charged particle is accelerated, it takes some time, because of the finite speed of light, to impart the effect to the surrounding fields. So, a component of the electrostatic field appears in the opposite direction of acceleration. As such, a reactive electric field of intensity $\mathbf{E}_a$ proportional to and in the opposite direction of acceleration is generated. In so far as an electric charge is always affected by an electric field, particularly its own electric field, it is proposed that $\mathbf{E}_a$ acts on the charge Q, producing it, to generate the reactive forceor inertial force $\mathbf{f} = Q\mathbf{E}_a$, such that:

$$\mathbf{f} = Q\mathbf{E}_a = -m\frac{d\mathbf{v}}{dt} \qquad (3)$$

For a body of mass M composedof $N/2$ positive charges and $N/2$ negative charges under acceleration dv/dt, the inertial forces on the respective charges add up to give the total **I**, as:

$$\mathbf{I} = N\mathbf{f} = NQ\mathbf{E}_a = -Nm\frac{d\mathbf{v}}{dt} = -M\frac{d\mathbf{v}}{dt} \qquad (4)$$

Each of the reactive electric fields ($\mathbf{E}_a$) acts only on the charge producing it and they are not externally manifested, as being equally positive and negative in a neutral body, they cancel out exactly. Equation (4) explains inertia **I** of a body, the tendency of a body to resist acceleration, as a self-induced reactive force on the electrical charges making the body [4, 5].

Magnetic field due a moving electric charge

A moving charged particle, with its electrostatic field, is associated with a magnetic field of intensity **H**, as shown in Figure 1. The magnetic field **H** and magnetic flux intensity **B** are given by Biot and Savart law [6, 7] of electromagnetism as vector (cross) product:

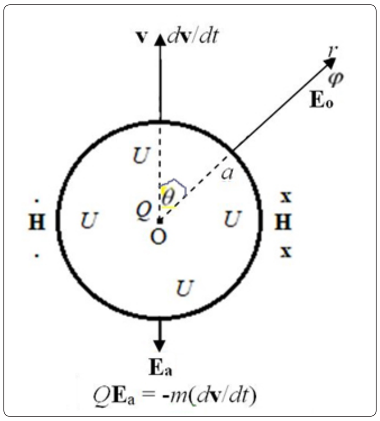

Figure 1: An electric charge Q, in the form of a spherical shell with centre O and radius a, and its radial electrostatic field $\mathbf{E}_o$ moving in a straight line at time t with velocity **v** and acceleration ($d\mathbf{v}/dt$), setting up a potential φ at angle θ and distance r from O and generating a magnetic field **H** (out on the left and in on the right) and a reactive electric field $\mathbf{E}_a$. The potential U is constant inside the charge.

$$\mathbf{B} = \mu_o \mathbf{H} = \mu_o \varepsilon_o \mathbf{v} \times \mathbf{E}_o \quad (5)$$

where μo is the magnetic permeability and $\mathbf{E}_o$ is the radial electrostatic field of the moving charge. Equation (5), with **v** as a vector in a straight line, can be expressed as vector:

$$\mathbf{B} = \mu_o \varepsilon_o \mathbf{v} \times \mathbf{E}_o = -\mu_o \varepsilon_o \mathbf{v} \times \nabla\varphi = \mu_o \varepsilon_o \nabla \times \varphi \mathbf{v} \quad (6)$$

where $\mathbf{E}_o = -\nabla\varphi$ and φ is the scalar potential at a point due to the charge, as given by Coulomb's law, ∇ denotes the 'gradient' of a scalarand ∇x denotes the 'curl' of a vector.

Reactive electric field due to acceleration

If an electric charge undergoes acceleration, a reactive electric field of intensity $\mathbf{E}_a$ is generated, as given by Faraday's law of electromagnetic induction [6, 7]:

$$\nabla \times \mathbf{E}_a = -\frac{d\mathbf{B}}{dt} \quad (7)$$

Since the potential φ is not a function of time t, equations (6) and (7) give:

$$\nabla \times \mathbf{E}_a = -\frac{d\mathbf{B}}{dt} = -\mu_o \varepsilon_o \nabla \times \varphi \frac{d\mathbf{v}}{dt}$$

$$\mathbf{E}_a = -\mu_o \varepsilon_o \varphi \frac{d\mathbf{v}}{dt} = -\frac{\varphi}{c^2} \frac{d\mathbf{v}}{dt} \quad (8)$$

where $c = \sqrt{\frac{1}{\mu_o \varepsilon_o}}$ is equal to the speed of light in a vacuum, a constant as determined by James Clerk Maxwell [8].

Inertial force on a moving charged particle

The fundamental assumption made is that the reactive electric field $\mathbf{E}_a$, in equation (8), acts on the same charge Q_i producing it to generate the inertial force $\mathbf{f}_i$, equal and opposite to the accelerating force. Thus equation (8) and Newton's second and third laws of motion give $\mathbf{f}_i$, on a particle of charge Q_i and mass m_i moving with acceleration dv/dt, as:

$$\mathbf{f}_i = Q_i \mathbf{E}_a = -\mu_o \varepsilon_o \varphi_i Q_i \frac{d\mathbf{v}}{dt} = -\mu_o \varepsilon_o U_i Q_i \frac{d\mathbf{v}}{dt} = -m_i \frac{d\mathbf{v}}{dt} \quad (9)$$

where mass m_i of a particle is considered a constant independent of its velocity **v**, φ_i is the potential at a point due to the charge and U_i is the electrostatic potential inside and at the surface of the spherical charge Q_i. At any point, other thanat the surface ofthe spherical shell, the product $\varphi_i Q_i$ is zero.

Inertial force on a moving body composed of electric charges

A neutral body is composed of equal amounts or equal numbers of positive and negative electric charges. A reactive field is felt only by the charge generating it; there is no action on the other (external) charges. So, for a body composed of $N/2$ positive and $N/2$ negative charges, the total inertial force or the unertia **I**, as in equation (4), becomes the summation:

$$\mathbf{I} = \sum_{i=1}^{N} \mathbf{f}_i = -\sum_{i=1}^{N} \frac{U_i Q_i}{c^2} \frac{d\mathbf{v}}{dt} = -\sum_{i=1}^{N} m_i \frac{d\mathbf{v}}{dt} = -M \frac{d\mathbf{v}}{dt} \quad (10)$$

where M is the mass of the body.

Mass-energy equivalence law

Equation (9) gives:

$$m_i = \mu_o \varepsilon_o U_i Q_i = 2\mu_o \varepsilon_o w_i \quad (11)$$

$$w_i = \frac{m_i}{2\mu_o \varepsilon_o} = \frac{1}{2} m_i c^2 \quad (12)$$

where w_i is the work done in creating the charge Q_i or the intrinsic energy of an electric charge Q_i in its own potential U_i. For a body of mass M composed of a number ofpositive and negative electric charges, equation (12) becomes:

$$E = \frac{1}{2} Mc^2 \quad (13)$$

Equations (13) is the mass-energy equivalence law, in contrast to the relativistic law $E = Mc^2$.

The total energy of a body of mass M moving with speed v, relative to an observer, is:

$$E_v = \frac{1}{2} M \left(c^2 + v^2\right) \quad (14)$$

The total energy of a body of mass M moving at the speed of light becomes Mc^2.

Mass and energy of an electric charge

For an electric charge Q_i as a spherical shell of radius a, the intrinsic potential U_i, is:

$$U_i = \frac{Q_i}{4\pi\varepsilon_o a} \tag{15}$$

Equation (11) becomes:

$$m_i = \mu_o \varepsilon_o U_i Q_i = \frac{\mu_o Q_i^2}{4\pi a} \tag{16}$$

The intrinsic energy w_i of an electric charge Qi in its own potential U_i (equation 12), is:

$$w_i = \frac{1}{2}U_i Q_i = \frac{Q^2}{8\pi\varepsilon_o a} = \frac{1}{2}m_i c^2 \tag{17}$$

This is the well-known classical formula for the electrostatic energy or intrinsic energy of a charge Qi in its own electrostatic potential Ui.

Result and discussions

Newton's second law of motion, Coulomb's law of electrostatic force and basic electrostatic, electromagnetic and electro-dynamic principles are employed to explain the origin of inertia (equations 9 and 10) and to derive a mass-energy equivalence law (equation13), without recourse to the theories of relativity or any other principle. The assumption made is that the reactive field $\mathbf{E}_a$, generated by an accelerated charge, acts on the same charge Q to create the inertial force $\mathbf{E}_a Q$ equal and opposite to the accelerating force.

The assumption here is backed by Newton's second and third laws of motion and Faraday's law of electromagnetic induction. Indeed, inertia is a manifestation of Newton's second and third laws of motion. If the impressed force is the action, the reaction is the inertial force equal and opposite of the accelerating force.

For a neutral body composed of equal numbers of positive and negative electric charges, the individual reactive fields act only on their respective charges, at their locations, adding up to produce the inertial force. The reactive fields of the charges have no external effects.

If an electric charge of magnitude Q is to assume any configuration, it is most likely to be a spherical shell of radius a, with mass $m=\mu_o Q^2/4\pi a$ and self energy $w = Q^2/8\pi\varepsilon_o a = ½\, mc^2$. Such particles should exist as indivisible negative charges (electrons) and positive charges (positrons), joining to form a doublet or unitron with centre separation of 2a to give potential energy $p = -Q^2/8\pi\varepsilon_o a$, mass $m = \mu o Q^2/4\pi a$ and intrinsic energy $w = Q^2/8\pi\varepsilon_o a = ½\, mc^2$.

Conclusion

A description of the cause of inertia has been given as the sum equal to $-M(d\mathbf{v}/dt)$ of self-induced electrical forces on the individual charges constituting a body of mass M that is moving with acceleration dv/dt. Inertia should be independent of velocity of a body.

This paper is based on the use of intrinsic energy U and mass m of a particle of charge Q, in the form of a spherical shell of radius a, to obtain the mass of a charged particle (equation 16). As a consequence, since electric charge is regarded a constant, mass of a charged particle should also be taken as a constant independent of speed, contrary to special relativity.

Another consequence of the explanation given here is making inertia electrical in nature and a property residing in a body. The derivation of a mass-energy equivalence law ($E = ½\, mc^2$) is quite straightforward but differs from the relativistic formula ($E = mc^2$) by a factor of one half. Whatever the case may be, E being the electrostatic energy of the electric charges constituting a body, makes things easier and brings a new insight into electrodynamics.

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