Inertia Explained

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Abstract

Using Newton's 2nd law $F = ma$, a very short derivation of the inertial mass m of an elementary particle like an electron is proposed, starting with the particle's rest energy E_o. A particle is proposed to be composed of a single circling photon-like object whose energy E_o is the rest energy of the particle. The derivation shows that a particle does not get its inertial mass directly from its rest energy E_o, as given by Einstein's well-known equation $E_o = mc^2$ for a resting electron or other resting object. Rather, a particle gets its inertial mass m from the time rate of change of the circling momentum vector $p = E_o / c$ of the proposed circling photon-like object composing the particle.

Key words: inertia, mass, inertial mass, energy, momentum, particle, $E_o = mc^2$, photon, electron, model

Introduction

The word "inertia" (Latin for "inactivity" or "idleness") was first used in a physical sense by Johannes Kepler to explain why a planet requires an external force to oppose its "inertial" tendency to slow down as the planet moves in its elliptical orbit around the Sun. The term was used in a different sense by Galileo Galilei to explain why objects move at a constant velocity horizontally unless acted on by friction or some other external force. The term was later used by Isaac Newton to explain why a body moves with a constant velocity in a straight line unless acted upon by an external force. This statement is Newton's well-known first law of motion, the "law of inertia". Newton's 2nd law of motion states that the total external force F applied to a body equals the mass m of the body times its acceleration a. We write Newton's 2nd law as $F = ma$ or more precisely with the vector equation $\Sigma\vec{F} = m\vec{a}$. The quantity m in Newton's 2nd law is known as the inertial mass of the object, or simply its mass. This mass m is not the same as the weight W of the object. Newton showed by his 2nd law that an object's weight W is given by $W = mg$, where the object's weight W is the force of gravity on the object, m is its mass and g is the acceleration of a falling object due to gravity.

Derivation of a particle's inertial mass *m* from its rest energy E_o

The inertial mass m of an elementary particle with rest energy E_o is derived below using $F = ma$. The particle is assumed to be composed of a circling light-speed object whose energy equals the particle's rest energy E_o. A similar inertial mass derivation is given in Gauthier[1] for the circulating spin-½ charged-photon model of the electron presented in Gauthier[2].

Several researchers such as Hestenes[3], Gauthier[4], Williamson and van der Mark[5], and Rivas[6], have modeled an electron as a circulating light-speed object moving in a circle or a helix. The energy of this circularly moving light-speed object is the particle's rest energy E_o. For an electron, E_o is 0.511 MeV (million electron volts). If the circling light-speed object were a photon, it would have a circling momentum equal to 0.511 MeV/c where MeV/*c* is a unit of momentum and *c* is the speed of light, $3.00 \times 10^8 m/s$.

Any object moving in a circle with a constant speed and a constant radius has a circling frequency *f* measured in cycles per second or hertz (Hz). A circling photon of energy E_o has a momentum $p = E_o / c$ whose momentum vector rotates at this same circling frequency *f*. The time rate of change of the circling photon's momentum vector is calculated from the value of the photon's momentum $p = E_o / c$ and the circling frequency *f* of the momentum vector. This time rate of change of the momentum vector *p* is called dp/dt. The value of dp/dt is $dp/dt = 2\pi fp = 2\pi fE_o / c$. The *dp/dt* vector always points towards the center of the photon's circle.

According to Newton's 2nd law, $F = dp/dt = ma$ where $F = dp/dt$ is the external total force vector on the object (equal to dp/dt, the rate of change of the momentum vector of the object), *m* is the inertial mass of the object, and *a* is the acceleration vector of the object. The 2nd law can be rewritten as $m = (dp/dt)/a$. Any object moving in a circle with a constant speed has an acceleration vector $a_{centripetal}$ pointing towards the center of the circle. This centripetal acceleration vector $a_{centripetal}$ is the time rate of change of the rotating velocity vector of the circling object. The well-known centripetal acceleration formula is $a_{centripetal} = (2\pi f)^2 R$ where *R* is the radius of the circular motion of the object.

When we calculate $m = (dp/dt)/a_{centripetal}$ using the above relationships $dp/dt = 2\pi fE_o / c$ and $a_{centripetal} = (2\pi f)^2 R$, we get $m = (2\pi fE_o / c)/(2\pi f)^2 R$, which gives $m = (E_o / c)/(2\pi Rf)$. But $2\pi Rf$ is equal to the circle's circumference $2\pi R$ times the frequency *f*, the number of circumferences of the circle that the photon moves around per second. Therefore $2\pi Rf$ is the total distance that the photon travels around the circle per second. This total distance per second traveled by a photon is the light-speed *c* of the circling photon, so $2\pi Rf = c$. If we substitute this result into the equation $m = (E_o / c)/2\pi Rf$ we get $m = (E_o / c)/c = E_o / c^2$ for the inertial mass of the particle.

Discussion

The formula $E_o = mc^2$, relating the rest energy E_o of a particle to its rest mass, invariant mass, inertial mass or just plain mass *m* of a resting elementary particle is already well-known in physics, and is well-grounded in experimental evidence. What is being proposed here is that an elementary particle does not derive its inertial mass directly from its rest energy E_o. Rather, an elementary particle derives its inertial mass from the circling momentum E_o / c of a photon-like object proposed to compose this elementary particle.

One can object that, although the derivation of a particle's inertial mass *m* from the circulating momentum of a photon or photon-like object using Newton's 2nd law may be correct, there is no experimental evidence that a photon or photon-like object can actually move in a circle or helix to form an elementary particle such as an electron. A normal spin-1 uncharged photon is not known to be able to move in a circle small enough to form an elementary particle. The same may not be true for a hypothesized new variety of photon that *can* move in a circle to form an electron. An electron has spin-½ and carries a negative electrical charge. Gauthier[2] proposed an electron model that is composed of a spin-½ negatively charged photon that moves along a circular trajectory (for a stationary electron) or along a helical trajectory (for a moving electron). In this model the electron, composed of a spin-½ charged photon, moves forward slower than the speed of light because the proposed spin-½ charged photon composing the electron is moving along its helical trajectory at the speed of light, and therefore moves in the forward direction at less than the speed of light. So far, no one to my knowledge has shown that this proposed spin-½ charged photon cannot exist or cannot move in a circular or helical trajectory to form an electron. In fact the electric charge of the proposed spin-½ charged photon may be what causes the charged photon to move in a circle or helix. It remains for experiment to test this spin-½ charged photon hypothesis. If a spin-½ charged photon does exist, it may not have been recognized yet partly because it has already been named an electron or some other known particle with mass.

It can also be objected that even if such a spin-½ charged photon does exist and composes an electron, it is not really a photon because it does not have spin 1 and has electric charge, unlike a normal photon. However, the proposed spin-½ charged photon has other properties of a photon. It obeys the well-known wave formula $\lambda f = c$ (where λ is the charged photon's wavelength and f is its frequency). It also obeys the well-known formulas for a photon's energy $E = hf$ (where *h* is Planck's constant) and momentum $p = hf / c$. I prefer to call this proposed spin-½ charged light-speed object a new variety of photon rather than giving it a completely different particle name.

Another possible objection to a circling-photon model of a fundamental particle is that a single photon would seem to violate the law of conservation of momentum by traveling in a circular trajectory instead of a straight trajectory. However, the circling-photon particle model assumes that the circling photon is acted on by a central force $F = dp / dt$, which changes the momentum vector *p* of the photon so that the photon moves in a circle instead of a straight line. According to Newton's 2nd law, this central force vector *F* equals the rate of change with time of the momentum vector E_o / c of the circling photon. It is this central force vector *F*, when divided by the circling photon's centripetal acceleration vector $a_{centripetal} = (2\pi f)^2 R$ as described above, that yields the inertial mass *m* of the circling photon and equivalently, the inertial mass *m* of the particle composed of the circling photon.

While the circling photon does not have a constant-direction momentum vector and therefore does not appear to conserve momentum, it is because the central force vector *F* keeps changing the direction of the photon's momentum vector and therefore the direction of the charged photon itself. The nature of this central force proposed to act on the circling photon composing a particle is currently unknown. Still, its value can be

calculated for any particular circling-photon model of a particle. For example, in the spin-½ charged-photon model of the electron, the value of the central force *F* acting on the double-looping circling charged photon is calculated in Gauthier[7] to be 0.424 Newtons, or 0.095 pounds. This is a remarkably strong force proposed to be related to a single electron.

The spin or angular momentum of an elementary particle is currently unexplained. Spin is considered to be an "intrinsic" property of an elementary particle like an electron. However, the spin of a particle like an electron can be explained by the internal circulation of a single charged photon composing the electron, but not without the charged photon appearing to violate the law of conservation of momentum. In the spin-½ charged-photon model of an electron, the electron model's spin *S* is calculated by multiplying the circling charged photon's momentum $p = E_o / c$ by the double-looping circle's radius $R = hc / 4\pi E_o$, giving $S = h / 4\pi$. This is the exact experimental value of the spin of an electron. If the charged photon did not appear to violate the conservation of linear momentum, it could not move in a double-looping circular trajectory to give the electron particle model the experimentally correct electron spin.

More generally, other non-light-speed fundamental particles with inertial mass such as quarks, neutrinos, W particles, Z particles, the Higgs boson and even some proposed dark matter particles may each be composed of an internally-circulating light-speed photon-like object. These other particles could also derive their inertial masses from their circulating internal momentum. In this view, the inertial mass of a particle is not the property of some material 'stuff' called "matter". Rather inertial mass is derived from the rate of change of the circling momentum vector of a photon-like object composing the particle. When this rate of change of circling momentum is combined with Newton's 2nd law of motion $F = ma$ and the circulating particle's centripetal acceleration, the result is the property of matter called inertial mass $m = E_o / c^2$ where E_o is the energy of the circling photon-like object having momentum E_o / c and composing the particle.

Usually Einstein's famous formula is written $E = mc^2$. This better-known formula is physically less precise than $E_o = mc^2$, because the total energy *E* of a moving particle increases with the particle's speed, while the moving particle's "invariant mass" or "rest mass" *m* is independent of the particle's speed and is always proportional to E_o. But why should the term c^2 even occur in the formula for the energy contained in a particle at rest like an electron that has inertial mass *m*? The easiest answer is that there is something in the particle moving at light-speed *c*. As mentioned above, several researchers have proposed that the electron is composed of something moving internally at light-speed *c*. But the origin of a particle's inertial mass *m* from the rotating momentum vector E_o / c of a circling photon-like object using Newton's 2nd law and the centripetal acceleration of the circulating photon-like object has, to my knowledge, not previously been demonstrated.

Conclusion

The inertial mass *m* of an elementary particle of rest energy E_o is derived from the rotating momentum of a proposed circling photon-like object composing the particle and

having energy E_o. The particle gets its inertial mass m from the time rate of change of the rotating momentum vector of the circulating photon-like object. A short calculation using Newton's 2nd law and the centripetal acceleration of the circling photon-like object yields the particle's resulting inertial mass $m = E_o / c^2$, or $E_o = mc^2$.

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