Re: .Re: Why all the fascination with E = mc^2 ??

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From: David McAnally (*D.McAnally_at_i'm_a_gnu.uq.net.au*)
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Date: 4 Jun 2004 08:59:58 GMT
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Firstly, I have to wonder how well you really understand the logical underpinnings of the Special Theory of Relativity. At least once below, you come dangerously close to stating that inertial frames of reference are distinguishable from each other. Such a statement would deny the Principle of Relativity (Einstein's First Postulate). This is also not the first time that I have seen you make such a statement.

In the Special Theory of Relativity, it is invalid to describe a material body just as stationary or moving. In the Special Theory of Relativity, material bodies are described as stationary or moving with respect to a specific frame of reference. If a body is described just as being stationary or as moving, then that means that an inertial frame of reference has already been specified, and all discussion is implicitly in that frame of reference.

An inertial frame of reference is not system of bodies. An inertial frame of reference is a system of coordinates which satisfy certain conditions.

This is an important point: an inertial frame of reference is a system of coordinates. It is not an experimental system, and it is not a system of bodies or particles.

Since you are obviously ignorant of the basics of the Special Theory of Relativity, as evidenced by many of the comments that you make below which betray your ignorance of these basics, then I would suggest that you learn the basics first, rather than trying something harder, where a knowledge of the basics (knowledge which you obviously don't have) is a necessary ingredient for understanding.

leoppard@MailAndNews.com (Leonard Pardin) writes:

>D.McAnally@i'm_a_gnu.uq.net.au (David McAnally) wrote in message news:<c9muid$qk4$1@bunyip.cc.uq.edu.au>...
>> leoppard@MailAndNews.com (Leonard Pardin) writes:
>>
>> <snip>
>>
>> > Einstein seems to be saying just what you said: mass/energy in one

>> >frame appears to be reduced in another frame.
>>
>> No. Einstein took the classical Conservation of Energy is both frames.
>>He
>> had already calculated how the energy of radiation transforms between
>> frames, so he could use Conservation of Energy in both frames, and
>> calculate how the energy of the body in question changes as a consequence
>> of the radiation.
>>
>> Einstein starts off with a body of a certain mass (M, say).

> Where are you getting that from? Einstein doesn't even mention
>mass until the conclusion.

All material bodies have mass. What I wrote was just another way of writing "Let M be the mass of the body." Einstein did not mention M, but I have only introduced M here to aid in a later part of the discussion.

>>He uses the
>> frame in which the body is stationary. He then allows, in the frame in
>> which the body is stationary, the body to radiate radiation of energy L/2
>> in one direction, and radiation of energy L/2 in the opposite direction.
>> This allows the body to remain stationary after the radiation (the
>> momentum of one lot of radiation cancels the momentum from the other lot
>> of radiation, so that the momentum of the body remains unchanged, i.e. at
>> zero).

> Okay. Total mass of the stationary body in the STATIONARY SYSTEM
>is L (1/2 L one way, and 1/2 L the other). Fine so far.

Wrong. I never said that. What you wrote does not even make sense.

Let M be the mass of the body. An energy of L/2 is radiated in one direction, and an energy of L/2 is radiated in the opposite direction. This means that the momenta of the two radiations are equal and opposite, so that the body remains stationary, by Conservation of Momentum.

>>Einstein then investigates the same set−up in another frame which
>> is moving relative to the original frame (at velocity −v). In this frame,
>> the body has mass M and is moving at velocity v, and then it radiates a
>> certain amount of energy in two directions

> HOLD IT!! Are we reading the same Einstein? That passage I
>posted is a quote from Einstein's 1905b paper. He says nothing about
>a second body in another frame.

Because it is the SAME body. I feel like you are deliberately misinterpreting what I write. It should have been obvious that I was discussing the same body as the one that was originally discussed.

> Instead, Einstein says that the energy radiated by the body in the
>STATIONARY SYSTEM

By which you mean the inertial frame of reference in which the body is stationary. The frame of reference is a system of coordinates. It is not a system comprised of the body and the radiated energy.

>is measured from the MOVING SYSTEM

By which you mean the second inertial frame of reference which was introduced, a frame of reference in which the body is moving. The frame of reference is a system of coordinates. It is not a system comprised of the body and the radiated energy.

>with different
>results. There is only one body,

I never said that there was more than one body. It's statement like this that make me wonder if you really understand what is actually happening in the Theory of Relativity.

>and it is located in the STATIONARY
>SYSTEM.

What you call the STATIONARY SYSTEM is the first inertial frame of reference (the one with respect to which the body is stationary), and it is a system of coordinates. Its relation to the body and the radiation is that it is possible to keep track of the coordinates of the body and radiation in the frame of reference. The body is not located in the frame of reference, since it does not make sense to describe anything as being located in a coordinate system.

It is, in fact, possible to keep track of the coordinates of the body and the radiation in ALL inertial frames of reference.

>So we are going to get two measurements: one set as measured
>from the STATIONARY SYSTEM and one set as measured from the MOVING
>SYSTEM.

What you call the MOVING SYSTEM is the second inertial frame of reference (one with respect to which the body is moving), and it is a system of coordinates. Its relation to the body and the radiation is that it is possible to keep track of the coordinates of the body and radiation in the frame of reference.

>>(with the energies being
>> calculated using the formula that Einstein had already derived), and then,
>> after radiation, the body continues to move with velocity v.

> WAIT A MINUTE! The body doesn't move at all in the STATIONARY
>SYSTEM. It just sits there radiating light.

The body is moving relative to the second frame, and I was specifically describing the body and radiation with respect to the second frame when I wrote that. In fact, I was very explicit about the fact that I was working in the second frame of reference and not the first when I wrote it. My exact words here were:

::Einstein then investigates the same set−up in another frame which is
::moving relative to the original frame (at velocity −v). In this frame,
::the body has mass M and is moving at velocity v, and then it radiates a
::certain amount of energy in two directions (with the energies being
::calculated using the formula that Einstein had already derived), and
::then, after radiation, the body continues to move with velocity v.

Note that throughout the above passage, I am describing the system as seen by the second frame of reference, so your objection to what I wrote falls down on the basis that you were working with the wrong frame of reference.

>The motion of the body as
>measured from the MOVING SYSTEM is due only to the motion of the
>MOVING SYSTEM.

This comes dangerously close to declaring a specific frame of reference to be special (and to be distinguishable from the others). Such a statement is a direct contradiction to the Principle of Relativity, and therefore to Einstein's First Postulate. Have you read and understood nothing of the logical underpinnings to the theory? This is not the first time that I have seen you trying to deny a consequence of the Principle of Relativity.

You CAN'T describe the second frame of reference as moving. All that you have is that the second frame of reference is moving with respect to the first frame of reference. But so what? The first frame of reference is no more special than the second frame of reference.

>> Later in
>> Einstein's working, he additionally assumes that |v| is much smaller than
>> c (this is so that he can use Newton's approximation for the formula for
>> the kinetic energy).

>Lucky for Einstein Newton provided a classical formula for kinetic
>energy.

Very funny. I admit that I made a mistake here. What I meant was "he can use the Newtonian approximation for the formula for the kinetic energy". I would point out here that when I write about Newtonian Mechanics, I am discussing the mechanics derived from Newton's Laws of Motion, etc. When I write about Newtonian Mechanics, I am not restricting myself to the results that Newton himself derived. The Lagrangian and Hamiltonian formulations in the eighteenth and nineteenth centuries still count as Newtonian Mechanics, even though Newton was dead by the time that these formulations appeared.

>> In the second frame of reference, the kinetic energy of the body before
>> radiation is 1/2 M v^2 (plus a series of terms too small to worry about).
>> The total energy content of the body in the second frame of reference is
>> equal to the total energy content of the body in the first frame of
>> reference plus the kinetic energy.

> Einstein mentions no body in the "second frame" (the MOVING
>SYSTEM); there is only one body, and it's in the STATIONARY SYSTEM.
>Are you getting your facts from a differenc source?

No. I am getting my facts from the same source. But I am getting my facts from the fact that I understand the logical underpinnings to the Special Theory of Relativity. It is becoming increasingly obvious that you do not.

The body is not "in a frame". The body is just there following a specific worldline in spacetime. Different frames of reference will see the body's behaviour in different ways. We are interested in how two specific frames of reference see the behaviour of the body: the frame in which it is stationary, and the second frame which was introduced above.

You seem to be obsessed with placing a body "in a frame". That is not what a frame of reference is. A frame of reference is a system of coordinates.

>> We know how the total energy content
>> of the body changes in the first frame of reference: the total energy
>> content reduces by L. Einstein used his transformation formulae for
>> radiated energy to show that the total energy content of the body reduces
>> by L + L v^2/(2 c^2) plus terms too small to worry about.

I should have mentioned that this is in the second frame of reference. Sorry for the omission.

> The measurement in the STATIONARY SYSTEM shows that the energy
>content of the body is reduced by L. Nothing unusual happens in the
>STATIONARY SYSTEM. Only the MOVING SYSTEM perceives a measurement that
>is less than the measurement taken in the STATIONARY SYSTEM.

>> Since the total
>> energy content of the body in the second frame after radiation is the
>> total energy content of the body in the first frame after radiation plus
>> the kinetic energy of the body in the second frame after radiation, then
>> the kinetic energy of the body after radiation drops by Lv^2/(2c^2) plus
>> terms too small to worry about.

> There is no second body in the second frame;

You keep making this nonsensical statement based on the fact that you obviously do not know what a frame of reference is.

>the MOVING SYSTEM
>contains no body.

This is also a nonsensical comment. Frames of reference do not contain
bodies. Frames of reference are systems of coordinates.

>Energy measurements by the MOVING SYSTEM are
>converted to Kinetic energy for the body in the STATIONARY SYSTEM.
>Kinetic energy as measured from the MOVING SYSTEM is less than the
>kinetic energy as measured from the STATIONARY SYSTEM containing the
>body. Measurements in the STATONARY SYSTEM where the body is located
>would show no loss of kinetic energy.

Try writing that again, while recognizing that an inertial frame of
reference is nothing more than a coordinate system.

>>The kinetic energy in the second frame
>> after the radiation is 1/2 M v^2 − 1/2 L/c^2 v^2 plus terms too small to
>> worry about, so that the mass of the body after radiation is M − L/c^2,
>> and the body has lost a nett mass of L/c^2.

> Only as measured from the MOVING SYSTEM. The kinetic energy
>measurements taken by the MOVING SYSTEM are smaller than the same
>kinetic energy measurements taken by the STATIONARY SYSTEM.

Whatever you mean by that.

> There are only three variables in the formula for kinetic energy
>(KE = 1/2 mv^2). The speed of light must remain constant, so v
>becomes c

This statement has no physical basis. WHY should v be equal to c?????

>and must stay the same. Therefore, as measured from the
>MOVING SYSTEM, if KE is less, then m must be reduced−−BUT ONLY FOR THE
>MOVING SYSTEM.

No. For ALL coordinate systems. The mass of a body is an invariant, so
it is the same with respect to ALL inertial frames of reference.

>There is an only an apparent reduction of mass and
>only as viewed from the MOVING SYSTEM.

Only if you don't really understand what's going on.

>>
>> The decrease of the mass of the body takes place in BOTH frames.

> What a jump!

It's not a jump. The mass of a material body is an invariant. It is the same in all frames of reference.

>The MOVING SYSTEM sees a reduction in mass in a body
>located in the STATIONARY SYSTEM. Those in the STATIONARY SYSTEM
>can't see it, can't measure it. It is happening right under their eyes
>but they can't measure it. To know what is happening, they have to
>contact the MOVING SYSTEM and get the measurements. But it must be
>happening because Einstein says that the reduced measurements taken in
>a different frame must apply to all frames.

> This is the famous Einstein derivation of E = mc^2 ?? You are
>joking, aren't you?

Since you have obviously never bothered to learn the basics of the Theory of Relativity, it is not surprising that the logic of the argument is beyond you. My advice to you is to learn the basics of the Special Theory of Relativity first before you attempt anything else. After all, you have to learn to walk before you can run.

Here is an analysis of Einstein's paper.

The set−up is as follows. We take a specific frame of reference. We set up a gedanken experiment in which a material body of mass M is stationary in the frame of reference (note that the body is not IN the frame of reference: frames of reference do not have bodies in them, but we can describe how the body acts relative to the frame of reference). At a specific moment, the body simultaneously radiates in two different directions. Specifically, with respect to the frame of reference, the body radiates an amount of energy equal to L/2 in one direction, and it radiates an amount of energy equal to L/2 in the opposite direction. As a consequence, the body remains stationary in the frame of reference.

So, with respect to the frame of reference, what happens is as follows.

1. The body of mass M is stationary.

2. The body radiates a nett energy of L.

3. The body is stationary.

Now, we take another frame of reference, travelling with respect to the first frame of reference at a speed v in the positive x direction. Let us investigate how the same system of body and radiation acts relative to the new frame of reference. What happens with respect to the new frame of reference is as follows.

1'. The body of mass M is moving in the negative x direction at speed v.

2'. The body radiates energy.

3'. The body is moving in the negative x direction at speed v.

Einstein had, in his previous paper, calculated how much energy is radiated in the new frame of reference, and he found that the nett energy radiated in the new frame of reference is:

$$L/2\ (1 - v \cos f/c)/\mathrm{sqrt}(1 - v^2/c^2)$$

$$+ L/2\ (1 + v \cos f/c)/\mathrm{sqrt}(1 - v^2/c^2)$$

$$= L/\mathrm{sqrt}(1 - v^2/c^2).$$

Relative to the first frame of reference, the energy of the body before radiation is E_0, and the energy of the body after radiation is E_1, so

$$E_0 = E_1 + L.$$

Relative to the second frame of reference, the energy of the body before radiation is H_0, and the energy of the body after radiation is H_1, so

$$H_0 = H_1 + L/\mathrm{sqrt}(1 - v^2/c^2).$$

These results follow from Conservation of Energy in each frame.

Relative to the first frame of reference, the body is stationary, both before and after radiation, so the body has no kinetic energy, and so E_0 and E_1 are the energies intrinsic to the body before and after radiation.

Relative to the second frame of reference, the body is moving at speed v in the negative x direction, both before and after radiation, so the body has a kinetic energy (with kinetic energy given by $1/2\ M v^2$ plus terms too small to worry about before radiation, if v is much smaller than c). Let K_0 and K_1 be the kinetic energy of the body relative to the second inertial frame of reference, before and after radiation, respectively.

Before radiation, the body has an intrinsic energy of E_0, and the only additional energy is kinetic energy, and so $H_0 = E_0 + K_0 + C$, where C is a constant introduced to take account a possible change in the datum of energy between the two frames. Similarly, after radiation, we obtain $H_1 = E_1 + K_1 + C$ (C remains unchanged as neither datum of energy changes). It follows that

$$K_0 - K_1$$

$$= (H_0 - E_0) - (H_1 - E_1)$$

$$= (H_0 - H_1) - (E_0 - E_1)$$

$$= L\ \{1/\mathrm{sqrt}(1 - v^2/c^2) - 1\}.$$

This means that for v much smaller than c, the kinetic energy of the body
relative to the second frame of reference is 1/2 M v^2 − 1/2 Lv^2/c^2
plus other terms too small to worry, having decreased by 1/2 Lv^2/c^2
plus terms too small to worry about. Since the speed of the body relative
to the second frame of reference remains unchanged, but the kinetic energy
relative to the second frame of reference drops, then there is a decrease
in the mass of the object by an amount equal to L/c^2. Since the mass of
a body is invariant (i.e. the same relative to ALL frames of reference),
then the mass of the body decreases by L/c^2 in ALL frames of reference,
including the frame of reference with which we started.

David

> And all dared to brave unknown terrors, to do mighty deeds,
> to boldly split infinitives that no man had split before −
> and thus was the Empire forged.

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