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Research Article

Induced Neutrino Charge for Line Spectrum From Spin Light of Neutrinos

Avijit K. Ganguly

Physics Department (MMV), Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India
avijitk@hotmail.com

Abstract. Induced neutrino charge for Dirac and Majorana type neutrinos has been investigated in this paper. There are some similar and dissimilar features that emerge from the study. That can be summarized as follows. The sign and magnitude of the induced charges depend on their helcities for the neutrino types under consideration. The magnitude can be helicity dependent and dependent on the type of neutrino. However, the induced charge is always anisotropic for both the Dirac type or Majorana type. The anisotropy depends on the angle between the direction of neutrino momentum and the ambient magneticfield.

Keywords. Neutrino, Helicity, Axial current

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1. Introduction

Electromagnetic properties of neutrinos are very important because of their role in various astrophysical and cosmological situations. Ever since the discovery of neutrino mass, the electromagnetic properties has assumed a greater significance. In the standard model of particle physics neutrinos are charge neutral, so one of the way to interact with photons is through the in-medium loop induced neutrino photon effective vertex (Giunti and Studentkin [2], Nieves and Pal [3]). There are various reasons for neutrinos to be realized as either Dirac or Majorana particles. Their magnetic and electric dipole moments differ from each other. The same contributes to their electromagnetic properties that can be used to distinguish them from each other.

2. The Off-Shell Vertex

The neutrino interaction with photons is describes in terms of the electromagnetic form factors of the neutrinos, that is in turn dependent on the vertex function. The off-shell electromagnetic vertex function γ_ν is defined so as to lead to the expression of $\nu\nu\gamma$ amplitude. For on-shell neutrinos, the transition matrix element is given, in terms of the same by:

$$\mathcal{M} = -i\bar{u}(k')\gamma_\nu u(k)A^\nu(q). \tag{2.1}$$

The effective vertex γ_ν given in eqn. (2.1) for Dirac neutrinos is given by

$$\gamma_\nu = -\frac{1}{\sqrt{2}e}G_F\gamma^\mu(1-\gamma_5)(g_\mathrm{V}\Pi_{\mu\nu} + g_\mathrm{A}\Pi^5_{\mu\nu}). \tag{2.2}$$

On the other hand, for Majorana neutrinos the same turns out to be

$$\gamma_\nu = -\frac{1}{\sqrt{2}e}G_F(-\gamma^\mu\gamma_5)(g_\mathrm{V}\Pi_{\mu\nu} + g_\mathrm{A}\Pi^5_{\mu\nu}). \tag{2.3}$$

The difference in the two vertex functions follows from the constraint that the Majorana neutrinos, are their own anti particles, i.e., $\nu_M = \nu^c_M = \mathcal{C}\bar{\nu}^T_M$, where $\mathcal{C} = i\gamma^2\gamma^0$ is the charge conjugation matrix. The coupling constants g_V and g_A are expressed in terms of the Weinberg angle as,

$$g_\mathrm{V} = 1-(1-4\sin^2\theta_\mathrm{W})/2, \tag{2.4}$$

$$g_\mathrm{A} = -1+1/2. \tag{2.5}$$

Lastly, the polarization and axial polarization tensors are denoted by $\Pi_{\mu\nu}$ and $\Pi^5_{\mu\nu}$. In the weak field limit, the polarization tensor $\Pi_{\mu\nu}$ being of order eB^2 does not contribute to the vertex, so the finite to γ_ν contribution comes from $\Pi^5_{\mu\nu}$. This piece has vacuum and medium dependent contributions. The vacuum contribution vanish in the limit of, $k_0 = \omega = 0$, $|k| \to 0$. As a result as we will see soon that there cannot be any contribution to neutrino effective charge coming from magnetized vacuum effect. The finite magnetized matter contribution has been investigated by Ganguly [1]. The contribution to neutrino effective charge e^ν_{efft} for Dirac and Majorana ν will be estimated using those results.

For massless Weyl spinors, effective charge follows from,

$$e^\nu_{\mathrm{eff}} = \frac{1}{2q_0}\mathrm{Tr}[\gamma_0(k_0=0, k\to 0)(1+\lambda\gamma^5)\not{q}]. \tag{2.6}$$

Using the same we would estimate the neutrino effective charge for massless Dirac and Majorana neutrino.

3. Estimates of Neutrino Charge

In this section, we will provide the estimate of the effective neutrino charge due to a relativistic degenerate background media, i.e., chemical; l potential μ much greater than the rest mass of the electrons. In this limit the expression for the effective charge for Dirac type neutrinos turn out to be:

$$e^{\nu_{\mathrm{Dirac}}}_{\mathrm{eff}} = -\sqrt{2}g_A G_F\frac{e^2\mathcal{B}}{\pi^2}\ln\left(2\cosh\left(\frac{\beta\mu}{2}\right)\right)(1-\lambda)\cos(\theta). \tag{3.1}$$

On the other hand, for Majorana neutrinos, the same turns out to be,

$$e^{\nu_{\mathrm{Majorana}}}_{\mathrm{eff}} = \frac{G_F g_A e^2\mathcal{B}}{\sqrt{2}\pi^2}\ln\left(\cosh\left(\frac{\beta\mu}{2}\right)\right)\cos(\theta), \tag{3.2}$$

where λ is the helicity of the neutrino spinners and β stands for inverse temperature $\frac{1}{T}$.

4. Observations

We note that the induced charge is anisotropic having estimated the effective neutrino charges for both Majorana and Dirac type neutrinos in a magnetized media in the weak field approximation. It depends on the angle between the direction of the neutrino and the $\mathcal{B}$ direction. for neutrinos moving orthogonal to the magnetic field the induced charge is zero. For Dirac type neutrino induced charge of one sign survives, however that of other sign vanishes. On the other hand for Majorana neutrinos with positive and negative helicity have induced charges of different sign. Lastly, the numerical size of the charge for both type differs from each other. More about these issues need further study for astrophysical situations.

Competing Interests

The author declares that he has no competing interests.

Authors' Contributions

The author wrote, read and approved the final manuscript.

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