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Comparison between asymmetric electric force and magnetic Force

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Abstract: Motion of an electric dipole, having same type of charge on both poles, in a parallel electric field is studied. The magnitude of the electric field is allowed to vary in the direction perpendicular to its polarization and to remain constant along the direction parallel to the polarization. This electric field applies asymmetric electric force on the dipole, which imprints a motion of rotation. Mathematical analysis of this motion proves that a single particle or a rigid body with inhomogeneous or homogeneous charge density distribution subjected to this electric field follows a motion of rotation too. This curved path appears to be analogous to the curved path followed by the same charged particle in the magnetic field produced by a straight long conductor carrying a steady electric current. However, the asymmetric electric force acts along the direction of motion and the magnetic force acts in the direction perpendicular to the motion of the charged particle, consequently, they produce different effects.

Keywords: Electric Force; Magnetic Force; Electric Dipole; Maxwell's Equations

1. Introduction

Literature survey shows that a transparent study of asymmetric force has not been done yet. For that we require a static parallel electric field whose magnitude should change in the direction perpendicular to its polarization and should remain constant in the direction parallel to the polarization. But such type of field is prohibited by the four Maxwell's equations of the classical electrodynamics [1]. It means such type of field cannot be produced experimentally by any type of static or dynamic distribution of electric charges. This is one of the reasons why no work has been reported on the asymmetric electric force. However, Katsuo Sakai [2] has reported some work under the title of asymmetric electric force but the electric field used by him is symmetric even if the charge distribution on which the force calculated is asymmetric. Our aim is to find out the effect of an asymmetric electric force on a single charged particle. The paper is formatted as follows.

In section 2, we consider an appropriate equation for the electric field and analyze mathematically motion of the said electric dipole. In section 3, we discuss the effect of the asymmetric electric force on a single charged particle. Section 4 is devoted to the discussion. In section 5, we draw a conclusion.

2. Asymmetric Electric Force on Electric Dipole Having Same Type of Charge on Both Poles

To examine the asymmetric electric force, we have to consider a parallel electric field. The magnitude of the field should vary in the direction perpendicular to its polarization and should remain constant in the direction parallel to the polarization. Such field may be represented by equation (1).

$$\boldsymbol{E}(r) = \hat{\boldsymbol{y}} \frac{E_0}{\sqrt{x^2 + z^2}} = \hat{\boldsymbol{y}} \frac{E_0}{r} \tag{1}$$

It is parallel to y-axis. We place an electric dipole having same type of charge on both poles as indicated in figure 1. Each pole bears a mass m and a charge $+q$. These poles are separated by a small distance r'. Further we assume the electric dipole has initial velocity $\boldsymbol{v}$ in the direction of the field. According to figure 1, the electric force F_1 on pole A and force F_2 on pole B respectively are

$$F_1 = \frac{qE_0}{r} \tag{2}$$

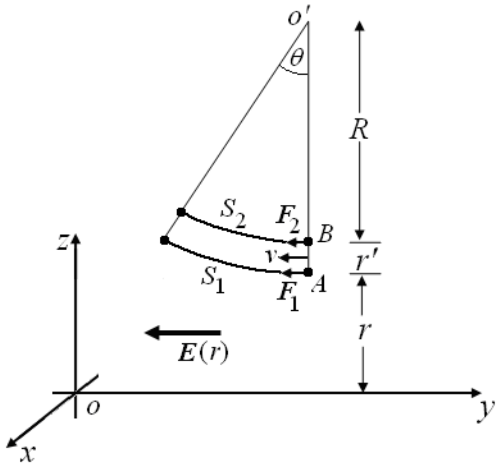

Figure 1. Electric dipole, having same type of charge +q on both poles, is placed in the parallel electric field described by equation (1). Initial velocity of the dipole is in direction of the field.

$$F_2 = \frac{qE_0}{(r + r')} \tag{3}$$

Distances S_1 and S_2 covered by the pole A and pole B in small time t, respectively, are

$$S_1 = vt + \frac{qE_0}{2m}\frac{t^2}{r} \tag{4}$$

$$S_2 = vt + \frac{qE_0}{2m}\frac{t^2}{(r + r')} \tag{5}$$

Due to the unequal distances ($S_1 \neq S_2$) the dipole follows a curved path. It turns away from y-axis or towards the weak field. The radius of the curved path followed by the dipole at initial point is

$$R = \frac{r' S_2}{S_1 - S_2} = r\left(\frac{2mv}{qE_0 t}(r + r') + 1\right) \tag{6}$$

If the dipole has initial velocity in opposite direction of the field then the electric force tries to decelerate the speed of the dipole. Because of the unequal forces on the dipoles it again follows a curved path but now it turns towards y-axis or towards the strong field as indicated in figure 2. At this time the radius of the curved path followed by the dipole obeys the following equation.

$$R = \frac{r' S_1}{S_2 - S_1} = \left(\frac{2mrv}{qE_0 t} - 1\right)(r + r') \tag{7}$$

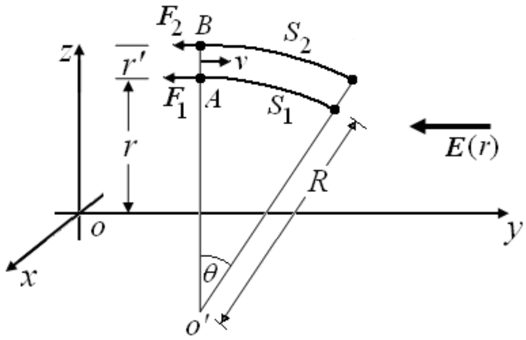

Figure 2. Electric dipole, having same type of charge +q on both poles, is placed in the parallel electric field described by equation (1). Initial velocity of the dipole is in opposite direction of the field.

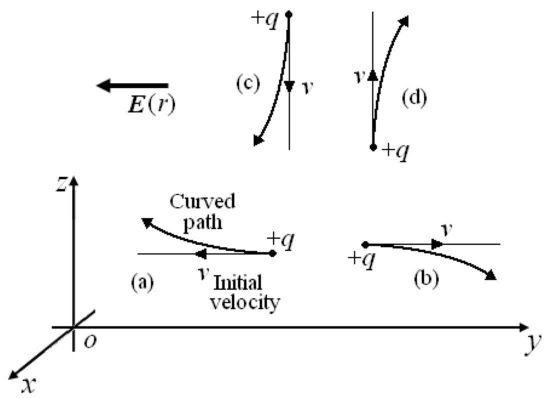

Figure 3. Possible motions of a single charged particle with different initial velocities in the parallel electric field described by equation (1).

3. Asymmetric Electric Force on a Single Charged Particle

Our aim of the work is to find out the effect of the asymmetric electric force on a single charged particle. For that the two poles of the considered dipole must coincide on each other and form a single charged particle having mass $2m$ and charge $+2q$. This will happen when $r' \to 0$. At this time equation (6) reduces to

$$R = \frac{r' S_2}{S_1 - S_2} = r\left(\frac{2mvr}{qE_0 t} + 1\right) \tag{8}$$

It is also radius of the curved path followed by a single charged particle having mass m, charge $+q$, with initial velocity v in the direction of the field and placed at distance r from the center of the field described by equation (1). This motion is represented by curve (a) in figure 3.

If the single charged particle has initial velocity in opposite direction of the field then the radius of the curved path becomes

$$R = \frac{r' S_1}{S_2 - S_1} = r\left(\frac{2mrv}{qE_0 t} - 1\right) \tag{9}$$

This motion is represented by curve (b) in figure 3.

For zero initial velocity of the particle, the radius of the curved path surprisingly depends only on initial position of the particle. For this equation (8) or equation (9) gives, in magnitude

$$R = r \tag{10}$$

Investigation of other two motions of the particle is also important in order to have complete information. One motion is when the particle approaches the center of the field in perpendicular direction of the polarization of the field. At this time the particle should get pushed along the direction of the field while coming towards y-axis. This motion is illustrated by curve (c) in figure 3. The last but interesting motion is when the particle tries to go away from center of the field in perpendicular direction of polarization of the field. At this time the particle should get turned in opposite direction of the force as represented by curve (d) in figure 3. This is the required motion which fits in the group of the previous three motions. It can also be understood from the dipole motion.

4. Discussion

It is obvious for the asymmetric electric force to come into survival the electric field must vary in the direction perpendicular to its polarization. It is further obvious that because of the asymmetric electric force, the particle never follows a straight path. It is always forced to follow a curved path. By observing the motions of the single charged particle in the field described by equation (1) and illustrated in figure 3, we immediately conclude that we are already acquainted with such motions. These are the motions of a single charged particle in the magnetic field produced by a straight long conductor carrying a steady electric current. It implies that the straight long conductor carrying a steady current might be producing a parallel electric field, like as described by equation (1), in opposite direction of the current. This evidently shows that the asymmetric electric force and magnetic force are analogous to each other. But as the asymmetric electric force acts along the direction of motion and the magnetic force acts perpendicular to the direction of motion of the fixed dipole or rigid body, hence they must produce different effects.

To show the similarity between asymmetric electric force and magnetic force an attempt has been made in [3]. But in [3] the author initially considered a single charged particle instead of a dipole for mathematical analysis and divided the particle into two hemispheres to calculate the asymmetric force. The division of the particle into two hemispheres seems to be a crude method. Since if we consider the particle as an electron then the division of electron into two hemispheres is bizarre. Further in that article it is shown that the curl of the electric field of an electric dipole is zero. It is true only when we first calculate the electric field on the axis of the dipole and then calculate the curl of the field. But if we add other components of the curl then it again becomes zero. Thus it preserves the four Maxwell's equations. Further it is mentioned that the asymmetric electric field exists only in curled electric fields. It isn't necessary according to the derivations presented in this paper. An electric field that varies only in the direction perpendicular to its polarization is sufficient to produce the asymmetric electric force. The field may or may not have nonzero curl.

5. Conclusion

An electric field whose magnitude varies in the direction perpendicular to its polarization is responsible to produce the asymmetric electric force. Because of the asymmetric electric force the subjected particle always follows a curved path. This curved path appears to be analogous to the curved path followed by the same charged particle in the magnetic field produced by a straight long conductor carrying a steady electric current. However, the asymmetric electric force acts along the direction of motion and the magnetic force acts along the direction perpendicular to the motion of the charged particle, these forces should produce different effects.

Acknowledgements

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