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Corresponding Author: Mr Ustin Chashchikhin,

Corresponding Author's Institution: Moscow State University

First Author: Ustin Chashchikhin

Order of Authors: Ustin Chashchikhin

Explanation of the observed cease of annihilation of antiparticles at low energies and a correction of Dirac equation

Ustin Chashchikhin

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Moscow State University, Moscow, Russia

Abstract

It was demonstated experimentally that the annihilation rate of protons and antiprotons falls below the background at energies $\ll$ 1 eV - "no annihilation can be observed", "very long storage times for antiprotons have been demonstrated" [Holzscheiter M.H. et al, "Are antiprotons forever?", Phys. Lett. A214 (1996) p. 279].

This experimental fact cannot be explained by Dirac's theory of antiparticles (with negative energy levels) and by Quantum Field Theory (with motion back in time).

Therefore we need to improve and correct the modern theory of antiparticles. And this is the scope of this article.

I correct Dirac equation and explain this experimental fact from viewpoint of modern scientific knowledge. Quantum Field Theory and QED remain practically unchanged after my corrections of Dirac equation.

I present a physically correct description of both particles and antiparticles of both fermions and bosons, without negative energies and without particles travelling back in time.

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Contents

1 The experimental fact of cease of annihilation at low energies

It was demonstated experimentally that the annihilation rate of protons and antiprotons falls below the background at energies $\ll 1$ eV [1]. "No annihilation can be observed", "very long storage times for antiprotons have been demonstrated" [1].

This experimental fact is unexplainable by Dirac's theory of antiparticles (with negative energy levels) and by quantum field theory (with motion back in time) [2-20]. Both theories predict the opposite phenomenon - annihilation at any energies.

This experimental fact shows that we need to improve and correct the theory of antiparticles in order to explain the observed fact of stop of annihilation at energies $\ll 1$ eV [1]. And this aim is achieved in this work.

I correct Dirac equation in chapters 3 and 8. My correction of the Dirac equation fits both modern Quantum Field Theory and the above experimental fact.

2 The explanation of the experimental fact - activation energy barrier

Analogous phenomenon takes places at chemical reactions between atoms and molecules. There is the **activation energy barrier** in chemical reactions: if energy of initial particles is less than the activation energy barrier, the reaction does not occur. Energy $E \ll 1$ eV corresponds to temperature $T \ll 7700K$:

$$T = 2E/3k \sim 7700K$$

where k is Boltzmann constant, $k = 1.38 * 10^{-23} J/K$. Compare: activation energies of most chemical reactions are $\sim$ 100...500 K $\ll$ 7700 K.

Therefore I offer the explanation of the observed experimental fact: **annihilation reaction has activation energy barrier which is $\approx$ 1 eV. And antiprotons having energy less than the activation energy barrier of the $p\bar{p}$ annihilation reaction, cannot annihilate due to lack of kinetic energy.**

If annihilation reaction has an activation energy barrier, also as chemical reactions, then annihilation of particle and antiparticle is not relaxation to a negative energy level, is not like electron-hole recombination in semiconductors. But it is a usual colliding reaction between material particles, like nuclear reactions between particles or nuclei and like chemical reactions between atoms and molecules.

Therefore, in order to explain this experimental fact, we have to admit that antiparticles are **normal physical objects**, but are not holes at Dirac's negative energy levels and are not particles moving back in time (in quantum field theory). We have to admit that "negative energy" has not physical sense and "motion back in time" contradicts causality principle.

In order to do this, I correct Dirac equation (chapter 8).

My theory of antiparticles can be tested experimentally. It predicts that not only antiprotons, but also **all pairs particle-antiparticle must not annihilate at energies $\ll 1$ eV** because any reaction, including annihilation reaction, has activation energy barrier.

3 Negative momentum vector has sense, while negative energy scalar has not sense

In order to explain the observed experimental fact [1] I correct Dirac equation. And in order to make a proper correction of Dirac equation, I have to revise Dirac's theory from the very beginning.

Energy E of a relativistic particle with mass m and momentum $\mathbf{p}$ is described by the formula:

$$E^2 = \mathbf{p}^2c^2 + m^2c^4 \tag{1}$$

This equation has 3 pairs of mathematical solutions:

$$\mathbf{p} = \pm\sqrt{E^2/c^2 - m^2c^2}$$

$$m = \pm\sqrt{E^2/c^4 - \mathbf{p}^2/c^2}$$

$$E = \pm\sqrt{\mathbf{p}^2c^2 + m^2c^4}$$

While Dirac saw only the third pair of solutions - with negative energies, but did not see first and second pairs [2-9]. If Dirac were right, then you have to take into account the full set of solutions - with negative masses, negative energies and negative momenta!

These 6 solutions of the equation (1) correspond to $2^3 = 8$ combinations which correspond to a particle with SEVEN (7) antiparticles with positive and negative masses, positive and negative energies and positive and negative momenta.

If Dirac were right, then you have to take into account the full set of solutions - all 6 solutions (8 combinations) with negative energies, negative masses and negative momenta. Yes, I have proved that Dirac's theory predicts 7 antiparticles for any particle! But this contradicts experiment - really any particle has one antiparticle (or zero, as e.g. photon), but not 7 antiparticles.

Therefore you have to admit the fact that Dirac was wrong.

Therefore, in order to describe particles and antiparticles, we need only **one pair of solutions! Therefore we must rule out other 2 pairs of solutions!** But which exactly? And why?

Which of these solutions are a physically correct description of a pair particle-antiparticle? And which are not?

Please pay attention that only momentum $\mathbf{p}$ is a vector here, while mass m and energy E are scalars. Vectors can be negative, while scalars canNOT be negative. **Negative vectors do exist - negative and positive momentum vectors show opposite directions in space, while negative scalars - mass and energy - are senseless!** *Specially for those editors who don't understand negative momentum idea, I have to say the following. For instance, if two particles inside of a collider - e.g. a proton and an antiproton - move towards each other in the same electromagnetic field, then they have* **opposite momenta - positive momentum and negative momentum**. *Yes, colliding protons and antiprotons have same positive masses, same positive energies, but opposite momenta - negative and positive.* When two any objects (e.g. cars or particles) move to each other or from each other, they have negative and positive momenta.

Therefore I rule out solutions with negative masses and negative energies, and thus I leave only solutions with negative momentum. According to my theory, colliding protons and antiprotons have same positive masses, same positive energies, but opposite momenta - negative momentum and positive momentum.

Be honest to yourself and admit that **negative energy and negative mass were never observed experimentally, while negative vector of momentum is a very usual thing which is observed experimentally every day everywhere by all of you.**

Dirac saw only one solution - with negative energies [2-5]:

$$E = \pm\sqrt{\mathbf{p}^2 c^2 + m^2 c^4}$$

Dirac did not saw and did not analyze the solutions with negative momenta and negative masses. Negative mass is as absurd as negative energy because both are scalars. Dirac made a big error when he ignored negative momentum and chose negative energy. Dirac described antiparticles as holes at fantastic negative energies' levels [2-5]. However Dirac's solution with negative energies:

$$E = -\sqrt{\mathbf{p}^2 c^2 + m^2 c^4} \tag{2}$$

leads to many contradictions [1, 8-9] which are discussed in chapter 6.

I offer another solution of (1) which eliminates negative energies and solves all problems of Dirac's theory of antiparticles - **vector of momentum $\mathbf{p}$ can be negative, it is normal for vectors. Negative and positive vectors show opposite directions in space.** My solution is:

$$\mathbf{p}^2 c^2 = E^2 - m^2 c^4$$

$$\mathbf{p} = \pm\sqrt{E^2/c^2 - m^2 c^2} \tag{3}$$

Energy and mass are scalars, absolute values. Scalars do not accept negative values, only vectors do. Therefore energy and mass accept positive values only (2). *Only momentum* $\mathbf{p}$ is vector in (1), therefore *only momentum* $\mathbf{p}$ *can accept* *negative values. Therefore the physically correct solution of (1) is (3). Negative energies have not physical sense* - also as negative volume, negative absolute temperature etc. Negative scalars have not physical sense. Dirac's solution (2) is just a mathematical abstraction without any physical sense, also as negative masses. Only my solution (3) with negative momentum and positive energies has physical sense.

For a *vector quantity momentum* **p** *negative values are quite natural and physically correct.* So, there are 2 sets differing in momentum **p** and (**-p**), one has positive momentum and the other has negative momentum:

$$E_1 = E_2 = \sqrt{\mathbf{p}^2 c^2 + m^2 c^4} > 0 \qquad (4a)$$

$$m_1 = m_2 = \sqrt{E^2/c^4 - \mathbf{p}^2/c^2} > 0$$

$$\mathbf{p}_1 = \sqrt{E^2/c^2 - m^2 c^2} > 0$$

$$\mathbf{p}_2 = -\mathbf{p}_1 = \sqrt{E^2/c^2 - m^2 c^2} < 0 \qquad (4b)$$

It is naturally to identify them with particle and antiparticle.

Since parity changes p into (-p), then I consider antiparticle as the mirror image of its particle. According to my theory, particles have structure, they are not point like. This description is much more natural, than negative energies.

And if Dirac's solution (2) were true, then solutions with negative masses:

$$m = -\sqrt{E^2/c^4 - \mathbf{p}^2/c^2}$$

would be true also because they obey (1) also; and Dirac cannot ignore them too because he needs full set of solutions. We need **physically** full set of solutions (4), but **not mathematically** full one (2). Physically full set of solutions is only (4) because only (4) corresponds to domains of functions E, **p**, m, where E and m are scalars and **p** is vector. But negative (also as imaginary and complex) scalars have **no physical sense** because scalar (energy, mass, temperature, frequency, length, magnitude of vector etc.) has physical sense only as an absolute value, i.e.

$$E > 0$$

$$m \geq 0$$

therefore for **physical quantities**, (1) is true then and only then when (4) is true. Thus, the correct solution of (1) must be written mathematically so:

$$\left\{ \begin{array}{r} \mathbf{p}^2 = E^2/c^2 - m^2 c^2 \\ E > 0 \\ m \geq 0 \end{array} \right. \Rightarrow \left\{ \begin{array}{c} (3), (4) \\ E > 0 \\ m \geq 0 \end{array} \right.$$

4 Antiparticles and asymmetric molecules: equal scalar properties and opposite vector properties

There is a big similarity between pair particle-antiparticle and asymmetric molecules. All scalar properties of asymmetric molecules are equal, and all their vector properties are opposite [21]. And all scalar properties of particle and antiparticle are also equal and all vector ones are also opposite. An asymmetric molecule and its mirror image differ in structure - they are right and left, they are called enantiomers in organic chemistry [21]. For asymmetric molecules $\bar{X} = CX = PX$ and $C = P$.

This may be used for construction of the new theory of antiparticles. Particle and antiparticle may be considered as mirror images of each other which differ in internal structure - right and left: $\bar{X} = CX = PX$ and $C = P$. So, the theory predicts internal structure of particles and antiparticles.

5 C and P symmetries

I solved equation (1) physically correctly (3)-(4). My solution describes antiparticles without negative energies and with negative momentum. Particle and antiparticle are transformed into each other by such symmetry operation where **p** becomes (**-p**). Two inversions do it: P and T. The momentum is:

$$\mathbf{p} = m\mathbf{v}/\sqrt{1 - v^2/c^2} = m\frac{\Delta\mathbf{r}}{\Delta t}\frac{1}{\sqrt{1 - v^2/c^2}} \tag{5}$$

Let, $\Delta\mathbf{r} \gg \lambda$. For momentum to be negative, either **r** or t must change the sign. Since antiparticles are not particles travelling back in time (chapter 6.2), then particle and antiparticle are transformed into each other by parity operator. This means that they (their wave functions) are mirror images of each other - right and left:

$$\bar{X} = PX \tag{6}$$

While by definition $\bar{X} = CX$. Hence, *for subatomic particles* $C = P$. So again we see that particles and antiparticles differ in parity like asymmetric molecules.

6 Other doubts in previous descriptions of antiparticles

6.1 Antiparticles of bosons

The first objection against Dirac's model is the existence of bosons.

Dirac's description of antiparticles was founded on error (2) and on Pauli principle for fermions. But bosons relax and accumulate together in the lowest energy state. Therefore if Dirac's model were true, all bosons would relax to the lowest energy state, emitting infinite energy. So, according to Dirac's theory, bosons could not have antiparticles and could not have positive energy. These errors of Dirac's solution contradict experiment - it's well known that bosons exist and have antiparticles too.

Hence existence of bosons and existence of antiparticles of bosons show that the lowest energy level is mc^2, but not negative energies. Consequently, Dirac solution (2) [2-5] of (1) is physically incorrect and must be ruled out.

6.2 Doubts in motion back in time

1. Antiparticles are considered in quantum field theory as particles traveling back in time [6-7]. This fantastic description also follows from Dirac's error -

a negative value must not be ascribed to a scalar. Time is scalar, not vector - also as energy and mass. Neither time nor energy nor mass can have a negative value. Because negative scalar has not physical sense.

The concept of "particles travelling back in time" contradicts causality principle. Therefore it is wrong.

Time travels, but not "particles travel in time". Otherwise particles would travel in time at *different speeds - ones would pass from past to future quicker than others do*, as motion in space where particles travel. However all particles and light everywhere travel from past to future at the same speed, even if they aren't causally bound with each other, in different galaxies. Hence *direction of time is same everywhere for all particles and time doesn't travel back anywhere. Hence antiparticles are not particles traveling back in time.* This description has not physical sense too.

If antiparticles were particles traveling back in time, then muon decay would be a collision:

$$\mu^- + \nu_{e(back\ in\ time)} \to e^- + \nu_\mu$$

Hence, particles (muon) would be stable until the chance of collision. Hence their life-time wouldn't be defined precisely, but would be a chance value. Hence antiparticles are not particles travelling back in time. The physical cause of the formation of antineutrino is the decay of the muon.

6.3 Annihilation is not relaxation

At relaxation only one photon is emitted, but at annihilation two or three photons are formed. Moreover, many other particles are formed at high energy annihilation at colliders. This does not take place at relaxation. Hence, *annihilation of particle and antiparticle is not relaxation of a particle to a free negative energy level.*

My theory explains these experimental facts very easily: annihilation is not relaxation, but is a usual reaction between two material objects as all chemical or nuclear reactions.

6.4 Other contradictions

Dirac just supposed that all particles at negative energy levels aren't observable [2-5]. He did not prove that. However fermions at negative energy levels would absorb photons of sufficient energy as atomic electrons do. High energy photons just moving in vacuum would produce pairs from vacuum because they would be absorbed by particles at negative energy levels, i.e. *they could not fly without pair production.* However we are able to register high energy cosmic ray photons which flew very great distances without pair production. This shows that Dirac's vacuum (with infinite quantity of particles at negative energies) does not exist. Hence pair production is not absorption of photon.

Dirac's model of antiparticles describes antiparticles incorrectly. All contradictions of Dirac's model were accepted because it predicted antiparticles of only fermions which are then observed experimentally, *but not because of logical harmony of Dirac's theory.* Therefore we need a new theory without contradictions. This is the subject of the present work.

7 New solutions of Klein-Gordon-Fock equation

It's usually accepted [7] that Klein-Gordon-Fock equation

$$\nabla^2\Psi - \frac{\partial^2\Psi}{c^2\partial^2 t} - \frac{m^2c^2\Psi}{\hbar^2} = 0 \tag{8}$$

has two solutions

$$\Psi_1 = Ae^{-iET/\hbar + i\mathbf{pr}/\hbar}$$
$$\Psi_1 = Ae^{iET/\hbar + i\mathbf{pr}/\hbar}$$

and it's accepted [7] also that $\Psi_2 = T\Psi_1 = C\Psi_1$ is particle travelling back in time [7]. However this is wrong (chapter 3.2), hence Ψ_2 doesn't exist and

$$\Psi_2 \neq C\Psi_1$$

This conception predicts here that neutral spin 0 bosons (π^0, η^0) have antiparticles, but this is wrong. They have not.

Due to (5) T**p = -p**, hence

$$\Psi_2 \neq T\Psi_1 \tag{9}$$

$$\Psi_3 = T\Psi_1 = Ae^{iET/\hbar - i\mathbf{pr}/\hbar}$$
$$\Psi_3 = T\Psi_2 = Ae^{-iET/\hbar - i\mathbf{pr}/\hbar}$$

i.e. π^0 would have 3 antiparticles, but this is wrong. Hence, some solutions of (8) are wrong and must be ruled out. For reasons discussed in chapter 3.2 we must rule out inverted in time functions Ψ_3 and Ψ_4. Note that (9) and

$$\Psi_2 \neq P\Psi_1$$

i.e. though Ψ_2 obeys (7), but it has negative energies and must be ruled out too. Then there remains only Ψ_1:

$$\Psi_1 = P\Psi_1$$

It describes spin 0 particle π^0, which coincides with its antiparticle.

8 Correction of Dirac equation

Let's consider Dirac equation

$$(\gamma^\mu p_\mu + m)\Psi_\mu = 0$$

where $\mu = 1, 2, 3, 4$ and

$$\gamma_0 = \begin{pmatrix} I & 0 \\ 0 & -I \end{pmatrix}; \quad \gamma_\alpha = \begin{pmatrix} 0 & \sigma_\alpha \\ -\sigma_\alpha & 0 \end{pmatrix}; \quad \alpha = 1, 2, 3$$

$$I = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}; \quad \sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

$$\sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}; \quad \sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

where σ_α are Pauli matrices).

Since negative energies don't exist, and (6) is true, then Dirac equation based on incorrect (2), describes positron incorrectly. Therefore it must obey (6), i.e. second pair of equations describing positron with spin $\pm 1/2$ must be got from the first pair

$$i\hbar\partial\Psi_1/\partial t = mc^2\Psi_1 + c(p_x - ip_y)\Psi_4 + cp_z\Psi_3$$
$$i\hbar\partial\Psi_2/\partial t = mc^2\Psi_2 + c(p_x + ip_y)\Psi_3 - cp_z\Psi_4$$

by change

$$\Psi_3 = P\Psi_1 = -\Psi_1$$
$$\Psi_4 = P\Psi_2 = -\Psi_2$$

(for electron and proton P= -1 because they have antiparticles). This leads to new equations

$$i\hbar\partial\Psi_3/\partial t = mc^2\Psi_3 + c(p_x - ip_y)\Psi_2 + cp_z\Psi_1$$
$$i\hbar\partial\Psi_4/\partial t = mc^2\Psi_4 + c(p_x + ip_y)\Psi_1 - cp_z\Psi_2$$

and new matrices

$$\gamma_0 = \begin{pmatrix} I & 0 \\ 0 & I \end{pmatrix}; \quad \gamma_\alpha = \begin{pmatrix} 0 & \sigma_\alpha \\ \sigma_\alpha & 0 \end{pmatrix}; \quad \alpha = 1, 2, 3$$

which describe positive-energy positron corresponding to (4b) and (6). *Note that the constraint of obeying (6) automatically deletes negative energies from Dirac equation!* My corrected equation is relativistically invariant also as the original Dirac equation [2-5], but it:

1. is without negative energies.
2. correctly and naturally describes spin 1/2 particle and antiparticle,
3. has corrected matrices γ^μ,
4. obeys (3)-(4), (6).

Relativistic corrections to fine structure of atomic energy levels depend on Pauli matrices, but not on Dirac matrices [22]. Therefore in the present theory they are the same as in Dirac's model of antiparticles [2-5, 21]. Spin is $j = \gamma^3\hbar/2$, also as in Dirac's model. Determinants of matrices are not changed in my theory.

9 Conclusions

You see that Dirac's model of antiparticles wrongly describes antiparticles, contradicts experiment [1] and logic.

My theory explains experiment [1] and is physically correct. My theory of antiparticles predicts that **all pairs particle-antiparticle must not annihilate at energies $\ll 1$ eV**. And this can be verified experimentally.

My new theory of antiparticles provides unified description of antiparticles of both fermions and bosons by one equation $C = P$, corrects Dirac equation, solves all problems of previous models. I explain why bosons also may have their antiparticles. Asymmetric particles are mirror images - right and left. Symmetric particles coincide with their mirror images.

We have to reject Dirac's theory of antiparticles with its fantastic "negative energy levels".

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