Is Charge another form of Energy?

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Abstruct

The kinetic energy of a moving mass is attributed to the mass increase because of its velocity. Thus, mass is recognized as a special form of energy. In contast to mass, charge is believed to be a constant entity, not affected by its velocity.

From the above, two questions might be asked:

1. Why charge remains a distinct entity while mass was discovered to be a special sort of enery.

2. If mass increase by velocity is recognized to be the cause of the kinetic enrgy embeded in a moving mass, what is the cause for the generation of a magnetic field while the charge is moving?

This article deals with these questions by executing the following "thinking exercise":

It assumes that charge is also another form of energy, as mass turned to be. This assumption makes Energy as the only distinct entity, a simpler and cleaner view of nature.

Then, it uses that assumption as follows:

It adds the following two assumptions:

1. The charge magnitude value is not a constant entity and it is affected by the charge velocity.

2. The increase of the charge magnitude because of its velocity is the cause for the generation of the magnetic field of a moving charge.

Then, by analyzing the existing experimental results related to charges and the fields they create from a new point of view, and applying these assumptions, the article tries to evaluate if these assumptions lead to new insights.

The result is the following four conclusions:

1. Charge magnitude increase because of its velocity is described by the following formula:

$$q = q_0/((1 - v_1^2/c^2))^{1/2}$$

This is very similar to the equation:

$$m = m_0/((1 - v^2/c^2))^{1/2}$$

Which describes the increase in mass when the mass is moving.

2. The magnetic field generated by a moving point charge is actually two moving field components. One of these moving field components is a moving electric field component. Another moving field component is perpendicular to this moving electric field and it can be seen as the actual magnetic field created. These two moving fields resemble and might be related to the electromagnetic emission from moving charges.

3. Since charge comes in two types, a positive charge and a negative charge, then the energy embeded in charge also comes in two energy types. The article assigns these energy types to one set of Energy Pairs.

4. A magnetic field energy conservation paradox is resolved using the above concept of Energy Pairs. This is done by assuming that Energies belonging to Energy Pairs, cancel each other if they coexist in the same space volume, such that only the net energy intensity of the energy type in the Energy pair that had initially more intensity, remains in the space volume where the two Energy Pairs coexist. Thus, energy conservation exists only when the total amount of energy in a specific volume in space contains only the net amount of one member of the energies which belong to an Energy Pair.

Thus, by assuming that charge is a special form of energy, and analyzing the existing data and knowledge according to this assumption, it seems that new insights can be found, and also an explanation can be supplied to a magnetic field energy conservation paradox.

Introduction

Mass is recognized as a special form of energy. It is not constant and mass increases by velocity according to: (Ref 1)

$$m = m_0/((1 - v^2/c^2))^{1/2}$$ where c is the speed of light.

And it can be converted entirely to energy according to: (Ref. 2)

$$E = mc^2$$ where E is energy, m is mass and c is the speed of light.

Thus, before the presentation of the special theory of relativity, the science of physics recognized actually three distinct entities: energy, mass and charge.

After the presentation of the special theory of relativity, the mass ceased to be a distinct entity, and it is recognized as a special form of energy. So, now there are only two distinct entities: energy and charge.

In contrast to the mass, the science of physics views the charge as an entity whose magnitude value is constant and not affected by its velocity.

From the above, two questions might be asked:

1. Why charge remains a distinct entity while mass was discovered to be a special sort of enery.

2. Because the increase in mass is understood to be the cause of the kinetic enrgy embeded in a moving mass, what is the cause for the generation of a magnetic field while the charge is moving?

These two questions are viable questions

Before the introduction of the special theory of relativity, nobody was bothered with the question what causes the kinetic energy embeded in a moving mass. Now, since it is clear that there is such a cause, and it is the increase of the mass because of its velocity, it is only normal to ask what is the cause for the magnetic field generated by a moving charge.

It cannot be the kinetic energy of the moving body which contains the electric charge because infinite cases can be devised, each with a body with a different mass but containing the same amount of charge, thus, each such body has a different kinetic energy but creates the same magnetic field.

Also, after mass was discovered to be a special form of energy. It is only natural to wonder now, if charge might be also a special form of energy.

This article deals with theses two questions by executing a "thinking exercise" while analyzing the existing formulae for charges and fields they create, from a new point of view, as will be described in the next chapters of this article.

Review of existing formulae

First, we will review the existing formulae related to point charges and the fields they create.

1. A point charge q induces an electric field E-> at a distance r from the charge as shown in Fig. 1:

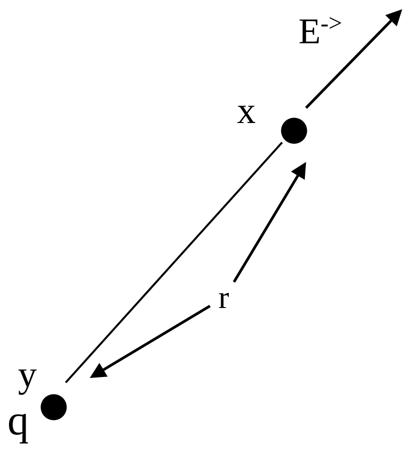

Fig. 1

The induced electric field is a vector E-> as expressed by the formula:
(Ref 3)

$$E^{->} = (1/(4\pi\varepsilon_0))(q r^{->}/r^2)$$

Where ε_0 is the vacuum permittivity and is equal to:
8.854187817…x 10^{-12} F/m (Farad per meter)

And r-> is a unit vector in the direction of the line xy, indicating that E-> is also a vector in that direction.

The magnitude of E-> is expressed by the formula:

$$|E^{->}| = (1/(4\pi\varepsilon_0))(q/r^2)$$

2. A moving point charge q moving at a constant velocity $v^{->}$ induces a magnetic field $B^{->}$ at a distance r from the charge, as shown in Fig. 2.

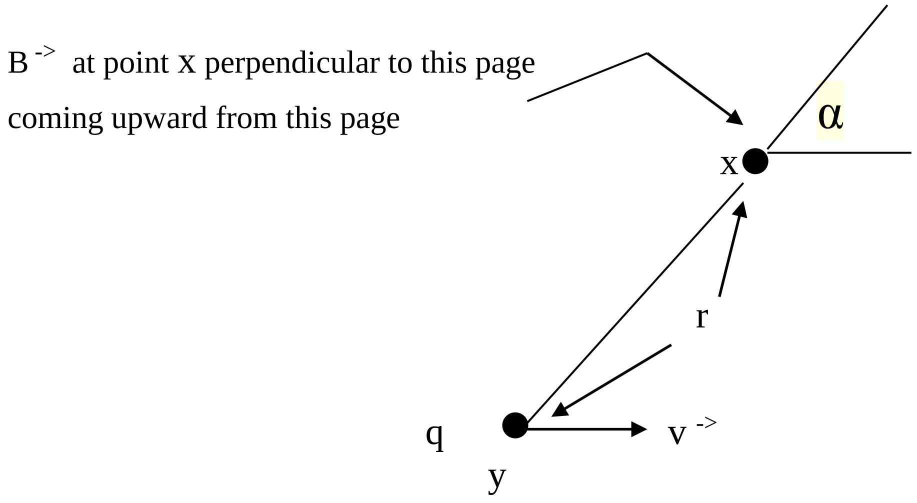

Fig. 2

The magnetic field $B^{->}$ is expressed by the formula:
(Ref 4)

$$B^{->} = (\mu_0/(4\pi))(q(v^{->} X \ r^{->})/r^2)$$

Where μ_0 is the vacuum magnetic permeability and is equal to:
$4\pi 10^{-7}$ H/m (Henry per meter).

Where $B^{->}$ is a vector which is the result of the vector multiplication of $\mathbf{v}^{->}$ and $r^{->}$, where $\mathbf{v}^{->}$ is the charge velocity vector and $r^{->}$ is a unit vector in the direction of the line xy.

The result of the vector multiplication of $\mathbf{v}^{->}$ and $r^{->}$ also give the magnitude of $B^{->}$ which is given by the following formula:

$$|B^{->}| = (\mu_0/(4\pi))((qv\sin \alpha)/r^2)$$

Where v is the magnitude of $v^{->}$ ($|v^{->}|$)

3. The force $F^{->}_E$ exerted on a point charge q residing in an electric field $E^{->}$ is expressed by the following formula:
(Ref 3)

$$F^{->}_E = E^{->} q$$

Where $F^{->}_{E}$ is a vector in the direction of the electric field $E^{->}$ whose magnitude is:

$$|F^{->}_{E}| = |E^{->}|q$$

4. The force $F^{->}_{B}$ exerted on a moving point charge q moving in a magnetic field $B^{->}$ at a constant velocity $v^{->}$ is shown in Fig. 3:

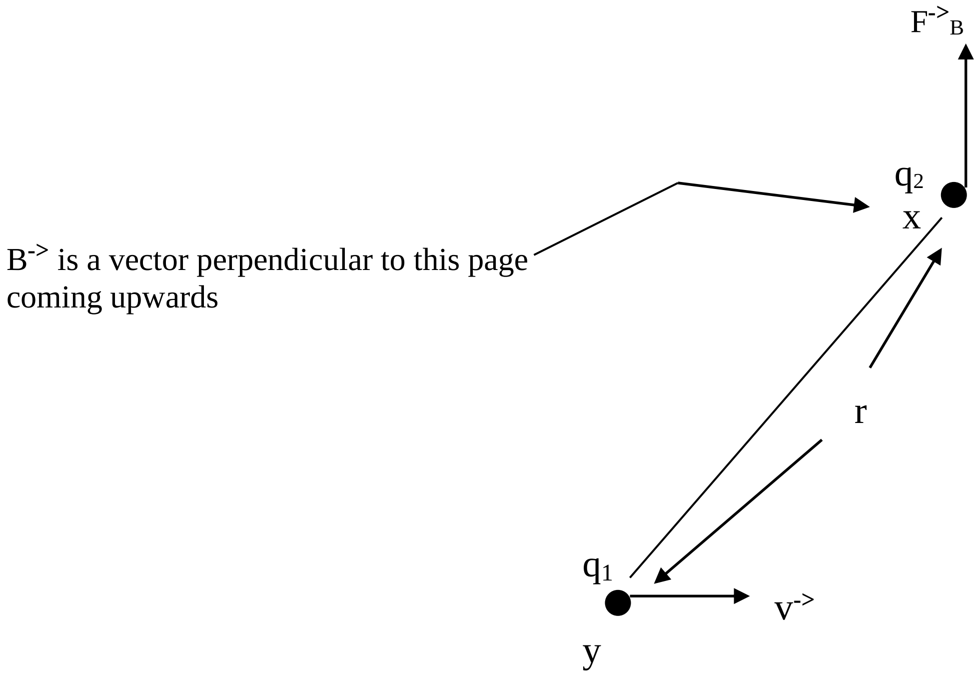

Fig. 3

The force $F^{->}_{B}$ is expressed by the following formula:
(Ref 5)

$$F^{->}_{B} = q\,(v^{->} \;X\; B^{->})$$

where $F^{->}_{B}$ is a vector resulting from the vector multiplication of $v^{->}$ and $B^{->}$.

The magnitude of $F^{->}_{B}$ is given by the following formula:

$$|F^{->}_{B}| = (\mu_0/(4\pi))((q_1 q_2 v^2 \sin \alpha)/r^2)$$

Where q_1 is the point moving charge generating the magnetic field $B^{->}$, the charge q_1 is moving at constant velocity v to the right from point y. q_2 is a point charge at point x at a distance r from y. q_2 is actually moving at a constant velocity v to the left relative to the magnetic field $B^{->}$, since $B^{->}$ is a magnetic field moving at a velocity v to the right since it is generated by the point charge q_1 moving at constant velocity v to the right.

Analysis

Now we can continue and add our assumptions that the magnetic field of a moving charge is a result from an increase of the charge magnitude because of its velocity.

It should be noted that direct measurement of mass increase by velocity is actually impractical, because it requires movement of the mass at very high speed (about or more than 0.1 the speed of light), and executing direct measurement of the mass magnitude while it is travelling at that speed.

Similarly, the measurement of charge magnitude was done for non moving charges, and direct measurement of charge magnitude while it is travelling at very high speed is not practical. So, the assumption that charge magnitude increases by velocity, should not contadict the known knowledge today.

To derive the formula for the charge increase because of the charge velocity we will refer to Fig. 4 :

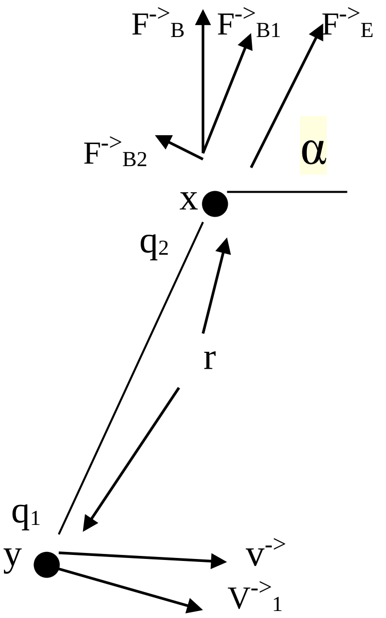

Fig.4

The charge q_1 at point y in space is a moving point charge, moving at a constant velocity v to the right. The charge q_2 is a point charge at point x in space, such that the line xy is at a distance r from y.

We will also give the notation q_{10} to the charge magnitude of q_1 when it is not moving and q_1 to its charge magnitude when it is moving, relative to an external spectator to the charge. In a similar way the notation q_{20} will be given to the charge magnitude of q_2 when it is not moving and q_2 to its charge magnitude when it is moving, relative to an external spectator to the charge.

The field $E^{->}$ is a vector in the direction of the line xy. The force $F^{->}_E$ is also a vector in the direction of the line xy and its magnitude is:

$$|F^{->}_E| = (1/(4\pi\varepsilon_0))(q_{10}q_{20}/r^2)$$

The field $B^{->}$ is a vector perpendicular to the plane where $v^{->}$ and the line xy reside and pointing upwards.

The force $F^{->}_B$ resides in the plane where $v^{->}$ and the line xy reside, is perpendicular to $v^{->}$ and points upward. The magnitude of $F^{->}_B$ is given by:

$$|F^{->}_B| = (\mu_0/(4\pi))((q_1q_2v^2\sin\alpha)/r^2)$$

In the equations of the force $F^{->}_B$ the moving point charges magnitudes q_1 and q_2 appear, which are bigger than q_{10} and q_{20} (for the non moving charges) which appeared in the equation for $F^{->}_E$, because q_1 is the moving charge that generated the magnetic field, and q_2 is a moving charge relative to the magnetic field that exerts forces on it.

The force $F^{->}_B$ can be disassembled into its two components, the one $F^{->}_{B1}$ parallel to $F^{->}_E$ and another, $F^{->}_{B2}$, perpendicular to $F^{->}_E$.

The magnitudes of these forces are:

$$|F^{->}_{B1}| = (\mu_0/(4\pi))((q_1q_2v^2\sin^2\alpha)/r^2)$$

$$|F^{->}_{B2}| = (\mu_0/(4\pi))((q_1q_2v^2\sin\alpha\cos\alpha)/r^2)$$

Since $F^{->}_{B1}$ is parallel to $F^{->}_E$ it can be argued that it represents an increase to the electric force caused by an increase of the magnitude of the moving point charge q_1.

Thus, it can be argued that on point charge q_2 a bigger electric field exerts a bigger electric force $F^{->}_{E}$(bigger) by the moving charge at q_1.

Also, since it is an electric force, it can be expressed by the formula that describes the forces exerted by electric fields on charges.

However, it is a bigger force, since it is a force generated by a moving charge q_1, and thus has a bigger magnitude comprared to a non moving charge q_{10}, and it is exerted on a moving charge q_2, moving relative to the magnetic field generated by point charge q_1, and thus, q_2 is also a bigger charge, as compared to the non moving charge q_{20}.

So, it can be argued that:

$$\vec{F}_E(\text{bigger}) = (1/(4\pi\varepsilon_0))(q_1q_2\,\vec{r}/r^2)$$

Then

Since $\vec{F}_E(\text{bigger}) = \vec{F}_E + \vec{F}_{B1}$

And since $\vec{F}_E$ is parrallel to $\vec{F}_{B1}$ and both are at the same direction, then

$$|\vec{F}_E(\text{bigger})| = |\vec{F}_E| + |\vec{F}_{B1}|$$

Then

$$(1/(4\pi\varepsilon_0))(q_1q_2/r^2) = (1/(4\pi\varepsilon_0))(q_{10}q_{20}/r^2) + (\mu_0/(4\pi))((q_1q_2v^2\sin^2\alpha)/r^2)$$

Since $\mu_0 = 1/(\varepsilon_0 c^2)$ (Ref 4) then

$$(1/(4\pi\varepsilon_0))(q_1q_2/r^2) =$$
$$= (1/(4\pi\varepsilon_0))(q_{10}q_{20}/r^2) + (1/(4\pi\varepsilon_0 c^2))((q_1q_2v\sin^2\alpha)/r^2)$$

This results in:

$$q_1q_2(1 - (v^2\sin^2\alpha/c^2)) = q_{10}q_{20}$$

From which q_1 and q_2 are derived from q_{10} and q_{20} as:

$$q_1 = q_{10}/((1 - (v\sin\alpha)^2/c^2))^{1/2}$$

$$q_2 = q_{20}/((1 - (v\sin\alpha)^2/c^2))^{1/2}$$

Now, $v\sin\alpha$ is the component of $\vec{v}$ which is perpendicular to the line xy which connects q_1 and q_2. This component is denoted $\vec{v}_1$. It should also be noted that the line xy is the line that connects each of the point charges q_1 and q_2, to the specific charge spectator, since the spectator of point charge q_1 reside where q_2 resides, and the spectator of point charge q_2 resides where q_1 resides, as will be explained immediately in the next paragraph.

So, the equations for q_1 and q_2 become:

$$q_1 = q_{10}/((1 - v_1^2/c^2))^{1/2}$$

$q_2 = q_{20}/((1 - v_1^2/c^2))^{1/2}$

Very similar to the equation that describes the increase of mass by velocity:

$m = m_0/((1 - v^2/c^2))^{1/2}$

As already mentioned above, it should be noted that when we talk about external spectators, the external spectators for the charges q_1 and q_2 are different spectators.

The external spectator for the point charge q_1 at point y in space is a spectator at point x in space where q_2 reside. This spectator measures the q_1 point charge by evaluating the fields and the forces q_1 creates at point x in space. For this spectator q_1 is moving with a constant velocity v to the right.

The external spectator for the point charge q_2 at point x in space is a spectator at point y in space where q_1 resides. This spectator measures the q_2 point charge by evaluation the motion of the q_2 point charge in the fields that q_1 created at point x in space. For this spectator q_2 is moving with a constant velocity v to the left relative to the magnetic field $B^{->}$ generated by q_1.

In addition to the above, apart from increasing the forces exerted by the electric field by the component $F^{->}_{B1}$, the velocity of the point charge q_1 also generates another force $F^{->}_{B2}$, as already noted, which is perpendicular to $F^{->}_{B1}$ (and thus, perpendicular to the increased electric field) and whose magnitude is : (as noted before)

$|F^{->}_{B2}| = (\mu_0/(4\pi))((q_1 q_2 v^2 \sin\alpha\cos\alpha)/r^2)$

Thus, it should be noted that, from the above, the velocity of a point charge q_1 actually create not just a single field, which is called today "the magnetic field", but two moving field components. One of these moving field components is a moving electric field component, which exerts the force $F^{->}_{B1}$ on point charge q_2. Another moving field component is the one that exerts the force $F^{->}_{B2}$ on point charge q_2 and it can be seen as the actual magnetic field created. These two moving field components are moving since they are created by the moving q_1 point charge. Also, these two moving field components are perpendicular to each other. Thus, they resemble and might be related to the electromagnetic emission from moving charges.

The Energy Pairs Theory

The assumption that charge is another form of energy can be used to provide an explanation to a magnetic field potential energy conservation paradox.

This magnetic field potential energy conservation paradox is described as follows:

When a body is charged with electric charges of a certain polarity (such as positive electric charges) and a certain amount of charge, and the body is moved at a spcific constant speed in a certain direction, it creates a magnetic field $B^{->}$ around it whose embeded energy per unit volume u is provided by the following formula:
(Ref. 6)

$$u = |B^{->}|^2/(2\,\mu_0)$$

Where μ_0 is the vacuum magnetic permeability and is equal to:
$4\pi 10^{-7}$ H/m (Henry per meter).

While the magnetic field $B^{->}$ was already shown in this article to be described by:

$$B^{->} = (\mu_0/(4\pi))(q(v^{->} \text{ X } r^{->})/r^2)$$

(Ref. 4)

When a second body is charged with electric charges of the opposite polarity (negative electric charges) but with the same amount of charge, and that body is also moved at the same constant speed in the same direction, it creates a magnetic field in the same space volume, whose magnitude is still expressed by the same formula that describes the magnetic field $B^{->}$ created by the first body when it was moved, but its direction (or polarity) is inverse to the polarity of the magnetic field $B^{->}$ that the first body created when it was moved. But, the embeded energy per unit volume of the magnetic field created by that second body is still expressed by the formula presented before for energy per unit volume in a magnetic field. (Ref. 6)

When both bodies are tied to an apparatus that keeps them very close to each other, (but inhibits them from being attracted completely to each other), and both bodies are moved together, at the same speed, in the same direction, no magnetic field is created arount them (or a negligible magnetic field, because the bodies are not exactly at the same point in space).

The reason why in that third case scenario basically no magnetic field was created is well understood.

Margnetic fields obey the superposition rule. Since the first body creates a magnetic field which has the same intensity, but inverse polarity compared to the magnetic field the second body creates, and both magnetic fields occupy the same volume in space, they cancel each other, and basically no magnetic field is created in that volume in space.

However, there is still a paradox, concerning the conservation of the energy embeded in these two magnetic fields.

The first body does not "know" that a second, inverse magnetic field is created, and it still creats is own magnetic field. This magnetic field embeds an energe per unit volume described by the formula above (Ref. 6). The same is true for the second body. So, the fact that each field cancels the other, contradicts the energy conservation principle, since the energies of both fields also disappear.

A logical explanation to that paradox might be the assumption, that certain energies, such as magnetic fields embeded energies, come in an Energy Pairs form, such that the member in that pair that has smaller intensity, can cancel the the amount of energy of the other member in that pair which is equal to its energy intensity, if both happen to coexist in the same space volume.

From the above, it is obvious that the Energy Pair for magnetic fields contains the following two energy types: one type is the energy embedded in magnetic fields created by positive charges, the other type is the energy embedded in magnetic fields created by negative charges.

The Energy Pairs assumption is actually derived from the assumption that charge is another form of energy, because such energy must have two values, one for the energy attributed to positive charges, and one for the energy attributed to negative charges.

This naturally results in the energy attribution (or type) assigned to the energy embeded in a magnetic field created by a positive charge, being different from the energy attribution (or type) assigned to the energy embeded in a magnetic field created by a negative charge. And, thus, these two types of magnetic energies belong to one set of Energy Pairs.

Thus, the assumption that charge is another form of energy, also provide the support for assuming that certain energies exist as Energy Pairs.

This brings about another conclusion which implies that energy conservation exists only when the total amount of energy in a specific volume in space contains only one member of energies which belong to this Energy Pairs.

Summary, Results and Conclusions

Before the presentation of the special theory of relativity, the science of physics recognized actually three distinct entities: energy, mass and charge.

After the presentation of the special theory of relativity, the mass ceased to be a distinct entity, and it is recognized as a special form of energy. So, now there are only two distinct entities: energy and charge.

Also, the special theory of relativity provided the explanation to the question what caused the kinetic energy of a moving mass. Its answer was that the increase in mass due the mass velocity is actually the kinetic energy of that mass.

Thus, in regard to the above, the questions why charge is still a distinct entity, and what cause the creation of the magnetic field created by a moving charge, remain open.

This article deals with these questions, by assuming that charge is also a special form of energy, that charge magnitude is not constant and increases by charge velocity, and that charge magnitude increase is the cause for the creation of the magnetic field.

Thus, if this assumption turns to be proved, the energy remains the only distinct entity, which turns to be a much simpler and cleaner view of nature.

Also by using these assumptions and by conducting a "thinking exercise" while analyzing the current equations from a new point of view, this article arrives at the following formula for the charge increase by velocity:

$$q = q_0/((1 - v_1^2/c^2))^{1/2}$$

This is very similar to the equation:

$$m = m_0/((1 - v^2/c^2))^{1/2}$$

Which describes the increase in mass when the mass is moving.

Moreover, the assumption that charge is a special form of energy was used to provide an explanation to a magnetic field potential energy conservation paradox.

This explanation also brought about another concept, the concept of Energy Pairs.

This concept states that certain potential energies, such as the potential energies embeded in magnetic fields, should exist as pairs of energies, such that the member in that pair that has smaller intensity cancels an energy portion equal to its energy amount of the other member in that pair, if both happen to coexist in the same space volume.

This brought about also another conclusion, which implies that energy conservation exists only when the total amount of energy in a specific volume in space contains only one member of energies which belong to this Energy Pairs.

Finally, a few comments about the methodology used in this article, and comments about possible future activities regarding the content of this article:

The assumptions that charge is a special form of energy, that charge increases by velocity and it is the cause for the creation of the magnetic field of a moving charge were presented here as claims, without direct proof.

However, the results of theses assumptions bring about new insights and aslo a resolution to a magnetic field energy conservation paradox.

Thus, although the article does not prove that energy is another form of energy, it points to the possibility that that might be the case. This should trigger further investigations in this matter, which might either discard this idea or strengthen it.

Although direct proof that charge increases by velocity might be impracticle, if a single polarity charge (such as an electron) can be annihilated completely to energy, and the resulting energy intensity will be greater than the mass converted to energy in this case, this might turn to be such a proof.

Such result was not demonstrated yet, although the annihilation and full conversion to energy of pairs of opposite polarities charges was demonstrated (such as converting pais of electron and positron to energy). But such conversion is not expected to generate additional energy, above the energy embeded in the converted masses, since they belong to one Energy Pair as assumed in this article.

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