The Physical Meaning of $E=mc^2$

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Many popular accounts maintain that $E = mc^2$ describes the conversion of matter into "pure energy," often construed as a kind of matterless motion. Today, "dark energy" and "dark matter" are spoken of as if they were two different "things." Some even hypothesize that the universe was filled with pure energy before it became filled with matter. This estrangement between matter and motion (*separability*) is common in popular culture and underlies the 20th century regression from realism to idealism in modern physics. There will be no fundamental change in modern physics until we adhere to the opposing assumption, INSEPARABILITY (Just as there can be no motion without matter, so there can be no matter without motion). Without it, it is impossible to explain the physical meaning of the equation. *Like all equations involving aspects of reality, $E=mc^2$ simply refers to the transformation of one kind of matter in motion into another kind of matter in motion and/or the transformation of one kind of the motion of matter into another kind of the motion of matter.* The experimental success of the equation led to the increasing objectification of energy. However, being a matter-motion term like momentum and force, energy neither exists, nor does it move. It is simply an idea, a concept, a mathematical description of the motion of matter. Matter does not "contain" energy, for matter only can "contain" other things in motion. Energy is simply a mathematical term necessary for describing and relating the various forms of the motion of matter. A speculative illustration involving electron-positron annihilation demonstrates how matter (electrons and positrons) appears to be converted into motion (EM radiation) without violating INSEPARABILITY. In essence, $E=mc^2$ describes the conversion of internal matter in motion to external matter in motion, and *vice versa*.

Introduction

Although Einstein's popularization of $E=mc^2$ made it the most famous equation in history, few people understand what it actually means in physical terms. Many popular accounts maintain that the equation describes the conversion of matter into energy, often construed as a kind of matterless motion [1]. Today, we are left with the impression that "dark energy" and "dark matter" are two different "things." Some even hypothesize that the universe was filled with pure energy before it became filled with matter: "a hot dense knot of energy burst outward, congealed into matter…" [2]. There is plenty of experimental evidence that the equation is correct and that, in nuclear reactions, a small amount of missing mass is associated with the appearance of a large amount of energy. But does this really mean that mass and energy are the same thing? In this paper I demonstrate that they are not. One only need apply common sense to this one equation to get at its "physical meaning," defined here as "what is happening to what." This approach has broad implications for understanding relativity's place in history.

History

The idea behind the equation has a long history, starting with Heraclitus 535 BC, Democritus 460 BC, Aristotle 384 BC, and Lucretius 99 BC. Newton's work and the subsequent development of classical mechanics implied that matter and the motion of matter somehow were related. Hegel's dictum (Just as there can be no motion without matter, so there can be no matter without motion) was the foundation of classical mechanism [3]. Preston, Poincaré, De Pretto, and many others were important in the development of the equation. In particular, Hasenöhrl published a paper in 1904 with a very similar equation, $m = (8/3)E/c^2$ that shortly was corrected to $m = (4/3)E/c^2$ in 1905 [4]. The paper even had a very similar title, "On the radiation of moving bodies," and was published in the same journal as Einstein's more famous 1905 paper, "On the electrodynamics of moving bodies" [5]. Although the equation is properly generalized to $E = mc^2/(1-v^2/c^2)^{1/2}$, I will use the customary case in which $v = 0$.

Assumptions

For the present work, I will put special emphasis on three of the ten assumptions of science [6]:

4. INSEPARABILITY-Just as there can be no motion without matter, so there can be no matter without motion.

5. CONSERVATION-Matter and the motion of matter neither can be created nor destroyed.

8. INFINITY-The universe is infinite, both in the microscopic and the macroscopic directions.

Assumptions 4 and 5 may seem quite obvious, although they are powerful antidotes to the more outrageous claims mentioned above. It is somewhat ironic that the highly unconventional assumption 8 is necessary for putting materialism back into physics. Nevertheless, without it, the physical meaning of $E = mc^2$ would remain unapproachable.

Language as the Key to Reality

All languages are based on nouns and verbs, that is, things and their motions. The "physical meaning" that we seek in our everyday life is none other than that formalized in the abstract as "matter" and "motion." The conceptualization, nevertheless, is somewhat difficult, so a little review seems necessary. My usage of those two terms is as follows:

"Matter" is the abstraction for "all things." Things have length, breath, and width; they have existence and location relative to other things. There is no such thing as "matter" *per se*, just as there is no such thing as "fruit" *per se*. We only have specific examples of individual things, just as we only have specific examples of fruit, such as apples or oranges. From INFINITY, we realize that each xyz portion of the universe contains matter, things that always contain other things, *ad infinitum*. In other words, we assume that there are no partless parts. Empty space and solid matter are ideas. Reality exists in the continuum between them. The further implications are that the empty space of the positivist cannot exist and that nonexistence is impossible.

"Motion" is the abstraction for what things do. Motion does not exist, it occurs. In my usage, "motion" is shorthand for the "motion of matter." Nonetheless, there is no "connection" between matter and motion, because that term is given only to matter. Again, motion is what matter does. Strictly speaking, motion is not "part" of the universe. This simple conception of matter and motion has fallen out of favor as idealists sought to claim relativity as proof of their viewpoint. It also is ironic that this view of INSEPARABILITY actually demands that we conceive of matter and motion as two separate categories. I like to think of them this way: if I can put it in my pocket, it is matter; if I can't, it is motion. Thus, legs consist of matter, but running does not; particles are matter, waves are motion.

Language, of course, is not infallible. The descriptions of matter easily and properly take the nominative form. Motion, however, is a

noun describing action. Thus we unavoidably objectify action simply by speaking of it as a noun. We commonly say that we have "things" to do when we actually mean that we will participate in various activities. In science we commonly refer to the "occurrence" of various specimens, when specimens really don't "occur," they "exist." These examples may seem mere quibbles, but they are symptoms of the problem that lies at the root of the misunderstandings surrounding Einstein's equation. The fact that it has spread from popular culture to scientific culture just shows how interconnected those two cultures are.

Matter-motion terms

Common to physics are numerous matter-motion terms, which I define as mathematical formulae that multiply measurements for matter times measurements for motion. Through common use in mathematics we have a tendency to forget that matter-motion terms are neither matter nor motion. They are ideas or concepts. We need to treat them differently from terms that refer to matter and motion directly.

Thus momentum, P = mv, is a tremendously useful matter-motion term that essentially describes the kinematics of Newton's First Law of Motion. But like all matter-motion terms, it presents some conceptual difficulties. Momentum is simply one way of describing matter in motion. Like all matter-motion terms, however, momentum lacks rigor: it may be thought of as matter on occasion and as motion on another occasion. Momentum does not exist, for it is not matter; it does not occur, for it is not motion either. A matter-motion term is like a description of a running dog; it is not a running dog. Matter, on the other hand, has existence. I can search for matter and bring you an example of it, but I will never be able to hand you an example of momentum.

Force, F = ma, is another important matter-motion term. It describes the dynamics of Newton's Second Law of Motion, which coincidently describes causality, the process by which the trajectory of one thing is influenced by another. Again force does not exist, nor does it occur. When we speak of the four "forces," we actually are referring to the motions of matter that produce the phenomena. Nevertheless, even in the pre-relativity days of the 19th century, when the terms matter and motion were commonplace, force had a tendency to get the upper hand. For instance, Buchner's wildly popular book "Force and Matter" [7] should have been more fundamentally and properly titled "Motion and Matter" or "Matter and Motion," like Maxwell's book [8].

One can write tomes on energy without really knowing what it is [1, 9]. Again, this is because energy is a matter-motion term used so commonly that even physicists are apt to believe that energy actually "exists" or actually "occurs." Like the other matter-motion terms, energy lacks the rigor that we commonly associate with mathematics. At one time it may have the connotation of matter and at another it may have the connotation of motion. Often, "stored" or "potential" energy is considered to be matter, while "kinetic energy" (KE) is considered to be motion. But as mentioned, energy is only a concept or idea as Feynman alluded to as he struggled to explain the Conservation of Energy:

> There is a fact, or if you wish, a law, governing natural phenomena that are known to date. There is no known exception to this law; it is exact, so far we know. The law is called conservation of energy; it states that there is a certain quantity, which we call energy, that does not change in manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number, and when we finish watching nature go through her tricks and calculate the number again, it is the same [10].

In other words, the Conservation of Energy is really the conservation of an idea. No wonder it has been considered ambiguous at best [11]. Feynman's "strange fact" involving the "tricks of nature" is not strange at all, once one realizes that it simply involves the conservation of matter and the motion of matter per the Fifth Assumption of Science mentioned above. The Conservation of Motion began with Aristotle, who considered the "motions of the heavens to be eternally constant," becoming more down-to-earth with Descartes [12]. Newton's First Law, of course, was simply a restatement implying that without some outside influence, the motion of an object was perpetual. Lavoisier's work, of course, was totally dependent on the Conservation of Matter. The weight of the atoms of iron plus the weight of the atoms of oxygen was the same before and after oxidation. Of course, for a reaction to occur at all, something must "change" (i.e., it must involve the motion of matter). Although matter and motion never could be "combined" in reality, it was easy to combine both phenomena with the use of the matter-motion terms mentioned above. The most convenient of all was the shorthand form calculated as "energy."

What is wrong with matter-motion terms? Nothing, as long as we: 1) Remember that they are concepts or abstractions, 2) Avoid objectifying the motion they seek to describe, and 3) Avoid deobjectifying the matter they seek to describe. Thus matter exists and motion occurs; they represent reality. Momentum, force, and energy neither exist nor occur; they represent ideality. The physical meaning of Einstein's equation cannot be known whenever we confuse reality and ideality, an affliction common to the 20th century regression in physics [13]. Actually, the principle behind the Conservation of Energy can be evaluated in terms of matter and motion alone.

Conservation of Matter and Motion

Just because "energy" is a convenient concept doesn't mean that we have to use it exclusively. All reactions, including those used most often to demonstrate Einstein's equation, can be explained in terms of matter and the motion of matter:

OLD: Conservation of Matter:

$$2H_2 + O_2 \longrightarrow 2H_2O \quad (1)$$
$$2x2\ g/mole + 2x16\ g/mole = 2x18\ g/mole = 36\ g/mole$$

NEW: Conservation of Matter and Motion:

All chemical and nuclear reactions are accompanied by a change in motion (absorbed or emitted motion of matter, conventionally designated as "energy"):

$$C_3H_8 + 5O_2 + \text{motion} \longrightarrow 4H_2O + 3CO_2 + \text{motion} \quad (2)$$
propane oxygen ignition water carbon dioxide heat

$$^{235}U + n + \text{motion} \longrightarrow 3n + {}^{92}Kr + {}^{141}Ba + \text{MOTION} \quad (3)$$
uranium neutron KE neutrons krypton barium KE + heat

In reaction 2, the motion on the reactant side is that required for ignition; the motion on the product side involves the kinetic motion of the products and the vibratory motion transferred to the surroundings as heat. In reaction 3, the motion on the reactant side is that required to initiate fission via neutron bombardment; the motion on the product side involves the kinetic motion of the products as well as the vibratory motion of the surroundings (heat). The most important consideration is that the total matter/motion on each side of all three equations is the same. However, both the kinds of matter and the kinds of the motion of matter on either side of the reactions have changed. Reaction 3 is particularly instructive because the internal motion associated with the 3 bound neutrons now appears as external motion associated with the fission products and the vibratory motion of the surroundings.

Vibratory Motion of the Surroundings

Much of the confusion surrounding the equation involves the interpretation of the transfer of motion from the system to its environment. Virtually all illustrations of the equation's validity involve electromagnetic radiation. However, when Einstein first rejected the existence of the ether, he theoretically removed the medium by which this transfer could occur [5]. This required him to adopt the corpuscular theory of light,

emphasizing the photon as the carrier of emitted motion. Because light clearly involves wave motion, he had to give wave-like properties to the photon, an idealization that was to become popular in the interpretation of quantum mechanics. Nonetheless, because the photon supposedly travelled at a velocity of c, Einstein's own equations implied that the photon would have an infinite mass. The photon thus had to be considered massless, a thing that was not a thing, much like the proverbial ghost. This manifest contradiction survives to this day, although it is bothersome only to those who seek the true physical meaning of the equation.

The only way out of the contradiction is found in Einstein's change of heart with respect to ether: "There is a weighty reason in favour of ether. To deny ether is to ultimately assume that empty space has no physical qualities whatever" [14].

The "Conversion" of Matter into Motion: A Speculation

What I am about to propose is indeed highly speculative. Nonetheless, the following physical model fulfills all the requirements for the Conservation of Matter and Motion, as well as the calculation of energy via $E = mc^2$. Although somewhat fanciful, the model illustrates the general principle that under the right conditions what we commonly think of as matter can appear as the motion of matter. First some additional assumptions:

1. The ether consists of ether particles moving in all directions at velocity c [15].
2. An electron is a vortex in the ether having a counter clockwise spin, with the rate of spin also having a velocity of c and a translational velocity less than c.
3. A positron is a vortex in the ether having a clockwise spin, with the rate of spin also having a velocity of c and a translational velocity less than c.

It is well known that electron-positron annihilation generally occurs with the production of two 511 kev gamma rays (considered to be massless photons). For this, we will consider the electron to be analogous to a dust devil spinning counter clockwise in a dust storm (Fig. 1). Like a hurricane in the northern hemisphere, it veers left. The positron is similar, but spins clockwise and veers right. Both the electron and positron, of course, are considered to be matter. They have xyz dimensions, locations, and masses of about 1/1836 of the hydrogen atom. Because they veer toward each other, two dust devils of opposite spin have a tendency to collide, demonstrating what is normally thought of as "attraction." They "annihilate" each other, becoming indistinguishable parts of their environments. Electron-positron annihilation is similar, with the kinetic energy calculated for the group of ether particles within the electron being $\frac{1}{2}mv^2$. Similarly, the kinetic energy calculated for the group of ether particles within the positron is $\frac{1}{2}mv^2$. Equal and opposite reactions according to Newton's Third Law result in the total energy change of mv^2. Because the velocity of the ether particles is c, the resulting increase in motion of the ether particles in the environment is equivalent to $E = mc^2$. This produces a "shock wave" within the ether that appears as an electromagnetic wave, a motion within the ether medium having a frequency corresponding to 511 kev. Galaxies of opposite spin provide a visible model of the disruptive effect of the collision between two vortices (Fig. 2).

This speculation satisfies two important claims:

1. $E = mc^2$
2. CONSERVATION: Matter and the motion of matter neither can be created nor destroyed.

The matter in motion that exists as the ethereal constituents of the electron and positron appears after the "annihilation" as the matter in motion of the ethereal constituents of the environment. What we once considered to be matter (the electron and positron) no longer exists, its various ethereal parts having been scattered throughout its ethereal environment. As pointed out for the chemical reactions mention above, the motion of matter of one kind now appears as the motion of matter of another kind. Above all, the "matter" within the electron and positron does not disappear into nothingness, nor does it become matterless motion. The reaction simply describes, as always, the conversion of matter in motion of one kind into matter in motion of another kind. $E = mc^2$ therefore is a restatement of the classical mechanics described by Newton's three laws of motion.

Conclusions

Physical meaning appears in the form of things and what they do. Reality consists of two broadly defined phenomena: matter and the motion of matter. Much of physics, however, involves ideas, concepts, and calculations whose physical significance remains obscure without a reality check. The conversion of mass into energy, for instance, appears as an almost mystical concept until one assumes the theoretical necessity of the ether as Einstein finally concluded in 1920. I speculate that measureable mass appears when the linear motion of ether particles becomes vortex motion. Instead of traveling in all directions at velocity c, ether particles circulate about a central point, which may translate at a velocity less than c, much as sand grains in a dust devil or air molecules in a hurricane. Thus, in electron-positron annihilation, vortices of opposite spin having kinetic energy $\frac{1}{2}mv^2$ collide, producing a shockwave having energy mv^2. Because this involves ether particles having velocity c both before and after the collision, the measured mass m disappears and the measured energy mc^2 appears as a wave in the ether spread in all directions. At a deeper level, the "immeasurable mass" and motion of the ether particles remains unchanged. Understood in this way, Einstein's equation may satisfy the Conservation of Energy, but only the Conservation of Matter and Motion can give it physical meaning.

Acknowlegements

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[15] This speculation was derived by using air as an analogous model. The velocity of a sound wave in air is 343 m/s, while the average translational velocity of air molecules is 500 m/s. Thus the translational velocities of ether particles actually might be greater than c.

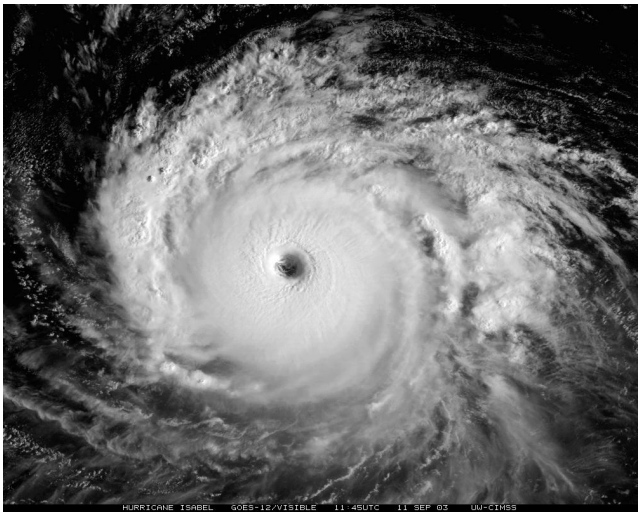

Figure 1. Hurricane rotating counter clockwise in the northern hemisphere. Dust devils in the northern hemisphere may rotate either counter clockwise or clockwise.

Figure 2. The collision between galaxies NGC 2207 and IC 2163 of opposite spin as a visible model for electron-positron annihilation (NASA Hubble Heritage Team STSci-PRC99-44).