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Methods for Solving Problems of Conservation Laws in the Section of Elementary Particle Physics

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***Abstract**: This article is devoted to the conservation laws of Elementary Particle Physics, those have a universal and approximate nature, that is, some of them are enforced in all possible interactions and have a universal character, and some of them is enforced in some interactions only and violated in others, mainly to the conservation laws of baryons and leptons.*

***Keywords:** elementary particle physics, the principle of intersubject interdisciplinary, baryonic and leptonic conservation laws.*

I. INTRODUCTION

Extensive research is being carried out to improve the efficiency of students development of Elementary Particle Physics on the basis of the principle of interdisciplinary communication [1-3]. For this, aspects of the conservation laws of Elementary Particle Physics were studied in relation to the application of other sections of physics and chemistry [2] and the role of this section in relation to other disciplines from the point of view of the object of research [3]. It is known that, unlike other branches of physics, the conservation laws in Elementary Particle Physics have a universal and approximate nature, that is, some of them are enforced in all kinds of interactions and have a universal character. some are preserved in some interactions, while in others they are violated, that is, they are approximate [4]. In this study, the laws of conservation of baryon and lepton charges, their great importance are described. Universal conservation laws are fulfilled in all basic interactions, and in approximate laws - only in some.

Laws of conservation of energy, momentum, and angular momentum are universal conservation laws. The conservation laws of all charges also universal conservation laws (we will discuss them below) [5].

The need to introduce charges (other than electricity) was compared with experimental data, which could only explain the existence of charges of a non-electrical nature. Each of these charges describes a certain intrinsic property of the particle.

II. MATERIAL AND METHODS

For elementary particles, much more conservation laws are satisfied than for macroscopic processes. All these laws are subdivided into exact and approximate ones. Exact conservation laws are fulfilled in all fundamental interactions, and approximate ones - only in some.

The laws of conservation of energy, momentum and angular momentum are exact. The laws of conservation of all charges are also exact (we will talk about them below).

The need for the introduction of charges (other than electric) was dictated by experimental facts, which could be explained only under the condition that there are charges of a non-electric nature, which are also conserved. Each of these charges characterizes some internal property of the particle.

Five charges are established: electric Q, baryonic B, and three lepton ones L_e, L_μ, L_r. For all elementary particles, these charges have only integer values (Q charge is the number of units of elementary charge e).

Baryon charge. If baryons and anti baryons are assigned a baryon charge such that

$$B = \begin{cases} +1 \text{ for baryons(nucleons and hyperons)} \\ -1 \text{ for antibaryons} \end{cases},$$

and all other particles have a baryon charge $B = 0$, then for all processes involving baryons and antibaryons the total baryon charge will be conserved. This is called the baryonic charge conservation law.

For example, this conservation law determines the stability of the lightest of baryons - the proton, inhibiting the process

$$p \to e^+ + \gamma$$

which would ultimately lead to the annihilation of atoms, since the resulting positrons would annihilate with the electrons of the atomic shells.

It follows from the same law that an antibaryon can be born only in a pair with its own baryon. For example, an antiproton is born in the reaction

$$p + p \to p + p + p + \overline{p}$$

The law of conservation of electric charge determines the stability of the lightest charged particle - an electron, forbidding, for example, the process

$$e^- \to \gamma + \gamma + \nu$$

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although it is permitted by all other conservation laws.

Lepton charges (numbers). There are three types of lepton charges: electronic L_e (for e and ν_e), muon (μ for and ν_μ) and tau L_τ (τ for and ν_τ). Here ν_e, ν_μ, ν_τ - electron, muon and tau neutrino, respectively. It follows from the experiment that these are different neutrinos.

We agreed to consider that

$$L_e = L_\mu = L_\tau = \begin{cases} +1 \text{ for leptons} \\ -1 \text{ for antileptons} \end{cases}$$

For all other elementary particles, lepton charges are taken to be zero.

The law of conservation of the lepton charge requires that during neutron decay

$$n \to p + e^- + \tilde{\nu}_e$$

together with the electron, an electron antineutrino was born, since the total lepton charge of these two particles is zero.

The law of conservation of lepton charge explains the impossibility of the following processes:

$$\nu_e + p \nrightarrow e^+ + n, \qquad \nu_\mu + p \nrightarrow \mu^+ + n$$

although they are permitted by other conservation laws. The processes

$$\tilde{\nu}_e + p \to e^+ + n, \qquad \tilde{\nu}_\mu + p \to \mu^+ + n,$$

satisfying the lepton charge conservation law were observed experimentally. After it was experimentally established that ν_e and ν_μ are different particles, different lepton charges L_e and L_μ were introduced. Similarly, the situation was with the introduction of the tau lepton charge L_τ [6-7].

III. RESULTS

We consider some problems below.
Example1: Baryon number conservation.

Based on the law of conservation of baryon number, which of the following reactions can occur?

$a)\ \pi^- + p \to \pi^0 + n + \pi^- + \pi^+$

$b)\ p + \overline{p} \to p + p + \overline{p}$

Strategy

Determine the total baryon number for the reactants and products, and require that this value does not change in the reaction.

Solution

For reaction (a), the net baryon number of the two reactants is $0+1=1$ and the net baryon number of the four products is $0+1+0+0=1$.

Since the net baryon numbers of the reactants and products are equal, this reaction is allowed on the basis of the baryon number conservation law.

For reaction (b), the net baryon number of the reactants is $1+(-1)=0$ and the net baryon number of the proposed products is $1+1+(-1)=1$. Since the net baryon numbers of the reactants and proposed products are not equal, this reaction cannot occur.

Significance

Baryon number is conserved in the first reaction, but not in the second. Baryon number conservation constrains what reactions can and cannot occur in nature.

Example2: Lepton number conservation

Based on the law of conservation of lepton number, which of the following decays can occur?

$a)\ n \to p + e^- + \overline{\nu}_e$

$b)\ \pi^- \rightarrow \mu^- + \nu_\mu + \bar{\nu}_\mu$

Strategy

Determine the total lepton number for the reactants and products, and require that this value does not change in the reaction.

Solution

For decay (a), the electron-lepton number of the neutron is 0, and the net electron-lepton number of the decay products is $0+1+(-1)=0$.

Since the net electron-lepton numbers before and after the decay are the same, the decay is possible on the basis of the law of conservation of electron-lepton number. Also, since there are no muons or tau-leptons involved in this decay, the muon-lepton and tau-lepton numbers are conserved.

For decay (b), the muon-lepton number of the π^- is 0, and the net muon-lepton number of the proposed decay products is $1+1+(-1)=1$.

Thus, on the basis of the law of conservation of muon-lepton number, this decay cannot occur.

Significance

Lepton number is conserved in the first reaction, but not in the second. Lepton number conservation constrains what reactions can and cannot occur in nature.

IV. CONCLUSION

Like the law of conservation of momentum, based on the isotropic nature of our ordinary space, a particular momentum-spin is conserved in all interactions. These conservation laws are fulfilled in all processes occurring with particles, and have the property of controlling all processes in the world of particles. When studying the physics of elementary particles, the analysis of the fulfillment of these conservation laws by the example of specific processes will undoubtedly help to increase the efficiency development of this field. To this end, the next task in studying the fundamentals of elementary particle physics is to create a database that unites various processes involving particles and provides interdisciplinary developments, control questions for their amplification, reflecting the mass, spin and other characteristics of particles. viewed as.

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