International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-9, December 2015
ISSN: 2395-3470
www.ijseas.com

# Relationships between the Electric and Magnetic Fields

**Takashi Kato**
Institute for Innovative Science and Technology, Graduate School of Engineering, Nagasaki Institute of Applied Science, 3-1, Shuku-machi, Nagasaki 851-0121, Japan

## Abstract

The relationships between the electric and magnetic fields are discussed. Because of any origin (i.e., Higgs boson, broken symmetry of chirality etc.), the mixture between the right- and left-helicity elements occurs. The mixtures between right- and left- handed helicity elements at the space- and time-axes, are the origin of the generations of the mass and electric charge, respectively. This result also explains how the left-handed helicity magnetic field can be induced when the negatively charged particles such as electrons move. The relationships between the magnetic forces, gravity, electric forces, and electromagnetic forces are also discussed. We show that the element of the gravity (i.e., mass) and electric forces (i.e., electric charge) can be generated by the cancellation of the element of the right- and left-handed magnetic forces (i.e., spin magnetic moment) at space- and time-axes, respectively.

***Keywords:*** Spin Magnetic Moment; Mass; Electric Charge; Ampère's Law; Mixture of the Helicity.

## 1. Introduction

The effect of vibronic interactions and electron–phonon interactions [1–7] in molecules and crystals is an important topic of discussion in modern chemistry and physics. The vibronic and electron–phonon interactions play an essential role in various research fields such as the decision of molecular structures, Jahn–Teller effects, Peierls distortions, spectroscopy, electrical conductivity, and superconductivity. We have investigated the electron–phonon interactions in various charged molecular crystals for more than ten years [1–8]. In particular, in 2002, we predicted the occurrence of superconductivity as a consequence of vibronic interactions in the negatively charged picene, phenanthrene, and coronene [8]. Recently, it was reported that these trianionic molecular crystals exhibit superconductivity [9].

In the recent research [10,11], we explained the mechanism of the Ampère's law (experimental rule discovered in 1820) and the Faraday's law (experimental rule discovered in 1831) in normal metallic and superconducting states [12], on the basis of the theory suggested in our previous researches [1–7]. However, we did not discuss how the left-handed helicity magnetic field can be induced when the negative charged particles such as electrons move.

In this article, we will discuss how the left-handed helicity magnetic field can be induced when the negatively charged particles such as electrons move. That is, we will discuss the relationships between the electric and magnetic fields. Furthermore, by comparing the spin magnetic moment, mass, and electric charge, we will suggest the origin of the electric charge in a particle. Furthermore, we discuss the relationships between the magnetic forces, gravity, electric forces, and electromagnetic forces.

## 2. Relationships between the Spin Magnetic Moment and Mass at Space Axis

### 2.1 Theoretical Background

According to the special relativity, the medium for an electron is time as well as space. Let us consider a particle such as an electron in three-dimensional space axis, as shown in Fig. 1. We can consider that the spin electronic state for an electron with mass $m$ can be composed from the right-handed chirality $\left|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\right\rangle$ or left-handed chirality $\left|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\right\rangle$ elements, defined as,

$$\left|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\right\rangle = c_{\boldsymbol{R}_R}(m)\left|\boldsymbol{R}_R(+\boldsymbol{k})\right\rangle + c_{\boldsymbol{R}_L}(m)\left|\boldsymbol{R}_L(-\boldsymbol{k})\right\rangle, \quad (1)$$

$$\left|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\right\rangle = c_{\boldsymbol{L}_L}(m)\left|\boldsymbol{L}_L(+\boldsymbol{k})\right\rangle + c_{\boldsymbol{L}_R}(m)\left|\boldsymbol{L}_R(-\boldsymbol{k})\right\rangle, \quad (2)$$

where the $\left|\boldsymbol{R}_R(+\boldsymbol{k})\right\rangle$ and $\left|\boldsymbol{R}_L(-\boldsymbol{k})\right\rangle$ denote the right- and left-handed helicity elements in the right-handed chirality $\left|\boldsymbol{R}\uparrow(m)\right\rangle$ state, respectively, and the $\left|\boldsymbol{L}_L(+\boldsymbol{k})\right\rangle$ and $\left|\boldsymbol{L}_R(-\boldsymbol{k})\right\rangle$ denote the left- and right-handed helicity elements in the left-handed chirality $\left|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\right\rangle$ state, respectively, at the space axis. By considering the normalizations of the $\left|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\right\rangle$ and $\left|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\right\rangle$ states, the relationships between the coefficients ( $0 \le c_{\boldsymbol{R}_R}(m), c_{\boldsymbol{R}_L}(m), c_{\boldsymbol{L}_L}(m), c_{\boldsymbol{L}_R}(m) \le 1$ ) can be expressed as

$$\left\langle \boldsymbol{R}\uparrow(m,\boldsymbol{k}) \middle| \boldsymbol{R}\uparrow(m,\boldsymbol{k})\right\rangle = c_{\boldsymbol{R}_R}^2(m) + c_{\boldsymbol{R}_L}^2(m) = 1, \quad (3)$$

$$\left\langle \boldsymbol{L}\downarrow(m,\boldsymbol{k}) \middle| \boldsymbol{L}\downarrow(m,\boldsymbol{k})\right\rangle = c_{\boldsymbol{L}_L}^2(m) + c_{\boldsymbol{L}_R}^2(m) = 1. \quad (4)$$

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ISSN: 2395-3470
www.ijseas.com

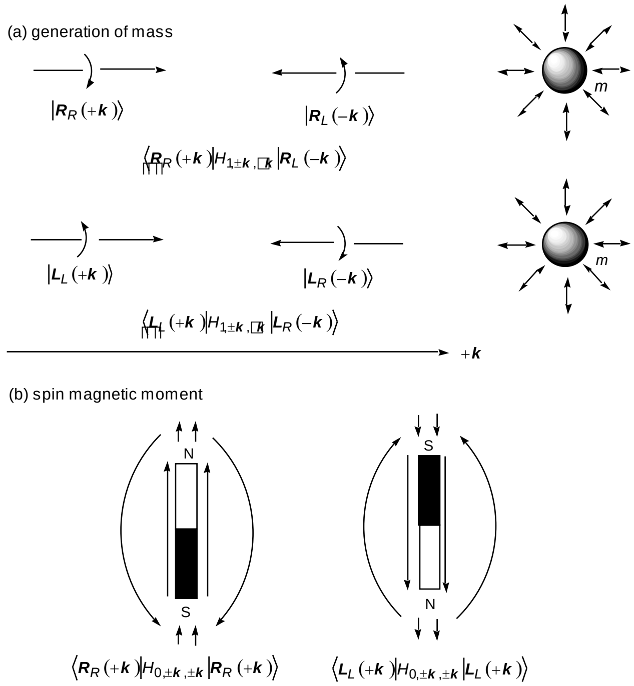

Fig. 1. Mass and spin magnetic moment.

Let us next consider the Hamiltonian $H_{\boldsymbol{k}}$ for an electron at the space axis, as expressed as,

$$H_{\boldsymbol{k}} = H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}} + H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}. \tag{5}$$

The energy for the right-handed chirality $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ states can be estimated as

$$\begin{aligned}
&\langle \boldsymbol{R}\uparrow(m,\boldsymbol{k})|H_{\boldsymbol{k}}|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle \\
&= \langle (c_{\boldsymbol{R}_R}(m)\boldsymbol{R}_R(+\boldsymbol{k})+c_{\boldsymbol{R}_L}(m)\boldsymbol{R}_L(-\boldsymbol{k}))|H_{\boldsymbol{k}} \\
&\qquad \times |(c_{\boldsymbol{R}_R}(m)\boldsymbol{R}_R(+\boldsymbol{k})+c_{\boldsymbol{R}_L}(m)\boldsymbol{R}_L(-\boldsymbol{k}))\rangle \\
&= \langle (c_{\boldsymbol{R}_R}(m)\boldsymbol{R}_R(+\boldsymbol{k})+c_{\boldsymbol{R}_L}(m)\boldsymbol{R}_L(-\boldsymbol{k}))| \\
&\qquad \times (H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}} + H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}) \\
&\qquad \times |(c_{\boldsymbol{R}_R}(m)\boldsymbol{R}_R(+\boldsymbol{k})+c_{\boldsymbol{R}_L}(m)\boldsymbol{R}_L(-\boldsymbol{k}))\rangle \\
&= c_{\boldsymbol{R}_R}^2(m)\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle \\
&+ c_{\boldsymbol{R}_L}^2(m)\langle \boldsymbol{R}_L(-\boldsymbol{k})|H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle \\
&+ 2c_{\boldsymbol{R}_R}(m)c_{\boldsymbol{R}_L}(m)\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle \\
&= c_{\boldsymbol{R}_R}^2(m)\varepsilon_{\boldsymbol{R}} + c_{\boldsymbol{R}_L}^2(m)\varepsilon_{\boldsymbol{L}} \\
&+ 2c_{\boldsymbol{R}_R}(m)\sqrt{1-c_{\boldsymbol{R}_R}^2(m)}\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle \\
&= (c_{\boldsymbol{R}_R}^2(m) - c_{\boldsymbol{R}_L}^2(m))\varepsilon_{\boldsymbol{R}} \\
&+ 2c_{\boldsymbol{R}_R}(m)\sqrt{1-c_{\boldsymbol{R}_R}^2(m)}\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle \\
&= (2c_{\boldsymbol{R}_R}^2(m)-1)\varepsilon_{\boldsymbol{R}} + 2c_{\boldsymbol{R}_R}(m)\sqrt{1-c_{\boldsymbol{R}_R}^2(m)}\, m_\infty c^2 \\
&= \varepsilon_{\boldsymbol{R}}(m) + mc^2,
\end{aligned} \tag{6}$$

where $\varepsilon_{\boldsymbol{R}}$ and $\varepsilon_{\boldsymbol{L}}$ denote the spin magnetic energies for the right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements in the right-handed chirality $|\boldsymbol{R}\uparrow(m)\rangle$, respectively, and can be defined as

$$\varepsilon_{\boldsymbol{R}} = \langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle, \tag{7}$$

$$\varepsilon_{\boldsymbol{L}} = \langle \boldsymbol{R}_L(-\boldsymbol{k})|H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle = -\varepsilon_{\boldsymbol{R}}, \tag{8}$$

and the $m_\infty c^2$ denotes the rest energy originating from the interaction between the right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements, which depends on the kind of particle, and related to the Higgs vacuum expectation value and Yukawa coupling constant,

$$m_\infty c^2 = \langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle, \tag{9}$$

and the $m$ denotes the generated mass for the right-handed chirality $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ state,

$$m = 2m_\infty c_{\boldsymbol{R}_R}(m)\sqrt{1-c_{\boldsymbol{R}_R}^2(m)}, \tag{10}$$

and furthermore, $\varepsilon_{\boldsymbol{R}}(m)$ denotes the spin magnetic energy for the right-handed chirality state with mass $m$,

$$\varepsilon_{\boldsymbol{R}}(m) = (2c_{\boldsymbol{R}_R}^2(m)-1)\varepsilon_{\boldsymbol{R}}. \tag{11}$$

Similar discussions can be made in the energy for the left-handed chirality $|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\rangle$ states,

$$\begin{aligned}
&\langle \boldsymbol{L}\downarrow(m)|H_{\boldsymbol{k}}|\boldsymbol{L}\downarrow(m)\rangle \\
&= \langle (c_{\boldsymbol{L}_L}(m)\boldsymbol{L}_L(+\boldsymbol{k})+c_{\boldsymbol{L}_R}(m)\boldsymbol{L}_R(-\boldsymbol{k}))|H_{\boldsymbol{k}} \\
&\qquad \times |(c_{\boldsymbol{L}_L}(m)\boldsymbol{L}_L(+\boldsymbol{k})+c_{\boldsymbol{L}_R}(m)\boldsymbol{L}_R(-\boldsymbol{k}))\rangle \\
&= \langle (c_{\boldsymbol{L}_L}(m)\boldsymbol{L}_L(+\boldsymbol{k})+c_{\boldsymbol{L}_R}(m)\boldsymbol{L}_R(-\boldsymbol{k}))| \\
&\qquad \times (H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}} + H_{1,\pm \boldsymbol{k},\mp \boldsymbol{k}}) \\
&\qquad \times |(c_{\boldsymbol{L}_L}(m)\boldsymbol{L}_L(+\boldsymbol{k})+c_{\boldsymbol{L}_R}(m)\boldsymbol{L}_R(-\boldsymbol{k}))\rangle \\
&= c_{\boldsymbol{L}_L}^2(m)\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}}|\boldsymbol{L}_L(+\boldsymbol{k})\rangle
\end{aligned}$$

$$+c_{L_R}^2(m)\langle \boldsymbol{L}_R(-\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle$$
$$+2c_{L_L}(m)c_{L_R}(m)\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\mp\boldsymbol{k}}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle$$
$$= c_{L_L}^2(m)\varepsilon_{\boldsymbol{L}} + c_{L_R}^2(m)\varepsilon_{\boldsymbol{R}}$$
$$+2c_{L_L}(m)\sqrt{1-c_{L_L}^2(m)}\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\mp\boldsymbol{k}}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle$$
$$= \left(c_{L_L}^2(m) - c_{R_R}^2(m)\right)\varepsilon_{\boldsymbol{L}}$$
$$+2c_{L_L}(m)\sqrt{1-c_{L_L}^2(m)}\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\mp\boldsymbol{k}}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle$$
$$= \left(2c_{L_L}^2(m) - 1\right)\varepsilon_{\boldsymbol{L}} + 2c_{L_L}(m)\sqrt{1-c_{L_L}^2(m)}\,m_\infty c^2$$
$$= \varepsilon_{\boldsymbol{L}}(m) + mc^2, \qquad (12)$$

$$\varepsilon_{\boldsymbol{L}} = \langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_L(+\boldsymbol{k})\rangle, \qquad (13)$$

$$\varepsilon_{\boldsymbol{R}} = \langle \boldsymbol{L}_R(-\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle = -\varepsilon_{\boldsymbol{L}}, \qquad (14)$$

$$m_\infty c^2 = \langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\mp\boldsymbol{k}}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle, \qquad (15)$$

$$m = 2m_\infty c_{L_L}(m)\sqrt{1-c_{L_L}^2(m)}, \qquad (16)$$

$$\varepsilon_{\boldsymbol{L}}(m) = \left(2c_{L_L}^2(m) - 1\right)\varepsilon_{\boldsymbol{L}}. \qquad (17)$$

2.2 The Relationships between the Magnetic Energy and the Rest Energy at Space Axis

Let us next consider the relationship between the magnetic energy and the rest energy of an electron. The spin magnetic energy $\varepsilon_{\boldsymbol{R}}(m)$ and the rest energy $\varepsilon_{\mathrm{rest}}(m)$ for the right-handed chirality $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ element can be defined as

$$\varepsilon_{\boldsymbol{R}}(m) = \left(2c_{R_R}^2(m) - 1\right)\varepsilon_{\boldsymbol{R}}, \qquad (18)$$

$$\varepsilon_{\mathrm{rest},\boldsymbol{R}}(m) = mc^2 = 2c_{R_R}(m)\sqrt{1-c_{R_R}^2(m)}\,m_\infty c^2. \qquad (19)$$

Let us consider the case of right-handed chirality element in an electron. If an electron is in the only right-handed helicity state ( $c_{R_R}(m) = 1$ ) the $\varepsilon_{\boldsymbol{R}}(m)$ and $\varepsilon_{\mathrm{rest}}(m)$ values can be estimated as

$$\varepsilon_{\boldsymbol{R}}(m) = \varepsilon_{\boldsymbol{R}}, \qquad (20)$$

$$\varepsilon_{\mathrm{rest},\boldsymbol{R}}(m) = mc^2 = 0. \qquad (21)$$

In such a case, the mass of an electron is 0, like light, and the spin magnetic energy becomes the maximum $\varepsilon_{\boldsymbol{R}}$. This can be understood as follows. When the mass of an electron is 0, the velocity of an electron becomes the velocity of the massless light $c$. In such a case, the mixture of the right- and left-handed helicity cannot occur. The degree of the mixture of the right- and left-handed helicity (because of any origin (i.e., Higgs boson, broken symmetry of chirality, etc.)) at space axis is closely related to the generation of the mass. That is, the angular momentum (spin magnetic energy) for the right-handed helicity is not canceled by that for the left-handed helicity. This is the reason why the angular momentum (spin magnetic energy) for the right-helicity state becomes the largest when the mass for this state becomes minimum (0).

The $\varepsilon_{\boldsymbol{R}}(m)$ and $\varepsilon_{\mathrm{rest},\boldsymbol{R}}(m)$ values decrease and increase with a decrease in the $c_{R_R}(m)$ value from 1 to $1/\sqrt{2}$, respectively. That is, the angular momentum and mass decrease and increase with an increase in the degree of the mixture of the right- and left-handed helicity elements, respectively. In such a case, the mass of an electron is not 0, unlike the light, and the spin magnetic energy is in the range between the maximum $\varepsilon_{\boldsymbol{R}}$ and minimum 0. This can be understood as follows. When the mass of an electron is not 0, the velocity of a massive electron becomes smaller than that of massless light. In such a case, the mixture of the right- and left-handed helicity can occur. The degree of the mixture of the right- and left-handed helicity at space axis is closely related to the generation of the mass. That is, the angular momentum (spin magnetic energy) for the right-handed helicity is somewhat canceled by that for the left-handed helicity. This is the reason why the angular momentum (spin magnetic energy) for the right-helicity state decreases when the mass for this state increases.

If an electron is in the mixture of the right- and left-handed helicity state in the same degree ( $c_{R_R}(m) = 1/\sqrt{2}$ ), the $\varepsilon_{\boldsymbol{R}}(m)$ and $\varepsilon_{\mathrm{rest}}(m)$ values can be estimated as

$$\varepsilon_{\boldsymbol{R}}(m) = 0, \qquad (22)$$

$$\varepsilon_{\mathrm{rest},\boldsymbol{R}}(m) = mc^2 = m_\infty c^2. \qquad (23)$$

In such a case, the mass of an electron becomes maximum ( $m_\infty$ ). And the spin magnetic energy becomes the minimum (0). This can be understood as follows. When the mass of an electron becomes $m_\infty$, the velocity of an electron becomes 0. In such a case, the complete mixture of the right- and left-handed helicity can occur. The degree of the mixture of the right- and left-handed helicity at space axis is closely related to the generation of the mass. That is, the angular momentum (spin magnetic energy) for the right- and left-handed helicity element is completely compensated by each other. This is the reason why the angular momentum (spin magnetic energy) for the right-helicity state becomes the smallest (0) when the mass for this state becomes maximum ($m_\infty$).

## 3. Relationships between the Mass and Charge at Time Axis

### 3.1 Theoretical Background

Let us consider an electron in time axis, as shown in Fig. 2. We can consider that the spin electronic state for an electron with electric charge $q$ can be composed from the right-handed chirality $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ or left-handed chirality $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ elements, defined as,

$$\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle = c_{\boldsymbol{R}_R}(q)\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle + c_{\boldsymbol{R}_L}(q)\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle, \quad (24)$$

$$\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle = c_{\boldsymbol{L}_L}(q)\left|\boldsymbol{L}_L(+t)\right\rangle\!\rangle + c_{\boldsymbol{L}_R}(q)\left|\boldsymbol{L}_R(-t)\right\rangle\!\rangle, \quad (25)$$

where the $\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle$ denote the right- and left-handed helicity elements in the right-handed chirality $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ state, respectively, and the $\left|\boldsymbol{L}_L(+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{L}_R(-t)\right\rangle\!\rangle$ denote the left- and right-handed helicity elements in the left-handed chirality $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ state, respectively. By considering the normalizations of the $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ states, the relationships between the coefficients $0 \le c_{\boldsymbol{R}_R}(q), c_{\boldsymbol{R}_L}(q), c_{\boldsymbol{L}_L}(q), c_{\boldsymbol{L}_R}(q) \le 1$ can be expressed as

$$\left\langle\!\langle \boldsymbol{R}\uparrow(q,+t)\middle|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle = c_{\boldsymbol{R}_R}^2(q) + c_{\boldsymbol{R}_L}^2(q) = 1, \quad (26)$$

$$\left\langle\!\langle \boldsymbol{L}\downarrow(q,+t)\middle|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle = c_{\boldsymbol{L}_L}^2(q) + c_{\boldsymbol{L}_R}^2(q) = 1. \quad (27)$$

Let us next consider the Hamiltonian $H_t$ for an electron at the time axis, as expressed as,

$$H_t = H_{0,\pm t,\pm t} + H_{1,\pm t,\mp t}. \quad (28)$$

The energy for the right-handed chirality $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ states can be estimated as

$$\begin{aligned}
&\left\langle\!\langle \boldsymbol{R}\uparrow(q,+t)\right|H_t\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle \\
&= \left\langle\!\langle \left(c_{\boldsymbol{R}_R}(q)\boldsymbol{R}_R(+t) + c_{\boldsymbol{R}_L}(q)\boldsymbol{R}_L(-t)\right)\right| H_t \\
&\qquad \times \left|\left(c_{\boldsymbol{R}_R}(q)\boldsymbol{R}_R(+t) + c_{\boldsymbol{R}_L}(q)\boldsymbol{R}_L(-t)\right)\right\rangle\!\rangle \\
&= \left\langle\!\langle \left(c_{\boldsymbol{R}_R}(q)\boldsymbol{R}_R(+t) + c_{\boldsymbol{R}_L}(q)\boldsymbol{R}_L(-t)\right)\right| \\
&\qquad \times \left(H_{0,\pm t,\pm t} + H_{1,\pm t,\mp t}\right) \\
&\qquad \times \left|\left(c_{\boldsymbol{R}_R}(q)\boldsymbol{R}_R(+t) + c_{\boldsymbol{R}_L}(q)\boldsymbol{R}_L(-t)\right)\right\rangle\!\rangle \\
&= c_{\boldsymbol{R}_R}^2(q)\left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle \\
&+ c_{\boldsymbol{R}_L}^2(q)\left\langle\!\langle \boldsymbol{R}_L(-t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle \\
&+ 2c_{\boldsymbol{R}_R}(q)c_{\boldsymbol{R}_L}(q)\left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{1,\pm t,\mp t}\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle \\
&= c_{\boldsymbol{R}_R}^2(q)\varepsilon_{\boldsymbol{R}} + c_{\boldsymbol{R}_L}^2(q)\varepsilon_{\boldsymbol{L}} \\
&+ 2c_{\boldsymbol{R}_R}(q)\sqrt{1-c_{\boldsymbol{R}_R}^2(q)}\left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{1,\pm t,\mp t}\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle \\
&= \left(c_{\boldsymbol{R}_R}^2(q) - c_{\boldsymbol{R}_L}^2(q)\right)\varepsilon_{\boldsymbol{R}} \\
&+ 2c_{\boldsymbol{R}_R}(q)\sqrt{1-c_{\boldsymbol{R}_R}^2(q)}\left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{1,\pm t,\mp t}\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle \\
&= \left(c_{\boldsymbol{R}_R}^2(q) - c_{\boldsymbol{R}_L}^2(q)\right)\varepsilon_{\boldsymbol{R}} \\
&+ 2c_{\boldsymbol{R}_R}(q)\sqrt{1-c_{\boldsymbol{R}_R}^2(q)}\left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{1,\pm t,\mp t}\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle \\
&= \left(2c_{\boldsymbol{R}_R}^2(q) - 1\right)\varepsilon_{\boldsymbol{R}} + 2c_{\boldsymbol{R}_R}(q)\sqrt{1-c_{\boldsymbol{R}_R}^2(q)}\,\varepsilon_{q_\infty,\boldsymbol{R}}(+t) \\
&= \varepsilon_{\boldsymbol{R}}(q) + \varepsilon_{q,\boldsymbol{R}}(+t),
\end{aligned} \quad (29)$$

where $\varepsilon_{\boldsymbol{R}}$ and $\varepsilon_{\boldsymbol{L}}$ denote the energies for the right- $\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle$ and left- $\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle$ handed helicity elements in the right-handed chirality $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$, respectively, and can be defined as

$$\varepsilon_{\boldsymbol{R}} = \left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle, \quad (30)$$

$$\varepsilon_{\boldsymbol{L}} = \left\langle\!\langle \boldsymbol{R}_L(-t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle = -\varepsilon_{\boldsymbol{R}}, \quad (31)$$

and the $\varepsilon_{q_\infty,\boldsymbol{R}}(+t)$ denotes the energy for the electric charge energy originating from the interaction between the right- $\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle$ and left- $\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle$ handed helicity elements at the time axis, which depends on the kind of particle,

$$\begin{aligned}
\varepsilon_{q_\infty,\boldsymbol{R}}(+t) &= \left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{1,\pm t,\mp t}\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle \\
&= \left\langle\!\langle \boldsymbol{R}_R(+t)\right|H_{1,\pm t,\mp t}\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle,
\end{aligned} \quad (32)$$

and furthermore, $\varepsilon_{q,\boldsymbol{R}}(+t)$ denotes the energy for the spin magnetic energy for the right-handed chirality state with charge $q$,

$$\varepsilon_{q,\boldsymbol{R}}(+t) = \left(2c_{\boldsymbol{R}_R}^2(m) - 1\right)\varepsilon_{q_\infty,\boldsymbol{R}}(+t). \quad (33)$$

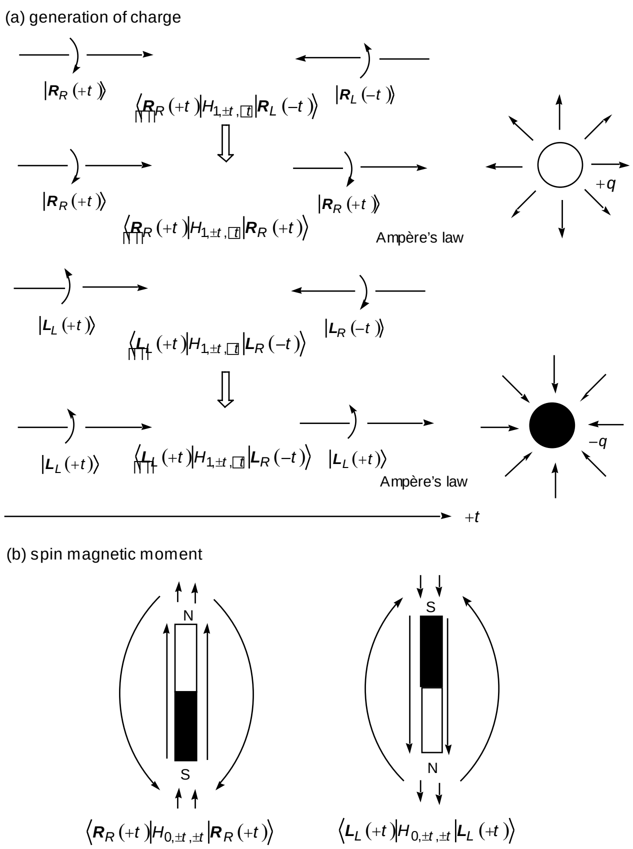


Fig. 2. Electric charge and spin magnetic moment.

Similar discussions can be made in the energy for the left-handed chirality $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ states,

$$\left\langle\boldsymbol{L}\downarrow(q,+t)\right|H_t\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$$
$$=\left\langle\left(c_{\boldsymbol{L}_L}(q)\boldsymbol{L}_L(+t)+c_{\boldsymbol{L}_R}(q)\boldsymbol{L}_R(-t)\right)\right|H_t$$
$$\times\left|\left(c_{\boldsymbol{L}_L}(q)\boldsymbol{L}_L(+t)+c_{\boldsymbol{L}_R}(q)\boldsymbol{L}_R(-t)\right)\right\rangle$$
$$=\left\langle\left(c_{\boldsymbol{L}_L}(q)\boldsymbol{L}_L(+t)+c_{\boldsymbol{L}_R}(q)\boldsymbol{L}_R(-t)\right)\right|$$
$$\times\left(H_{0,\pm t,\pm t}+H_{1,\pm t,\Box}\right)$$
$$\times\left|\left(c_{\boldsymbol{L}_L}(q)\boldsymbol{L}_L(+t)+c_{\boldsymbol{L}_R}(q)\boldsymbol{L}_R(-t)\right)\right\rangle$$
$$=c^2_{\boldsymbol{L}_L}(q)\left\langle\boldsymbol{L}_L(+t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{L}_L(+t)\right\rangle$$
$$+c^2_{\boldsymbol{L}_R}(q)\left\langle\boldsymbol{L}_R(-t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{L}_R(-t)\right\rangle$$
$$+2c_{\boldsymbol{L}_L}(q)c_{\boldsymbol{L}_R}(q)\left\langle\boldsymbol{L}_L(+t)\right|H_{1,\pm t,\Box}\left|\boldsymbol{L}_R(-t)\right\rangle$$
$$=c^2_{\boldsymbol{L}_L}(q)\varepsilon_{\boldsymbol{L}}+c^2_{\boldsymbol{L}_R}(q)\varepsilon_{\boldsymbol{R}}$$
$$+2c_{\boldsymbol{L}_L}(q)\sqrt{1-c^2_{\boldsymbol{L}_L}(q)}\left\langle\boldsymbol{L}_L(+t)\right|H_{1,\pm t,\Box}\left|\boldsymbol{L}_R(-t)\right\rangle$$
$$=\left(c^2_{\boldsymbol{L}_L}(q)-c^2_{\boldsymbol{L}_R}(q)\right)\varepsilon_{\boldsymbol{L}}$$
$$+2c_{\boldsymbol{L}_L}(q)\sqrt{1-c^2_{\boldsymbol{L}_L}(q)}\left\langle\boldsymbol{L}_L(+t)\right|H_{1,\pm t,\Box}\left|\boldsymbol{L}_R(-t)\right\rangle$$
$$=\left(c^2_{\boldsymbol{L}_L}(q)-c^2_{\boldsymbol{L}_R}(q)\right)\varepsilon_{\boldsymbol{L}}$$
$$+2c_{\boldsymbol{L}_L}(q)\sqrt{1-c^2_{\boldsymbol{L}_L}(q)}\left\langle\boldsymbol{L}_L(+t)\right|H_{1,\pm t,\Box}\left|\boldsymbol{L}_L(+t)\right\rangle$$
$$=\left(2c^2_{\boldsymbol{L}_L}(q)-1\right)\varepsilon_{\boldsymbol{L}}+2c_{\boldsymbol{L}_L}(q)\sqrt{1-c^2_{\boldsymbol{L}_L}(q)}\,\varepsilon_{q_\infty,\boldsymbol{L}}(+t)$$
$$=\varepsilon_{\boldsymbol{L}}(q)+\varepsilon_{q,\boldsymbol{L}}(+t), \qquad (34)$$

$$\varepsilon_{\boldsymbol{L}}=\left\langle\boldsymbol{L}_L(+t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{L}_L(+t)\right\rangle, \qquad (35)$$

$$\varepsilon_{\boldsymbol{R}}=\left\langle\boldsymbol{L}_R(-t)\right|H_{0,\pm t,\pm t}\left|\boldsymbol{L}_R(-t)\right\rangle=-\varepsilon_{\boldsymbol{L}}, \qquad (36)$$

$$\varepsilon_{q_\infty,\boldsymbol{L}}(+t)=\left\langle\boldsymbol{L}_L(+t)\right|H_{1,\pm t,\Box}\left|\boldsymbol{L}_R(-t)\right\rangle$$
$$=\left\langle\boldsymbol{L}_L(+t)\right|H_{1,\pm t,\Box}\left|\boldsymbol{L}_L(+t)\right\rangle, \qquad (37)$$

$$\varepsilon_{q,\boldsymbol{L}}(+t)=\left(2c^2_{\boldsymbol{L}_L}(m)-1\right)\varepsilon_{q_\infty,\boldsymbol{L}}(+t). \qquad (38)$$

3.2 The Relationships between the Magnetic Energy and the Electric Charge Energy at Time Axis

Let us next consider the relationship between the magnetic energy and the electric charge energy of an electron. The spin magnetic energy $\varepsilon_{\boldsymbol{R}}(q)$ and the electric charge energy $\varepsilon_{q,\boldsymbol{R}}(+t)$ for the right-handed chirality $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ element can be defined as

$$\varepsilon_{\boldsymbol{R}}(q)=\left(2c^2_{\boldsymbol{R}_R}(q)-1\right)\varepsilon_{\boldsymbol{R}}, \qquad (39)$$

$$\varepsilon_{q,\boldsymbol{R}}(+t)=2c_{\boldsymbol{R}_R}(q)\sqrt{1-c^2_{\boldsymbol{R}_R}(q)}\,\varepsilon_{q_\infty,\boldsymbol{R}}(+t). \qquad (40)$$

Let us consider the case of right-handed chirality element in an electron. If an electron is in the only right-handed helicity state ( $c_{\boldsymbol{R}_R}(q)=1$ ) the $\varepsilon_{\boldsymbol{R}}(q)$ and $\varepsilon_{q,\boldsymbol{R}}(+t)$ values can be estimated as

$$\varepsilon_{\boldsymbol{R}}(q)=\varepsilon_{\boldsymbol{R}}, \qquad (41)$$

$$\varepsilon_{q,\boldsymbol{R}}(+t)=0. \qquad (42)$$

In such a case, the mass and charge of an electron are 0, like light, and the spin magnetic energy becomes the maximum $\varepsilon_{\boldsymbol{R}}$. This can be understood as follows. When the mass of an electron is 0, the velocity of an electron becomes the velocity of the massless light $c$. In such a case, the mixture of the right- and left-handed helicity cannot occur. The degrees of the mixture of the right- and left-handed helicity (because of any origin (i.e., Higgs boson, broken symmetry of chirality, etc.)) at space and time axes are closely related to the generation of the mass and electric charge, respectively. That is, the angular momentum (spin magnetic energy) for the right-handed helicity is not canceled by that for the left-handed helicity. This is the reason why the angular momentum (spin magnetic energy) for the right-helicity state becomes the largest when the mass and charge for this state become minimum (0).

The $\varepsilon_{\boldsymbol{R}}(q)$ and $\varepsilon_{q,\boldsymbol{R}}(+t)$ values decrease and increase with a decrease in the $c_{\boldsymbol{R}_R}(q)$ value from 1 to $1/\sqrt{2}$, respectively. That is, the angular momentum, and mass and charge, decrease and increase with an increase in the degree of the mixture of the right- and left-handed helicity elements, respectively. In such a case, the mass and electric charge of an electron are not 0, unlike the light, and the spin magnetic energy is in the range between the maximum $\varepsilon_{\boldsymbol{R}}$ and minimum 0. This can be understood as follows. When the mass of an electron is not 0, the velocity of a massive electron becomes smaller than that of massless light. In such a case, the mixture of the right- and left-handed helicity can occur. The degrees of the mixture of the right- and left-handed helicity at space and time axes are closely related to the generation of the mass and electric charge, respectively. That is, the angular momentum (spin magnetic energy) for the right-handed helicity is somewhat canceled by that for the left-handed helicity. This is the reason why the angular momentum (spin magnetic energy) for the right-helicity state decreases when the mass and electric charge for this state increase.

If an electron is in the mixture of the right- and left-handed helicity state in the same degree ($c_{\boldsymbol{R}_R}(q)=1/\sqrt{2}$), the $\varepsilon_{\boldsymbol{R}}(q)$ and $\varepsilon_{q,\boldsymbol{R}}(+t)$ values can be estimated as

$$\varepsilon_{\boldsymbol{R}}(q)=0, \tag{43}$$

$$\varepsilon_{q,\boldsymbol{R}}(+t)=\varepsilon_{q_\infty,\boldsymbol{R}}(+t). \tag{44}$$

In such a case, the mass and electric charge of an electron become maximum. And the spin magnetic energy becomes the minimum (0). This can be understood as follows. When the mass of an electron becomes $m_\infty$, the velocity of an electron becomes 0. In such a case, the complete mixture of the right- and left-handed helicity can occur. The degrees of the mixture of the right- and left-handed helicity at space and time axes are closely related to the generation of the mass and electric charge, respectively. That is, the angular momentum (spin magnetic energy) for the right- and left-handed helicity element is completely compensated by each other. This is the reason why the angular momentum (spin magnetic energy) for the right-helicity state becomes the smallest (0) when the mass and electric charge for this state become maximum.

## 4. Relationships between the Spin Magnetic Moment, Mass, and Electric Charge

### 4.1 Spin Magnetic Moment

The energies for the spin magnetic moment for the $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ state can be expressed as Eq. (11). At the time of the big bang, the $\varepsilon_{\boldsymbol{R}}(m)$ and $\varepsilon_{\boldsymbol{L}}(m)$ values were the maximum ($c_{\boldsymbol{R}_R}(m)=1$), as shown in Fig. 3. That is, there is no mixture between right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements, and thus the spin magnetic moment was the largest at the big bang. In other words, the mass and intrinsic electric charge were not generated at that time. However, since temperatures immediately decrease after big bang, because of any origin (i.e., Higgs boson, broken symmetry of chirality etc.), the mixture between right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements has begun to occur. The mixture between right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements increases with an increase in time (with a decrease in the $c_{\boldsymbol{R}_R}(m)$ value). Similar discussions can be made in the $|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\rangle$ state,

We can see from Figs. 1 and 2 that the $\varepsilon_{\boldsymbol{R}}(m)$ and $\varepsilon_{\boldsymbol{L}}(m)$ values are not equivalent in the space axis. The total chirality and momentum in the both $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ and $|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\rangle$ states are not zero. This is the reason why the number of elements for magnetic spin moments is two, and thus there are attractive and repulsive forces between two magnetic moments.

The spin magnetic energy is proportional to the $\langle\boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and $\langle\boldsymbol{L}_L(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_L(+\boldsymbol{k})\rangle$ values (Figs. 1 (b) and 2 (b)),

$$\varepsilon_{\boldsymbol{R}}(m)=k_{m_s,\boldsymbol{R}}\langle\boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle, \tag{45}$$

$$\varepsilon_{\boldsymbol{L}}(m)=k_{m_s,\boldsymbol{L}}\langle\boldsymbol{L}_L(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_L(+\boldsymbol{k})\rangle, \tag{46}$$

The $k_{m_s,\boldsymbol{R}}$ and $k_{m_s,\boldsymbol{L}}$ values are different between the kinds of particles. This is the reason why we cannot theoretically predict the intensity of the spin magnetic moment for each particle. In summary, because of the $\langle\boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and

$\langle \boldsymbol{L}_L(+\boldsymbol{k}) | H_{0,\pm \boldsymbol{k},\pm \boldsymbol{k}} | \boldsymbol{L}_L(+\boldsymbol{k}) \rangle$ terms, originating from the finite right- and left-handed helicity elements, respectively, the magnetic field goes from the infinitesimal source point to the infinitesimal inlet point at finite space axis. This is the reason why the path of the magnetic field is like loop-type, as shown in Figs. 1 and 2.

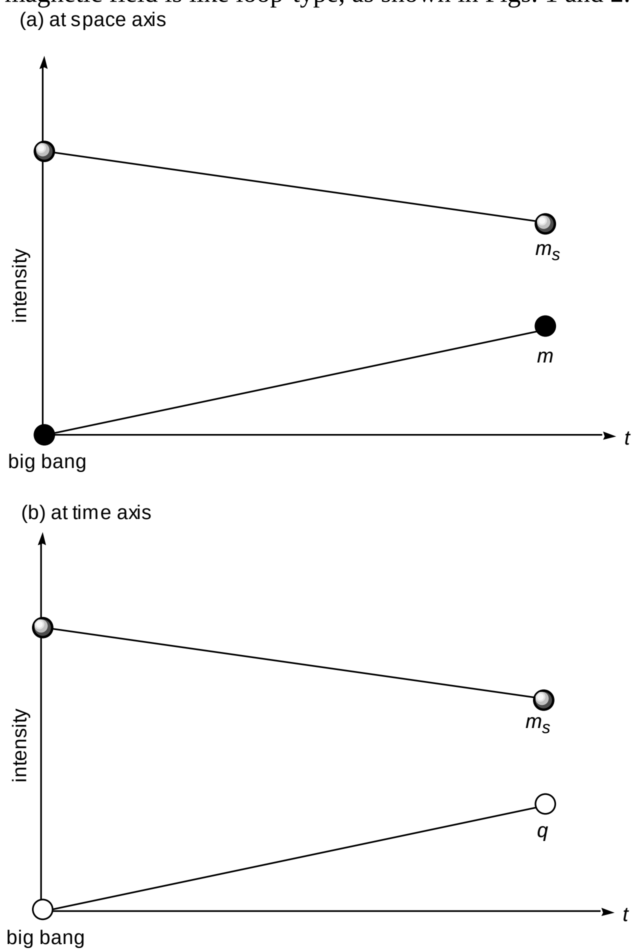


Fig. 3. (a) Intensity of the spin magnetic moment (shaded circles) and mass (closed circles) versus time. (b) Intensity of the spin magnetic moment (shaded circles) and electric charge (opened circles) versus time.

4.2 Mass

The rest energy $\varepsilon_{\text{rest},\boldsymbol{R}}(m)$ for the right-handed chirality $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ element can be defined as Eq. (19). At the time of the big bang, the $\varepsilon_{\text{rest},\boldsymbol{R}}(m)$ value was the minimum ($c_{\boldsymbol{R}_R}(m)=1$), as shown in Fig. 3 (a). That is, there was no mixture between the right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements, and thus the rest energy was zero at the big bang. In other words, the mass was not generated at that time. However, after that, temperature significantly decreases, and thus because of any origin (i.e., Higgs boson, broken symmetry of chirality etc.), the mixture between the right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ helicity elements has begun to occur. The mixture between right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements increases with an increase in time (with a decrease in the $c_{\boldsymbol{R}_R}(m)$ value). Similar discussions can be made in the $|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\rangle$ state.

The rest energy is proportional to the $\langle \boldsymbol{R}_R(+\boldsymbol{k}) | H_{1,\pm \boldsymbol{k},\square \boldsymbol{k}} | \boldsymbol{R}_L(-\boldsymbol{k}) \rangle$ and $\langle \boldsymbol{L}_L(+\boldsymbol{k}) | H_{1,\pm \boldsymbol{k},\square \boldsymbol{k}} | \boldsymbol{L}_R(-\boldsymbol{k}) \rangle$ values (Fig. 1 (a)),

$$\begin{aligned} \varepsilon_{\text{rest}}(m) &= k_m \langle \boldsymbol{R}_R(+\boldsymbol{k}) | H_{1,\pm \boldsymbol{k},\square \boldsymbol{k}} | \boldsymbol{R}_L(-\boldsymbol{k}) \rangle \\ &= k_m \langle \boldsymbol{L}_L(+\boldsymbol{k}) | H_{1,\pm \boldsymbol{k},\square \boldsymbol{k}} | \boldsymbol{L}_R(-\boldsymbol{k}) \rangle . \end{aligned} \tag{47}$$

The $k_m$ values are different between the kinds of particles. This is the reason why we dot theoretically predict the mass for each particle.

We can see from Fig. 1 that the $\varepsilon_{\text{rest},\boldsymbol{R}}(m)$ and $\varepsilon_{\text{rest},\boldsymbol{L}}(m)$ values are equivalent in the space axis. The total chirality and momentum in the both $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle$ and $|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\rangle$ states are zero. We can consider that the mass is generated by the mixture of the right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle$ handed helicity elements at the space axis. In the real world we live, the reversible process ( $-\boldsymbol{k}$ ) can be possible in the space axis while the reversible process ( $-t$ ) cannot be possible in the time axis (irreversible). This is the reason why the number of elements for mass is only one, and thus there is only attractive force between two masses. In summary, because of the $\langle \boldsymbol{R}_R(+\boldsymbol{k}) | H_{1,\pm \boldsymbol{k},\square \boldsymbol{k}} | \boldsymbol{R}_L(-\boldsymbol{k}) \rangle$ and $\langle \boldsymbol{L}_L(+\boldsymbol{k}) | H_{1,\pm \boldsymbol{k},\square \boldsymbol{k}} | \boldsymbol{L}_R(-\boldsymbol{k}) \rangle$ terms, originating from the cancellation of the right- and left-handed helicity elements at space axis, the gravitational field only spring out from the infinitesimal source point to any direction in space axis.

4.3 Electric Charge

The energy for the electric field $\varepsilon_{\boldsymbol{R}}(q)$ for the right-handed chirality $|\boldsymbol{R}\uparrow(q,+t)\rangle$ element can be defined as Eq. (33). At the time of the big bang, the $\varepsilon_{\boldsymbol{R}}(q)$ value was the minimum ($c_{\boldsymbol{R}_R}(q)=1$), as shown in Fig. 3 (b). That is, there was no mixture between the right- $|\boldsymbol{R}_R(+t)\rangle$ and left- $|\boldsymbol{R}_L(-t)\rangle$ handed helicity elements, and thus the electric field energy was zero at the big bang. In other words, the charge was not generated at that time. However, after that, temperature significantly decreases, and thus because of any origin (i.e., Higgs boson, broken symmetry of chirality etc.), the mixture between the right- $\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle$ and left- $\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle$ helicity elements at the time axis has begun to occur. The mixture between right- $\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle$ and left- $\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle$ handed helicity elements at the time axis increases with an increase in time (with a decrease in the $c_{\boldsymbol{R}_R}(q)$ value). Similar discussions can be made in the $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ state.

The electric field energy is proportional to the $\langle\!\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_R(+t)\rangle\!\rangle$ and $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle$ values (Fig. 2 (a)),

$$\varepsilon_{q,\boldsymbol{R}}(+t) = k_{q,\boldsymbol{R}}\langle\!\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_R(+t)\rangle\!\rangle, \qquad (48)$$

$$\varepsilon_{q,\boldsymbol{L}}(+t) = k_{q,\boldsymbol{L}}\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle, \qquad (49)$$

On the other hand, the $k_{q,\boldsymbol{R}}$ and $k_{q,\boldsymbol{L}}$ values are different between the kinds of particles. For example, neutron has no electric charge ( $\varepsilon_{q,\boldsymbol{R}}(+t)=0$ ) while it has spin magnetic moment, like left-handed helicity ( $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle \neq 0$ ). This is because the $k_{q,\boldsymbol{L}}$ value for the neutron is zero. Zero value of the $k_{q,\boldsymbol{L}}$ is the main reason why the neutron has no electric charge ( $\varepsilon_{q,\boldsymbol{R}}(+t)=0$ ) while it has spin magnetic moment, like left-handed helicity ( $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle \neq 0$ ). Furthermore, similar discussions can be made in neutrino; neutrino has no electric charge while it has spin magnetic moment. The difficult estimation of the $k_{q,\boldsymbol{R}}$ and $k_{q,\boldsymbol{L}}$ values are the main reason why we cannot theoretically predict the charge and spin magnetic moment for each particle.

It has been considered that for an elementary particle to have an intrinsic magnetic moment, it must have both spin and electric charge. On the other hand, the neutron has spin 1/2, but it has no net charge. The existence of the neutron's magnetic moment was puzzling and defied a correct explanation until the quark model for particles was developed in the 1960s. It has been explained that the neutron is composed of three quarks, and the magnetic moments of these elementary particles combine to give the neutron its magnetic moment. However, if the neutrino, which is elementary particle, has spin magnetic moment, this quark model for the explanation of the spin magnetic moment in the neutrons is not necessarily correct. According to our theory, it is possible that for an elementary particle to have an intrinsic magnetic moment, it does not necessarily to have electric charge if the $k_{q,\boldsymbol{R}}$ and $k_{q,\boldsymbol{L}}$ values are zero. The finite magnetic moments for the neutron and neutrino can be naturally explained by our theory.

According to the conventional Ampère's law, it has been considered that the moving charged particle induces the magnetic field. On the other hand, according to our theory, the angular momentum for the moving particle can induce the magnetic field.

The neutron behaves as if it has negative charge even though the neutron does not have charge as a whole. This is because the chirality of the neutron is left-handed and thus it behave as if it has negative charge. On the other hand, the $k_{q,\boldsymbol{L}}$ value for the neutron is zero. This is the reason why the neutron behaves as if it has negative charge even though the neutron does not have charge as a whole. Similar discussions can be made in the magnetic moment in the neutrino.

We can see from Fig. 2 that the $\varepsilon_{q,\boldsymbol{R}}(+t)$ and $\varepsilon_{q,\boldsymbol{L}}(+t)$ values are equivalent in the space axis. The total momentum in the both $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ states are not zero. And the total chirality in the $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ states are opposite each other at time axis, as shown in Fig. 2. We can consider that the charge is generated by the mixture of the right- $\left|\boldsymbol{R}_R(+t)\right\rangle\!\rangle$ and left- handed $\left|\boldsymbol{R}_L(-t)\right\rangle\!\rangle$ handed helicity elements at the time axis. In the real world we live, the reversible process ( $-\boldsymbol{k}$ ) can be possible in the space axis. This is the reason why the total chirality and momentum in the both $\left|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\right\rangle\!\rangle$ and $\left|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\right\rangle\!\rangle$ states are zero at the space axis, and the number of elements for mass is only one, and thus there is only attractive force between two masses. On the other hand, in the real world we live, the reversible process ( $-t$ ) cannot be possible in the time axis (irreversible). Therefore, we must consider the $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle$ state instead of the $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle\!\rangle$ state. This is the reason why the total chirality in the $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ states are not zero, and the opposite by each other, and the number of elements for electric charge is two, and thus there are attractive and repulsive forces between two electric charges. Because of the $\langle\!\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_R(+t)\rangle\!\rangle$ terms, the electric field only spring out from the infinitesimal source point to any direction in space and time axes. On the other hand, because of the $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle$ terms, the electric field only comes into the infinitesimal inlet point from any direction in space and time axes. In summary, because of the $\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_L(-t)\rangle$ and $\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle$ terms, originating from the cancellation of the right- and left-handed helicity elements, the electric field springs out from the infinitesimal source point to any direction in time axis, or comes into the infinitesimal inlet point from any direction in time axis.

4.4 Relationships between the Magnetic and Electric Fields

The space integration of the magnetic field becomes zero because of its loop-type flowing, on the other hand, that of the electric field does not become zero because of its spring out-type flowing, as shown in Fig. 4,

$$\oint BdS = 0, \qquad (50)$$

$$\oint EdS \neq 0. \qquad (51)$$

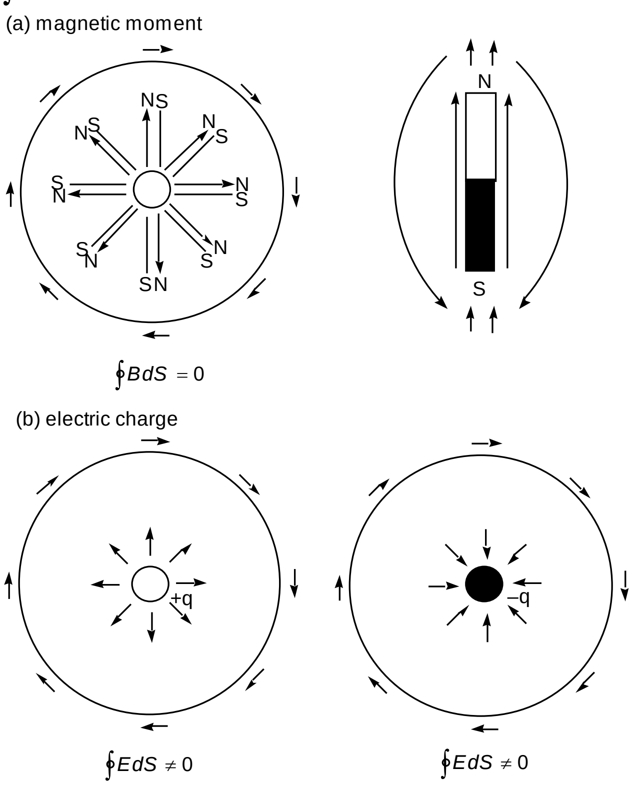


Fig. 4. Space integration under the no applied magnetic and electric field. (a) Spin magnetic momentum. (b) Electric charges.

Under the no magnetic and electric field, there is no net magnetic field and induced current in any direction, on the other hand, there are net electric field in any direction equivalently, as shown in Fig. 4. This is the reason why the electric charge exists while no spin magnetic moment has been observed under the no magnetic and electric field.

Let us next compare the $\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_L(-t)\rangle$ and $\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle$ terms in Eqs. (29) and (34), respectively, as shown in Figs. 2 and 5. We can see from Figs. 2 and 5 that right-handed helicity magnetic field can be induced when the positive charge moves while the left-handed helicity magnetic field can be induced when the negative charge moves. Therefore, the Ampére's law can be explained by our theory if we consider that the angular momentum for the right-handed helicity at the time axis is defined as positive charge (Figs. 2 and 5 (a)) and that for the left-handed helicity at the time axis is defined as negative charge (Figs. 2 and 5 (b)). Therefore, the negatively charged electron has the left-handed helicity element even though it has mainly been considered to belong to the left-handed helicity element in the previous discussions in this article.

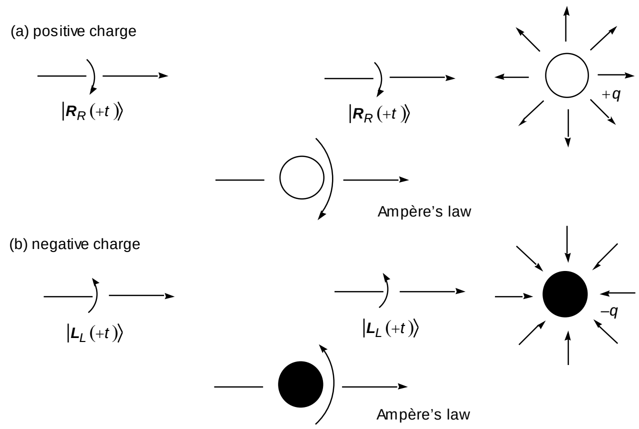


Fig. 5. Ampère's law (a) Positive charge. (b) Negative charge.

4.5 Unified Interpretations of the Spin Magnetic Moment, Mass, and Electric Charge

Let us next look into the relationships between the spin magnetic moment, mass, and electric charge, and between the magnetic forces, gravity, and electric forces. We can see from Fig. 6 that at the time of big bang, only spin magnetic moment, which is the element of the magnetic forces, existed. On the other hand, as the temperature decreases, because of any origin (i.e., Higgs boson, broken symmetry of chirality, etc.), the mass, which is the element of gravity, and the electric charge, which is element of electric force, can be generated. That is, we can consider that the element of the gravity and electric forces can be generated by the cancellation of the element of the right- and left-handed magnetic forces. As soon as the element of the electric force has been generated, the magnetic and electric field has been related by the

Ampère's law and Faraday's law. Now, we observe these elements as elements of two of four forces; spin magnetic moments and electric charge for the electromagnetic forces, and the mass for the gravity.

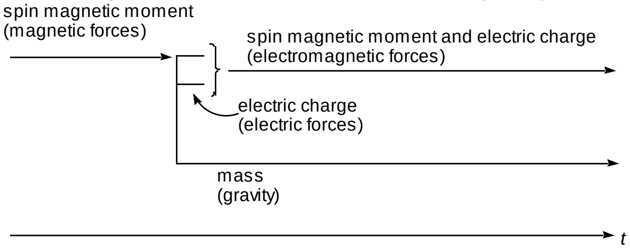


Fig. 6. Relationships between the elements of the magnetic forces (spin magnetic moment), gravity (mass), and electric forces (electric charge).

After the intrinsic spin magnetic moment, mass, and, and electric can be decided, one electron can be expressed as follows, and the discussions in Refs. [10] and [11] can be made,

$$\left|\boldsymbol{k}_{\text{one,av.}}(c_{+\boldsymbol{k}}, c_{-\boldsymbol{k}})\right\rangle\!\rangle = \sqrt{P_{\boldsymbol{k}_{\text{ground}}}(T)}\left|\boldsymbol{k}_{\text{ground}}(c_{+\boldsymbol{k}}, c_{-\boldsymbol{k}})\right\rangle\!\rangle + \sqrt{P_{\boldsymbol{k}_{\text{excited}}}(T)}\left|\boldsymbol{k}_{\text{excited}}(c_{+\boldsymbol{k}}, c_{-\boldsymbol{k}})\right\rangle\!\rangle, \quad (52)$$

where

$$\left|\boldsymbol{k}_{\text{ground}}(c_{+\boldsymbol{k}}, c_{-\boldsymbol{k}})\right\rangle\!\rangle = c_{+\boldsymbol{k}}\left|+\boldsymbol{k}\downarrow\right\rangle + c_{-\boldsymbol{k}}\left|-\boldsymbol{k}\uparrow\right\rangle, \quad (53)$$

$$\left|\boldsymbol{k}_{\text{excited}}(c_{+\boldsymbol{k}}, c_{-\boldsymbol{k}})\right\rangle\!\rangle = c_{+\boldsymbol{k}}\left|+\boldsymbol{k}\uparrow\right\rangle + c_{-\boldsymbol{k}}\left|-\boldsymbol{k}\downarrow\right\rangle. \quad (54)$$

## 5. Concluding Remarks

In this article, we investigated the relationships between the electric and magnetic fields. We discuss how the right- and left-handed helicity magnetic field can be induced when the positively and negatively charged particles, respectively, move. Furthermore, by comparing the spin magnetic field, mass, and electric charge, we suggest the origin of the electric charge in a particle.

We discuss the origin of the spin magnetic momentum, mass, and electric charge. Because of any origin (i.e., Higgs boson, broken symmetry of chirality etc.), the mixture between the right- and left-helicity elements occurs.

The mixtures between right- and left- handed helicity elements at the space-axis ($\langle\!\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\square}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle\!\rangle$ and $\langle\!\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\square}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle\!\rangle$), are the origin of the generations of the mass. Furthermore, the mixtures between right- and left- handed helicity elements at the time-axis ( $\langle\!\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_L(-t)\rangle\!\rangle \left(=\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_R(+t)\rangle\right)$ and $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle\!\rangle \left(=\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\right)$ ), are the origin of the generations of the electric charge. Because of the $\langle\!\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\square}|\boldsymbol{R}_L(-\boldsymbol{k})\rangle\!\rangle$ and $\langle\!\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{1,\pm\boldsymbol{k},\square}|\boldsymbol{L}_R(-\boldsymbol{k})\rangle\!\rangle$ terms, originating from the mixture of the right- and left-handed helicity elements at space axis, the gravitational field only spring out from the infinitesimal source point to any direction in space axis. In a similar way, because of the $\langle\!\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_L(-t)\rangle\!\rangle$ and $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle\!\rangle$ terms, originating from the mixture of the right- and left-handed helicity elements, the electric field springs out from the infinitesimal source point to any direction in time axis, or comes into the infinitesimal inlet point from any direction in time axis.

On the other hand, the right- ( $\langle\!\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle\!\rangle$ ) and left- ( $\langle\!\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_L(+\boldsymbol{k})\rangle\!\rangle$ ) handed helicity elements themselves, which are not mixed by each other, are the origin of the generations of the spin magnetic moment. Because of the $\langle\!\langle \boldsymbol{R}_R(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{R}_R(+\boldsymbol{k})\rangle\!\rangle$ and $\langle\!\langle \boldsymbol{L}_L(+\boldsymbol{k})|H_{0,\pm\boldsymbol{k},\pm\boldsymbol{k}}|\boldsymbol{L}_L(+\boldsymbol{k})\rangle\!\rangle$ terms, originating from the finite right- and left-handed helicity elements themselves, respectively, the magnetic field goes from the infinitesimal source point to the infinitesimal inlet point at finite space axis. This is the reason why the path of the magnetic field is like loop-type, as shown in Figs. 1 and 2.

We can consider that the mass is generated by the mixture of the right- $|\boldsymbol{R}_R(+\boldsymbol{k})\rangle\!\rangle$ and left- $|\boldsymbol{R}_L(-\boldsymbol{k})\rangle\!\rangle$ handed helicity elements at the space axis. In the real world we live, the reversible process ( $-\boldsymbol{k}$ ) can be possible in the space axis. This is the reason why the total chirality and momentum in the both $|\boldsymbol{R}\uparrow(m,\boldsymbol{k})\rangle\!\rangle$ and $|\boldsymbol{L}\downarrow(m,\boldsymbol{k})\rangle\!\rangle$ states are zero at the space axis, and the number of elements for mass is only one, and thus there is only attractive force between two masses.

On the other hand, we can consider that the charge is generated by the mixture of the right- $|\boldsymbol{R}_R(+t)\rangle\!\rangle$ and left-handed $|\boldsymbol{R}_L(-t)\rangle\!\rangle$ handed helicity elements at the time axis. In the real world we live, the reversible process ( $-t$ ) cannot be possible in the time axis (irreversible). Therefore, we must consider the $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_L(+t)\rangle\!\rangle$ state instead of the $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle\!\rangle$ state. This is the reason why the total chirality in the $\left|\boldsymbol{R}\uparrow(q,+t)\right\rangle\!\rangle$ and $\left|\boldsymbol{L}\downarrow(q,+t)\right\rangle\!\rangle$ states are not zero, and the opposite by each other, and the number of elements for electric charge is two, and thus there are attractive and repulsive forces between two electric charges.

By comparing the $\langle\!\langle \boldsymbol{R}_R(+t)|H_{1,\pm t,\square}|\boldsymbol{R}_L(-t)\rangle\!\rangle$ and $\langle\!\langle \boldsymbol{L}_L(+t)|H_{1,\pm t,\square}|\boldsymbol{L}_R(-t)\rangle\!\rangle$ terms in Eqs. (29) and (34), respectively, as shown in Figs. 2 and 5, we can see that right-handed helicity magnetic field can be induced when the positive charge moves while the left-handed helicity magnetic field can be induced when the negative charge moves. Therefore, the Ampére's law can be explained by our theory if we consider that the angular momentum for the right-handed helicity at the time axis is observed as positive charge (Figs. 2 and 5 (a)) and that for the left-handed helicity at the time axis is observed as negative charge (Figs. 2 and 5 (b)).

We look into the relationships between the spin magnetic moment, mass, and electric charge, and between the magnetic forces, gravity, and electric forces. At the time of big bang, only spin magnetic moment, which is the element of the magnetic forces, existed. On the other hand, as the temperature decreases, because of any origin (i.e., Higgs boson, broken symmetry of chirality, etc.), the mass, which is the element of gravity, and the electric charge, which is element of electric force, can be generated. That is, we can consider that the element of the gravity and electric forces can be generated by the mixture of the element of the right- and left-handed magnetic forces. As soon as the element of the electric force has been generated, the magnetic and electric field has been related by each other by the Ampère's law and Faraday's law. Now, we observe these elements as elements of two of four forces; spin magnetic moments and electric charge for the electromagnetic forces, and the mass for the gravity.

**Acknowledgments**

This work is supported by The Iwatani Naoji Foundation's Research Grant.

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**Author Profile**

Dr. Takashi Kato is a Professor at Nagasaki Institute of Applied Science, Japan. He completed his doctorate in physical chemistry with the theory of vibronic interactions and Jahn–Teller effects at Kyoto University (PhD (Engineering)), Japan, in 2000. During October 2001-February 2003, he has performed research concerning prediction of the occurrence of superconductivity of graphene-like aromatic hydrocarbons such as phenanthrene, picene, and coronene at Max-Planck-Institute for Solid State Research in Stuttgart, Germany, as a visiting scientist. In 2010, his prediction of the occurrence of superconductivity of picene and coronene were experimentally confirmed at Okayama University, Japan, and in 2011, that of phenanthrene was

experimentally confirmed at University of Science and Technology of China. His theory and calculations concerning the guiding principle towards high-temperature superconductivity are highly regarded and recently reported several times in newspaper (The Nikkei), which is the most widely read in Japan, as follows ((1) July 8, 2014, The Nikkei; (2) October 19, 2013, The Nikkei; (3) November 7, 2011, The Nikkei; (4) January 14, 2011, The Nikkei; (5) November 22, 2010, The Nikkei; (6) November 18, 2010, The Nikkei).