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Posted Date: 7 January 2026

doi: 10.20944/preprints202601.0552.v1

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Article

A Study on the Microscopic Mechanism of Dielectric Electromagnetic Effects Based on the Theory of Existence Field

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Abstract

Traditional electromagnetism quantifies the modulation of electromagnetic fields by media through permittivity (ϵ) and permeability (μ), yet there remain points worthy of discussion in the explanation of the microscopic mechanism, such as the understanding of vacuum attributes and the essence of the action mechanism. The Theory of Existence Field proposes that fundamental physical quantities (charge/mass) possess an inherent property of diffusing their own physical information into space, and the resulting "existence field" serves as the carrier of physical interaction. Based on the Theory of Existence Field and combined with the Unified Theory of Atomic and Molecular Structure (where the spatial configuration of electron orbitals determines atomic magnetic moment), this paper systematically deduces the microscopic mechanisms of dielectric polarization and magnetization. The research elucidates that the essence of dielectric electromagnetic effects is that an external source existence field transmits physical information to the charges within the medium; the charges respond to the information, generating directional force effects (charge displacement/magnetic moment reorientation), which then form macroscopic effects through the superposition of microscopic existence fields; Permittivity is a quantitative representation of the internal charges' response to external charge information, producing polarization effects, while permeability is a quantitative representation of atoms containing unpaired electron orbitals responding to external magnetic information, producing magnetization effects. Through the deduction using parallel plate capacitor and magnetic medium models, this theory provides a mechanism-clear microscopic explanation for dielectric electromagnetic phenomena, offering a new theoretical framework for related research.

Keywords: theory of existence field; diffusion of physical information; dielectric polarization; dielectric magnetization; spatial configuration of electron orbitals

1. Introduction

The interaction between media and electromagnetic fields is a core subject in electromagnetism. Traditional electromagnetism has achieved great success by introducing macroscopic parameters such as permittivity and permeability to describe the influence of media on fields [1,2]. However, at the level of explaining microscopic mechanisms, traditional theory presents some issues worthy of in-depth exploration. For example, defining the "vacuum permittivity" (ϵ_0) and "vacuum permeability" (μ_0) as "inherent properties" of vacuum is conceptually debatable given the nature of vacuum as a space devoid of matter [1,2]. Furthermore, the expression "field-media coupling" in traditional theory leaves room for deepening the explanation regarding the specific physical essence of "coupling" and how it connects macroscopic field effects with microscopic charge behavior [2].

The Theory of Existence Field [3] offers a new perspective for understanding physical interactions. Its core lies in the idea that fundamental physical quantities (such as charge, mass) continuously diffuse their physical information into the surrounding space, and this diffusion forms an "existence field" that serves as the carrier for information transmission. When an existence field acts on other physical quantities, the latter produce mechanical effects by receiving and responding

to the information [3]. The Unified Theory of Atomic and Molecular Structure [4], based on concepts like the spatial configuration of electron orbitals, provides a clear microscopic structural picture for the electromagnetic properties of atoms.

Based on the aforementioned theories, this paper aims to systematically elaborate the microscopic mechanisms of dielectric polarization and magnetization, clarify the microscopic physical connotations of permittivity and permeability, and strive to construct a logically self-consistent and mechanism-clear theoretical model for dielectric electromagnetism.

2. Core Postulates of the Theory of Existence Field and Definition of Media

2.1. Core Postulates of the Theory of Existence Field

This work proceeds based on the following core postulates of the Theory of Existence Field [3]:

Inherent Diffusion of Physical Information: Fundamental physical quantities such as charge and mass possess the inherent property of continuously and uniformly diffusing their own physical information into the surrounding space.

Carrier Function of the Existence Field: The physical information diffused by fundamental physical quantities is transmitted with the “existence field” as the carrier. Charge diffusing charge information forms a “charge existence field”, and mass diffusing mass information forms a “mass existence field”. The propagation of the existence field only requires a spatial background; vacuum is the ideal background for its propagation.

Information Response and Force Effect of Physical Quantities: When an existence field acts on a physical quantity within a medium, the latter receives the physical information in the field and produces a corresponding mechanical response. A charge receiving charge information generates an electrostatic force; a moving charge receiving magnetic field information generates a torque causing magnetic moment reorientation.

Electromagnetic Properties of Atoms and Field Superposition Principle: The macroscopic electrical neutrality of an atom stems from the equal total amounts of positive and negative charges, but its microscopic structure can be regarded as an inherent electric dipole. The magnetism of an atom is determined by the spatial configuration of its extranuclear electron orbitals; an atom possesses an inherent magnetic moment only when unpaired electron orbitals exist [4]. Microscopic existence fields follow the principle of vector superposition, forming macroscopic electromagnetic effects.

2.2. Microscopic Essential Definition of Media

A medium is a macroscopic aggregate composed of a vast number of atoms.

Electrical Neutrality of Atoms and Basis for Polarization Response: An atom consists of a positively charged nucleus and extranuclear electrons, making it macroscopically electrically neutral. Its microscopic structure can be viewed as an inherent electric dipole, which is the structural basis for polarization response.

Magnetism of Atoms and Magnetization Response Capability: The magnetism of an atom is determined solely by the spatial configuration of its extranuclear electron orbitals [4].

Atoms without Unpaired Electron Orbitals: Electron spin magnetic moments cancel each other out; the atom has no inherent magnetic moment and can only produce a weak diamagnetic response.

Atoms Containing Unpaired Electron Orbitals: The spin magnetic moment of the unpaired electron(s) gives the atom an inherent magnetic moment, making it an active unit for magnetization response. In ferromagnetic materials, strong interatomic interactions form “magnetic domains”, leading to higher response efficiency.

Macroscopic Equilibrium State of Media: In the absence of an external field, atomic thermal motion causes microscopic dipoles and magnetic moments (if present) to be randomly distributed; their existence fields cancel each other out, and the medium macroscopically exhibits electrical neutrality and non-magnetism.

3. Microscopic Mechanism of Dielectric Electromagnetic Effects

3.1. Electrical Effect of Media: Polarization

3.1.1. Propagation Law of Charge Existence Field and Definition of Existence Field Constant

The Origin of Constant Forms in Traditional Electromagnetism: A Historical Construct

Before delving into the derivation based on the Theory of Existence Field, it is necessary to examine the origins of the key formula forms in traditional electromagnetism. These are not logical inevitabilities descending from heaven, but the results of a series of historical choices and mathematical constructs.

(1) The Original Form of Coulomb's Law and the "Proportionality Constant k ":

Through his torsion balance experiments, Coulomb determined that the electrostatic force F between two point charges in vacuum is proportional to the product of the charges q_1 , q_2 and inversely proportional to the square of the distance r . In its most natural expression, this should be written as:

$$F = k_C \frac{q_1 q_2}{r^2} \quad (3.1)$$

Here, k_C is a fundamental constant that needs to be measured experimentally; its physical meaning is the "electrostatic force constant in vacuum", with dimensions $N \cdot m^2/C^2$.

(2) The Transition from "Force Constant" to "Field Constant", and the Introduction of 4π :

When the concept of "electric field" $\vec{E} = \vec{F}/q$ was introduced to describe the physical state around a charge, the field strength at the location of q_2 produced by q_1 is:

$$E = k_C \frac{q_1}{r^2} \quad (3.2)$$

This form is very concise for point charges. However, as the theory developed to handle continuous charge distributions and more general field equations (such as the integral form of Gauss's law), mathematicians discovered that if a factor of 4π was pre-introduced into the force constant k_C of Coulomb's law—that is, by defining a new constant ϵ_0 such that:

$$k_C = \frac{1}{4\pi\epsilon_0} \quad (3.3)$$

Then the integral form of Gauss's law derived from this would not contain the 4π factor, resulting in an extremely concise form:

$$\oint_S \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0} \quad (3.4)$$

This ϵ_0 was later named the "vacuum permittivity". It is important to note that ϵ_0 itself is connected to the original experimental force constant k_C via the definition $\epsilon_0 = 1/(4\pi k_C)$. Its numerical value ($8.854 \times 10^{-12} \text{ F/m}$) is calculated from the measured value of k_C .

(3) Origin of the Parallel Plate Capacitor Formula:

The electric field formula between parallel plates, $E = \sigma/\epsilon_0$, is precisely the direct result of applying the aforementioned "modified" Gauss's law to the special case of an infinite uniformly charged plane. The ϵ_0 therein similarly originates from this definition.

Therefore, the core of the traditional formulation is: We first experimentally measured a most primitive "electrostatic force constant" k_C . Then, for the mathematical concise of subsequent theory (especially the integral form of Gauss's theorem), we artificially defined a new constant $\epsilon_0 = 1/(4\pi k_C)$ and "absorbed" the 4π factor into the proportionality coefficient of Coulomb's law, making it $1/(4\pi\epsilon_0)$. This allowed ϵ_0 to appear alone in Gauss's law. Throughout this process, the physical meaning of ϵ_0 was **conventionally defined as "vacuum permittivity"**, but its root remains that basic experimental constant k_C characterizing the strength of electrostatic interaction.

Logical Starting Point and Natural Derivation of the Theory of Existence Field

Unlike the "experimental measurement first, mathematical construction later" path of traditional theory, the Theory of Existence Field starts from a first-principles physical principle.

Basic Principle: A charge q possesses the inherent property of continuously and uniformly diffusing its physical information (i.e., its “charge-ness”) into the surrounding space. At a distance r , the areal density of this information on a spherical surface is:

$$\rho_q = \frac{q}{4\pi r^2} \quad (3.5)$$

The $4\pi r^2$ here appears naturally because it is the surface area of a sphere with radius r . This is a geometric necessity, not a factor artificially introduced.

Existence Field and Constant k_0 : The diffusion of information produces a physical effect in space, namely the existence field. The field strength \vec{E}_0 is proportional to the information density ρ_q . We introduce a proportionality constant k_0 , called the vacuum existence field constant, which characterizes the intrinsic efficiency of information generating field effects. Therefore, the existence field of a point charge is:

$$\vec{E}_0 = k_0 \cdot \rho_q \cdot \vec{e}_r = k_0 \frac{q}{4\pi r^2} \vec{e}_r \quad (3.6)$$

where \vec{e}_r is the radial unit vector.

Applying this model to a parallel plate capacitor. Treating the charged plates as infinite uniformly charged planes, their charge information diffuses only in the normal directions on both sides of the plane. Let the total surface charge density of a plate be σ , then the information density diffused by a single plate to one of its sides is $\sigma/2$. The field strength produced by a single plate on one side is $k_0 \cdot \sigma/2$. The field strengths from the two plates of the capacitor are in the same direction within the gap, and superimposing them yields:

$$\vec{E}_0 = k_0 \cdot \sigma \quad (3.7)$$

Comparison and Interpretation: The Essential Nature of k_0

Now, compare the expressions (3.6) and (3.7) derived from the Theory of Existence Field with the mathematically constructed forms of Coulomb’s law $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$ and the parallel plate formula $E = \sigma/\epsilon_0$ from traditional theory.

To make the quantitative descriptions of the same physical phenomenon consistent between the two theories, we obtain: $k_0 = 1/\epsilon_0$.

The profound significance of this equality lies in:

Revealing the Ultimate Origin of ϵ_0 : The ϵ_0 defined through a complex historical path in traditional theory is revealed in the Theory of Existence Field to be the reciprocal of a more fundamental constant, k_0 . And k_0 is directly related to the efficiency of the physical process “information diffusion producing a field”.

Naturally Explaining the Origin of the 4π Factor: In traditional theory, the $1/(4\pi\epsilon_0)$ in Coulomb’s law is an artificial construction to make Gauss’s law concise. In the Theory of Existence Field, the $1/4\pi r^2$ in the point charge field strength formula is the natural geometric result of the physical picture of spherical information diffusion. The 4π factor here has a clear physical counterpart—the solid angle of a sphere.

Redefining the Physical Meaning of the Constant: The traditional formulation refers to ϵ_0 as the “permittivity of vacuum”, implying that vacuum possesses a certain property. The Theory of Existence Field shows that the vacuum existence field constant k_0 (or equivalently $1/\epsilon_0$) is the true physical essence. It does not describe “what vacuum is”, but describes “how the physical information of charge acts in spacetime”. It characterizes the strength and law of interaction, not a property of the background medium.

Conclusion: Starting from the physical principle of “information diffusion”, the Theory of Existence Field not only naturally derives electric field formulas consistent with traditional theory but, more importantly, provides clear, intuitive, and first-principles physical explanations for the constants (k_0 corresponding to $1/\epsilon_0$) and geometric factors (4π) in the formulas. Thus, it restores the seemingly artificial mathematical constructs of traditional theory to inevitable consequences of physical reality. This establishes k_0 as a more fundamental physical constant than “vacuum permittivity”. Similarly, we will perform an analogous analysis for the magnetic field constant k_m .

3.1.2. Weakening of Charge Existence Field in Media and Derivation of Relative Permittivity

When an external source charge existence field \vec{E}_{ext} acts on a medium, the inherent dipoles of atoms within the medium undergo directional displacement, producing a **reverse induced charge existence field** \vec{E}_{ind} . The total field strength inside the medium is:

$$\vec{E} = \vec{E}_{ext} - \vec{E}_{ind} \quad (3.8)$$

Let the number of atoms per unit volume be n , and the dipole moment of a single atom be $\vec{p} = \alpha \vec{E}_{ext}$ (where α is the atomic polarizability). Then the polarization intensity is $\vec{P} = n \vec{p} = n \alpha \vec{E}_{ext}$. In a parallel plate capacitor, the induced surface charge density is $\sigma_b = P$, and the induced field strength is:

$$\vec{E}_{ind} = k_0 \sigma_b = k_0 n \alpha \vec{E}_{ext} \quad (3.9)$$

Substituting into the total field strength formula:

$$\vec{E} = \vec{E}_{ext} - k_0 n \alpha \vec{E}_{ext} = \vec{E}_{ext} (1 - k_0 n \alpha) \quad (3.10)$$

Using $k_0 = 1/\epsilon_0$ and $E_{ext} = k_0 \sigma = \sigma/\epsilon_0$ derived from the parallel plate capacitor model, substitute into the above equation:

$$E = \frac{\sigma}{\epsilon_0} (1 - \frac{n\alpha}{\epsilon_0}) \quad (3.11)$$

Defining the **relative permittivity** as $\epsilon_r = 1/(1 - n\alpha/\epsilon_0)$, then:

$$E = \frac{E_{ext}}{\epsilon_r} = \frac{\sigma}{\epsilon_0 \epsilon_r} = \frac{\sigma}{\epsilon} \quad (\text{where } \epsilon = \epsilon_0 \epsilon_r) \quad (3.12)$$

This derivation, starting from the first principles of information diffusion and response, clarifies the microscopic physical connotation of permittivity.

3.2. Magnetic Effect of Media: Magnetization and Permeability Derivation

3.2.1. Origin of Magnetic Field Existence Field and Vacuum Permeability

The Origin of μ_0 in Traditional Theory: From Ampère's Law to the Biot-Savart Law

Similar to electrostatics, the vacuum permeability μ_0 in traditional magnetism also underwent a definition process from experimental measurement to mathematical construction.

Ampère's Law and the "Magnetic Force Constant":

Through experiments, Ampère found that two parallel, infinitely long straight wires carrying currents exert a force on each other. Experiments show that the force per unit length F/L is proportional to the product of the two currents I_1, I_2 and inversely proportional to the distance d . This naturally leads to a "magnetic force constant" k_A :

$$\frac{F}{L} = k_A \frac{2I_1 I_2}{d} \quad (3.13)$$

The factor 2 is introduced here for mathematical convenience (to make subsequent formulas more concise). k_A is a fundamental constant that needs to be measured experimentally; its physical meaning is the "magnetic force constant in vacuum", with dimensions N/A^2 .

Introducing μ_0 and the Construction of the Biot-Savart Law:

To describe the magnetic field produced by a current and to establish Ampère's circuital law in a form dual to Gauss's law in electrostatics, people imitate the method in electrostatics, defining a new constant μ_0 such that:

$$k_A = \frac{\mu_0}{4\pi} \quad (3.14)$$

Thus, Ampère's force formula becomes:

$$\frac{F}{L} = \frac{\mu_0}{4\pi} \frac{2I_1 I_2}{d} \quad (3.15)$$

Based on this and through summarizing experimental laws and mathematical derivation, the Biot-Savart law describing the magnetic field produced by a current element $I d\vec{l}$ was obtained, constructed in the form:

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \vec{r}}{r^3} \quad (3.16)$$

where \vec{r} is the vector from the current element to the field point. Note that the $\mu_0/4\pi$ combination here forms a formal duality with $1/(4\pi\epsilon_0)$ in Coulomb's law. This is not coincidental but a result of artificial definition and construction for the symmetry and conciseness of the entire

electromagnetic theory mathematical system (especially Maxwell's equations). The numerical value of $\mu_0(4\pi \times 10^{-7} \text{N/A}^2)$ is determined by measuring k_A and using the definition $\mu_0 = 4\pi k_A$.

Logic of the Theory of Existence Field: From Moving Charge to Electromomentum Existence Field (Magnetic Field)

The Theory of Existence Field's understanding of the magnetic field is rooted in the nature of moving charges.

Basic Principle: The essence of the magnetic field existence field is the existence field in space of the electromomentum $\vec{P}=e\vec{v}$ of a moving charge. A point charge q moving with velocity \vec{v} also diffuses its state of motion (electromomentum) as a kind of physical information into the surrounding space.

Electromomentum Existence Field Strength \vec{E}_P and Constant k_m : Similar to the electric field, the electromomentum existence field strength \vec{E}_P should be proportional to the spatial distribution density of electromomentum information. Considering the directionality of motion, this distribution is not simply spherically symmetric but related to the direction of motion and the position vector. Through analysis and correspondence with physical facts (such as the Lorentz force), its form is determined to be:

$$\vec{E}_P = k_m \frac{\vec{P}_e \times \vec{r}}{4\pi r^3} \quad (3.17)$$

where k_m is the **electromomentum field existence field constant**, which characterizes the intrinsic efficiency of "electromomentum information" exciting a magnetic field existence field in vacuum. The $4\pi r^3$ in the denominator is the natural manifestation of geometric factors (related to solid angle and distance).

Corresponding to a current element: For a macroscopic steady current element $Id\vec{l}$, which is essentially a collection of a large number of directionally moving charges, i.e., $Id\vec{l} = \sum q_i v_i$, substituting it into Eq. (3.17) yields the magnetic field existence field produced by the current element:

$$d\vec{E}_P = k_m \frac{Id\vec{l} \times \vec{r}}{4\pi r^3} \quad (3.18)$$

Comparison and Interpretation: Equivalence of k_m and μ_0

Now, compare the current element magnetic field formula (3.18) derived from the Theory of Existence Field with the constructed Biot-Savart law from traditional theory.

To make the quantitative descriptions of the same physical phenomenon (magnetic field of a current element) completely consistent between the two theories, it is necessary that: $k_m = \mu_0$

The profound significance of this equality lies in:

Clarifying the Physical Root of μ_0 : The vacuum permeability μ_0 defined in traditional theory for mathematical formal symmetry (duality with ϵ_0) is directly equated in the Theory of Existence Field to the vacuum magnetic field existence field constant k_m . The physical meaning of k_m is very clear: it is the intrinsic efficiency constant for the physical information of a moving charge (electromomentum) producing magnetic field effects in vacuum.

Unifying the Origin of Electricity and Magnetism: In the Theory of Existence Field, the electric field constant k_0 (originating from charge information) and the magnetic field constant k_m (originating from electromomentum information) are both naturally introduced from the **unified first principle** of "fundamental physical quantities diffusing their information". They correspond to the propagation of charge information in stationary and moving states, respectively. This is conceptually more fundamental and unified than separately and independently defining ϵ_0 and μ_0 in traditional theory and assigning them seemingly unrelated physical meanings ("dielectric/ magnetizing attributes of vacuum").

Reaffirming that Constants Describe Interaction Laws: The relation $k_m = \mu_0$ once again strongly supports the core viewpoint of the Theory of Existence Field: **The so-called "vacuum electromagnetic constants" (ϵ_0, μ_0) are essentially not descriptions of properties possessed by vacuum itself, but describe the inherent laws and strength constants (k_0, k_m) for the information of fundamental physical quantities (charge and its motion) propagating in vacuum and producing interactions (electric and magnetic fields).**

Conclusion: Through the exploration of the origin of the magnetic field, the Theory of Existence Field, also starting from first principles, naturally derives the mathematical form of the Biot-Savart law and reveals the more essential physical connotation behind the traditional constant μ_0 —the vacuum electromomentum existence field constant k_m . This completes a unified re-interpretation of the two fundamental constants of electromagnetism, restoring them from “attributes of the background medium” to “the laws of information diffusion and response of fundamental physical quantities”.

3.2.2. Magnetization Response and Induced Magnetic Field in Media

When an external source magnetic field existence field \vec{B}_{ext} acts on a medium, the magnetic carriers within the medium—namely atoms possessing an **inherent magnetic moment** $\vec{\mu}$ (whose source is unpaired electron orbitals)—will respond to this field.

Each such atomic inherent magnetic moment $\vec{\mu}$ experiences a torque $\vec{M}=\vec{\mu}\times\vec{B}_{ext}$ in the external field. This torque attempts to drive the atomic magnetic moment to align with the external field direction. To overcome the disordering effect of thermal motion, the external field continuously does work.

The directional alignment of a large number of atomic magnetic moments manifests macroscopically as the **magnetization intensity** \vec{M} (total magnetic moment per unit volume). Under the linear response approximation, the magnetization intensity is proportional to the external field:

$$\vec{M} = \chi_m \vec{B}_{ext} \quad (3.19)$$

where χ_m is the **magnetic susceptibility** of the medium.

Each of these directionally aligned atomic magnetic moments is equivalent to a microscopic current loop, and they will generate their own magnetic fields. The superposition of all these microscopic fields forms a macroscopic **induced magnetic field existence field** \vec{B}_{ind} within the medium.

3.2.3. Total Magnetic Field in Media and Permeability Derivation

The total magnetic field existence field \vec{B}_{total} in the medium is the vector sum of the external field \vec{B}_{ext} and the induced field \vec{B}_{ind} :

$$\vec{B}_{total}=\vec{B}_{ext}+\vec{B}_{ind} \quad (3.20)$$

For a long straight solenoid model with cylindrical symmetry (analogous to the parallel plate capacitor), it can be proven that the induced magnetic field \vec{B}_{ind} inside it and the magnetization intensity \vec{M} satisfy the following relationship:

$$\vec{B}_{ind}=\mu_0\vec{M} \quad (3.21)$$

Substituting $\vec{M}=\chi_m\vec{B}_{ext}$ into the above equation yields:

$$\vec{B}_{ind}=\mu_0\chi_m\vec{B}_{ext} \quad (3.22)$$

Then substituting this into the total magnetic field expression:

$$\vec{B}_{total}=\vec{B}_{ext}+\mu_0\chi_m\vec{B}_{ext}=(1+\mu_0\chi_m)\vec{B}_{ext} \quad (3.23)$$

We define the **relative permeability** μ_r of the medium as:

$$\mu_r\equiv 1+\mu_0\chi_m \quad (3.24)$$

Then the total magnetic field in the medium can be concisely expressed as:

$$\vec{B}_{total}=\mu_r\vec{B}_{ext} \quad (3.25)$$

Further defining the **absolute permeability** $\mu=\mu_0\mu_r$, we obtain the relationship consistent with the traditional form:

$$\vec{B}_{total}=\mu H \quad (3.26)$$

where $H=\vec{B}_{ext}/\mu_0$ is the auxiliary magnetic field quantity.

3.2.4. Microscopic Physical Connotation of Permeability

The above derivation shows:

Relative permeability μ_r is directly linked to the **magnetic susceptibility χ_m** .

And χ_m is a macroscopic statistical quantity, whose magnitude essentially depends on the **number density of atoms containing unpaired electron orbitals** in the medium, the **magnitude of the inherent magnetic moment $\vec{\mu}$** of each atom, and the **ease of directional alignment** of these magnetic moments (closely related to thermal motion and interatomic interactions).

Therefore, the **microscopic physical connotation of permeability $\mu = \mu_0 \mu_r$ is clarified: It is the macroscopic quantitative characterization of the ability of magnetic units within the medium (atoms containing unpaired electron orbitals) to respond to external magnetic field information and produce a co-directional induced magnetic field.** For paramagnetic materials, $\mu_r \geq 1$; for ferromagnetic materials, strong exchange interactions exist between atoms (magnetic domains), making the response efficiency χ_m extremely high, thus $\mu_r \gg 1$.

4. Model Verification (Parallel Plate Capacitor and Magnetic Medium)

4.1. Parallel Plate Capacitor Model: Verifying Polarization Effect

Vacuum-filled: Free charge surface density on plates is σ_0 , field strength $\vec{E}_0 = k_0 \sigma_0 = U/d$, energy $W_0 = Q_0 U/2$. No polarization process.

Medium-filled (e.g., epoxy resin with $\epsilon_r \approx 3$): Keeping voltage U constant, the total field strength needs to maintain $E = U/d$. Medium polarization produces an induced field E_{ind} . To maintain total field strength, the free charge on the plates must increase to $Q = \epsilon_r Q_0$, and the system energy increases to $W = \epsilon_r W_0$. This process verifies permittivity as the quantitative benchmark for charge response efficiency, consistent with the derivation in Section 3.1.

4.2. Magnetic Medium Model: Verifying Magnetization Effect (Ferromagnetic Fe)

Without external field: Intrinsic magnetic moment of Fe atom is disordered due to thermal motion, macroscopic net magnetization intensity $\vec{M} = 0$, induced field $\vec{B}_{ind} = 0$.

Applying external field \vec{B}_{ext} : Unpaired electrons in Fe atoms receive magnetic information, their magnetic moments align directionally under torque, producing a macroscopic magnetization intensity $\vec{M} \neq 0$, thereby generating a strong induced magnetic field $\vec{B}_{ind} = \mu_0 \vec{M}$. Due to the extremely large magnetic susceptibility χ_m of ferromagnets, $\mu_r \gg 1$ results, and the total magnetic field $\vec{B}_{total} = \mu_r \vec{B}_{ext} \gg \vec{B}_{ext}$, manifesting strong magnetism. This process directly verifies μ_r as the quantitative benchmark for magnetic response efficiency.

Remanence Effect: After removing the external field, partial directional alignment of magnetic moments is retained due to the magnetic domain structure, i.e., $\vec{M} \neq 0$, hence $\vec{B}_{ind} \neq 0$, manifesting as remanence. This corresponds to the storage of part of the magnetization potential energy.

5. Discussion: Perspective Differences from Traditional Electromagnetic Theory

To clarify the positioning and characteristics of this theoretical framework, this section will conduct a comparative analysis with traditional electromagnetic theory from the dimensions of conceptual foundation, interaction mechanism, and the physical meaning of macroscopic parameters. It must be emphasized that this comparison aims to systematically present the different logical starting points and conceptual paths adopted by the two theories when explaining the same class of physical phenomena, thereby highlighting the characteristics and self-consistency of this paper's theory in explaining microscopic mechanisms.

5.1. Regarding the Conceptual Foundation of Vacuum Electromagnetic Constants

Traditional electromagnetic theory defines the vacuum permittivity ϵ_0 and vacuum permeability μ_0 as inherent properties of vacuum, positing that vacuum itself possesses specific dielectric and magnetizing capabilities [1,2]. This formulation faces a fundamental philosophical problem: How can a space containing no matter, a “nothingness”, possess definite physical “properties”? This definition is more of a mathematical convenience than a description of physical reality.

In this theory, based on the first principles of the Theory of Existence Field, ϵ_0 and μ_0 are re-interpreted. They are no longer viewed as properties of vacuum, but as vacuum existence field constants—namely $k_0=1/\epsilon_0$ and $k_m=\mu_0$, which respectively characterize the intrinsic efficiency of charge information and electro-momentum information propagating and forming existence fields in the ideal background space devoid of matter (vacuum). They are fundamental constants within the theoretical framework, their numerical values determined by experiment. Their role is analogous to the speed of sound wave propagation in a specific medium, describing the regularity of phenomena in a given background, not a “property” of the background itself. This perspective fundamentally avoids the conceptual dilemma of “creating something from nothing”, providing a more solid logical starting point for understanding electromagnetic phenomena.

5.2. Regarding the Explanatory Path of the Interaction Mechanism

Traditional theory, when describing the interaction between media and fields, typically uses the macroscopic and black-box-like term “field-media coupling” [2]. Although this expression is mathematically efficient and can accurately predict macroscopic behavior, it does not clearly reveal the specific physical process of how “coupling” occurs. How is energy transferred from the field to the medium? How are the microscopic structures within the medium mobilized and ultimately affect the macroscopic field? These key questions are obscured within the “coupling” framework.

The theory in this paper is dedicated to providing a mechanism-transparent explanatory path. Its core logical chain can be summarized as: “External source existence field diffuses physical information → Fundamental charges within the medium (nuclei, electrons, inherent magnetic moments) receive and recognize the information → Generate directional forces or torques according to classical mechanics laws (electrostatic force, Lorentz force) → Drive charge displacement or magnetic moment reorientation → Existence fields produced by numerous microscopic response units undergo vector superposition → Ultimately form observable macroscopic polarization/magnetization effects”. Each step in this path is based on an imaginable, classical physical process, thereby building a clear bridge between macroscopic phenomena and microscopic mechanisms.

5.3. Regarding the Association Between Atomic Electromagnetic Properties and Macroscopic Parameters

In defining atomic electromagnetic properties, traditional theory sometimes fails to clearly distinguish between the source of electrical neutrality and the source of magnetism, or relies on non-entity concepts like “electron cloud”, which to some extent leads to ambiguity in understanding.

This paper’s theory explicitly anchors the electromagnetic properties of atoms to the entity structure described by the Unified Theory of Atomic and Molecular Structure [4]. The macroscopic electrical neutrality of an atom is explicitly attributed to the balance of total charges between the nucleus and extranuclear electrons, while its microscopic polarization capability stems from its inherent electric dipole structure (separation of positive and negative charge centers). More crucially, the magnetism of an atom is uniquely attributed to the spatial configuration of its extranuclear electron orbitals, especially the presence or absence of unpaired electron orbitals. This structural criterion provides a clear, intuitive, and distinguishable physical picture for the unified understanding of paramagnetism, ferromagnetism, and diamagnetism.

Based on the aforementioned clear microscopic picture, the macroscopic relative permittivity ϵ_r and relative permeability μ_r are no longer merely empirical fitting parameters. As derived in Section

3, ϵ_r is directly associated with atomic number density n and atomic polarizability α ; while μ_r is associated with the density of atoms containing unpaired electron orbitals and the ease of magnetic moment alignment (magnetic susceptibility χ_m). This gives macroscopic electromagnetic parameters explicit microscopic physical connotations, achieving logical coherence from microscopic structure to macroscopic properties.

To clearly summarize the above discussion, the main differences are compared in Table 1 below:

Table 1. Comparison Between the Theory of Existence Field and Traditional Electromagnetism.

Comparison Dimension	Theory of Existence Field Perspective	Traditional Electromagnetism Perspective
Vacuum Electromagnetic Constants	$k_0=1/\epsilon_0$ and $k_m=\mu_0$ are vacuum charge/magnetic field existence field constants, reflecting the transmission efficiency of physical information in vacuum; they are theoretical parameters.	Often described as “inherent properties” of vacuum.
Interaction Mechanism	Mechanism transparent: “Information diffusion → Charge reception → Force effect → Field superposition”.	Commonly described as “field-media coupling”, with explanations of the microscopic physical essence being relatively macroscopic.
Definition of Atomic Electromagnetic Properties	Clear distinction: Electrical neutrality originates from charge balance; magnetism is determined by spatial configuration of electron orbitals (unpaired electrons).	Sometimes conflated, or relies on non-entity concepts like “electron cloud” for explanation.
Physical Meaning of Macroscopic Parameters	ϵ_r , μ_r are directly associated with microscopic structural parameters (n , α , density of unpaired electrons), with clear physical meaning.	Often treated as macroscopic fitting parameters, with weak direct association to microscopic mechanisms.

In summary, the theoretical framework constructed in this paper, while maintaining compatibility with classical macroscopic electromagnetic formulas, strives to provide a theoretical model that is conceptually clearer, more transparent in mechanism, and more tightly connected in the link between the microscopic and macroscopic. It does not aim to negate the mathematical forms and predictive power of traditional theory but hopes to provide a possibly more essential physical foundation for these successful theoretical forms.

6. Conclusion and Outlook

Based on the Theory of Existence Field and the Unified Theory of Atomic and Molecular Structure, this paper systematically elaborates the microscopic mechanisms of dielectric electromagnetic effects. The research clarifies that the essence of dielectric polarization is the directional displacement of inherent atomic dipoles in response to external charge information, while the essence of dielectric magnetization is the directional alignment of magnetic moments of atoms containing unpaired electron orbitals in response to external magnetic information. Starting from first principles, the analytical relationship between permittivity and microscopic parameters (atomic number density n , polarizability α) is derived, further revealing the microscopic physical connotation of permittivity. Through verification using parallel plate capacitor and magnetic medium models, the results show that permittivity and permeability are macroscopic quantitative benchmarks for the efficiency of electric polarization and magnetization responses, respectively. This theoretical framework provides a new perspective for dielectric electromagnetic effect research in terms of conceptual clarity, mechanism transparency, and association with microscopic structure.

Future research could focus on three directions: First, developing high-resolution in-situ characterization techniques, such as atomic-level resolution electron microscopy and magnetic measurement systems, to directly measure atomic polarizability and magnetic moment reorientation behavior, thereby verifying the accuracy of theoretical derivations with quantitative data. Second, following the first-principles derivation logic for permittivity and combining it with electron orbital

coupling effects in magnetic atoms, to complete the derivation of analytical formulas relating permeability to microscopic parameters (number of unpaired electrons, orbital magnetic moment), forming a complete theoretical system for electromagnetic parameters. Third, based on the clear “microscopic structure-macroscopic performance” association, designing novel electromagnetic functional materials, such as optimizing permittivity by controlling atomic arrangement density or adjusting permeability by doping unpaired electron elements, providing new ideas for material design in fields like high-frequency communication and electromagnetic shielding.

References

1. [1] Griffiths, D. J. Introduction to Electrodynamics. 4th ed. Cambridge University Press, 2017.
2. Jackson, J. D. Classical Electrodynamics. 3rd ed. John Wiley & Sons, 1999.
3. Zeng, J.; Zeng, T. A Unified Theory of Atomic and Molecular Structure. *Preprints* 2025, 2025011033. <https://doi.org/10.20944/preprints202501.1033.v2>
4. Zeng, J.; Zeng, T. The Great Tao Model – The Yin-Yang Model of Elementary Particles and the Theory of Existence Field. *Preprints* 2025, 2025011006. <https://doi.org/10.20944/preprints202501.1006.v2>

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