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Research Article

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Using the Method of Contradiction to Prove that the Definition of Magnetic Field in Maxwell's Theory is Incorrect

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Abstract

The author discovers an error in the definition of the magnetic field in Maxwell's classical electromagnetic theory. This paper employs a proof by contradiction to demonstrate that the error occurs during the transition from quasi-static electromagnetic fields to radiating electromagnetic fields. Initially assuming the correctness of Maxwell's electromagnetic theory, the paper derives Poynting's theorem and subsequently derives the theorem of mutual energy flow. Following the principles of the latter theorem, the magnetic field is defined, and methods for measuring it are established. It is further demonstrated that the magnetic field obtained using this method is consistent with classical electromagnetic theory under quasi-static conditions. However, in the transition to radiating electromagnetic fields, the newly defined or measured magnetic field conflicts with classical electromagnetic theory. This indicates a flaw in Maxwell's classical electromagnetic theory. The author identifies this flaw as stemming from Maxwell defining the magnetic field as the curl of the magnetic vector potential, a definition valid only under quasi-static conditions. This definition undergoes a change in radiating electromagnetic fields, a change is overlooked by Maxwell and subsequent researchers. The author proposes a corrective solution to this error in Maxwell's electromagnetic theory.

Keywords: Poynting's Theorem, Maxwell's Equation, Classical Electromagnetic Field, Magnetic Field, Retarded Potential, Advanced Potential, Quasi Static State, Curl, Wrong

1. Introduction

The original definition of magnetic field was defined by Biota's law and Ampere's law of force. Under quasi-static conditions, William Thomson Lord Kelvin discovered that the curl of a magnetic vector potential is consistent with the magnetic field defined by Biota's law, so the definition of a magnetic field can be changed to the curl of a magnetic vector potential. Maxwell followed Lord Kelvin and changed the definition of magnetic field to the curl of magnetic vector potential. But when it comes to radiated electromagnetic fields, the magnetic vector potential needs to consider the retardation factor. Is the curl of a retarded magnetic vector potential still a magnetic field? Maxwell thought without hesitation that it was. The author notes that researchers at the same time as Maxwell, such as Kirchhoff's 1857 paper and Lorenz's 1867 paper, did not define electric and magnetic fields [1,2]. That is to say, they do not define the curl of the magnetic vector potential as a magnetic field, that is, they are likely to believe that,

$$\boldsymbol{B} =? \nabla \times \boldsymbol{A}^{(r)}$$

The symbol "=?" indicates that the relationship is uncertain. The relationship is uncertain to the electric field too,

$$\boldsymbol{E} =? -\nabla\phi^{(r)} - \frac{\partial}{\partial t}\boldsymbol{A}^{(r)}$$

Lorenz gave the retarded potential of the electromagnetic field in 1867, but in fact, the general solution of Maxwell's equation also depends on Lorenz's retarded potential solution [2]. Lorenz's electromagnetic theory was based on Kirchhoff's electromagnetic theory. In his 1857 paper, Kirchhoff proposed the continuity equation of current, Kirchhoff gauge, and scalar imaginary wave equation inside the current. If Kirchhoff had used Neumann's vector potential at that time, he would have obtained the wave equation of the scalar potential inside the current, not just the imaginary wave equation. Kirchhoff did not define the concepts of electric and magnetic fields, he only used vector potentials and scalar potentials. Lorenz used Neumann's vector potential in his 1867 paper, thus obtaining the wave equations for vector potential and scalar potential, as well as the solutions for these equations with respect to retarded potential. Lorenz, like Kirchhoff, did not define magnetic and electric fields. It seems that only Maxwell defined the curl of the retarded potential as a magnetic field. It is worth discussing whether this definition is reasonable.

The author proposed the mutual energy theorem and inner product of two electromagnetic fields (that is the mutaul energy flow) in 1987 [3-5], and 30 years later, the author discovered that this theorem is a Fourier transform of Welch's time-domain reciprocity theorem published in 1960 [6]. Therefore, it can be regarded as a same theorem. This theorem has also been independently proposed by many different people, including the Rumsey new reciprocity theorem in 1963, the De Hoop cross relative reciprocity theorem in 1987, and Petrusenko's second reciprocity theorem in 2009 [7-9]. Welch's reciprocity theorem involves advanced waves. The author has read works on advanced waves, including Wheeler and Feynman's absorber theory [10,11]. This further revealed Dirac's theory of self-force [12]. Discovered the theory of action at a distance [13-15]. Discovered the quantum mechanical transctional interpretation of Cramer, and the advanced wave theory of [16-18]. In 2017, the author proposed that the mutual energy theorem should be the law of conservation of energy, and developed the mutual energy flow theorem. And interpret quantum mechanics using mutual energy flow. During this process, the author found that self energy flow should not be involved in electromagnetic radiation. Therefore, the concept of reverse collapse of self energy flow was proposed [19]. In recent years, the author has been studying the application examples of mutual energy flow, and in this process, the author has found that the self energy flow must be reactive power However, the electromagnetic and magnetic field phases obtained by solving the Maxwell equation are in phase, indicating that the electromagnetic wave has active power [20-33]. The author's findings contradict the conclusions of Maxwell's classical electromagnetic theory. The author believes that the solution to Maxwell's equation went wrong somewhere. Later, it was discovered that Maxwell did define the magnetic field as the curl of the vector potential, and made an error when considering the retardation factor in the vector potential.

This article explains that in the theory of radiated electromagnetic fields, the magnetic field should be defined according to the quantity related to the Poynting vector. But the Poynting vector is not easy to measure. However, it can also be defined according to the mutual energy flow. The mutual energy flow density is a mixed Poynting vector. The mutual energy flow represents the energy flow density from the primary coil to secondary coil of a transformer. Mutual energy flow is also the energy flow density from the transmitting antenna to the receiving antenna. The mutual energy flow theorem can be derived from the Poynting theorem, so it is still the correct energy theorem even within the framework of Maxwell's electromagnetic theory. Therefore, this article adopts the method of proof by contradiction, first assuming that Maxwell's electromagnetic theory is correct. The mutual energy flow theorem is derived from this. Therefore, the mutual energy flow theorem is also correct according to Maxwell's equations, allowing the magnetic field to be determined (defined and measured) later by the mutual energy flow theorem. Using this method, it is found that there should be a 90 degree phase difference between the magnetic and electric fields of electromagnetic waves. This contradicts the fact that the electric and magnetic fields of electromagnetic waves in Maxwell's electromagnetic theory are in phase, indicating that Maxwell's electromagnetic theory is incorrect. Since Maxwell's theory is incorrect, the author has revised the definition of magnetic field in Maxwell's electromagnetic theory.

What is new in this paper: (1) define the magnetic field according to Poynting vector and the mutual energy flow. (2) Introduce the concept of synchronization of two electromagnetic fields. (3) Introduce a method to measure the magnetic field defined by the mutual energy flow. (4) Using method of contradiction to prove there is a bug in Maxwell's classical electromagnetic field theory. (5) Correct the phase of the magnetic field obtained from Maxwell's theory.

2. The Definition of Magnetic Field is Incorrect

We know that the solution to the electromagnetic field equation under quasi-static conditions is,

$$\boldsymbol{A} = \frac{\mu_0}{4\pi} \int_V \frac{\boldsymbol{J}}{r} dV \tag{1}$$

$$\boldsymbol{B}_{Maxwell} \triangleq \nabla \times \boldsymbol{A} = \frac{\mu_0}{4\pi} \int_V \nabla \frac{1}{r} \times \boldsymbol{J} dV \tag{2}$$

We use the subscript Maxwell to remind readers that the definition of this magnetic field was completed by Maxwell and it may be controversial, so there is,

$$\boldsymbol{B}_{Maxwell} = \frac{\mu_0}{4\pi} \int_V \boldsymbol{J} \times \frac{\boldsymbol{r}}{r^3} dV \tag{3}$$

We also know that according to Biota's law, the magnetic field is,

$$\boldsymbol{B} \triangleq \frac{\mu_0}{4\pi} \int_V \boldsymbol{J} \times \frac{\boldsymbol{r}}{r^3} dV \tag{4}$$

The symbol "≜" represents the meaning of the definition, so we conclude that,

$$\boldsymbol{B}_{Maxwell} = \boldsymbol{B} \tag{5}$$

This indicates that the magnetic field defined by Maxwell under quasi-static conditions is the same as the magnetic field defined by Biota's law. But when it comes to radiated electromagnetic fields, the vector potential must consider the retardation factor, which is present in the frequency domain,

$$\boldsymbol{A} = \boldsymbol{A}^{(r)} = \frac{\mu_0}{4\pi}\int_V \frac{\boldsymbol{J}}{r}\exp(-jkr)dV \tag{6}$$

Therefore,

$$\boldsymbol{B}_{Maxwell} = \nabla \times \boldsymbol{A}^{(r)} = \frac{\mu_0}{4\pi}\int_V \nabla(\frac{1}{r}\exp(-jkr)) \times \boldsymbol{J}dV \tag{7}$$

Therefore,

$$\boldsymbol{B}_{Maxwell} = \frac{\mu_0}{4\pi}\int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{jk\hat{r}}{r})\exp(-jkr))dV \tag{8}$$

Obviously,

$$\boldsymbol{B}_{Maxwell} \neq \boldsymbol{B} \tag{9}$$

Therefore, there is no reason to believe that $\boldsymbol{B}_{Maxwell}$ is the magnetic field $\boldsymbol{B}$. Let's take a step back and consider,

$$\lim_{kr\to 0}\boldsymbol{B}_{Maxwell} = \frac{\mu_0}{4\pi}\int_V \boldsymbol{J} \times (\frac{\boldsymbol{r}}{r^3} + \frac{jk\hat{r}}{r})dV$$

$$= \boldsymbol{B} + j\frac{\mu_0}{4\pi}\int_V \boldsymbol{J} \times (\frac{k\hat{r}}{r})dV \tag{10}$$

At this point, there are still,

$$\lim_{kr\to 0}\boldsymbol{B}_{Maxwell} \neq \boldsymbol{B} \tag{11}$$

We know that,

$$kr \to 0 \tag{12}$$

imply

$$\frac{2\pi}{\lambda}r \to 0 \tag{13}$$

Or,

$$r \ll \lambda \tag{14}$$

This situation has degenerated to quasi-static conditions, but $\lim_{kr\to 0}\boldsymbol{B}_{Maxwell}$ still cannot degenerate to the magnetic field $\boldsymbol{B}$. Therefore, The reason why $\boldsymbol{B}_{Maxwell}$ is called a magnetic field is insufficient. Let's compare the situation of induced electric fields,

$$\boldsymbol{E}_i \triangleq -\frac{\partial}{\partial t}\boldsymbol{A} \tag{15}$$

In the frequency domain,

$$\boldsymbol{E}_i \triangleq -j\omega\boldsymbol{A} = -j\omega\frac{\mu_0}{4\pi}\int_V \frac{\boldsymbol{J}}{r}dV \tag{16}$$

When it comes to radiating electromagnetic fields,

$$\boldsymbol{E}_{iMaxwell} \triangleq -j\omega\boldsymbol{A}^{(r)} = -j\omega\frac{\mu_0}{4\pi}\int_V \frac{\boldsymbol{J}}{r}\exp(-jkr)dV \tag{17}$$

Therefore,

$$\lim_{kr\to 0}\boldsymbol{E}_{iMaxwell} = -j\omega\frac{\mu_0}{4\pi}\int_V \frac{\boldsymbol{J}}{r}\exp(-jkr)dV = -j\omega\frac{\mu_0}{4\pi}\int_V \frac{\boldsymbol{J}}{r}dV \tag{18}$$

That is,

$$\lim_{kr\to 0} \boldsymbol{E}_{iMaxwell} = \boldsymbol{E}_i \quad (19)$$

From this, it can be seen that $\boldsymbol{E}_{iMaxwell}$ can degenerate into $\boldsymbol{E}_i$. But $\boldsymbol{B}_{Maxwell}$ cannot degenerate into $\boldsymbol{B}$. Actually, if we consider

$$\boldsymbol{E}_s \triangleq -\nabla\phi, \quad (20)$$

$$\boldsymbol{E}_{sMaxwell} \triangleq -\nabla\phi^{(r)} \quad (21)$$

$$\lim_{kr\to 0} \boldsymbol{E}_{sMaxwell} \neq \boldsymbol{E}_s \quad (22)$$

Therefore, the electrostatic field $\boldsymbol{E}_{sMaxwell}$ cannot degenerate to either $\boldsymbol{E}_s$. Therefore, There are also issues if $\boldsymbol{E}_{sMaxwell}$ is defined as $\boldsymbol{E}_s$. But this article will not discuss that issue. Only discuss the issue of magnetic fields.

3. Energy Related Theorems

We know that the following Poynting's theorem holds under both magnetic quasi-static conditions and radiation electromagnetic field conditions,

$$-\oiint_\Gamma (\boldsymbol{E}\times\boldsymbol{H})\cdot\hat{n}d\Gamma = \int_V (\boldsymbol{E}\cdot\boldsymbol{J})dV + \frac{\partial}{\partial t}U \quad (23)$$

In magnetic quasi-static state, the energy is only magnetic field energy,

$$U = \frac{1}{2}\int_V (\boldsymbol{H}\cdot\boldsymbol{B})dV \quad (24)$$

Under radiation electromagnetic field conditions, the energy is,

$$U = \frac{1}{2}\int_V (\boldsymbol{E}\cdot\boldsymbol{D} + \boldsymbol{H}\cdot\boldsymbol{B})dV \quad (25)$$

Consider the integration of energy over time,

$$\int_{t=-\infty}^{\infty} dt \frac{\partial}{\partial t}U = U(\infty) - U(-\infty) = 0 \quad (26)$$

U(-∞), *U(∞)* is the energy at the beginning of the system and the energy at the end of the system, both of which should be zero. Integrating Poynting's theorem in time with time can eliminate the energy term, resulting in,

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma (\boldsymbol{E}\times\boldsymbol{H})\cdot\hat{n}d\Gamma = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}\cdot\boldsymbol{J})dV \quad (27)$$

Consider that the current source consists of two current elements, and then consider the superposition principle,

$$\boldsymbol{J} = \sum_{i=1}^{2} \boldsymbol{J}_i, \quad \boldsymbol{E} = \sum_{i=1}^{2} \boldsymbol{E}_i, \quad \boldsymbol{H} = \sum_{i=1}^{2} \boldsymbol{H}_i \quad (28)$$

Using the above superposition principle in (27),

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma \sum_{i=1}^{2}\sum_{j=1}^{2} (\boldsymbol{E}_i\times\boldsymbol{H}_j)\cdot\hat{n}d\Gamma = \sum_{i=1}^{2}\sum_{j=1}^{2}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i\cdot\boldsymbol{J}_j)dV \quad (29)$$

According to (27),

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma \sum_{i=1}^{2} (\boldsymbol{E}_i\times\boldsymbol{H}_i)\cdot\hat{n}d\Gamma = \int_{t=-\infty}^{\infty} dt \int_V \sum_{i=1}^{2} (\boldsymbol{E}_i\cdot\boldsymbol{J}_i)dV \quad (30)$$

Subtract (30) from (29) to obtain,

$$-\int_{t=-\infty}^{\infty} dt \oiint_\Gamma \sum_{i=1}^{2}\sum_{j=1,j\neq i}^{2} (\boldsymbol{E}_i\times\boldsymbol{H}_j)\cdot\hat{n}d\Gamma = \sum_{i=1}^{2}\sum_{j=1,j\neq i}^{2}\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_i\cdot\boldsymbol{J}_j)dV \quad (31)$$

Alternatively,

$$-\int_{t=-\infty}^{\infty} dt \oiint_{\Gamma} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2 + \boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV \quad (32)$$

We assume that $\boldsymbol{J}_1$ is a radiation source, therefore $\boldsymbol{E}_1$, $\boldsymbol{H}_1$ It is a retarded wave, assuming $\boldsymbol{J}_2$ is a radiation sink, such as a receiving antenna, so $\boldsymbol{E}_2$, $\boldsymbol{H}_2$ is not a retarded wave. According to Maxwell's electromagnetic theory, the receiving antenna does not produce radiation, and the far-field of this electromagnetic wave is zero. According to Wheeler Feynman's absorber theory, Cramer's quantum mechanics transactional interpretation, or the author's advanced wave theory, $\boldsymbol{E}_2$, $\boldsymbol{H}_2$ is an advanced wave. This $\boldsymbol{E}_1$, $\boldsymbol{H}_1$ and $\boldsymbol{E}_2$, $\boldsymbol{H}_2$ Not reaching surfaces with infinite radii at the same time Γ. Therefore, the surface integral on the surface Γ is zero,

$$\oiint_{\Gamma} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n} d\Gamma = 0 \quad (33)$$

Obtained from (32, 33),

$$\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2 + \boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV = 0 \quad (34)$$

Or,

$$-\int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV = \int_{t=-\infty}^{\infty} dt \int_V (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2) dV \quad (35)$$

The above equation is the Welch time-domain reciprocity theorem [6], which we obtained from the Poynting theorem, therefore it is an energy theorem. Transform to frequency domain as,

$$-\int_{V_1} (\boldsymbol{E}_2^* \cdot \boldsymbol{J}_1) dV = \int_{V_2} (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2^*) dV \quad (36)$$

The above equation is the mutual energy theorem proposed by the author [3-5] in 1987. Since it is derived from Poynting's theorem, it is also the energy theorem. Consider $\Gamma = \Gamma_1$ in (32) , Γ_1 is only contains one current $\boldsymbol{J}_1$ Therefore, there are,

$$-\int_{t=-\infty}^{\infty} dt \oiint_{\Gamma_1} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_{V_1} (\boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV \quad (37)$$

Consider that the outer normal of the surface coincides with the normal from region 1 to region 2,

$$\hat{n} = \hat{n}_{1\to 2} \quad (38)$$

$$-\int_{t=-\infty}^{\infty} dt \oiint_{\Gamma_1} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n}_{1\to 2} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_{V_1} (\boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV \quad (39)$$

Consider in (32) $\Gamma = \Gamma_2$, Γ_2 only contains one current $\boldsymbol{J}_2$. Therefore, there are,

$$-\int_{t=-\infty}^{\infty} dt \oiint_{\Gamma_2} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_{V_2} (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2) dV$$

Consider that the normal direction outside the surface is opposite to the normal direction from region 1 to region 2,

$$\hat{n} = -\hat{n}_{1\to 2}$$

have obtained,

$$\int_{t=-\infty}^{\infty} dt \oiint_{\Gamma_2} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n}_{1\to 2} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_{V_2} (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2) dV \quad (40)$$

By combining (39), (40), and (36), it can be concluded that,

$$-\int_{t=-\infty}^{\infty} dt \int_{V_1} (\boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV = \int_{t=-\infty}^{\infty} dt \oiint_{\Gamma_1} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n}_{1\to 2} d\Gamma$$

$$= \int_{t=-\infty}^{\infty} dt \oiint_{\Gamma_2} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n}_{1\to 2} d\Gamma = \int_{t=-\infty}^{\infty} dt \int_{V_2} (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2) dV \quad (41)$$

The two surface integrals in the above equation can be combined to form one,

$$-\int_{t=-\infty}^{\infty} dt \int_{V_1} (\boldsymbol{E}_2 \cdot \boldsymbol{J}_1) dV$$
$$= \int_{t=-\infty}^{\infty} dt \oiint_{\Gamma} (\boldsymbol{E}_1 \times \boldsymbol{H}_2 + \boldsymbol{E}_2 \times \boldsymbol{H}_1) \cdot \hat{n}_{1\to 2} d\Gamma$$
$$= \int_{t=-\infty}^{\infty} dt \int_{V_2} (\boldsymbol{E}_1 \cdot \boldsymbol{J}_2) dV \quad (42)$$

In the given equation, the surface Γ represents any closed surface that separates the currents $\boldsymbol{J}_1$, $\boldsymbol{J}_2$, or an infinite open surface that separates them, such as an infinite plane. The equation is then transformed into the Fourier frequency domain:

$$-\int_{V_1}(\boldsymbol{E}_2^*\cdot\boldsymbol{J}_1)dV=\oiint_\Gamma(\boldsymbol{E}_1\times\boldsymbol{H}_2^*+\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}_{1\to2}d\Gamma=\int_{V_2}(\boldsymbol{E}_1\cdot\boldsymbol{J}_2^*)dV \qquad (43)$$

In the given equations (42,43), the mutual energy flow theorem was proposed by the author in 2017 [19]. This theorem holds under both quasi-static and radiating electromagnetic field conditions, considering the situation of retarded potentials. Therefore, assuming Maxwell's electromagnetic theory is correct, we can derive the mutual energy flow theorem (43).

3.1 Synchronization

If we consider the principle of half retardation and half advance in the above equation, there is a correction factor of 1/2. The idea of this principle can be derived from [10, 11]. That is,

$$-\int_{V_1}(\boldsymbol{E}_2^*\cdot\boldsymbol{J}_1)dV=\frac{1}{2}\oiint_\Gamma(\boldsymbol{E}_1\times\boldsymbol{H}_2^*+\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}_{1\to2}d\Gamma=\int_{V_2}(\boldsymbol{E}_1\cdot\boldsymbol{J}_2^*)dV \qquad (44)$$

In fact, the author believes that the above equation can be broken down into:,

$$Action=\oiint_\Gamma(\boldsymbol{E}_1\times\boldsymbol{H}_2^*)\cdot\hat{n}_{1\to2}d\Gamma=\int_{V_2}(\boldsymbol{E}_1\cdot\boldsymbol{J}_2^*)dV \qquad (45)$$

$$Reaction=\int_{V_1}(\boldsymbol{E}_2^*\cdot\boldsymbol{J}_1)dV=-\oiint_\Gamma(\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}_{1\to2}d\Gamma \qquad (46)$$

$$Action=-Reaction \qquad (47)$$

Action is an action of electric field $\boldsymbol{E}_1$ to current $\boldsymbol{J}_2$. The function of action is achieved through $\oiint_\Gamma(\boldsymbol{E}_1\times\boldsymbol{H}_2^*)\cdot\hat{n}_{1\to2}d\Gamma$. Reaction is an action of the electric field $\boldsymbol{E}_2$ to current $\boldsymbol{J}_1$. This function is achieved through $-\oiint_\Gamma(\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}_{1\to2}d\Gamma$. The above equation should be an extension of Newton's third law when objects are not in contact with each other. The above formula means,

$$\oiint_\Gamma(\boldsymbol{E}_2^*\times\boldsymbol{H}_1)\cdot\hat{n}_{1\to2}d\Gamma=\oiint_\Gamma(\boldsymbol{E}_1\times\boldsymbol{H}_2^*)\cdot\hat{n}_{1\to2}d\Gamma \qquad (48)$$

Therefore, the mutual energy flow can be calculated using any of the following pairs, ($\boldsymbol{E}_1$,$\boldsymbol{H}_2$) or ($\boldsymbol{E}_2$,$\boldsymbol{H}_1$).

When the current element $\boldsymbol{J}_1$ generates a retarded field $\boldsymbol{E}_1$ reaching the current $\boldsymbol{J}_2$, $\boldsymbol{J}_2$ precisely has a current in phase with $\boldsymbol{E}_1$. At this point, $\boldsymbol{J}_2$ generates an advanced field $\boldsymbol{E}_2$, and the field of $\boldsymbol{E}_2$ reaching the current $\boldsymbol{J}_1$ is exactly 180 degrees out of phase with $\boldsymbol{J}_1$. This indicates that the two electric fields $\boldsymbol{E}_1$, $\boldsymbol{E}_2$ are synchronized. The 180-degree phase difference here is due to the negative sign on the right side of equation (44). When they are in sync, $\boldsymbol{E}_1$, $\boldsymbol{H}_2$ have the same phase, and $\boldsymbol{E}_2$, $\boldsymbol{H}_1$ have the same phase.

4. Proof of Contradiction Proves that the Definition of Maxwell's Magnetic Field is Incorrect

4.1 Theoretical Definition of Magnetic Field

The method of definition is to seek a formula that includes a magnetic field, such as the Poynting vector, which is a good formula for defining a magnetic field,

$$\boldsymbol{E}\times\boldsymbol{H}=\boldsymbol{S} \qquad (49)$$

If we know $\boldsymbol{S}$ and $\boldsymbol{E}$, we can obtain $\boldsymbol{H}$. This is obvious. However, the Poynting vector itself is not an easily measurable quantity, so the significance of the magnetic field defined above is not significant. In fact, we usually calculate the Poynting vector based on electric and magnetic fields. But not the opposite. Therefore, this definition of magnetic field is Ok but not very good. We also need to consider ease of measurement when defining a magnetic field. In addition, there is no dispute about the magnitude of the magnetic field value, only the phase of the magnetic field is disputed. Therefore, what we will focus on discussing below is the definition of the phase of the magnetic field.

Consider the formula (43). This formula is derived from Maxwell's equation and Poynting's theorem. Therefore, according to Maxwell's electromagnetic theory, it is a correct formula. Consider current $\boldsymbol{J}_2$ It is a straight wire antenna, or a dipole antenna. We use this receiving antenna to measure the magnetic field $\boldsymbol{H}_1$. Firstly, consider the load resistance of this antenna,

$$R_2\gg\omega L_2 \qquad (50)$$

L_2 is the inductance of the secondary coil (i.e. the receiving antenna), so the above equation means that the load on the secondary coil is resistive. The current on the secondary coil is,

$$I_2 = \frac{\mathcal{E}_{1\to 2}}{R_2+\omega L_2} \simeq \frac{\mathcal{E}_{1\to 2}}{R_2} \sim \mathcal{E}_{1\to 2} \sim E_1 \quad (51)$$

The symbol "~" indicates proportionality, which is only sensitive to phase. Not sensitive to numerical values. The electric field we considered above on a straight wire,

$$\mathcal{E}_{1\to 2} = \int \boldsymbol{E}_1 \cdot d\boldsymbol{l} = E_1 \int \hat{E}_1 \cdot d\boldsymbol{l} \sim E_1$$

In this case, the energy received by the secondary coil is a real number because I_2 and its induced electromotive force $E_{1\to 2}$ maintains the same phase, so the energy provided by the mutual energy flow must also be real, that is,

$$\frac{1}{2}\oint\!\!\!\oint_\Gamma (\boldsymbol{E}_1 \times \boldsymbol{H}_2^* + \boldsymbol{E}_2^* \times \boldsymbol{H}_1) \cdot \hat{n}_{1\to 2} d\Gamma$$

$$= \int \boldsymbol{E}_1 \cdot d\boldsymbol{l} I_2^* = \mathcal{E}_{1\to 2} I_2^* = Real \quad (52)$$

This means that two electromagnetic fields $\xi_1 = [\boldsymbol{E}_1, \boldsymbol{H}_1]^T$, $\xi_2 = [\boldsymbol{E}_2, \boldsymbol{H}_2]^T$, are synchronous see subsection 3.1, i.e

$$\boldsymbol{H}_1 \sim \boldsymbol{E}_2 \quad (53)$$

$$\boldsymbol{E}_1 \sim \boldsymbol{H}_2 \quad (54)$$

$\boldsymbol{H}_1$ and $\boldsymbol{E}_2$ are in phase, $\boldsymbol{H}_2$ and $\boldsymbol{E}_1$ are in phase. So we can use $\boldsymbol{E}_2$ to measure the magnetic field based on phase definition of $\boldsymbol{H}_1$. Further, the phase of $\boldsymbol{E}_2$ can be determined by current $\boldsymbol{I}_2$,

$$\boldsymbol{E}_2 = -j\omega \boldsymbol{A}_2 \sim -j\omega I_2 \hat{z} \quad (55)$$

So we can adjust the current I_2 to define and measure the phase of magnetic fields $\boldsymbol{H}_1$. Below, we will use two examples to illustrate the definition and measurement of magnetic field phase.

4.2 Measuring the Magnetic Field of a Long Straight Wire

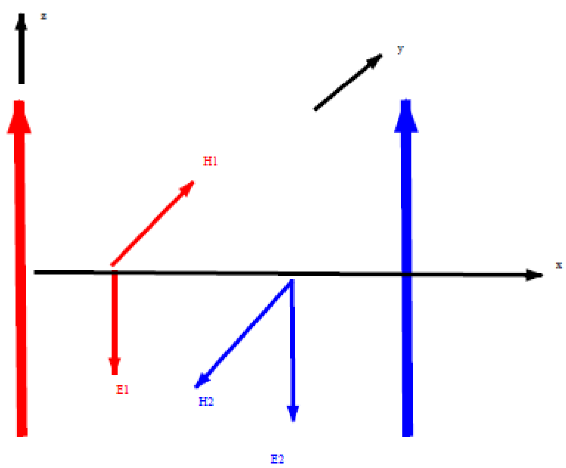

Figure 1: We Need to Measure the Magnetic Field of Straight Wire 1 (red). Measure with Another Straight Wire 2 (blue), a Transformer is Composed of two Parallel Wires

Consider using a long straight wire 2 (blue) to measure the magnetic field of another long straight wire 1 (red). The working principle of two long straight wires is similar to that of a transformer. The first long straight wire is the primary coil 1. The second long straight wire is secondary coil 2. Transformers operate under quasi-static magnetic conditions. Assuming that both the primary and secondary coils are straight wires, assuming that both wires are along the z-axis. See Figure 1. Assuming the secondary is connected to a large load resistance, and the primary is connected to an AC current source. The primary current is,

$$I_1\hat{z} = I_{10}\exp(j\omega t)\hat{z} \quad (56)$$

Assuming the wire is relatively long, therefore the electrostatic field $\boldsymbol{E}_s = -\nabla\phi$ can be ignored. The electric field is an induced electric field,

$$\boldsymbol{E}_1 = \boldsymbol{E}_{1i} = -\frac{\partial}{\partial t}\boldsymbol{A}_1 \sim -j\omega I_1\hat{z} \quad (57)$$

For this situation, we know the magnetic field, which can be determined by Ampere's circuital law. Therefore, we know the magnetic field,

$$\boldsymbol{H}_1 = \frac{1}{2\pi r}\hat{\theta} \sim I_1\hat{y} \quad (58)$$

Assuming $\boldsymbol{H}_1$ is unknown, we measured the magnetic field $\boldsymbol{H}_1$ using the method described in the previous section, and the current of the secondary coil is,

$$I_2 = \frac{\mathcal{E}_{1\to 2}}{R_2 + j\omega L_2} \simeq \frac{\mathcal{E}_{1\to 2}}{R_2} \sim \mathcal{E}_{1\to 2} \sim \boldsymbol{E}_1 \cdot \hat{z} \quad (59)$$

$\varepsilon_{1\to 2}$ is the induced electromotive force generated by the primary coil current on the secondary coil. The above equation indicates the induced current I_2 on the secondary coil depends on the induced electromotive force generated by the primary coil on the secondary coil $\varepsilon_{1\to 2}$. Because the secondary coil is a straight wire, the induced electromotive force and the electric field E_1 of the primary coil is consistent. Considering current I_2 along the direction of $\hat{z}$, consider (57)

$$I_2 \sim -jI_1 \quad (60)$$

Then using I_2 calculate induced electric field $\boldsymbol{E}_2$

$$\boldsymbol{E}_2 = \boldsymbol{E}_{2i} = -j\omega\boldsymbol{A}_2$$

$$\sim -j\omega I_2\hat{z} \sim jI_2(-\hat{z}) \quad (61)$$

Consider $\boldsymbol{E}_2$ The direction is in ($-\hat{z}$), so $\boldsymbol{E}_2$ The size of is,

$$E_2 \sim jI_2 \quad (62)$$

According to the methods of measurement and definition of the magnetic field mentioned earlier (53), the phase of $\boldsymbol{H}_1$ is consistent with the phase of the electric field $\boldsymbol{E}_2$.

$$H_1 \sim E_2 \sim jI_2 \quad (63)$$

Consider (60),

$$H_1 \sim j(-jI_1) = I_1 \quad (64)$$

This implies that the phase of the measured magnetic field is consistent with the current I_1. This indicates that our newly defined magnetic field is consistent with the traditional definition (58). In other words, under quasi-static conditions, we encounter no issues. Everything is normal.

4.3. Planar Electromagnetic Waves

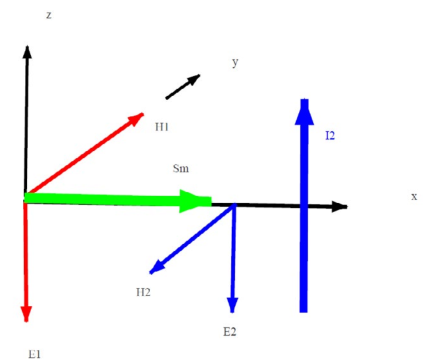

Figure 2: Use a Dipole Antenna to Receive Plane Waves

Assuming there is a plane wave propagating in the x direction. That is,

$$\boldsymbol{E}_1 = jE_{10}\exp(-jx)(-\hat{z}) \quad (65)$$

The preceding $\boldsymbol{j}$ and the subsequent $-\hat{z}$ are introduced for convenience. According to Maxwell's electromagnetic theory, the magnetic field is defined as,

$$\boldsymbol{H}_{1Maxwell} = \frac{1}{\eta}jE_{10}\exp(-jx)(\hat{y}) \quad (66)$$

The above equation indicates that the magnetic field and electromagnetic phase calculated according to Maxwell's definition are in phase. The measurement occurs at $x = L$, therefore,

$$\boldsymbol{E}_1(x = L) = jE_{10}\exp(-jL)(-\hat{z}) \quad (67)$$

The antenna is measured using current elements,

$$I_2 d\boldsymbol{l} = I_2 dl\hat{z} \quad (68)$$

Considering the same reasons as (59),

$$I_2 = \boldsymbol{E}_1 \cdot \hat{z} = -jE_{10}\exp(-jL) \quad (69)$$

From this current element, the electric field can be calculated,

$$\boldsymbol{E}_2 \sim -j\omega I_2\hat{z} \sim jI_2(-\hat{z}) \quad (70)$$

Electric field $\boldsymbol{E}_2$ The size of is,

$$E_2 \sim jI_2 \quad (71)$$

According to (53),

$$H_1 \sim E_2 \sim jI_2 \quad (72)$$

Hence, there is,

$$\boldsymbol{H}_1 \sim jI_2\hat{y} \quad (73)$$

Consider (69),

$$\boldsymbol{H}_1 \sim j(-jE_{10}\exp(-jL))\hat{y}$$

$$\sim E_{10}\exp(-jL)\hat{y} \quad (74)$$

We know that for the magnitude of a plane wave magnetic field and the electromagnetic difference of one wave impedance η, there is,

$$\boldsymbol{H}_1 = \frac{1}{\eta}E_{10}\exp(-jL)\hat{y} \quad (75)$$

So we conclude that the magnetic field is,

$$\boldsymbol{H}_1 = \frac{1}{\eta}E_{10}\exp(-jx)\hat{y} \quad (76)$$

Compared with the electric field (67), it is found that the phase of the magnetic field between the magnetic field $\boldsymbol{H}_1$ and electric field $\boldsymbol{E}_1$ is maintained at 90 degrees.

This is how we use current I_2 to measure the magnetic field. Comparing the formulas (76) and (65), we know that the phase difference between the magnetic and electric fields of electromagnetic waves is 90 degrees. This contradicts the in-phase relationship with the phase of electromagnetic waves obtained according to Maxwell's electromagnetic theory, as compared in equations (65, 66). This constitutes a contradiction. Therefore, we use proof by contradiction to demonstrate the error in Maxwell's electromagnetic theory.

This indicates that our electromagnetic field theory tells students that there is a problem with the phase difference between the electric and magnetic fields of electromagnetic waves. In this example, we have proven the inaccuracy of Maxwell's electromagnetic theory using the proof by contradiction method. Below is the author's revision of the definition of magnetic field.

5. Revisions to the Definition of Magnetic Fields

5.1 Maxwell's Equation

If the magnetic field is defined incorrectly, it does not mean that the Maxwell equation must be completely negated. The Maxwell equation can still be used. It should just be rewritten as,

$$\nabla \cdot \boldsymbol{E}_{Maxwell} = -\rho/\epsilon_0 \quad (77)$$

$$\nabla \cdot \boldsymbol{B}_{Maxwell} = 0 \quad (78)$$

$$\nabla \times \boldsymbol{E}_{Maxwell} = -\frac{\partial}{\partial t}\boldsymbol{B}_{Maxwell} \quad (79)$$

$$\nabla \times \boldsymbol{H}_{Maxwell} = \boldsymbol{J} + \frac{\partial}{\partial t}\epsilon_0 \boldsymbol{E}_{Maxwell} \quad (80)$$

From this, the solution for the retarded potential can also be obtained

$$\boldsymbol{A}^{(r)} = \frac{\mu_0}{4\pi}\int_V \frac{[J]}{r} dV \quad (81)$$

$$\phi^{(r)} = \frac{\mu_0}{4\pi}\int_V \frac{[\rho]}{r} dV \quad (82)$$

Square brackets mean retardation, for example,

$$[f] \triangleq [f(\boldsymbol{x}', t)] \triangleq f(\boldsymbol{x}', t - r/c) \quad (83)$$

We can obtained,

$$\boldsymbol{E}_{Maxwell} = -\frac{\partial}{\partial t}\boldsymbol{A}^{(r)} - \nabla\phi^{(r)} \quad (84)$$

$$\boldsymbol{B}^{(r)}_{Maxwell} = \nabla \times \boldsymbol{A}^{(r)} \quad (85)$$

Above, we solved $\boldsymbol{E}^{(r)}_{Maxwell}$, $\boldsymbol{B}^{(r)}_{Maxwell}$, there is still some difference between $\boldsymbol{E}^{(r)}_{Maxwell}$, $\boldsymbol{B}^{(r)}_{Maxwell}$ and $\boldsymbol{E}$, $\boldsymbol{B}$.

We already know the induced electric field,

$$\boldsymbol{E}_i = \boldsymbol{E}_{iMaxwell} = -\frac{\partial}{\partial t}\boldsymbol{A}^{(r)} \quad (86)$$

As for the static electric field $\boldsymbol{E}_s$ The author will consider it in another article. But the correction of the magnetic field is [28, 29, 30, 31, 32, 33],

$$\boldsymbol{B}^{(r)}_n \triangleq \boldsymbol{B}^{(r)}_{nMaxwell} \quad (87)$$

$$\boldsymbol{B}^{(r)}_f \triangleq (-j)\boldsymbol{B}^{(r)}_{fMaxwell} \quad (88)$$

After this correction, $\boldsymbol{B}^{(r)}_f$ and $\boldsymbol{B}^{(r)}_n$ maintain the same phase. Therefore, the magnetic field defined by the author is based on the principle of field retardation, unlike Maxwell's electromagnetic theory, which is defined based on the retardation of potentials.

5.2 Measurement of Magnetic Field

For the measurement of the magnetic field, it is still done according to the subsection 4.1. Regarding the far-field of the magnetic field, a dipole antenna is placed in a direction perpendicular to the magnetic field, and the dipole antenna is loaded with a resistive load, i.e., connected to a relatively large load resistor. The current I_2 of the dipole antenna is measured, and this current is used to calculate the electric field $\boldsymbol{E}_2$ generated by this current. The $\boldsymbol{E}_2$ has the same phase as the magnetic field $\boldsymbol{H}_1$. This provides the phase information of the magnetic field $\boldsymbol{H}_1$.

5.3 Examples of Electromagnetic Waves

Consider electromagnetic waves,

$$\boldsymbol{E}_{Maxwell} = jE_0 \exp(-jkx)(-\hat{z}) \quad (89)$$

$$\boldsymbol{H}_{Maxwell} = \frac{jE_0}{\eta}\exp(-jkx)(\hat{y}) \quad (90)$$

After correction,

$$\boldsymbol{E} = \boldsymbol{E}_{Maxwell} = jE_0 \exp(-jkx)(-\hat{z}) \quad (91)$$

$$\boldsymbol{H} = (-j)\boldsymbol{H}_{Maxwell} = \frac{E_0}{\eta}\exp(-jkx)(\hat{y}) \quad (92)$$

$$\boldsymbol{E}\times\boldsymbol{H}^* = (jE_0\exp(-jkx)(-\hat{z}))\times(\frac{E_0}{\eta}\exp(-jkx)(\hat{y}))^*$$

$$= j\frac{E_0E_0^*}{\eta} \quad (93)$$

$$\Re(\boldsymbol{E}\times\boldsymbol{H}^*) = 0 \quad (94)$$

This indicates that electromagnetic waves are reactive power waves.

5.4 Discussion

In middle school and university textbooks, we often hear that electromagnetic waves are converted into each other, with electric fields producing magnetic fields and magnetic fields producing electric fields. This is a continuous process of transformation. Since it is an electric field that generates a magnetic field, and a magnetic field that generates an electric field, of course, the magnetic field should be at its maximum change (when the electric field is zero). Similarly, when the magnetic field is zero, the electric field is maximum. In this way, the electric and magnetic fields actually maintain a phase difference of 90 degrees. This is very natural. However, the electric and magnetic fields obtained by solving Maxwell's equations are in phase, and it is difficult for us to explain to students why. It is often heard that electric and magnetic fields move independently, rather than electric fields producing magnetic fields. Magnetic fields produce electric fields. Now the author explains that the phase difference between electric and magnetic fields is indeed 90 degrees. We can easily explain this issue to the students.

The electric and magnetic fields remain at 90 degrees, so electromagnetic waves are reactive power waves, which will have a huge impact on the entire modern physics. It means that this wave, not just an electromagnetic wave, can be an electron wave that satisfies the Schrodinger equation or Dirac equation, and should be of reactive power. In quantum mechanics, we often say that waves are probabilistic. The concepts of reactive power wave and probability wave are very similar. It can be seen as an event. All represent that this wave does not transmit energy. The waves in classical Maxwell's electromagnetic theory are active power waves, which are waves that transfer energy and are completely different from probability waves in quantum mechanics.

Probability waves are certainly not waves that transmit energy. Since waves do not transmit energy, energy is transmitted by particles. There will be no problem. In quantum mechanics, if a wave is of reactive power, then the wave does not need to collapse. The purpose of wave collapse is to concentrate the energy of the wave onto the absorber or onto an eigenvalue. If the wave is of reactive power, this collapse is unnecessary. Therefore, we can omit the concept of wave collapse in quantum mechanics. In addition, we also need to make appropriate modifications to quantum mechanics, transforming it into reactive power waves.

In the author's electric field theory, the self energy flow, that is, the energy flow of waves, or the Poynting vector, are all reactive power. They do not transmit energy. Electromagnetic energy is transmitted by mutual energy flow. Mutual energy flow has the shape and properties of photons, so it is actually photons. In other waves, such as electron waves, it is also easy to construct mutual energy flows [20]. Therefore, the author can confidently say that all particles are a mutual energy flow of some kind of wave.

6. Summary

This article uses the proof by contradiction to prove that Maxwell's electromagnetic theory has loopholes, i.e. bugs. This vulnerability lies in the definition of magnetic fields. Maxwell defined the magnetic field B using the curl of vector potential A, which is only feasible under quasi-static conditions. For radiated electromagnetic fields, that is, considering a retarded electromagnetic field, the curl of the vector potential is no longer the magnetic field. We use the proof by contradiction to prove this point. We assume that Maxwell's electromagnetic theory is correct, and thus derive the theorem of mutual energy flow. We define and measure magnetic fields based on mutual energy flow. The magnetic field and electric field defined or measured in this way always maintain a 90 degree phase difference, whether under quasi-static or radiated electromagnetic field conditions. The magnetic field obtained in this way is consistent with classical electromagnetic theory under quasi-static conditions, while the results under radiated electromagnetic field conditions conflict with Maxwell's electromagnetic theory, which proves that Maxwell's electromagnetic theory is problematic. The author found that the problem lies in the definition of magnetic field. Since the magnetic field obtained by Maxwell's method is problematic, the author has made corrections to the magnetic field obtained according to Maxwell's electromagnetic theory. The revised principle is based on field retardation rather than potential retardation.

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