# Chapter 32

## THE MASS, MATTER AND ENERGY RELATIONSHIPS

*Einstein has been credited with discovering the 'equivalence of matter and energy' in September of 1905. He ultimately rationalized his way to a very different concept in December 1907. There is a relationship between matter and energy, but in spite of the* ad hoc *equation $E = mc^2$, it is not complete equivalence. Rather, such relationship is only 'partial convertibility.' In any event, such relationship should not be considered to be a relativistic concept, and most of Einstein's conclusions concerning mass, matter and energy were based on the prior work of others.*

### A. What is Energy, Mass and Matter?

Energy on the macro level can be broadly defined as any fundamental physical process that can perform work or make something physically happen. This definition can be made somewhat more meaningful by brief descriptions and oversimplified illustrations of the major manifestations of energy, which often can be readily converted from one form of energy to another.

1. Gravitational energy is exemplified by the mutual attractions and resulting gravitational accelerations of all material bodies, respectively in proportion to and inversely to the proportion of their masses, and relative to the inverse square of their distances apart. One practical terrestrial application is water falling from the top of a dam, which turns a dynamo and generates electricity. Another is the rise and fall of tidal waters, which also can be applied to perform work.

2. Chemical energy holds combinations of atoms together as molecules. The release of this energy can be manifested by explosions, fires and other chemical interactions.

3. Heat energy results when atomic particles wiggle or vibrate "in a random and

 

confused manner."[1] (Feynman, 1963, p. 4-6) A practical application is the heating of water with a fire that produces steam pressure that drives a mechanical engine, which in turn produces work.

4. Electrical energy is manifested by the pushing and pulling of electric charges. (*Id*.) Practical applications include an electrical motor that produces mechanical work, or that generates electricity that ultimately produces light.

5. Radiant energy is transmitted by electromagnetic radiation in the form of light, heat waves, x-rays, radio waves, gamma waves, etc. (see Chapter 6 and Figure 6.9) EM radiation received from the Sun can be converted to electricity by solar voltaic cells, or it can be stored in the form of plants, animals or fossil fuels (oil, coal, natural gas) and later burned to produce heat and ultimately work. Plants convert solar energy and chemical energy into matter (stored energy) by the process of photosynthesis. Animals convert solar energy, chemical energy and the stored energy of plants and other animals into matter by the processes of life, growth and reproduction.

6. Elastic energy is exemplified by the potential force of a spring under tension. (*Id*.) When the tension is released the spring can perform work.

7. Kinetic energy is "the energy of motion" of a body or subatomic particle.[2] (*Id*., p. 4-5) Practical macro applications include wind power that can propel sailing ships or turn windmills, a rifle bullet that can cause destruction, and the motion of a truck, a ship, an airplane or a rocket, which can transport a load of matter.

8. There are also several types of nuclear energy which we should briefly consider separately.

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[1] The wiggling of such atoms is sometimes characterized as 'vibration energy.'

[2] The theoretical vibrating motions of a subatomic particle (i.e. an electron) are considered to be a form of kinetic energy.

a. Natural Radioactive Decay. The unstable nucleus of naturally occurring heavy atoms (such as radium or uranium-235) spontaneously emit subatomic particles such as an electron (beta decay) and thereby transforms itself into a different nuclide.[3] This process is sometimes described as 'spontaneous fission,' which means a partial disintegration of the nucleus. Radioactive decay releases a small fraction of the binding energy that holds the nucleus together (sometimes called 'disintegration energy'), and the energy released is very much greater than for a similar chemical process. Over great intervals of time this natural radioactive decay process continues to produce different nuclides progressively down the periodic table of elements until a stable nuclide of lead ($^{206}Pb$) is eventually reached. (see Halliday, pp. 1147 – 1153, 1168 – 1169, A-5 to A-7)

b. Nuclear Fission. Nuclei of atoms are composed of positively charged protons and neutral neutrons. The 'binding energy' (the total internal energy of the nucleus) holds these two particles together.[4] In order to keep the Coulomb repulsive force of the positively charged protons from splitting the nucleus apart, the neutrons (with their associated 'strong force') progressively outnumber the protons as we proceed up the periodic table of elements.[5] Nuclear fission occurs when the massive unstable nucleus of a heavy element (i.e. nuclide $^{235}U$) splits

[3] A 'nuclide' is defined as a different species of nucleus. (Halliday, p. 1143)
[4] 'Binding energy is comprised of the 'strong force' between the particles, the Coulomb repulsive force between the positively charged protons, and the kinetic energies of the two particles. (Halliday, p. 1145)
[5] For example, lithium (the third lightest element after hydrogen and helium) has three protons and four neutrons, whereas $^{238}U$ (the heaviest naturally occurring element) has 92 protons and 146 neutrons. (Halliday, pp. 1143 – 1144)

and its protons and neutrons are reassembled into two stable middle mass nuclei.[6] (*Id*., pp. 1143 – 1146) During this process large amounts of binding energy are released, and the energy released per atom is roughly a million times larger than that of similar chemical events. (*Id*.) The chain reaction of nuclear fission events in an atomic bomb is obviously uncontrolled. However, in a nuclear reactor located in an electrical power plant, or on board a ship, it is controlled and slowed down by water and cadmium control rods to remain exactly critical for steady energy release and power production. (*Id*., pp. 1171 – 1172) The by-product of controlled nuclear fission is heat, which boils water. The steam pressure operates a turbine, which drives a generator of electricity that in turn produces work. (*Id*., pp. 1172 – 1173)

c. Thermonuclear Fusion. Binding energy can also be released where two light hydrogen nuclei are combined or fused to form a single heavier nucleus, thus creating a different element (usually helium). This process, called thermonuclear fusion, is the reverse of fission. It occurs naturally inside the Sun and other stars, and results in solar radiation. (Halliday, pp. 1146, 1175) Thermonuclear fusion requires much more bulk than nuclear fission. It also requires much higher temperatures to ignite and sustain a chain reaction. Therefore, a nuclear fission bomb is used as its trigger. (*Id*., pp. 1175 – 1176, 1178) The energy released by a thermonuclear fusion event is roughly 20 million times the energy released by a similar chemical event. But there is one major problem. "A sustained and controllable thermonuclear power source—a fusion reactor—is proving much

[6] The idea of an atomic fission bomb is to cause a chain reaction of fission events that will propagate itself. The fuel $^{235}U$ (which normally constitutes only 0.7% of natural uranium) is usually enriched to several percent, because the remaining $^{238}U$ is not fissionable by thermal neutrons. (Halliday, p. 1171)

 

more difficult to achieve."[7] (*Id*., p. 1178)

It follows from the above discussion that energy in all of its observed forms results from actions on the quantum level. When energy in any form excites electrons and raises their energy state, other forms of energy are observed. For example, the act of rubbing amber with a cloth (relative motion) may transfer electrons to the cloth creating positive ions that result in static electricity. An electric current results from directing the random motions of electrons (a charge) in a particular direction, i.e. along a wire, or a lightning bolt from clouds to the ground. Chemical and biological reactions, electricity, and rotary motion can induce the excitement of electrons and result in heat or light. "Sources of light depend ultimately on the motion of electrons." (Halliday, p. 890)

What is matter? For the purposes of this chapter, let us define matter as all of the atoms, atomic particles, galaxies, stars, planets, asteroids, comets, and other celestial bodies existing in the cosmos. Matter does not include any independent form of electromagnetism, such as electric charges, electric currents, electricity, magnetism, EM fields, light, photons or EM radiation.

What are the concepts and definitions of mass? In classical physics, 'mass' was a definition of the quantity of matter that existed for a particular purpose. For example, the 'inertial mass' of a material body was defined as the theoretical measure of its inertia (resistance) to being accelerated by a force (applied energy).[8] On the other hand, the

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[7] At least two generations of scientists and engineers have tried and failed to develop a controlled, sustained fusion process using lasers to ignite a pellet of a bubble of plasma (of other materials than hydrogen, such as deuterium, tritium, and/or boron), using intense magnetic fields to contain the reaction. (see wikipedia.org/wiki/Fusion_power) The hydrogen fusion process that occurs naturally inside the Sun is also naturally controlled, because rare proton-proton collisions, which form a deuteron ($^2H$), occur just frequently enough to release the even flow of binding energy that we observe. (Halliday, p. 1177)

[8] The inertial mass m of a body in empty space (where there is no resistance of the medium) is equal to the force F applied to the body divided by the acceleration a: $m = F/a$. In the medium of empty space, the inertial mass of a body is a constant quantity. However, on the Earth this formula overstates the mass of a

'gravitational mass' of a material body was defined as its proportional force of attraction with respect to another material body, diminished by the square of their distance apart. This latter measure was first articulated by Newton in 1687 and it implies a mass-energy (or matter-energy) relationship of the gravitating material bodies.[9] Sometimes the energy stored or theoretically contained in matter is described as 'mass-energy.' There are also the dubious concepts of Electromagnetic Mass and Relativistic Mass, which we have previously described in Chapters 17 and 31 respectively.

### B. Einstein's 1905 Concepts Concerning Mass and Energy

All of the concepts contained in Einstein's Section 10 and in his September 1905 treatise were generally known by physicists at the turn of the 19th century, such as Kaufmann, Abraham, Lorentz, Poincaré, Heavyside, Bucherer and Max Planck. They had been experimenting with and theorizing about the relationship between the kinetic energy and the electromagnetic energy of the electron and its electromagnetic mass and inertia for years. Before 1905, they knew of the equation $E = mc^2$ in some of its various forms, that electromagnetic mass (an electromagnetic resistance) was a measure of an electron's electromagnetic energy and its electromagnetic inertia, and that even when the electron was at rest it contained a new form of energy which was associated solely with its atomic structure.[10] (see Sobel, p. 205) Some physicists, including Abraham and Einstein, also believed that light had some form or magnitude of mass, which was

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material body relative to the force applied or the resulting acceleration due to the resistance (R) of its medium or environment (i.e. the friction of air and/or of a surface) which is often factored in as part of the mass. Thus, the formula must be changed to $m - R = F/a$, or its equivalent, in order to properly account for R. (see Chapter 17)

[9] More recently, mass (on a sub-atomic level) has been described (in part) as "the effect of the interaction between particles and the Higgs field." (Close, 2002, p. 193)

[10] In his Special Theory, Einstein and his followers later called this new internal energy of the atom, 'rest energy.'

capable of imparting a force or pressure on a body that received such light.

The major difference between the experiments and theories of the other physicists and Einstein's relativistic theories of 1905 was that Einstein was mathematically attempting *ad hoc* to apply and generalize the concepts of electromagnetic mass and the energy and inertia of an electron to the ponderable mass of atomic matter. As Sobel puts it:

> "The theory of relativity, in 1905, showed that the increase in mass with velocity is to be expected on general grounds as a consequence of the new transformation principles of space and time [the Lorentz transformations]; it applies not only to the electron but to any particle, any matter, whether electrically charged or not." (*Id*., pp. 205 – 206)

Einstein was also attempting *ad hoc* to extrapolate this general conclusion to include the phenomena of light and EM radiation.

After reviewing his June 30, 1905 Special Relativity paper for several weeks, Einstein wrote to his colleague, Habicht, and conjectured as follows:

> "…a consequence of the work on electrodynamics has suddenly occurred to me, namely, that the principle of relativity in conjunction with Maxwell's fundamental equations requires that the mass of a body is a direct measure of its energy content—that light transfers mass.[11] An appreciable decrease in mass must occur in radium."[12] (see Miller, p. 333; Folsing, p. 196)

What do the above conjectures by Einstein tell us? First of all, they demonstrate that Einstein falsely equated the material atomic particle radiation of radium with the non-material electromagnetic radiation of light, and falsely concluded that in both cases the result would be a decrease in the mass of the emitting body, because "light transfers

[11] Einstein referred to this theoretical concept "that light transfers mass" as "an amusing and attractive thought." (Miller, p. 333)

[12] Radium is an unstable radioactive metallic element that naturally gives off atomic particle radiation. It was discovered by Marie and Pierre Curie in 1898. Radium-226 has a half-life of 1,602 years and decays into the element radon. (see Oxford Dictionary of Physics, p. 408) Such atomic particle radiation would *a priori* result in a decrease in the inertial mass of such radium, but this has nothing to do with light (EM) transferring mass. On the contrary, everything still exists with radium. Part of the radium has just been converted to a different form: atomic particle radiation.

 

mass."[13] Why did Einstein make this generalized assertion? Probably because in his September 1905 paper he was going to attempt to demonstrate the *ad hoc* concept which he asserted in § 10 of his Special Theory…that Relativistic Mass and Relativistic Kinetic Energy should generally apply to the ponderable mass of a material body, as well as to the electromagnetic mass (resistance or inertia) of an election.[14] The reason that Einstein gave for this proposed *ad hoc* generalization made absolutely no sense. It was:

> "because a ponderable material point can be made into an electron (in our sense of the word) by the addition of an electric charge, *no matter how small*."[15] (Einstien, 1905 [Dover, 1952, p. 63])

Secondly, the consequence that suddenly occurred to Einstein, "namely…that light transfers mass," implies that Einstein believed that light (and EM radiation in general) contained a magnitude of mass.[16] This must have been the consequence that suddenly occurred to Einstein, because otherwise the phrase "that light transfers mass" would have been a non sequitur with respect to the prior phrase that it follows.[17]

These thoughts were further developed by Einstein into a short 3-page follow-up paper to his Special Theory entitled, "Is the Inertia of a Body Dependant Upon its Energy Content." (Einstein, 1905e [Dover, 1952, pp. 69 – 71]) It was received by the editors of

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[13] In fact, in his September 1905 paper Einstein refers to the 'energy of radiation' in generic terms as if it applied generally both to light and radium; and he concluded that "radiation conveys inertia between the emitting and absorbing bodies," where he also equated 'inertia' and 'mass.' As it turns out, one might conclude that Einstein really didn't know what he was talking about.

[14] Remember that in § 10 of his Special Theory, Einstein conjectured *ad hoc* that the relativistic electromagnetic mass and the relativistic kinetic energy that he mathematically derived and deduced for the electron should also apply to ponderable material masses. (Einstein, 1905d [Dover, 1952, pp. 63, 64])

[15] This silly justification constitutes a false premise for his entire September 1905 paper.

[16] In due course, we will demonstrate how Einstein deduced from § 8 and § 10 of his Special Theory that light must contain a magnitude of mass.

[17] Thus, it becomes obvious that the directly preceding phrase "the mass of a body is a direct measure of its energy content" was not the consequence nor the primary concept which Einstein was attempting to demonstrate in his September 1905 paper. It was merely a supportive concept and a step in Einstein's mathematical generalization that 'light has and transfers mass' (or that 'radiation has and conveys inertia'). Both of these general conclusions would be consistent with the then prevailing concepts of electromagnetic mass and electromagnetic inertia.

*Annalen der Physik* on September 27, 1905, and was published in their next edition.

Einstein began this three-page thought experiment with the following statement: "The results of the previous investigation lead to a very interesting conclusion, which is here to be deduced."[18] (*Id*., p. 69) Thereafter, Einstein stated that based upon the Maxwell-Hertz field equations for empty space and his own expanded principle of relativity he had deduced in § 8 of his Special Theory the equation for the energy of a light ray $L_0$ emitted from the stationary inertial system K, as measured in inertial system k relatively moving at v. This equation was:[19]

> "$$L = L_0 \frac{1 - v/c \cos \Phi}{\sqrt{(1 - v^2/c^2)}}$$
>
> where *c* denotes the velocity of light.[20] We shall make use of this result in what follows." (Einstein, 1905e [Dover, 1952, p. 69])

One might ask: What relevance did the result which Einstein deduced in § 8 have for his September 1905 paper? In § 8, Einstein deduced that the energy of the light which was emitted by system K and which was incident upon the moving mirror in moving system k was different than the energy of the light leaving the surface of the mirror in k. By the principle of the conservation of energy, Einstein speculated that such difference in energy must be "the <u>work</u> done by the <u>pressure</u> of light" on the mirror.[21] (Einstein, 1905d [Dover, 1952, pp. 58 – 59])

We know from our prior discussion of the classical concept of energy in Chapter

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[18] As we shall soon discover, the previous investigations that Einstein was mainly referring to were those in § 8 and § 10 of his June 1905 Special Theory.
[19] Remember that this equation was substantially similar to Einstein's formula for the relativistic Doppler effect of light and for the relativistic aberration of starlight in Section 7 of his Special Theory.
[20] Such equation does not define what the magnitude of energy of a light ray is. It only asserts that the energy of a light ray emitted from stationary system K, whatever its magnitude might be, will be different when measured in system k moving at v.
[21] Actually such difference was probably only due to his application of the Lorentz transformations to the emitted light from system K, or to the lesser frequency of the light received by the receding mirror. (see Chapter 30B)

31D that work results from a force, that a force (i.e. pressure) results from the motion (kinetic energy) of a mass, and that the work done on an object (i.e. a mirror) by a moving mass is equal to the change in kinetic energy of the mass. Einstein must have put all of the above concepts and deductions together, along with his deductions of Relativistic Mass and Relativistic Kinetic Energy in § 10, and concluded that the energy of a light ray must have a magnitude of mass. There is no other rational explanation for Einstein's above quote in § 8 about "the work done by the pressure of light," for Einstein's 1905 conclusion to Habicht "that light transfers mass," and for Einstein's similar conclusions at the end of his September 1905 thought experiment. Resnick's statement that Einstein's equation, $E_0 = mc^2$, "asserts that energy has mass," also tends to confirm the author's above conclusions. (see Resnick, 1992, p. 167)

Let us now return to Einstein's September 1905 thought experiment. After his above described preliminary comments, Einstein imagined that a body at rest in inertial system K had an energy of $E_0$ (as properly measured in K), and that it had an energy of $H_0$ (as measured by coordinates in system k which had a relative velocity of v).[22] Why was the body at rest in system K in his September 1905 paper, whereas in § 10 of his Special Theory the electron was slowly accelerated in system K? Probably because when Einstein reflected on § 10, he realized that if the kinetic energy W of the electron was $mc^2$ times some factor relating to the relative velocity of the electron, then it follows algebraically that without that relative velocity factor the total energy of the electron relativistically at rest should be $E_0 = m_0c^2$ in system K.

The body at rest then emitted two light rays of energy ½ L each in two opposite

[22] If we Lorentz transform $E_0$ from K to k, then $H_0$ is different than $E_0$. What is the physical reason for this *ad hoc* change? There is none.

 

directions,[23] and thereafter the energy of the body was $E_1$ and $H_1$ as measured in K and k, respectively. Applying the relativistic transformation equations for the energy of a light ray which he obtained from § 8 of his Special Theory to $E_0$ and $H_0$, Einstein eventually (after much algebraic manipulation) arrived at the following equation:[24]

$$K_0 - K_1 = L \left\{ \frac{1}{\sqrt{(1 - v^2/c^2)}} - 1 \right\}$$

(*Id*., pp. 70 – 71) Einstein then conjectured: "The kinetic energy of the body <u>with respect to k diminishes</u> as a result of the emission of light, and the amount of diminution is independent of the properties of the body.[25] Moreover, the difference $K_0 - K_1$, like the kinetic energy of the electron (§ 10), <u>depends on the velocity</u>."[26] (*Id*., p. 71) Therefore, "$K_0 - K_1 = ½ L/c^2 v^2$." (*Id*.) "From this equation it directly follows that: *If a body gives off the energy L in the form of radiation, its <u>mass</u> diminishes by $L/c^2$.*" (*Id*.)

It follows from the above, that the body's mass $m_0$ (like its kinetic energy $k_0$) only diminishes by $L/c^2$ <u>as measured by coordinates in system k</u>. In other words, such diminution of mass is at least partly an illusionary relativistic decrease which only occurs because of the relative velocity and because of Einstein's contrived system of measurement.

With the above considerations in mind, let us slightly revise what Einstein stated after he concluded that the body's "*mass diminishes by $L/c^2$.*"

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[23] In other words, the inertially moving body at rest in K emitted "pulses of [light] radiation at angles Φ and Φ + 180º with respect to the x-axis of K." (Miller, p. 333)

[24] The rest kinetic energy of the body before the emission of light radiation was $K_0 = H_0 - E_0$. The kinetic energy of the body in system K after the emission of light radiation was $K_1 = H_1 - E_1$. (see Einstein, 1905e [Dover, 1952, p. 71])

[25] Here Einstein is only talking about the diminution of the kinetic energy of the body <u>as measured by coordinates in system k</u>. Therefore, such diminution is partly an illusionary relativistic decrease which only occurs because of the relative velocity (as Einstein pointed out in the next sentence), and because of Einstein's bizarre system of measurement.

[26] But which is it: the emission of light or the relative velocity which diminishes the kinetic energy? We will discuss this issue in the next section.

> "The fact that the energy withdrawn from the body becomes energy of [light] radiation evidently makes no difference,[27] so that we are led to the more general conclusion that
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> The mass of a body [in K as measured by coordinates in system k] is a measure of its energy-content; if the energy [in K as measured by coordinates in system k] changes by L, the mass changes in the same sense by $L/9x10^{20}$."  (Einstein, 1905e [Dover, 1952, p. 71])

One might ask:  What relevance do distorted coordinate measurements of mass and energy made in system k have to do with anything?

The biggest problems with these derivations, speculations, rationalizations and conclusions by Einstein are:  1) they are all completely *ad hoc*;  2) they depend upon the *ad hoc* concepts of Relativistic Mass and Relativistic Kinetic Energy, which we demonstrated in Chapter 31 are empirically invalid;  3) they depend upon Electromagnetic Mass, which is only an electromagnetic resistance and an electromagnetic form of inertia;  4) they depend upon the empirically invalid *ad hoc* concept that light has a magnitude of material mass, and finally  5) they depend upon Einstein's artificial and distorting relativistic system of measurement.  How can conclusions and concepts which are based upon so many false assumptions and *ad hoc* concepts have any validity?

How and why did Einstein suddenly interject the word 'mass' into the discussion? All prior discussions in his September 1905 paper had been all about light, energy and radiation.  Was this merely a non sequitur?  Not really.  The 'mass' that Einstein was referring to was not the ponderable mass of a material body.  It was only the 'electromagnetic mass' in his concept of Relativistic Mass, which he was attempting to

[27] This was a false premise, because if light does not have a magnitude of mass (which we now know to be the case), then this fact does make a huge difference for all of Einstein's mass-energy conclusions contained in his September 1905 paper.

generalize so that it could apply to a "ponderable material point." (see Chapters 17 and 31B) However, this attempted *ad hoc* generalization has no reasonable validity either.

Prior to 1905, Kaufmann (in unpublished calculations) "defined the electron's kinetic energy as the difference between the electron's total and rest energies." (Miller, p. 313) Therefore, "this definition of kinetic energy…was in use before the appearance of Einstein's" relativistic equation for kinetic energy. (*Id*.) In early 1905, Abraham published Kaufmann's definition of kinetic energy in his widely read textbook on the theory of electricity and electromagnetism. (*Id*.) Was Kaufmann the source for the definition of kinetic energy in § 10 of Einstein's Special Theory and for his September 1905 paper? (*Id*.) Quite possibly.

Regardless of their *ad hoc* nature, all of Einstein's assertions and conclusions in his September 1905 paper were also quite ambiguous. For example, what did Einstein mean by the term 'inertia'?

1. Did he mean the inertial resistance of matter to being moved, measured by the formula F = ma?
2. Did he mean the electromagnetic inertia (resistance) of an electromagnetic field to a charged particle or body moving through it?
3. Did he mean the motion or momentum of a body through empty space, apparently without applied rectilinear force (inertial motion)?
4. Was he using inertia as a synonym for mass?
5. Did he mean some combination of the above, or something else?

What did Einstein mean by the term 'mass'?

1. Did he mean atomic matter measured as inertial mass by the formula F = ma?
2. Did he mean the 'apparent mass' of an electromagnetic resistance?
3. Did he only mean that the electromagnetic mass diminishes by $L/c^2$?
4. Did he mean the rigid or deformable body of a particle, such as an electron?
5. Did he mean the magnitude of mass that he assumed that a light ray possessed?
6. Did he mean some combination of the above, or something else?

What did Einstein mean by the term 'energy content'?

 

1. Did he mean 'mass-energy;' the total energy stored in matter?
2. Did he mean every form of energy that can be associated with matter?
3. Did he mean the electromagnetic charge of a particle or body?
4. Did he mean that kinetic energy is 'contained' within a body?[28]
5. Did he mean some combination of the above, or something else?

What did Einstein mean by the phrase "a measure of"?

1. Did he mean the complete equivalence and complete convertibility of the two phenomena (matter and energy)? If so, how did he get to this conclusion?
2. Did he mean only a partial convertibility of matter into energy?
3. Did he only mean some indefinite amount of mass or energy, the magnitude of which can only be determined empirically on a case-by-case basis?
4. Did he mean some combination of the above, or something else?

What did Einstein mean by the term 'energy of radiation?'

1. Was he describing a new and separate general classification of energy?
2. Did he mean the energy of any type of radiation: atomic (i.e. radium) or electromagnetic (light)?
3. Was he describing the different type of energy of EM radiation and the toxic energy from disintegrating atoms?
4. Did he mean some combination of the above, or something else?

What did Einstein mean by the phrase 'light (or radiation) transfers mass (or inertia)?'

1. Did he mean that light transfers electromagnetic mass and electromagnetic inertia?
2. Was he assuming that light has a magnitude of material mass?
3. Was he assuming that the pressure of light on an absorbing body causes the body to move inertially?
4. Was he only referring to the atomic radiation emitted by disintegrating radium?
5. Did he mean some combination of the above, or something else?

Did Einstein even know what he was conjecturing? In his September 1905 article, Miller concludes that Einstein "focused on the problem that he thought to be of basic importance—the nature of radiation." (Miller, p. 333) Were all of the ambiguous

[28] How can the energy of motion of a mass be physically contained within a body? When a force (energy) moves a body in empty space, energy is conserved by the body's kinetic energy of motion, but is the atomic density of the body's inertial mass increased? Of course not.

conjectures in his September 1905 article merely Einstein's attempts to better understand the nature of radiation? His mathematical conjectures that "mass diminishes by $L/c^2$" and that "the mass of a body is a measure of its energy content" could easily be interpreted to be merely supportive of his ultimate and general conclusion concerning the nature of radiation—"radiation conveys inertia between emitting and absorbing bodies." (*Id.*)

Later, of course, Einstein's conjecture that "mass diminishes by $L/c^2$" was interpreted to empirically mean $m = L/c^2$, and thereafter $E = mc^2$ (the equivalence of matter and energy).[29] Einstein's conjectures of: "the fact that the energy withdrawn from the body becomes energy of radiation evidently makes no difference, so that we are led to the more general conclusion that the mass of a body is a measure of its energy-content," were also later interpreted by Einstein and many of his followers to mean "the equivalence of [material] mass with any form of energy."[30] (Miller, p. 333) Same problems and same comments.

### C. Numerous problems with $E_0 = m_0c^2$ and with $E = mc^2$.

The problems with Einstein's September 1905 thought experiment, along with the above gratuitous interpretations and 'in hindsight' conclusions, include the following:

1. First and foremost, the thought experiment that Einstein concocted in his September 1905 paper was completely *ad hoc*. It was based on all of the empirically invalid *ad hoc* assumptions and relativistic concepts contained in the kinematic part of his Special Theory. It was also derived from the *ad hoc* and empirically invalid equations,

[29] But why not $c^2 = mE$, the velocity of light squared equals electromagnetic mass times the energy of the electromagnetic field? $m = L/c^2$ only refers to the electromagnetic energy of the two emitted light rays in a thought experiment about light and radiation, and some possible electromagnetic mass involved, not the vastly different E (any form of energy, including atomic energy). How could $m = L/c^2$ mean the equivalence of material mass and energy, if light L does not have any magnitude of material mass?
[30] Even with this very gratuitous *ad hoc* interpretation, we must still define what the word 'equivalence' means.

conclusions and concepts contained in the dynamical part of his Special Theory.

2. Einstein referred to the energy of the stationary body (before its emission of light) by the relativistic algebraic symbol $E_0$ (or rest energy), a relative velocity dependent quantity in Special Relativity. Therefore, in order to remain consistent with Special Relativity, the mass of the stationary body should have been algebraically designated $m_0$ (for rest mass), a relative velocity dependent quantity. In fact, Einstein later designated the kinetic energy of the body with the relativistic algebraic symbol $K_0$ (for rest kinetic energy), because (as Einstein asserted) it depends on the relative velocity when measured by coordinates in system k. (Einstein, 1905e [Dover, 1952, pp. 70, 71]) Therefore, the equation which he derived should have been written $E_0 = m_0/c^2$.

But this relative velocity dependent equation would only be valid for an observer properly measuring in system K.[31] Only the distant observer in system k would measure the energy and the mass to increase with relative velocity, and these measurements would only be an <u>artifact</u> of observation and they would only result from Einstein's bizarre system of measurement. (see Goldberg, pp. 141, 147) How can this artificial process result in a law or relationship of nature?

3. With equation $E_0 = m_0c^2$, the properly measured energy in system K would not be equivalent to the variable magnitude of mass measured by coordinates in system k, and the variable magnitude of energy measured by coordinates in system k would not be equivalent to the properly measured mass in system K. How can these bizarre, contrived and conflicting relativistic measurements result in a fundamental relationship of nature?

[31] Feynman agreed with the author, that Einstein was dealing with Relativistic Mass and the equation $E_0 = m_0c^2$. Feynman stated in his lecture: "We start with a body at rest, when its <u>energy is $m_0c^2$</u>." (Feynman, 1963, p. 15-10)

4. The 'mass' ($m_0$) that Einstein was referring to throughout § 10 of his Special Theory and throughout his September 1905 paper (except with respect to radium) was only an 'electromagnetic mass' masquerading as Relativistic Mass, which as we have previously discovered in Chapter 17 was really only an electromagnetic 'resistance' that algebraically was only characterized to be a mass in order to remain somewhat consistent with F = ma. Electromagnetic mass was nothing like the ponderable material inertial mass that Newton, Euler, Levoissier and all of the other classical physicists were referring to.[32]

Photons of light radiation, if they exist, are *a priori* massless particles or quanta of energy.[33] (Okun, 1989, p. 34) Radioactive atomic particles with material mass that are emitted from radium undoubtedly would cause the mass of a material body composed of radium to diminish. But how can the massless particles of EM radiation (light) diminish the mass of a material body by $L/c^2$, or by any other magnitude? (*Id.*)

Contrary to Einstein's assertion, the fact that the energy withdrawn from the body becomes the energy of massless electromagnetic radiation does make a huge difference. It is not the same as the material atomic radiation of particles given off by unstable elements such as radium (uranium and plutonium), which particles *a priori* do have material mass. Einstein could not be led from his thought experiment concerning massless photons to a more general conclusion that "the [ponderable material] mass of a body is a measure of its energy content." Nor could he be led to the conclusions that "[massless] light radiation transfers mass," or that "[massless light] radiation conveys inertia between the emitting and absorbing bodies." Nor could Einstein be led to the

[32] 'Lavoissier's law' concerned the conservation of inertial mass in chemical reactions. (Miller, p. 357)
[33] "The photon has a rest mass of precisely zero." (Sobel, p. 206) "Thus we have infinity times zero" (*Id.*) equals zero for the mass of a propagating light ray in a vacuum.

general conclusion that all energy and all mass are totally equivalent: E = m$c^2$. Therefore, Einstein's assertion that it makes no difference what the type of energy is was a major false premise for his September 1905 theory, and his later theories about the 'inertia of energy.'

5. In his September 1905 thought experiment, Einstein arbitrarily equated at least four very different types of energy. A) There was $E_0$ (rest energy) and $E_1$, which stood for the total of all energies associated with a body respectively before and after the emission of light as properly measured in system K. B) There was $H_0$ and $H_1$, which stood for the total of all energies associated with a body respectively before and after the emission of light, as relativistically measured by coordinates in system k. C) There was $L_0$, which stood for the energy of light radiation emitted in two opposite directions from the body at rest, as properly measured in system K. D) There must also have been the different magnitude L, which would stand for the energy of the two light rays, as measured by coordinates in system k. E) There was $K_0$ and $K_1$, which stood respectively for the kinetic energy of motion of the body before and after the emission of light, as respectively properly measured in system K and by coordinates in system k (or by Lorentz transformations). F) Finally, there was the toxic and radioactive energy of atomic radiation emitted from the disintegrating nuclei of the atoms of radium salts.

Einstein conjectured that "the fact that the energy withdrawn from the body becomes energy of radiation evidently makes no difference." (Einstein, 1905e [Dover, 1952, p. 71]) In other words, he was conjecturing that all energy is the same. Where did Einstein get this *ad hoc* idea and what was the justification for it? There was none. It was simply pure speculation on Einstein's part. Einstein's attempted generalization of energy was also a fundamental false premise for his September 1905 paper.

How can the energy of EM radiation (i.e. light) be the same as the energy of the atom? Light cannot produce an atomic explosion because it has no magnitude of mass, it is not composed of atoms, and it is not radioactive. It cannot even be converted into fissionable uranium or plutonium in order to produce an atomic explosion. By the same token, kinetic energy, the energy of a body's motion, is only theoretical potential energy which is theoretically capable of performing work. Theoretical kinetic energy cannot produce an atomic explosion, because it is only theoretical, because it is independent from the mass of the moving body, and because it is not composed of atoms. Nor can kinetic energy even be converted into fissionable material such as uranium or plutonium.[34] Light radiation and atomic radiation are also very different phenomena for another reason. One is radioactive and toxic, and the other is not. It becomes obvious that such energies are not all the same.

6. Einstein asserted that the mass and the kinetic energy of motion of the stationary body would diminish as a result of the emission of light where L is the energy given off "in the form of radiation." (Einstein, 1905e [Dover, 1925, p. 71]) He also asserted that this diminution, $K_0 - K_1$, "depends on the velocity" of the body. (*Id.*) But which is it, the emission of light or the relative velocity or both that causes the diminution of such mass-energy? Because of these circular and contradictory assertions, the equation

$$K_0 - K_1 = \frac{1}{2}\frac{L}{c^2}v^2$$

has no clear meaning.

[34] The same is basically true of gravitational energy, and its potential pulling power.

 

There is another problem with such equation. If the difference $K_0 - K_1$ depends solely upon the relative velocity of the inertial reference frames and if such relative velocity approximates zero, then one is left with: $K_0 - K_1 = ½ L/c^2 0^2 = 0$. It does not follow from this last equation that $m = L/c^2$, because there would be no diminution of kinetic energy, therefore L would be meaningless or zero, and mass m would also be zero. In this case, $E = mc^2$ would also be zero and meaningless. In addition, Einstein derived his equation, $K_0 - K_1 = ½ L/c^2 v^2$, by application of the *ad hoc* and meaningless Lorentz transformations, therefore his equation for the kinetic energy at any velocity must also be *ad hoc*, totally flawed and meaningless.

7. All of the derived equations in Einstein's September 1905 thought experiment directly or indirectly result from the algebraic symbol ½L which he arbitrarily gave to the energy of light waves emitted from the body. Why did Einstein use this symbol? It only refers to the energy of a light ray, which is very different than the theoretical potential kinetic energy of a moving body or the toxic atomic energy emitted from radium.[35]

Based on ½L, Einstein ultimately derived $m = L/c^2$. If he was only referring to electromagnetic mass in an EM field then this equation could have some meaning, but it has no meaning for the atomic mass of a material body. Material mass m cannot be equated with light energy, *inter alia*, because light does not have any magnitude of mass. On the other hand, if Einstein was talking about material mass, then how can he get from $m = L/c^2$, where L is the energy of a massless light ray, to $m = E/c^2$, where E is the total energy of a material body? All of these facts lead the skeptic to the conclusion that either Einstein's final equation ($m = L/c^2$) was meaningless, or the interpretation of it ($E = m/c^2$)

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[35] The radioactive radiation from the disintegration of an atomic nucleus has atomic mass, kinetic energy only has potential and theoretical mass, and light energy has no magnitude of mass whatsoever.

 

was *ad hoc* and contrived.

**D. Revisions to Einstein's Section 10 and his September 1905 theories.**

Over the next three years, Einstein would re-rationalize and change Section 10 of his Special Theory and his September 1905 theories in many ways, always attempting to generalize his conclusions in Section 10 to apply to ponderable masses of material bodies. In May 1906, Einstein published a follow-up paper to this September 1905 paper, on what he called 'The Inertia of Energy.'[36] (Einstein, 1906 [Collected Papers, Vol. 2, pp. 200 – 206]) At the beginning of his May 1906 paper, Einstein described a conclusion of his September 1905 paper, as follows: "the mass of a body changes with the change in its energy content, no matter what kind of change of energy this may be."[37] (*Id*., p. 200) This conclusion basically describes the conversion of one form of energy into another form, not the equivalence of mass and energy. For example, it describes what happens when a body burns and part of its matter (mass) is converted into heat and gases.

Thereafter, Einstein acknowledged that the considerations necessary to prove the purpose of his May 1906 paper were "in the main already contained in a work by H. Poincaré."[38] (*Id*.) Okun describes how Einstein then "rederived Poincaré's formula

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[36] In 1921, Einstein further explained what he meant by "the inertia of energy:" "It was found that inertia is not a property of matter…but a property of energy."[36] (Einstein, 1921 [Nature, Vol. 106, p. 783]) Does this mean that the energy potential of gravity has inertia? Does this mean that a hydrogen bomb before it explodes has more inertia than an equal volume or weight of lead?

[37] Like his September 1905 paper, Einstein's May 1906 paper was based solely upon electromagnetic theory, his principle of relativity, and the principle of energy conservation. (Einstein, 1906 [Collected Papers, Vol. 2, p. 200]) The stated *ad hoc* purpose of his May 1906 paper was to demonstrate that his September 1905 paper was a necessary condition for the conservation of motion (momentum). (*Id*.; see Miller, p. 334) But if momentum is mv (where m is material mass), then there is no connection between the conservation of momentum and Einstein's September 1905 paper.

[38] Einstein cited "Poincaré in Lorentz-Festschrift (1900): 252 – 278." In his 1900 paper, "Poincaré derived the equation $E = mc^2$ in an implicit form." (Pavlovic, Section 23.6.2)

[E = m$c^2$] by considering a photon…that is emitted at one end of a hollow cylinder and absorbed at the other end…"[39] (Okun, 1989, p. 34) However, as Okun asserted:

> "The conclusion of [Einstein's May 1906] paper was that light with energy *E* transfers mass $m = E/c^2$ and that to any energy *E* there corresponds a mass equal to $E/c^2$ (which we now know is not so correct because the photon is massless)." (*Id.*)

Thus, Einstein's conclusion was both empirically incorrect and internally inconsistent, because how can "the absorption of a massless particle change the mass of the absorbing body?"[40] (*Id.*) This was the same obvious contradiction and criticism that anyone should also have with the similar conclusions of Einstein's September 1905 paper. Okun went on to describe the contradictions and inconsistencies that he believed existed between Einstein's two papers on the 'inertia of energy.'[41] (Okun, 1989, p. 32)

In May 1907, Einstein wrote a third paper on the 'Inertia of Energy.' In the first paragraph of this paper, Einstein again described conclusions that he believed needed to be drawn from his September 1905 paper:

> "…the inertia of a body increases or decreases with its energy content…
>
> "…to an increase in the body's energy ΔE there must always correspond an increase in the mass $\Delta E/c^2$…" (Einstein, 1907 [Collected Papers, Vol. 2, p. 238])

These conclusions were nothing more than a repeat of the conclusions from his May 1906 paper. The criticisms of them are also the same.

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[39] This thought experiment has become a standard thought demonstration for Einstein's 'inertia of energy' concept. (Miller, p. 334)

[40] What was the reason for this incorrect assertion by Einstein? Originally, because "only by attributing a mass to the radiation emitted or absorbed," could Einstein conserve the motion (momentum) of a mass which he needed for his proof in his May 1906 paper. (see Miller, p. 334; Einstein, 1906 [Collected Papers, Vol. 2, p. 206]) However, later it also became useful for his Theory of General Relativity. (Okun, 1989, p. 34)

[41] Okun also pointed out that in 1912, Tolman derived relativistic mass as $m_0/\sqrt{1 - v^2/c^2}$ and Wolfgang Pauli adopted it and E = m$c^2$ for his widely read 1921 textbook, *The Theory of Relativity*. As a result, now almost everyone except elementary particle physicists accepts these equations as correct relativistic terminology. (Okun, 1989, p. 35)

Immediately thereafter, Einstein told his readers what the subject of his May 1907 paper would be:

> "the circumstance that the special case discussed [in the September 1905 paper] necessitates an assumption of such extraordinary generality (about the dependence of the inertia on the energy), demands that the necessity and justification of this assumption be examined in a more general way." (*Id*.)

The 'extraordinary assumption' that Einstein was referring to and conjecturing about was that the dependence of inertia on energy must also apply to ponderable material masses as well as to electromagnetic masses (resistances).[42] He then stated that he had "taken the first step in this respect" in his May 1906 paper that dealt with the inertia of energy and "the constancy of the motion [momentum] of the center of gravity" of a ponderable mass. (*Id*.)

Einstein thereafter described another imaginary case where an external electromagnetic field transferred kinetic energy to the ponderable mass of a rigid body moving at a constant velocity. (*Id*., pp. 240 – 243) An avowed reason for this thought experiment was to show that the equation for the kinetic energy ($K_0$) of the body at rest (in § 10 of his Special Theory) "does not hold any longer if the body is acted upon by external" electromagnetic forces.[43] (*Id*., p. 240) He then also considered the 'self' "electromagnetic field produced by the electric masses of the body"[44] and concluded that the inertial mass of the electrified body (i.e. an electron) had increased by $E/c^2$. Einstein the conjectured *ad hoc*: "The law of the inertia of energy is thus confirmed" for

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[42] Einstein had previously conjectured this same assumption in § 10 of his Special Theory with respect to the longitudinal and transversal masses of electromagnetic mass and the kinetic energy of an electron. (Einstein, 1905d [Dover, 1952, pp. 63, 64])
[43] The *ad hoc* implication being that such external EM forces transfer mass and inertia to such body.
[44] The self EM field produced by the electromagnetic mass (resistance) of an electron is what Einstein was referring to. (see Chapter 17)

ponderable masses.[45] (*Id*., pp. 243 – 246) One must give Einstein credit for being persistent, even though the substance of his persistence is not correct.

In his December 1907 Jahrbuch article, Einstein wrote a fourth article on the same subject, this time entitled: 'On the Dependence of Mass [Inertia] upon Energy.'[46] In this article, Einstein compared the energy E of a ponderable physical system with inertial mass, to the kinetic energy K of an electron with electromagnetic mass μ and concluded that "with regard to the dependence of the energy on the translational velocity" they behave the same.[47] (Einstein, 1907e [Collected Papers, Vol. 2, p. 286]) In other words, Einstein conjectured that the energy of a ponderable inertial mass and the kinetic energy of an electron's electromagnetic resistance are both velocity dependent, and in this regard they become the same.[48] Einstein then conjectured:

> "This result is of extraordinary theoretical importance because the inertial mass and the energy of a physical system appear in it as things of the same kind.[49] With respect to inertia, a mass μ is equivalent to an energy content of magnitude $\mu c^2$." [50] (*Id*.)

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[45] Not so. Merely describing an electron as an electrified ponderable body with an inertial mass, or describing an electromagnetic resistance as an inertial mass, does not result in Einstein's desired generalization and confirmation.
[46] Note that Einstein again equated the word 'mass' with 'inertia' in this title.
[47] This, of course, was consistent with Einstein's 'principle of relativity,' that the laws of nature (and the ways they may change) are independent of, and not affected by, uniform translatory motion (velocity). (see Einstein, 1905e [Dover, 1952, p. 69]) However, the internal contradiction with these ideas was, as always, that in order to make the laws of nature co-variant with respect to Lorentz transformations, Einstein had to arbitrarily change the laws of nature so that they were velocity dependent.
[48] Of course an electromagnetic resistance is velocity dependent, because without the velocity of an electric charge there is no EM resistance. However, the same is not true with a ponderable inertial mass. Therefore, Einstein's attempted analogy of equivalence of an electromagnetic resistance and an inertial mass fails. Even if, for sake of argument, an electromagnetic resistance and an inertial mass were relative velocity dependent, this does not mean that they are "things of the same kind." Relative velocity dependent 'length' and 'time intervals' in Einstein's Special Theory are not 'things of the same kind.'
[49] Here, again, Einstein was (by analogy) attempting to equate inertial mass with electromagnetic mass. But Einstein's desires and persistence cannot make it so. Inertial mass is of course defined as the magnitude of resistance of a body to being moved by a force. But a material resistance and an EM resistance do not have the same cause: a material mass.
[50] Here, as usual, Einstein was referring to the 'apparent' electromagnetic mass μ of an electron, which is actually an EM resistance. Again, he was arbitrarily comparing and interchanging an inertial mass with an electromagnetic mass, like apples with watermelons.

In effect, Einstein was stating: "With respect to inertia, an apparent electromagnetic mass μ is <u>equivalent</u> to an energy content of a magnitude electromagnetic resistance μ times $c^2$."

This was Einstein's real statement of mass-energy equivalence. In effect it was an EM resistance-EM energy equivalence. Now we know what Einstein was talking about in his September 1905 paper.

Thereafter, Einstein continued his conjecture about inertial mass, electromagnetic resistance and energy.

> "Since we can arbitrarily assign the zero-point of $E_0$ [relativistic rest energy], we are <u>not even able to distinguish between a system's 'actual' and 'apparent' mass</u> [electromagnetic mass] without arbitrariness. It seems far more natural[51] to consider any inertial mass as a reserve of energy."[52] (*Id*., pp. 286 – 287)

In other words, just because Einstein was having difficulty arbitrarily distinguishing between an inertial mass and an apparent electromagnetic mass (a resistance), he decided to abandon his original false concept of EM mass and *ad hoc* decided to "consider any inertial mass as a reserve of energy" instead. (*Id*., p. 287) Einstein was obviously very confused about the entire subject of mass, resistance, inertia, energy, electromagnetism and matter, and very frustrated in his *ad hoc* attempts to generalize EM mass to include a ponderable material inertial mass.

The concept of 'inertial mass as a reserve of energy' is now called 'mass energy,' the energy which is stored in material bodies at rest, and which may be partially converted to other forms or manifestations of energy. In other words: "An object has

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[51] Far more natural than what? Far more natural than considering electromagnetic energy as equivalent to electromagnetic mass (a resistance) times $c^2$.

[52] In his 1921 article in Nature Magazine, after much theorizing and many experiments by others, Einstein re-interpreted this statement to mean: "a body of mass m is to be regarded as a store of energy of magnitude $mc^2$." (Einstein, 1921 [Nature, Vol. 106, p. 783]) However, because both m's in this 1921 statement refer to Relativistic Mass as measured by coordinates by a distant observer in system S' moving at relative velocity v, this 1921 statement is also meaningless.

energy from its sheer *existence*." (Feynman, 1963, p. 4-7) But, if we apply this concept to uranium-238 it has little or no meaning, because this isotope is not fissionable. If we cannot release any of the energy in a chunk of pure $^{238}U$, what is the practical (or even the theoretical) meaning of the concept that the energy of $^{238}U$ is equivalent to its mass times $c^2$?[53] The same question applies to enriched uranium where the percentage of fissionable uranium-235 is increased, but still only a tiny amount of enriched uranium can be converted to energy. Even inside the Sun at its current temperatures, helium and many other heavier elements cannot naturally be converted into energy. (Halliday, p. 1178)

Nevertheless, the relativists claim that Einstein's "equivalence of mass and energy has been beautifully verified by experiments in which matter is annihilated—converted totally to energy." (Feynman, 1963, p. 15-11) Regardless of these claims of equivalence, these experiments rely almost completely upon theoretical assumptions, inferences and interpretations, and (as Dingle stated) they only hang together if Special Relativity is applied to them and is assumed to be valid. Let us assume, for sake of argument, that anti-matter actually exists, and that when two identical subatomic particles with opposite charges (i.e. an electron and a positron) are made to collide under artificially controlled conditions, they can change into different particles and/or a form of energy (i.e. gamma rays). (*Id.*) Even this does not demonstrate the complete equivalence (or even substantial partial convertibility) under any conditions of large quantities of heavy ponderable matter and all forms of energy, as Einstein and his followers have conjectured.

The relativists claim that all four of Einstein's papers on the inertia of energy, taken together, result in the assertion of the total equivalence of the ponderable inertial

[53] Lead and numerous other elements heavier than iron ($^{56}Fe$) are in the same category as $^{238}U$ in this regard.

mass of matter and its energy content. However, we have repeatedly demonstrated that this is not what Einstein was directly asserting in such papers. Rather, he was merely trying to indirectly generalize an electromagnetic mass to include the ponderable inertial mass of a material body, by analogies and *ad hoc* persuasions. The clarifications in his December 1907 Jahrbuch article describe this difference. They should have been the 'coup d' grave' for Einstein's attempted artificial generalizations.

However, by 1916, Einstein grew much bolder. In his book, *Relativity*, he directly reinterpreted his prior papers on the 'inertia of energy' to mean and include ponderable inertial mass, and he expanded his concepts of the mass-energy relationship *ad hoc*, with the following axiomatic and relativistic conjectures:

> "In accordance with the theory of relativity the kinetic energy of a material point of mass *m* is no longer given by the well-known expression
>
> $$m \frac{v^2}{2},$$
>
> but [by] the expression
>
> $$\frac{mc^2}{\sqrt{1 - v^2/c^2}}.$$
>
> This expression approaches infinity as the velocity *v* approaches the velocity of light *c*. [see Chart 16.___ and Figure 16.2B] The velocity must therefore always remain less than *c*, however great may be the energies used to produce the acceleration." (Einstein, *Relativity*, p. 50)
>
> "A body moving with the velocity *v*, which absorbs an amount of energy $E_0$ in the form of radiation without suffering an alteration in velocity in the process, has, as a consequence, its energy increased by an amount [54]
>
> $$\frac{mc^2 + E_0}{\sqrt{1 - v^2/c^2}}."$$ (*Id*., pp. 51 – 52)

[54] "$E_0$ is the energy taken up, as judged from a co-ordinate system moving with the body." (*Id*., p. 51)

> "If a body takes up an amount of energy $E_0$, then its inertial mass increases by an amount $E_0/c^2$; the inertial mass of a body is not a constant, but varies according to the change in the energy of the body."[55] (*Id*., p. 52)

Einstein finally achieved his generalization *ad hoc* by edict.

Apparently, all of these conjectures only relate to one frame, the frame where the energy and the inertial mass are properly measured. Therefore, *a priori*, after 1916 the magnitudes of mass and energy are no longer relativistic or distorted. Presumably, such conjectures also include the energy of massless light and EM radiation. But, again, how can the inertial mass of a body increase when it absorbs a massless photon or quanta of light energy? (see Okun, 1989, p. 34)

So what does the theoretical concept of the equivalence of mass and energy really mean? In general, such theoretical equivalence is only a mathematical consequence of a dubious equation ($E = mc^2$) and an equally dubious theoretical goal. Empirically, in nature, the equivalence of mass and energy only means a minimal or partial convertibility under certain circumstances.[56] Without substantial further explanation and equivocation, the formulas $E = mc^2$ or $E_0 = mc^2$ or $E_0 = m_0c^2$ do not describe or confirm any of their claimed empirical results.

### E. What is the real relationship between the mass of matter and its energy?

There is a long-standing principle of physics known as the conservation of energy, which we briefly discussed in Chapter 31D. Among other things, it may be interpreted to state that one form of energy may be partially converted into another form,

[55] Here, Einstein directly and axiomatically generalized his concept of electromagnetic mass to include the ponderable inertial mass of a material body, almost as if it was a postulate. In 1921, Einstein even conjectured that his papers on the inertia of energy were "of fundamental importance [with respect to] the nature of inertial mass." (Einstein, 1921 [Nature, p. 783])

[56] For example, over eons of time the Sun converts only a small part of its hydrogen into helium and into radiation energy.

but that energy itself can never be created nor destroyed. (see Resnick, 1992, p. 164) The previous descriptions of energy in this Chapter appear to demonstrate this principle. The facts that energy may be stored in matter (atoms), that matter (atomic particles) may be energized, and that a small part of the matter can be converted into energy are consistent with the principle of energy conservation. But such partial convertibility does not mean that the two phenomena (matter and energy) are equivalent or the same thing. Each phenomenon has its own properties. Atoms are not light and protons are not photons. Photons or quanta of light cannot be split or fused to produce enormous amounts of nuclear energy. They are not equivalent to the nucleus of an atom. There is a relationship between the two phenomena (matter and energy), but it is clearly <u>not</u> total equivalence.

A body of matter that has been agitated or energized (i.e. by heat) has more energy (wiggling atoms) than when not energized (heated). Therefore, under any definition of mass or energy, the mass-energy of the heated body has increased. The same (or a similar process) may occur with a body that has been accelerated, a body that is being gravitationally pulled by another body, a body that has been agitated by a chemical interaction, by an electric charge, by an electromagnetic field, by a magnetic force, by atomic radioactivity, or by solar radiant energy. In all of these cases the matter (atomic particles) of the body has been 'energized,' and its atoms wiggle more. This energized state may be manifested in many ways (i.e. by the emission of heat, by the emission of light, by a chemical reaction, by radioactivity, etc.) and such manifestations of energy may be at least partially convertible into other categories or forms of energy.

However, this scenario does not mean that the neutrons, protons, electrons and atoms that comprise the material body have increased or changed in size, density or number. What can happen is when heat energy (for example) is applied to a body or a gas, the 'vibration energy' of its atoms increases as the temperature rises. This increase in vibration energy normally causes the separation between the atoms to increase, and thus the volume of the entire body or gas expands.[57] (Resnick, 1992, p. 503) But this does not mean that the energized matter (its inertial mass) is equivalent to all of the various types of energy applied to it or associated with it, including the potential release of the nuclear binding energy attributed to the possible fusion or fission of the nuclei of its atoms. During a nuclear fission event, less than 5% of the enriched uranium is fissionable, and much less than that (i.e. one gram) is converted to energy. (see Feynman, 1963, p. 15-11) Even during a thermonuclear fusion event, only a tiny amount of the original matter in the bomb is converted to various forms of energy.

What is the meaning of $E = mc^2$, which was derived *ad hoc* from $E_0 = m_0c^2$, from Einstein's September 1905 thought experiment, and from his related conjectures? $E = mc^2$ has been interpreted and conjectured by Einstein and his followers to mean the total physical equivalence of energy and material mass. Even if this conclusion was true, it cannot be based on Einstein's *ad hoc* relativistic equation $E_0 = m_0c^2$. On its face, $E = mc^2$ asserts that classical non-velocity dependent energy E is equal in magnitude to classical non-velocity dependant material mass m times $c^2$. $E_0 = m_0c^2$, on the other hand, asserts that the Relativistic Energy and the Relativistic Mass of a body change in magnitude depending upon relative velocity, as measured by a distant inertial observer.

[57] However, certain temperature regions of some crystalline solids may even contract. (Resnick, 1992, p. 503)

In fact, $E = mc^2$ is only an artificial construct. It was only intended by Einstein as a rough approximation, expression or illustration of the enormous potential energy contained within any lump of atomic matter. As Einstein once stated: "$E = mc^2$ …showed that a very small amount of mass [matter] may be converted into a very large amount of energy…" Similarly, in 1946, Einstein summarized what he meant by the equation $E = mc^2$.

> "It is customary to express the equivalence of mass and energy (though somewhat inexactly) by the formula $E = mc^2$, in which *c* represents the velocity of light, about 186,000 miles per second. *E* is the energy that is contained in a stationary body; *m* is its mass. The energy that belongs to the mass *m* is equal to this mass, multiplied by the square of the enormous speed of light—which is to say, a vast amount of energy for every unit of mass." (Einstein, 1946 [Ideas and Opinions; 1954, p. 375])

As such an inexact approximation and as a metaphor, $E = mc^2$ has great meaning. But such equation cannot be, and was never intended to be, applied literally. For example, a lump of non-fissionable coal (carbon) and a lump of fissionable uranium-235 (both having the same weight or inertial mass), contain vastly different quantities of convertible energy. The convertible energy contained in a lump of coal might be described as $E = 1/1{,}000{,}000mc^2$ when compared to the convertible energy contained in a lump of fissionable uranium-235.

The word 'equivalence,' when applied to energy and mass, only has a highly theoretical, metaphorical and speculative meaning. It asserts that if we were able to access all of the atomic and other energy theoretically contained in a lump of coal and convert it into an explosion so that all of its matter was annihilated and totally converted into the energy of the explosion, then its mass would to some extent be equivalent to its energy released.

 

But since we are not capable of performing such magic of total conversion, and probably never will be, such theoretical equivalence has no practical meaning. The only practical relationship between mass and energy that we now have (theoretical particle annihilations aside), and possibly ever will have, is that of 'partial convertibility.' In other words, 'equivalence' means: to what extent can we convert or release part of the theoretical energy contained in a lump of matter; equivalence is only a theoretical dream.

The fact that a negatively charged electron and a theoretical positively charged electron (a positron) may collide in a particle accelerator and theoretically be totally converted into other particles and gamma rays (energy), does not even demonstrate the equivalence of the original particle as compared to the two surviving particles and their energy, let alone the equivalence of the matter of the Earth and its energy.[58] The highly theoretical 'annihilation' of two subatomic particles and their dubious total conversion to another form, does not translate into the concept that all of the matter of the cosmos may be totally converted into energy.[59]

The Sun has been trying to turn all of its hydrogen into energy for the past 5 billion years and still over half of it remains as hydrogen. The rest has been converted into helium and a few other heavier elements, plus a constant stream of EM radiation (i.e. light) and particle radiation (i.e. cosmic particles such as neutrinos). When a giant star, much larger than the Sun, has exhausted most of its hydrogen, *a priori* it may suddenly disintegrate and explode as a supernova with energy propagated and star fragments being

[58] This process is often mischaracterized as 'annihilation,' suggesting that something has been destroyed and no longer exists. The same is true with respect to two protons that collide inside the Sun and form a deuteron ($^2H$), a neutrino, and a positron (or two gamma ray photons), and release energy in the process. (Halliday, p. 1177)

[59] Good luck trying to totally convert a lump of lead or a neutron star into energy. On the other hand, the assertion that matter and energy are equivalent states of the same phenomenon may have merit.

propelled in all possible directions at several thousand km/sec, leaving a white dwarf, a neutron star or pulsar in its wake. Thus, after the giant star has been substantially annihilated (it no longer exists as a giant star), only a relatively small part of it has actually been converted into energy. Again, this partial convertibility of matter is also dramatically demonstrated by a fission bomb, where only about one gram of the original bomb material is converted into energy. (see Feynman, 1963, p. 15-11)

How did Einstein interpret the presence of $c^2$ in the equation $E = mc^2$? In a 1946 treatise on $E = mc^2$, Einstein explained what the factor $c^2$ meant to him: It showed that there is "a vast amount of energy for every unit of mass." (Einstein, 1946 [Ideas and Opinions, 1954, p. 375]) In other words, the factor $c^2$ just showed that a very small amount of mass [matter] may be converted into a very large amount of energy.

As Einstein himself acknowledged in 1946, the equation $E = mc^2$ was only a mathematical way of making a general statement or approximation that an undetermined magnitude of energy can be released from an undetermined magnitude of matter (mass), depending upon the specific mass/energy conversion involved. For example, the magnitude of energy ($mc^2$) would be small where radiation is naturally emitted by the radioactive decay of radium, and this conversion might be approximated by the equation $E = 1/100{,}000mc^2$. The magnitude of $mc^2$ would be larger for the nuclear generation of electricity, and this conversion might be approximated by the equation: $E = 1/10{,}000mc^2$. On the other hand, the magnitude of $mc^2$ would be relatively enormous for a Chernobyl meltdown, a fission bomb, a fusion bomb, or a supernova. Respectively, these conversions might be approximated by the equations: $E = 1/1{,}000mc^2$ or even $E = 1/100mc^2$. But certainly not $E = 100\%mc^2$, because there is always a substantial quantity of original mass or matter left over from any such explosion, such as a neutron star or a white dwarf. For all of the above reasons, $E = mc^2$ was never intended to signify a specific magnitude of energy or convertibility. Rather, it only attempts to describe a general mass-energy relationship and some possible convertibilities.[60]

Einstein did not use the term or concept of 'equivalence' in his September 1905 paper. The phrase 'a measure of' is completely ambiguous as to what sort or magnitude of measure Einstein might reasonably be suggesting. Such phrase is certainly not equal to the term: 'equivalence.' Any implied conclusion concerning the equivalence of the ponderable inertial mass of matter and its energy was completely based on Einstein's mathematics and his *ad hoc* conjectures, because it was not supported by any empirical data. He only generally suggested that his theory (whatever it was) might be tested by the radioactive particle emissions of radium.[61] (Einstein, 1905e [Dover, 1952, p. 71]) Einstein's suggestion that atomic radiation released from radium may test his theory merely predicts a kind "of circumstance under which energy and mass are exchanged but gives no insight into the nature of the process."[62] (Goldberg, p. 159) In any event, as we have just demonstrated, the so-called equivalence of mass and energy (in nature) empirically means at most only partial convertibility.

### F. Who really discovered the mass-matter-energy relationship?

A general statement may be made that the discovery of the mass-matter-energy relationship was in fact a long drawn out process and that many scientists contributed to

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[60] $E = mc^2$ is therefore only a metaphor, a general approximation for a mass-energy relationship. The factor $c^2$ only signifies that the atomic energy stored in a piece of matter is many, many times greater than the chemical energy that it may contain or release.
[61] Radioactive particle emissions and EM wave emissions are two completely different types of radiation.
[62] This insight came from those who developed the atom bomb. But, to refer to Einstein as the father of the atomic bomb is like referring "to Isaac Newton as the father of the intercontinental ballistic missile." (Goldberg, p. 156)

 

its early and current state of understanding, including Einstein. The earliest clue might have been when philosophers realized the proportional relationship between the energy necessary to move a body and its resulting motion. Newton's 1687 articulation of this relationship (inertial mass) and of the correlation between a quantity of matter and the proportional attractive energy or gravitational force that it exerted upon other quantities of matter (masses) certainly implied some sort of mass-matter-energy relationship. One could easily conclude from Newton's writings about gravity that 'the mass (quantity of matter) of a gravitating body is a measure of its applied gravitational energy.'

Now fast-forward two centuries. During the period between 1880 and 1904, British physicist J. J. Thompson,[63] Austrian physicist F. Hasenöhrl, American physicist D. F. Comstock, Max Plank and Max Abraham in Germany were all at different times experimenting with and theorizing about EM radiation trapped within a 'black body.' (Goldberg, pp. 153 – 154) All of these theories and experiments were based on the assumption that EM radiation energy possessed momentum (mv) and could exert pressure on objects that it struck.[64] (*Id*., p. 154) Such experimenters gave similar descriptions between the <u>inertia</u> of such trapped radiation and the energy of the system. (*Id*.)

In 1889, British physicist Oliver Heavyside derived the equation $E = \frac{3}{4}mc^2$. (Pavlovic, Section 23.6.2) The equation $E = \frac{3}{4}mc^2$ was generally interpreted as the mass content of the energy of the radiation. (*Id*., pp. 154 – 155) Because $mc^2$ had an

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[63] In 1881, Thompson discussed the association between mass and energy in an electromagnetic theory.
[64] Abraham was the first to propose a magnitude for 'light pressure.' (Goldberg, p. 154) In 1905, Einstein also theorized in § 8 of his Special Theory about "the work done by the pressure of light…" (Einstein, 1905d [Dover, 1952, p. 59]) Both of these theories undoubtedly were based upon the false assumption that light possesses both mass (m) and momentum (mv). Also, this is probably the reason that Einstein concluded in his 1905e paper with the conclusion that light radiation conveys inertia.

ambiguous, variable and undetermined value, Heavysides's equation could easily be considered as equivalent to E = m$c^2$. In a 1900 paper, French scientist Henri Poincaré derived the equation E = m$c^2$ in an implicit form.[65] (Pavlovic, Section 23.6.2) Since Resnick concludes that the equation $E_0$ = m$c^2$ "asserts that energy has mass" (Resnick, 1992, p. 167), why are not Heavyside and Poincaré considered to be the fathers of the mass-energy relationship and of the concept of mass and energy are equivalent?

In 1904, a prize-winning paper by Friedrich Hasenöhrl (1874 – 1915) was published in Annalen der Physik[66] and showed "that radiation enclosed in a vacuum has to be credited with an <u>apparent mass</u>, <u>proportional</u> to the energy of the enclosed radiation." This statement implied that mass and energy are in some way equivalent, and Folsing concludes that Einstein must have read Hasenöhrl's paper. (Folsing, pp. 196, 197; Jammer, p. 72) Also during 1904, numerous research projects on the relationship between mass and energy were being conducted by scientists at various locations, including Einstein's own Patent Office in Bern, Switzerland. (Folsing, p. 196) In early 1905, French scientist Gustave Le Bon published a book on the evolution of matter, which he later claimed anticipated the equivalence between mass and energy.[67] (Jammer, 2000, p. 72)

It thus becomes obvious that the origin of the concept of a relationship, convertibility and/or equivalence of mass, matter and energy "emerged from a program of scientific research." (see Goldberg, p. 156) Einstein could certainly be considered as

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[65] Also during the period 1880 – 1904, J. J. Thompson, Heavyside, Kaufmann, Abraham, Lorentz, Poincaré, Einstein, and others were experimenting with and theorizing about a phenomenon they called electromagnetic mass, which was related to EM charges, currents, radiation and other forms of EM energy. (see Chapters 17 and 31)

[66] Volume 15, pp. 344 – 370. Einstein was an avid reader of and contributor to this scientific journal.

[67] Einstein understood and wrote in the French language. (Jammer, 2000, p. 72, fn 23)

a member of this group program, but he only joined it toward the tail end, not at the beginning. Yet he is often credited as being the founder of the mass-energy relationship, whatever it is, and even the father of the atomic bomb.[68]

The equation, E = m$c^2$, has of course become the most famous equation in physics, especially for the general public. Pavlovic concluded, that:

> "it is this equation that has contributed most to Einstein's fame and the fame of the theory of relativity, although it is not a relativistic equation nor was it derived by Einstein." (Pavlovic, Section 23)

These latter conclusions by Pavlovic may also surprise many readers, but not the author. (see Chapters 32B and 32C, supra)

Pavlovic asserts that Einstein did not quantify or prove his general conclusions concerning the mass-energy relationship, and that he did not derive E = m$c^2$ correctly. (Pavlovic, Sections 23.6.3 and 23.7) There is substantial support for Pavlovic's assertions. In 1907, Max Planck published a manuscript in which he stated that Einstein's 1905 derivation of E = m$c^2$ included assumptions only valid to the first approximation. (Jammer, 2000, pp. 64 – 65) In 1952, Herbert Ives claimed that Einstein's 1905 derivation was a logical fallacy and circular, because it arbitrarily introduced a relation that was "the very relation the derivation was supposed to yield." (*Id*., pp. 62 – 65) Einstein himself was not satisfied with his 1905 so-called derivation, but despite his many later efforts, he was unable to arrive at a general proof for the

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[68] It was not until the mid 1920's that the concepts of quantum mechanics were created by Born, Heisenberg, Dirac, Schrödinger and others. It was not until the mid 1930's that the real technical work on atomic energy began with the work of Italian-American scientist Enrico Fermi and others, and continued for a decade until August 1945 and Hiroshima. E = m$c^2$ may be a very rough first approximation for the energy released by a fission bomb. Heavyside's E = ¾m$c^2$ may be just as valid. E = m$c^2$ may even be a better first approximation for the energy released by a fusion bomb. However, all of these equations are merely extremely rough and ambiguous approximations. Referring to any of these early scientists, much less Einstein, as the father of the atomic bomb is ludicrous. The only thing that Einstein did with regard to the atomic bomb was to sign a letter (because of his great prestige) drafted by nuclear scientists that informed President Roosevelt that such a device was possible. (Cropper, p. 354)

 

relation it asserted. (*Id*., pp. 66 – 67)

In a 1922 letter, Einstein acknowledged and asserted: "that the idea that mass and energy are the same had long ago been proclaimed by many authors, but it is only the theory of relativity that gave a true proof of this equivalence." (Jammer, 2000, p. 72) This was not a correct claim by Einstein, for the following reasons. Einstein's relativistic proofs were only mathematical (not empirical); they falsely assumed that light has a magnitude of material mass, and they only dealt with Relativistic Mass and Relativistic Kinetic Energy, neither of which exists. It is true that Einstein repeatedly used the Lorentz transformations to derive some variation of $E = mc^2$, but the Lorentz transformations by themselves are not Special Relativity, and using them is not the only way to achieve such derivation. For example, in 1907, Max Plank published a paper wherein he deduced the equivalence of mass and energy based on concepts obtained from his black body experiments. (Miller, pp. 340 – 342) Fritz Rohrlich in 1990 and Ralph Baierlein in 1991 derived the mass-energy equivalence relation from the classical Doppler effect (without applying the Lorentz transformation). (*Id*., pp. 68 – 71) In 1988, Feigenbaum and Mermin claimed a derivation of the mass-energy relation "without ever leaving the realm of mechanics." (*Id*., pp. 74 – 76) Even Einstein in 1906 derived the relation to a first approximation using only principles of classical mechanics. (*Id*., pp. 77 – 79)

In any event, as Pavlovic correctly points out, the equation $E = mc^2$ itself has nothing to do with relativity, and should not be considered as a part of Special Relativity. It is purely a classical equation that asserts the general relationship between mass and energy at various magnitudes of the variables. Even mass 'm' in the equation refers to classical mass, rather than relativistic mass.[69] (see Pavlovic, Section 23.8) A correct relativistic formula for the theoretical mass-energy relationship of equivalence would be $E_0 = m_0c^2$ (or the equivalent), where $E_0$ is the proper (velocity dependent) rest energy of a body and $m_0$ is the body's proper (velocity dependent) rest mass.[70]

In 1916, Einstein attempted, *ad hoc*, to convert $E = mc^2$ into a relativistic equation by adding the Lorentz transformation factor to it as a denominator, vis.:

$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}}$$

According to Einstein, this new equation describes what happens when the energy, the mass and/or the velocity of a material object changes. [71] (Einstein, *Relativity*, p. 50) There may be some empirical support for this conjecture by Einstein, but certainly it is not as a result of the Lorentz transformation. If the Lorentz transformation factor, $\sqrt{1 - v^2/c^2}$, is *ad hoc* (Chapter 27); invalid for Length Contraction and for the Dilation of Time (Chapter 28); and invalid for Relativistic Mass, Relativistic Momentum and Relativistic Kinetic Energy (Chapter 31); why should we suddenly believe that it is valid with respect to mass and energy?

Thus, the conclusions attributed to Einstein—that the mass or matter of a material body is a direct measure of its energy content and that a body's matter can be totally converted to energy (*Id.*)—are at best misleading or hyperbole.[72]

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[69] However, in order to be a relativistic equation consistent with Einstein's Special Theory, it should be written: $E_0 = m_0c^2$ or the equivalent, in order to show that it is velocity dependent. (see Einstein, 1905 [Dover, 1952, pp. 70 – 71])

[70] It was in his September 1905e paper that Einstein began the practice of adding a subscript zero to indicate that the object or phenomena to be relativistically measured was at rest in an inertial reference system.

[71] This new equation leads to a relevant question: Is this manipulation of algebraic symbols endowed with any physical meaning?

[72] Much of the confusion depends upon what is meant by the words: equivalence, annihilation and convertibility.