The Failure of $E=mc^2$

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Over the course of some years I have had many long and intense telephone conversations with John Chappell. We were in full agreement with regard to the unsatisfactory status of the teaching of physics. Our arguments concerned what the Natural Philosophy Alliance should do to try to remedy the situation. John felt our primary purpose was to reveal to the profession and the general public what is wrong with Einstein's relativity theories. My view has been—and still is—that science would be better served if we proposed and discussed alternative physics paradigms. However, to honor Chappell's wish in this lecture, I will comply with it and criticize relativity theory.

Abstract

The origin of $E=mc^2$ is a three-page paper by Einstein published in 1905, just a few months after the special theory of relativity appeared in print. In the short paper Einstein gave an affirmative answer to the question: "Does the inertia of a body depend upon its energy content?" His derivation of the mass-energy law was not based on the special theory of relativity but on Maxwell's electromagnetic field theory. After World War II and the explosion of atomic bombs, Einstein returned to $E=mc^2$ in two essays. He again claimed that the formula was inherent in pre-relativistic physics, but now Newton's law of momentum conservation was foremost in Einstein's mind.

Problems with the mass-energy law arose in the restricted area of electrodynamics. It was not until the 1980s, decades after Einstein's death, that Pappas of the University of Athens, Greece, demonstrated with a ballistic pendulum that, if momentum is conserved, $E=mc^2$ predicts the consumption of far more energy than was actually expended in his experiment. In the same way, the mass-energy law has been disproved with railguns and induction motors.

$E=mc^2$ is not a law of the Newtonian electrodynamics which preceded the Maxwell-Einstein field theory. Abolishing the instantaneous matter interactions of the Newtonian physics paradigm, therefore, appears to have led to Einstein's law. Nothing said in this talk precludes the validity of $E=mc^2$ in nuclear physics.

The Origin of $E=mc^2$

In the history of science it is difficult to find a simple mathematical formula which has had a greater impact on humanity than $E=mc^2$. It persuaded the President of the United States to launch the Manhattan Project and develop the atomic bomb. This weapon of mass destruction has brought the human race to the brink of an immense catastrophe. None of this was foreseen by Einstein when he first proposed the simple formula equating energy to mass. He was thinking of the benign effect of light pressing on matter and that light is a substance and has inertial mass but no weight.

In the original special relativity paper, titled "On the Electrodynamics of Moving Bodies,"[1] Einstein pointed out that the relative motion of a magnet with respect to an electric conductor induces an electromotive force in the conductor, regardless of which of the two bodies is deemed to be at rest and which in motion. This clashed with Maxwell's electromagnetic field theory which predicted that, contrary to experiment, no induction should take place if the magnet is at rest in the laboratory. This obvious flaw of Maxwell's theory was eliminated by Einstein with the Lorentz transformations. In so doing he converted the electromagnetic field theory to the special theory of relativity. There is no mention of $E=mc^2$ in Einstein's original relativity paper.[1]

The energy-mass equivalence was an afterthought which Einstein published a few months later, still in 1905. The second paper was only three pages long. Under the title "Does the Inertia of a Body Depend Upon Its Energy Content?" Einstein answered the question in the affirmative. His proof led to his historical statement:[2]

> If a body gives off the energy E in the form of radiation, its mass diminishes by $E/9x10^{20}$, the energy being measured in ergs, and the mass in grams.

This amounted to $E=mc^2$, where c is the velocity of light and m the inertial mass of the traveling energy. Einstein was not the first to suggest that mass and energy were convertible into each other. What was new was that Einstein provided a mathematical formula for treating the mass-energy conversion quantitatively. Field theoreticians later went further and described the immaterial energy traveling through space with the help of the Poynting vector. This was supposed to carry momentum and exert an impact force when colliding with solid matter and a recoil force when leaving solid matter. No other mechanism is available in field theory for producing the Lorentz force. All this led to the firm belief that energy and light could be transported from one place to another with the fixed velocity c and that the light substance possessed inertial mass.

The revolutionary aspect of the Maxwell-Einstein radiation processes was that the universe now consisted not only of ponderable matter but also of the additional substance of free energy which behaved like a mass bearing fluid. Matter and light both possessed inertial mass which obeyed Newton's second law of motion and momentum conservation, but light refused to behave like gravitational mass.

Problems with the Magnetic Field

Our civilization has greatly benefited from the existence of electromagnetic radiation, particularly in the fields of optics and radio, television, and radar communications. All these applications rely essentially on the laws of electromagnetic induction. The inertial property of the traveling energy leads to radiation pressure. But this remains hidden in everyday experiments. It is only when slowly varying magnetic fields exert large forces, which are used to drive electric motors and similar machinery, that impact and recoil forces of field energy become noticeable. It is in connection with such electromechanical applications of the Maxwell-Einstein field theory that the formula $E=mc^2$ has failed.

The first to prove the failure of $E=mc^2$ was Professor Panos Pappas of the University of Athens, Greece.[5] Pappas set out to show, by experiment, that the Lorentz force of conventional field theory did not agree with the mechanical force experienced by part of a current loop. Unexpectedly, Pappas found that in his experiment $E=mc^2$ was also violated. The author confirmed Pappas' experiment in his MIT laboratory and called it "the impulse pendulum experiment." A full description of it, complete with the theoretical analysis, will be found in the *Newtonian Electrodynamics* book.[3]

It was discovered that the measured momentum, electromagnetically imparted to the impulse pendulum, required, according to $E=mc^2$, the impact of 52.4 MJ of field energy. The energy stored in the capacitor bank and actually expended to drive the pendulum was, however, only 25.6 kJ. This meant $E=mc^2$ overestimated the Maxwell field energy impinging on the pendulum by a factor of more than 2,000. Hence, Einstein's law failed to comply with experiment.

Einstein's 1946 Essays on the Mass-Energy Equivalence

In 1946, that is after the Hiroshima and Nagasaki atomic bomb explosions, Einstein wrote two essays,[6] entitled "$E=mc^2$" and "An Elementary Derivation of the Equivalence of Mass and Energy." While the whole world believed that it was his law and his relativity theory which caused the invention of atomic weapons, Einstein felt less certain about his contribution.

The first essay begins with a discussion of the swinging pendulum continuously exchanging potential and kinetic energy. He goes on to describe the generation of heat by friction and how this relates to potential and kinetic energy. Einstein points out that the mass increase which should occur when an object is heated is too small to be experimentally observable. The essay makes no attempt to derive $E=mc^2$ from special relativity and the Lorentz transformations. Nor does the essay recognize the fact that the inertial mass of radiation is already an inherent property of Maxwell's field theory.

The second essay derives the mass-energy formula from three pre-relativistic laws, that is:

(1) The law of conservation of momentum.
(2) The pressure of radiation on an absorbing body.
(3) The aberration of stellar light.

Again, the special theory of relativity is not mentioned. The conclusion that Einstein should have drawn, but failed to spell out, is that $E=mc^2$ is not a result of special relativity, but a consequence of Maxwell's field theory.

$E=mc^2$ Violates Momentum Conservation

In his second essay Einstein claims he derived his mass-energy law from—amongst other laws—Newton's momentum conservation. However, Pappas' impulse pendulum experiment proves that $E=mc^2$ violates classical momentum conservation. Einstein was not aware of this.

In all experiments of this kind, an electric conductor is placed into a magnetic field. When the conductor carries current, it will experience the Lorentz force of field theory. If the conductor is free to move, it will accelerate. Consider the case where the magnetic field is due to the discharge of an amount of energy E_c from a capacitor into an electric circuit. Assume the capacitor discharge current accelerates the conductor of mass m to the velocity v so that the conductor absorbed the measured momentum mv. This has to be provided by field energy momentum of electromagnetic mass m_e, traveling at the velocity c, colliding with the conductor and being arrested by it. Momentum conservation therefore requires

$$m\,v = m_e\,c. \tag{1}$$

According to field theory, the energy E striking the conductor should be

$$E_f = m_e\,c^2 = m\,v\,c. \tag{2}$$

This may now be compared with the energy that was stored in the capacitor. If Einstein's law turns out to be correct, we should find $E_f / E_c \leq 1$. Instead the impulse pendulum experiment furnished the following energy ratio:

$$E_f / E_c = 52.4 \times 10^6 / 25.6 \times 10^3 \approx 2{,}000.$$

Hence, Einstein's law failed to comply with experiment and we have to conclude that it does not agree with momentum conservation.

Railguns, which are electrodynamically similar to impulse pendulums, furnish many more instances of the failure of Einstein's energy law. The *Newtonian Electrodynamics* book shows a railgun example in which $E_f / E_c \sim 24{,}000$. Millions of induction motors are continuously in operation around the world. They all defy electromagnetic momentum conservation.[7]

Conclusion

If the essence of the special theory of relativity is expressed by the Lorentz transformation added to Maxwell's field equations, then $E=mc^2$ is not a consequence of Einstein's relativity theories. Einstein himself has shown that the energy law is inherent in pre-relativistic electromagnetism as formulated by Maxwell and his followers. The fundamental hypothesis of Maxwell's theory is the existence of the electromagnetic field which he and Faraday introduced in order to supersede the instantaneous action at a distance concept of the older Newtonian electrodynamics.[3] The first electrodynamic theory is primarily due to Ampere, F.E. Neumann, and Kirchhoff. It was of critical importance to the introduction of the electrical age, but it did not deal with electromagnetic radiation. It is in full harmony with Newton's laws of motion and gravitation and fully complies with momentum conservation. In the Newtonian electrodynamics, energy is not considered to be a substance which can fly through space, nor can it be associated with inertial mass.

Where does this leave us with respect to the explosion of atomic bombs? There is no doubt that enormous amounts of energy are stored in the bonds between nuclear particles. Manipulation of these bonds is the cause of nuclear explosions. No evidence has been quoted in this talk which indicates that mass in nuclear reactions cannot be converted to non-material energy. If nature allows this conversion, then some law like Einstein's may correctly predict the conversion quantities. There remains much to be discovered in the field of nuclear physics.

It was a guess when Einstein claimed that the inertia of a body depended on its energy content and that the energy could be radiated away. The experiments mentioned before question the validity of Einstein's guess.

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