



Research Journal of **Physics**

ISSN 1819-3463



Academic
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www.academicjournals.com

Theoretical Proofs for the Negative Charge of the Neutron

Hassan Saadat

Department of Physics, Islamic Azad University, Marvdasht Branch, Marvdasht, 71555-477, Shiraz, Iran

ABSTRACT

In this study, we prove that the neutron has infinitesimal negative electrical charge which is also in agreement with the neutrality of the free neutron. In some previous experiments it has been shown that neutron have negative electrical charge of order 10^{-18} , now by using simple classical physics we confirm theoretically the results of the previous experiments and find that the infinitesimal negative charge of the neutron is due to gravity.

Key words: Gravity, neutron, conservation law, electromagnetic

INTRODUCTION

In the context of modern unified theories, such as string theory (Green *et al.*, 1987; Polchinski, 1998a, b), even an infinitesimal electric charge of the neutron would lead to important consequences. For example, if we assume that the charge conservation still valid then, a finite neutron charge implies that a neutron-antineutron transition is not allowed and this is in contrast with prediction of some theories (Glashow, 1979). In that case, the electric charge has to change its sign in such a transition. The electric charge determines the strength of the electromagnetic interaction of particles and tells that a particular reaction can take place or not. In that case, there are some experiments on the charge of electron, proton and neutron. The method of the experiment is to study the deflection of a molecular beam in a homogeneous electric field. The results agree with the principle that atoms and molecules have no net electric charge and they can be interpreted to provide an upper limit to the difference between the magnitudes of the electron and proton charges and also to the charge of the neutron. There have been many measurements in the past testing the neutrality of atoms, in that case only the sum of proton, electron and neutron charge is determined. These called indirect measurements and lead to neutron charge of order 10^{-21} (Baumann *et al.*, 1988) or 10^{-20} (Gahler *et al.*, 1982). Also a review of the various experiments has been given by Petley (1988). It is also conjectured that the negative infinitesimal charge of neutron can explained the rate of Universe expansion as an electric repulsion (Lyttleton and Bondi, 1959). In another word, the observed expansion of Universe would follow from a neutron charge of about $2 \times 10^{-18} q_e$, where q_e denotes electron charge. On the other hand the direct measurement on the neutron charge, based on the deflection of a neutron beam in a strong homogeneous electric field, yields to a limit on the neutron charge of order $q_n \approx -10^{-18} q_e$ (Shull *et al.*, 1967). In this way, the equality of electron and proton charges is crucial assumption which is important for the theory of elementary particles (Feinberg and Goldhaber, 1959; Gell-Mann, 1960). As we know the standard model of particle physics predicts a tiny separation of positive and negative charge within the neutron leading to a permanent electric dipole moment (Li *et al.*, 1994). It is clear that the standard model is not the final and full description of all particles and their interactions. New theories going beyond the standard model generally lead to much larger predictions for the electric dipole moment

of the neutron. One may think the electric dipole moment as origin of the negative charge of the neutron. In the recent study, it is noted that the neutron has a negatively charged exterior (Miller, 2007).

In this study, we are going to obtain measured value of the neutron charge by the simple ways of classical physics. We give two independent pictures and obtain same results.

THE FIRST PROOF

In this section, we consider macroscopic system involves two matters of deuteron, M_1 and M_2 , which separate their center of mass by distance of r . We assume that the system is in mechanical equilibrium. In that case, the electromagnetic and gravitational forces should cancel each other to give system at rest. There are five forces between two matters, one of them is gravity between M_1 and M_2 which is given by the following expression:

$$F_g = G \frac{M_1 M_2}{r^2} \quad (1)$$

where, $G = 6.67 \times 10^{-11}$ is the gravitational constant. Other forces are electromagnetic forces between the negative and positive charges of the mass M_1 and the negative and positive charges of the mass M_2 . We assume that the total negative electrical charge of deuteron denoted by \tilde{e} and total positive electrical charge of deuteron denoted by p . In that case one can write:

$$\tilde{e} = j p \quad (2)$$

where, the coefficient $j-1$ specifies charge of the neutron. If $j = 1$ then the neutron becomes neutral, but we will show that $j \neq 1$, so one can obtain charge of neutron. Therefore, one can write total electromagnetic force as the following;

$$F_k = -kn^2 \frac{\tilde{e}\tilde{e}}{r^2} + kn^2 \frac{\tilde{e}p}{r^2} + kn^2 \frac{p\tilde{e}}{r^2} - kn^2 \frac{pp}{r^2} \quad (3)$$

where, $k = 8.9874 \times 10^9 \text{ N.m}^2/\text{c}^2$ and n denotes total number of electron insight each matter. Therefore, n denotes total number of proton and neutron. Mechanical equilibrium tells that:

$$F_k + F_g = 0 \quad (4)$$

Comparing relations Eq. 1-4 yield to the following relation:

$$j-1 = \frac{1}{np} \sqrt{\frac{GM_1 M_2}{k}} \quad (5)$$

If we assume that $M_1 = M_2 = 1 \text{ kg}$, then one can obtain:

$$j-1 \approx 1.8 \times 10^{-18} q_e = -2.88 \times 10^{-37} e \quad (6)$$

As mentioned in the introduction, $q_n \approx -10^{-18} q_e$ agree with the measurements. Our calculations show that the origin of negative charge of neutron is gravity, so if one neglects gravity between M_1 and M_2 then $j-1 = 0$ and neutron becomes neutral.

THE SECOND PROOF

Here, we consider a microscopic system involve two atom of deuteron which separate by distance of r . Each of them includes an electron e , a proton p and a neutron n . As before, the system is in mechanical equilibrium. The gravitational force between the two deuterons is given by the following relation:

$$F_G = G \frac{(m_e + m_p + m_n)^2}{r^2} \quad (7)$$

where, $m_e = 9.1095 \times 10^{-31}$ kg, $m_p = 1.6726 \times 10^{-27}$ kg and $m_n = 1.6749 \times 10^{-27}$ kg are electron, proton and neutron masses, respectively. Other forces are electromagnetic forces between the electron, proton and neutron of the first deuteron and the electron, proton and neutron of the second deuteron. Therefore, one can write total electromagnetic force as the following relation:

$$F_k = -k \frac{(e + p + n)^2}{r^2} \quad (8)$$

As before, the mechanical equilibrium (4) together with original assumption of $e = -1$ and $p = 1$ yields to the following relation:

$$-k \frac{1+1+n^2-2-2n+2n}{r^2} + G \frac{(m_e + m_p + m_n)^2}{r^2} = 0 \quad (9)$$

Equation 9 reduced to $n \approx 1.8 \times 10^{-18} q_e = -2.88 \times 10^{-37} c$ which is exactly in agreement with the relation Eq. 6. So, microscopic and macroscopic pictures coincide with the experiment.

CONSEQUENCE OF INFINITESIMAL NEUTRON CHARGE

In the previous sections, by two independent ways, we show that the neutron is negatively charged. This infinitesimal negative charge may be affect on the neutron interactions. In that case, one can obtain charge of other neutral particles. Below, we list some important interactions involve neutron. Free neutrons decay by emission of an electron and an electron antineutrino to become a proton, a process known as beta decay:

$$n \rightarrow p^+ + e^- + \bar{\nu}_e \quad (10)$$

Neutrons in unstable nuclei can also decay in this manner. However, inside a nucleus, protons can also transform into a neutron via inverse beta decay. This transformation occurs by emission of a positron and a neutrino:

$$p^+ \rightarrow n + e^+ + \nu_e \quad (11)$$

or

$$p^+ + \bar{\nu}_\mu \rightarrow n + e^+ \quad (12)$$

The transformation of a proton to a neutron inside of a nucleus is also possible through electron capture:

$$p^+ + e^- \rightarrow n + \nu_e \quad (13)$$

Positron capture by neutrons in nuclei that contain an excess of neutrons is also possible but is disturbed because positrons are repelled by the nucleus and quickly annihilate when they encounter electrons. Also there is the other interaction where a baryon decays to neutron and a meson:

$$\Sigma^+ \rightarrow n + \pi^+ \quad (14)$$

Now, we would like to discuss about charge of the particles which participate in neutron interactions. The neutrality of the proton-electron systems (the neutrality of the hydrogen atom) and the Eq. 10 under assumption of charge conservation tell us that electron antineutrino should be charged by:

$$q_{\bar{\nu}} \approx 108 \times 10^{-18} q_e$$

Similarly from the Eq. 11 one finds that electron neutrino has positive charge with the same value of electron antineutrino charge. The Eq. 12 gives also similar result of the Eq. 10. Also the Eq. 13 gives similar result of the Eq. 11. In summary we find that electron neutrino and electron antineutrino is positively and negatively charged, respectively. Study of the interaction (14) is also interesting, in that case one can find Σ^+ should positively charged by $(1+1.8 \times 10^{-18})q_e$. It means that Σ^+ has positive charge less than one. Significant result is that charge of π^+ (and we conclude that all meson) not change and is equal one. By using these results one can find exact charge of other baryons.

CONCLUSION

In this study, by using the simplest ways, we tried to obtain charge of the neutron which already measured by the experiments. In the microscopic and macroscopic pictures we found that the neutron is negatively charged by $q_n \approx -10^{-18} q_e$. This value agree with the previous experiment where the neutron charge obtained by direct measurement. This value can explain expansion rate of the universe. Then, we considered some important interactions involve neutron and found that there are other neutral particles, such as neutrino which are infinitesimally charged. Moreover, we found exact charge of some baryonic particles. It should be noted that we used classical physics, so it is interesting to work in quantum physics. In that case, it is important to have a theory of

quantum gravity. So, some quantum effect, just as string loop effect (Saadat *et al.*, 2010), may be give us more excellent solutions. This point of view is the subject of our future study.

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