Inertial Mass and Gravitational Mass - What They Are and the Fundamental Reason Why They Are Equal

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Abstract

Why do objects possess inertia at all ? *What* is gravity ? Why are inertial and gravitational masses equal ? These are some of the great puzzles and mysteries in physics that have not been really solved to date. This paper reveals these mysteries. Inertia and electrical self- inductance are not only analogous, but they are the same phenomena: electromagnetism ! Inertia is 'self-inductance' or electromagnetic radiation reaction. The radiation reaction of an accelerating electron is the *same* as its inertial mass. Electrostatic force and gravitational force are not only analogous, but they are basically the same phenomena: electrostatics. Both inertial mass and gravitational mass depend on the same quantity: the total number of electrons, protons and neutrons in an object, i.e. the *total* (NOT *net*) charge in the object. This is the fundamental reason why inertial mass and gravitational mass are equal. Universal speed limit is due to non-linear law of self- inductance or radiation reaction.

Introduction

Inertial mass is a measure of the resistance of a body to acceleration, and is defined in Newton's second law of motion. It is the constant of proportionality in Newton's second law.

$$F = m\,a$$

The larger the inertial mass of an object, the less it responds to an applied force, i.e. the less its acceleration will be for the same magnitude of force.

But *why* do objects possess inertia at all ? This is a centuries old question with no answer to date.

Gravitational mass is defined in Newton's law of gravitation.

$$F = G\,\frac{M\,m}{r^2}$$

The more the gravitational mass (m) of an object, the more the gravitational force of another body (with mass M) acting on it.

But *what* is gravity ? Newton's law of gravitation provides only a model for the behavior of gravity and does not explain *what* gravity is ?

The inertial mass and gravitational mass have been confirmed experimentally to be equal to a high level of precision. If two objects have the same gravitational mass, for example as measured by suspending each on a spring and observing the amount by which each extends the spring, then

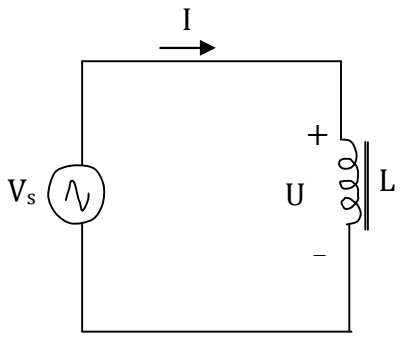
they will also undergo the same acceleration if subjected to equal forces in free space, for example.

There is no known fundamental reason so far as to *why* these two masses should be equal. This paper solves these long standing puzzles and mysteries.

Inertial mass

Why do objects possess inertia ?

Let us consider the familiar electrical self-inductance. Consider the following inductive circuit, with an inductor of iron core.

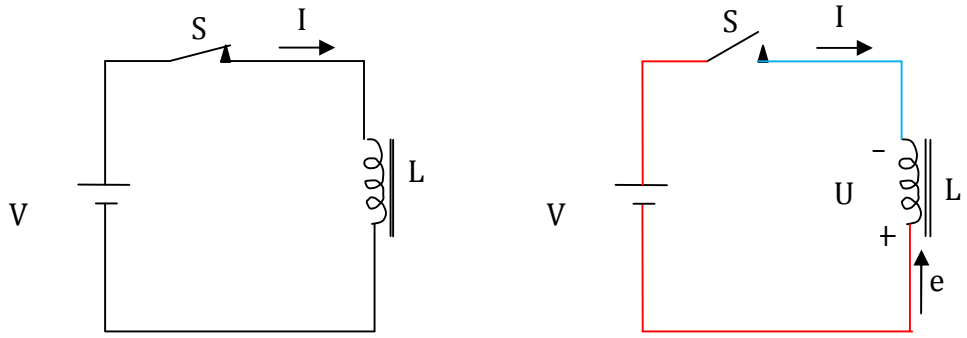


$$U = L \frac{dI}{dt}$$

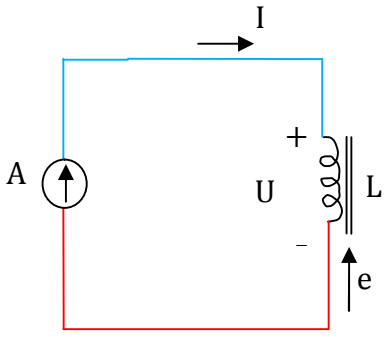
From electrical circuit theory, we know the property of the inductor that it resists any change in the current I passing through it. If the voltage V_s is DC and if the circuit is in steady state condition, there will be no induced voltage across the inductor and the electrons move inside the coil conductor at some constant average velocity. The current is limited by the internal resistance of the source and by the coil resistance. If the voltage changes (increased), the increased electric field tends to accelerate the electrons. However, the property of the self inductance (L) resists instantaneous change in current (instantaneous change in the velocity of the electrons) because the magnetic field of the inductor cannot change instantaneously. Therefore, the change in current lags in time behind the change in voltage.

Suppose that the following circuit is initially in steady state condition, with steady state current I flowing in the circuit, while switch S is closed (see next figure). Suppose that the switch S is then suddenly opened. We know that a high voltage is induced across the inductor with sign as shown so that the current will continue flowing to avoid instantaneous change in the current and the magnetic field, and making sparks.

A change in current in the inductor will induce voltage across the inductor, so it is the induced voltage that makes the current to continue flowing and making sparks across the open switch. We interpret this as follows. As the switch is opened, the electrons already moving in the inductor continue to move in the same direction due to their large inertia, accumulating in the blue part of the circuit and depleting from the red part of the circuit, hence voltage building up across the switch and making sparks. The inertial mass of an electron moving inside the inductor coil is large depending on the permeability of the inductor core. This means that the electron has less inertial mass if the core is air than if the core is iron. Note that the electron flow is opposite to the conventional current flow.



Let us consider the inductor circuit again by using a current source, as shown in the next figure, to further clarify the idea. Suppose that the current I is initially zero and then continuously increased at some rate. This means that the current source is *forcing* current through the circuit, with the electron flow as shown.



Since

$$U = L\frac{dI}{dt}$$

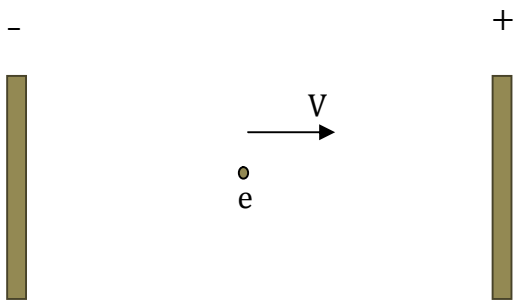
a voltage will be induced across the inductor proportional to the rate of change of current. If the rate of change of current is high, the induced voltage will also be high. The new explanation being proposed is that as the current source is forcing electrons through the inductor, with the current increasing linearly for example, the electrons are being accelerated. The force needed to accelerate the electrons in the inductor coil is:

$$F = m\frac{dV}{dt}$$

Since the mass of the electrons is large in the inductor coil, the force needed to accelerate them is also large compared to the force needed to accelerate the electrons in other part of the circuit. Hence the voltage drop across the inductor is also large.

$$V = L\frac{dI}{dt}$$

Next consider an electron moving between two parallel plates connected to a high voltage source.



Suppose that the electron is initially moving with some constant velocity V. This can be done by initially switching on the voltage across the plates briefly and switching it off, discharging the plates so that the electric field will be zero. With zero electric field, the electron will continue moving with a constant velocity.

Now suppose that the voltage across the plates is suddenly increased, increasing the magnitude of the electric field between the plates. The electron will accelerate with a finite value of acceleration. The electron will not accelerate infinitely, i.e. it can't change its velocity instantaneously. From conventional physics, this is due to the inertial mass of the electron. According to the new theory, this mass is explained as follows. The electron resists infinite

acceleration due to its 'self-inductance'. The magnetic field of the moving electron cannot change instantaneously, for the same reason that the magnetic field of the inductor cannot change instantaneously. The inertial mass of the electron is due to its 'self-inductance'.

We make a proposal that *self-inductance is electromagnetic radiation reaction*. As the current in an inductor coil (or an antenna) changes, there will be change in the magnetic field surrounding the coil and hence there will be electromagnetic radiation. The self-inductance of the inductor (i.e. the reaction to change in current) is radiation reaction. *Therefore, the inertial mass of an electron is also due to its electromagnetic radiation reaction* [1].

An expected question is: what about electrically neutral objects ? The same law applies to neutral objects. A neutral object is one that contains equal amounts of negative charges and positive charges. Each electron and proton in the neutral object behaves as the isolated electron discussed above[1]. The only difference is that, whereas the electric and magnetic fields of the isolated electron can be detected, the electric and magnetic field of an electron in the accelerating neutral object are 'cancelled' by the electric and magnetic field of a proton, respectively, and cannot be detected. That the electric and magnetic fields cannot be detected doesn't mean that they don't exist. This is a strange, unique nature of electromagnetic fields and waves.

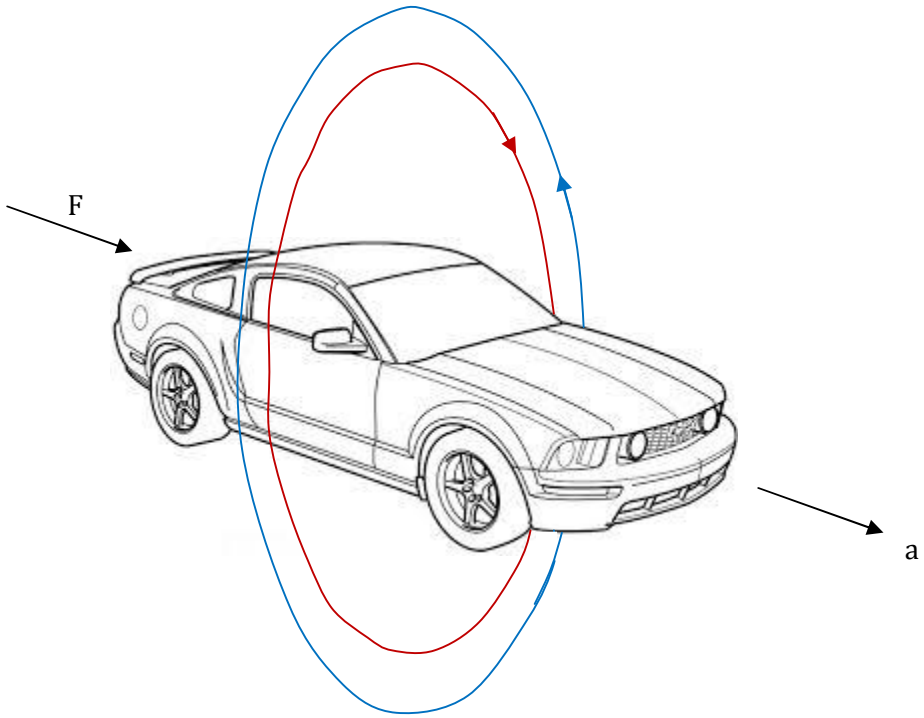
When a car accelerates, it will make electromagnetic radiation and its inertial mass is due to 'self -inductance', or radiation reaction. However, unlike acceleration of an isolated electron or proton, the electromagnetic radiation from a car cannot be detected and hence it is *inaccessible* because the radiation from the positive charges of the car will be 'cancelled' by the radiation from the negative charges of the car. This (‘cancelled’) *doesn't mean* that an isolated electron will radiate if accelerated whereas an electron in a neutral object will not radiate[1]. The electron in a neutral object behaves exactly as the isolated electron: for the same amount of acceleration both will radiate identically. The presence of oppositely charged protons in the neutral object doesn't prevent the electrons in the neutral object from radiating during acceleration; it *only* makes the radiation of the electrons *inaccessible*, undetectable.

A neutron also has inertia because of the 'self-inductance' or radiation reaction of its charges. A neutron makes electromagnetic radiation from its positive charges and its negative charges, but the radiations from the negative and positive charges 'cancel' each other and are inaccessible. A neutron has a zero *net* charge but NOT a zero *total* charge. That a neutron has inertia shows that it contains positive and negative charges, because inertia is radiation reaction of accelerated charges.

It follows that the *total* charge of a proton is not equal to its known *net* charge if the proton is not an elementary particle and the total charge of an electron is equal to its known net charge if the electron is an elementary particle.

Therefore, the inertia of a car is due to electrical 'self-inductance', or radiation-reaction, of the electrons, protons and neutrons it contains. The velocity of the car cannot change instantaneously

(zero inertial mass) because the magnetic fields created by its electrons, protons and neutrons cannot change instantaneously, for the *same* reason that the magnetic field of an inductor in an electrical circuit cannot change instantaneously.



The electrons, protons and neutrons in the car create magnetic fields around themselves and around the car. As force F is applied to the car, the car will resist change in velocity because of the self inductance of the protons, electrons and neutrons in the materials from which the car is made. The car will change its speed with some finite acceleration and will not change its speed instantaneously. This is because the magnetic field of the car particles (electrons, protons, neutrons) cannot change instantaneously for the *same* reason that the magnetic field of an inductor cannot change instantaneously.

From this theory it follows that the greater the *total* (NOT *net*) positive and negative charge an object has, the larger will be its inertia. Conversely, objects with large inertia have large *total* charge .

The law of motion of an object or a particle is given by:

$$F = K \frac{dV}{dt}$$

where K is the proportionality constant. The constant K is directly proportional to the *total* (not *net*) amount of charge (positive and negative). The constant K is what is conventionally known as mass, m . Therefore, the inertial mass of an object is a measure of the *total* amount of charge it contains. Conventionally, mass is known ambiguously as 'amount of matter' inside an object.

For example, a neutron is said to be made of one up quark and two down quarks. Up quarks have a charge of +2/3e, and down quarks have a charge of -1/3e. The *net* charge of the neutron is zero. But the *total* charge of the neutron will be :

$$\frac{2}{3}e + \frac{1}{3}e + \frac{1}{3}e = \frac{4}{3}e$$

Inertia and moment of inertia

Just as a car's inertia is due to radiation reaction, the moment of inertia of a body about an axis is also due to radiation reaction.

Universal speed limit

I propose in this paper that the mass of particles increases with velocity because of a non-linear law of self-induction or radiation reaction[1]. We know that the universal light speed limit has been confirmed by many experiments.

The accurate formula for self-induction of a particle, therefore, will be:

$$F = \frac{1}{\sqrt{1 - \frac{V^2}{c^2}}} K \frac{dV}{dt}$$

The inductance of an inductor will also increase as the current increases, for the same reason that the mass (self- induction) of an electron or a neutron increases with increasing velocity. Just as there is light speed limit to the velocity of particles, there will also be a maximum limiting current I_C for the inductor circuit. Of course, the limiting current is because of the light speed

limit to the velocity of the electrons in the inductor coil conductor. Therefore, for the inductor circuit, the accurate formula will be:

$$u = \frac{1}{\sqrt{1 - \frac{I^2}{I_C{}^2}}} \; L \; \frac{dI}{dt}$$

Gravitational mass

What is gravity ? I have already proposed in [1] that gravity is a result of slight difference between electrostatic attraction and repulsion forces. The electrostatic attraction force is slightly greater than the electrostatic repulsion force.

There is an attractive gravitational force between two neutral objects A and B because the sum of electrostatic attractive forces (assume the objects contain only protons and electrons and no neutrons, for simplicity)

between protons in A and electrons in B and

between electrons in A and protons in B

is slightly greater than the sum of electrostatic repulsive forces

between protons in A and protons in B and

between electrons in A and electrons in B

Since neutrons also contain (equal amounts of) positive and negative charges, they will also contribute to the gravitational force between the two neutral objects.

I have proposed in [2] the laws for electrostatic attraction and repulsion forces as follows:

$$F_{att} = \frac{1}{4\pi\varepsilon_0} \; \frac{Q_1 \, Q_2}{r^2} \; K_{att1} \qquad (K_{att1} \cong 1)$$

$$F_{rep} = \frac{1}{4\pi\varepsilon_0} \; \frac{Q_1 \, Q_2}{r^2} \; K_{rep1} \qquad (K_{rep1} \cong 1)$$

K_{att1} and K_{rep1} are numbers very close to 1. It is the extremely small difference between K_{att1} and K_{rep1} that will give rise to gravitational force. Since gravitational force is attractive, K_{att1} should be greater than K_{rep1} .

Equality of inertial mass and gravitational mass

From the above theories, *both* inertial mass and gravitational mass depend on the *total* amount of *charge* in an object. Therefore, two neural objects with equal gravitational masses will have equal *total* amounts of charges, from which follows equal inertial masses.

Discussion

According to the above theory that gravitational force is a difference between electrostatic attractive and repulsive forces, there can be no gravitational force between two electrons, if electrons are elementary particles, because only repulsive force exists between the two. However, there will be gravitational force between an electron and proton, between an electron and a neutron.

A neutral elementary particle will have zero inertial mass (and zero gravitational mass) because inertial mass is electromagnetic radiation reaction. Since we think that all material objects and particles will have mass, we conclude that such particles do not exist and that all elementary particles have charge.

The author recommends the papers[3][4][5][6][7][8][9][10][11] on related theoretical research .

Conclusion

This paper has solved some of the great puzzles and mysteries in physics. Inertia of an object has been shown to be due to electrical self-inductance or radiation reaction of the charges in the object. The radiation reaction of an accelerating electron is the mass of the electron itself. Gravitational force is the difference between electrostatic attraction forces and electrostatic repulsion forces. Inertial mass and gravitational mass are equal because both depend on the *total* (NOT *net*) amount of (positive and negative) charge in an object. Conventionally mass is vaguely defined as ‘amount of matter’ in an object. In this paper mass has been clearly defined as the *total* amount of charge in an object.

Thanks to God and His Mother Our Lady Saint Virgin Mary

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