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Maxwell's Equations for the Electromagnetic Dynamic Dyon

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Abstract

This paper shows how Maxwell's equations can be derived from first submicroscopic principles, which involves understanding the detailed structure of real physical space, that is, introducing basic concepts such as charge, electric and magnetic fields. Consideration at the level of elementary particles indicates that particles can be studied without involving the concept of electric current, although the presence of current density is an important component in Maxwell's equations used in classical electrodynamics. A moving charged particle interacts with space organised in the form of a tessellattice, and this allows the identification of subtle nuances of the behaviour of the particle within the particle's de Broglie wavelength $\lambda = \frac{h}{m\upsilon}$. Namely, a charged particle behaves like a dynamic dyon, whose state periodically changes from the state of an electric charge to the state of a magnetic monopole with the spatial period λ. Thus, Maxwell's equations explicitly include the magnetic monopole as a source of the magnetic field, and therefore monopoles should appear in experiments conducted by particle physicists, although until now they have not focused on the direct manifestation of magnetic properties of elementary particles.

Keywords

Physical Space, Tessellattice, Electric Charge, Magnetic Monopole, Maxwell's Equations

1. Foreword

I can never satisfy myself until I can make a mechanical model of a thing. If I can make a mechanical model, I can understand it.

Lord Kelvin (*William Thomson*)

2. Introduction

The theory of electrodynamics is a fairly well-developed discipline, and one might ask what else can be found in its structure and properties? Of course, specific features should appear when considering the equations of electrodynamics in complex environments. But classical electrodynamics should be clear and stable. In addition, classical electrodynamics was further developed into quantum electromagnetic field theory, which takes into account the interaction of a charged particle with its field, and this science evolved into quantum electrodynamics (QED), which became a theory describing microscopic interactions of electromagnetic fields.

Nevertheless, QED is not without its own internal difficulties. In this article, we draw the reader's attention to some serious flaws in quantum electrodynamics that are largely ignored by researchers. Next, we will focus on particle physics, namely how the theory of electrodynamics emerges from first principles, that is, from the theory of real physical space.

3. Conceptual difficulties of QED

For example, in the case of the so-called anomalous photoelectric effect, the energy of a photon of the incident laser light is significantly lower than the ionisation potential of rarefied noble gas atoms and the work function of the metal. The multiphoton concept used by the researchers was stemming from a standard time dependent perturbation theory describing the probability of an atom transitioning from the bound state $|b\rangle$ to a state $\langle c|$ in the continuum per unit time. On the next stage the concept modified the simple photoelectric effect to a nonlinear one in which the atom is ionised by gradually absorbing about a dozen photons, step by steps. As a result, the Nth order time dependent perturbation theory changes the usual Fermi golden rule to the N-photon absorption that produces a quite complicated probability.

QED quantizes classical electrodynamics in such a way that only one photon can occupy a volume λ^3 where λ is the wavelength of the photon. Therefore the multiphoton concept can suggest only a gradual absorption of photons by an atom. However, on the other hand, quantum mechanics prohibits the gradual accumulation of photon energy to overcome the activation threshold of the atom. Hence, to explain the phenomenon of multiphoton absorption we must accept that the N-photon absorption is instantaneous and that the volume λ^3 is filled simultaneously with N-photons [1] [2]: N photons are absorbed by the atom's inerton cloud, the cross-section of which overlaps this number of photons from the laser beam.

Thus, although it is fundamentally important for the QED formalism, the normalization of the phase volume cell λ^3 by one photon is erroneous. This also means that the representation of the Hamiltonian of electromagnetic field in the form of secondary quantization

$$\hat{H} = \sum_k \hat{a}_k^\dagger \hat{a}_k + \sum_k f(k)\left(\hat{a}_{-k}^\dagger - \hat{a}_k\right)\left(\hat{a}_{-k} + \hat{a}_k^\dagger\right) + \infty \qquad (1)$$

is very approximate and not universal.

Both in QED and classical electrodynamics there are no known exact solutions to the equations for the complete dynamical system of charges and radiation. Approximate solutions are of course possible if the coupling between the charge and the radiation is weak. In such a case the perturbation theory works successfully because it uses the small fine-structure constant α, which gives a measure of the strength of the coupling: $e^2/(4\pi\varepsilon_0\hbar c) \approx 1/137$. This small dimensionless constant allows one to expend the calculation of any electromagnetic interaction in a series of α.

However, in the 1930-1940s it was found that the calculations for many processes, when taken beyond the first approximation, gave divergent results. For example, Healy [3] and Du and Yang [4] describe the history of the development of QED as follows. Nowadays all experimental tests of electromagnetic interactions with sufficient precision, which have been conducted as deep as 10^{-19} - 10^{-16} m, are consistent with QED. This theory was finally constructed mainly by R. Feynman, J. Schwinger, S. Tomonaga and F. J. Dyson in 1940-1950s. They developed renormalization methods, which is used to systematically eliminate the infinity in the calculation of higher-order expansions. The general idea of their consideration is reduced to calculations of the energy levels of atomic hydrogen based on Dirac's single-particle relativistic wave equation, which additionally includes corrections based on the fine-structure constant. Namely, the electromagnetic field cannot be switched off from a particle (electron or positron), so the inertia associated with this field should also contribute to the observed mass of the electron. Particle physicists consider the electromagnetic field as always accompanied by a current of electrons and positrons. Then electron-positron pairs must also contribute to the measured value of the g-factor. Hence, the parameters of mass and charge had to be renormalized to express the theory in terms of observable quantities. The results for the shift of energy levels (the Lamb shift) and the anomalous magnetic moment of the electron (g-factor) then turned out to be finite and were, moreover, in good agreement with experimental results.

The electromagnetic interactions of charged leptons (electrons, muons, taus and their anti-partners) are the same. Charged leptons also participate in the weak interaction, which led to a unified theory of the electromagnetic and weak interactions, *i.e.* the electroweak theory. However, the majority of known elementary processes are rather electromagnetic ones, which thus fall within the subject of QED.

In spite of that not everything is so smooth in QED, there are many controversial issues. Comay [5] shows that the Maxwell-Lorentz electrodynamics is different from that one constructed on the basis of variational electrodynamics because they are resting on different postulates; at the same time these two theories are applicable to the same classical system. Comay [5] shows that the gauge transformation, which is well-established in particle physics,

$$A_\mu(x) \to A_\mu(x) + \Lambda(x)_{,\mu}; \quad \psi(x) \to \exp(-ie\Lambda(x))\psi(x) \tag{2}$$

has no profound physical meaning. The electromagnetic 4-potential seems is rather not a 4-vector. The Maxwell-Lorentz electrodynamics hides erroneous elements of the gauge transformation. A photon cannot rather be attributed to a specific charge of the radiating system and charges are not an independent quantity of the radiated and bound fields, and therefore the renormalization procedure looks unnecessary.

Comay [6] goes on to state that the electroweak theory of the Standard Model of particle physics violates inviolable principles of physics. In particular, he demonstrates that the electroweak description of the of the $W^\pm$ particles violates Maxwell's electrodynamics because there is no a coherent $W^\pm$ 4-current for its electromagnetic interaction $j^\mu A_\mu$, and the electroweak description of the Z particle violates the de Broglie principle of the wave nature of quantum particles (the same regarding the so-called the Higgs boson H, see also [7] [8]).

Next, in his review analytical article, Consa [9] demonstrates that calculations of the g-factor for the electron were conducted in a very suspicious way. In particular, he shows that the diagrams introduced by Feynman essentially have no physical meaning and they gave an erroneous result, but it is precisely this approach, which introduced renormalization, that is now the main one in particle physics, in particular in quantum chromodynamics (the latter was thoroughly criticised by Unzicker [7], Comay [10] [11] and the author of the present work [2] [8] [12] [13]). Unzicker [14] also criticised QED noting that no understanding production of photons at high energy and that gauge equations used in the theory do not have physical solutions. In addition, it should be pointed that there is no physical sense in assuming that virtual electron-positron pairs affect the electron spectrum in the hydrogen atom.

The key parameter in QED is the fine structure constant α, since it sets the scale of the electromagnetic interaction, which also allows the experimenters to determine the value of α [15]. Recent studies shows that the fine structure constant is related to the geometry of the golden section of the hydrogen atom [16]. Furthermore, the origin of the fine structure constant lies in the two proper frequencies of the electron, which are approximately 10^{20} and 10^{22} Hz [17].

The true nature of the α was revealed in my book [2], which also includes the features mentioned above: the constant α is directly related to the constitution of real physical space and the definition of mass and charge. In fact, the electron's mass induces a volumetric deformation coat around the particle (cells of the space become somewhat stretched) and the electron's charge initiates its own surface deformation coat (the surfaces of cells become partly polarised), such that the ratio of the radii of these two sub-coats precisely defines the fine-structure constant. So, for an electron, these two named radii of two deformation sub-coats are, respectively, the Compton wavelength λ_{Com} and the Thomson's classical radius of the electron r_e:

$$\alpha = 2\pi \frac{r_e}{\lambda_{\text{Com}}} = 7.2973525662 \times 10^{-3}. \tag{3}$$

Thus, the α relates the volumetric deformed dimension to the surface deformed dimension of the space deformed around the particle [2], *i.e.*, relates mass to charge (**Figure 1**). In addition, these disclosed subtle nuances clearly indicate that elementary particles cannot be considered as mathematical points with zero dimension.

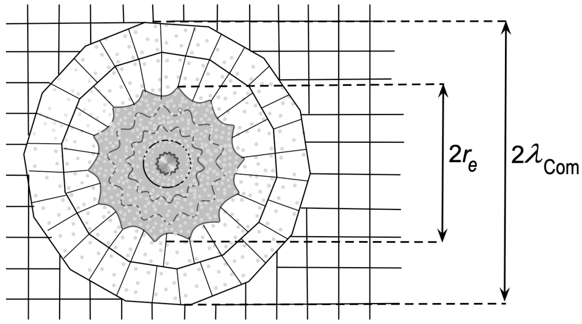

Figure 1. Deformation coat emerges in space around the created elementary particle (more details in the text below). The deformation coat consists of the inertial sub-coat initiated by the mass m, which is depicted by radius λ_{Com}, and the electrical sub-coat launched by the charge e, which is illustrated by the radius r_e.

Then the g-factor together with the first correction can in fact be presented as

$$\text{g} = 1 + \frac{r_e}{\lambda_{\text{Com}}} \equiv 1 + \frac{\alpha}{2\pi} \tag{4}$$

because the deformation coat of the electron with its two sub-coats, inertial (caused by the particle mass m) and electrical (caused by the particle charge e), can also contribute to the g-factor. Here we go into details that are beyond the scope of quantum mechanics and quantum field theory. But these details are very important because they provide the opportunity to rightly understand the origin of the correction to the unit in the expression for g-factor (4).

Thus, the inertial deformation sub-coat of the electron has a radius λ_{Com}, and the electrically polarised deformation sub-coat of the electron has a radius r_e, and the inequality $\lambda_{\text{Com}} \gg r_e$ is preserved.

In paper [18] we considered dynamical quantum systems and showed that the Klein-Gordon equation

$$\left(\nabla^2 - \frac{m_0^2}{\hbar^2}\right)\Psi = \frac{1}{c^2}\frac{\partial^2 \Psi}{\partial t^2}, \tag{5}$$

which is used to describe an abstract relativistic particle that has no spin, may relate to a real object and such an object is the deformation sub-coat related to inertia, *i.e.* mass. Hence, the inertial sub-coat has the property of oscillating.

The electrically-polarised sub-coat can also oscillate being must obey Maxwell's equations in its behaviour and therefore must also exhibit oscillatory properties.

The behaviour of the electrically polarised sub-coat is governed by Maxwell's equations, yet at the submicroscopic level they also undergo changes, which will be shown below.

Thus, not directly the fine structure constant, but these two oscillatory sub-coats are the source of the small correlation to the g-factor, even so exploring this is beyond the scope of this article.

Regarding the current j of electron/positron or another charged particle, it is reasonable to say that this term was borrowed from the concept of current in solid conductors. But is this term really needed in particle physics when applied to individual particles? In particle physics, current is a phenomenological parameter, although particle theories seem to work with individual microscopic objects and the interactions between them. The current density that is available in Maxwell's classical equations has been mechanistically transferred to particle physics, and then the current j automatically entered Maxwell's equations already in quantum theories of particles. Although they are entities of the microworld and hence the phenomenological notion of the current j should be recosidred from a submicroscopic point of view.

4. Real Physical Space

Real physical space begins with the definition, which has to substitute such vague undetermined notions as a physical vacuum and/or aether. In reference scientific literature, the fundamental concepts of physics are very poorly defined because scientists have practically no desire to investigate the primary origins of the concepts with which they operate on a daily basis. For example, physicists know that there are such primary elements as the electron and the photon. Then, in the nuclear transformation reactions, a particle that was not there at first got out from somewhere, so it was called a neutrino and that's enough—what it is, what is its size, and how and where it came from—there is no interest in that.

So, having a set of particles—electrons, photons, neutrinos (and others), they can be studied further, namely: how they interact with each other, with matter, how and what they transform into, etc. But no one studies what they are, what their origin is, and what they come from. Although these particles can appear anywhere in the universe, no one cares how the universe is arranged to allow stable tiny particles to appear anywhere.

The constitution of the universe starts from the construction of its elements that can be treated in terms of mathematics, namely, in terms of space. The term 'space' is used somewhat differently in different fields of study. In physics 'space' is defined via measurement and the standard space interval, called a standard meter or simply meter, is defined as the distance travelled by light in a vacuum per a specific period of time and in this determination the velocity of light c is treated as constant.

In classical physics, space is a three-dimensional Euclidean space where any position can be described using three coordinates. In relativistic physics researchers operate with the notion space-time in which matter is able to influence space. Riemann [19] and Poincaré [20] stated that the question of the geometry of physical space does not make sense independently of physical phenomena, *i.e.*, that space has no geometrical structure until we take into account the physical properties of matter in it, and that this structure can be determined only by measurement. In their opinion the physical matter determines the geometrical structure of space.

In microscopic physics, or quantum physics, the notion of space is associated with an "arena of actions" in which all physical processes and phenomena take place. This arena of actions is subjectively felt as a "container of subjects". The measurement of physical space has long been important. The International System of Units (SI) is the most common system of units used in the measuring of space, and is almost universally used within physics.

However, let us critically look at the determination of physical space as an "arena of actions". In such a determination there exists subjectivity and objects themselves that play in processes cannot be examined at all (for instance, size, shape and the inner dynamics of the electron, how to understand the notion/phenomenon "wave-particle", etc.). Nevertheless, the arena of actions can be completely formalised, so that all ambiguities and incomprehensibility will receive precise definitions. This can be done starting from pure mathematical constructions, which then will clarify all the fundamental physical notions used in quantum and particle physics. A detailed mathematical study [2] [13] [21]-[24], has shown that physical space is a peculiar substrate that is subject to certain pure mathematical laws. Such a view allows us to completely remove any subjectivity, such that the figurants of fundamental physical processes become completely defined.

In mathematics, a space is treated as a set with some particular properties and usually some additional structure. It is not a formally defined concept as such but a generic name for a number of similar concepts, most of which generalise some abstract properties of the physical concept of space. Distance measurement is abstracted as the concept of metric space and volume measurement leads to the concept of measured space.

Generalisation of the concept of space was done [21] [22] through set theory, topology and fractal geometry, which allowed us to look at the problem of the constitution of physical space from the most fundamental standpoint.

The fundamental metrics of our ordinary space-time is a convolution product in which the embedded part D4 looks as follows

$$\mathrm{D4} = \int \left\{ \int_{\mathrm{d}S} \left[\mathrm{d}\vec{x} \cdot \mathrm{d}\vec{y} \cdot \mathrm{d}\vec{z} \right] * \mathrm{d}\Psi\left(w\right) \right\} \tag{6}$$

where $\mathrm{d}S$ is the element of space-time, $\mathrm{d}\Psi\left(w\right)$ is the function that accounts for the expansion of 3D coordinates to 4th dimension through the convolution $*$ with the volume of space.

Set theory, topology and fractal geometry allow us to consider the problem of structure of space as follows. According to set theory only an empty set $\varnothing$ can represent nothing. Following von Neumann, Bounias considered an ordered set $\{\varnothing,\{\varnothing\}\}$, $\{\varnothing,\{\varnothing,\{\varnothing\}\}\}$, $\{\varnothing,\{\varnothing,\{\varnothing,\{\varnothing\}\}\}\}$, $\cdots$ and so on. By examining the set, we can count its members: $\{\varnothing\}=0$, $\{\varnothing,\{\varnothing\}\}=1$, $\{\varnothing,\{\varnothing,\{\varnothing\}\}\}=2$, $\cdots$ This is the empty set as long as it consists of empty members and parts. On the other hand, it has the same number of members as the set of natural integers, $N=0,1,2,3,\cdots,n$. Although it is proper that reality is not reduced to enumeration, empty sets give rise to mathematical space, which in turn brings about physical space. So, something can emerge from emptiness.

The empty set is contained in itself, hence it is a non-well-founded set, or hyperset, or empty hyperset. Any parts of the empty hyperset are identical, either a large part $(\varnothing)$ or the singleton $\{\varnothing\}$; the union of empty sets is also the same: $\varnothing\cup(\varnothing)\cup\{\varnothing\}\cup\{\varnothing,\{\varnothing\}\}\cup\cdots=\varnothing$.

This is the major characteristic of a fractal structure, which means the self-similarity at all scales (in physical terms from the elementary sub-atomic level to cosmic sizes). One empty set $\varnothing$ can be subdivided into two others; two empty sets generate something $(\varnothing)\cup(\varnothing)$ that is larger than the initial element. Consequently, the coefficient of similarity is $\varrho\in[1/2,1]$. In other words, ϱ realizes fragmentation when it falls within the interval $]1/2,1[$ and the union of ϱ with interval $]0,1/2[$ gives the interval $]0,1[$. The coefficient of similarity ϱ allows us to estimate the fractal dimension of the empty hyperset; since this dimension contains the interval $]0,1[$ as one of its components, it turns out that it is a 'fuzzy' dimension.

4D mathematical spaces have parts in common with 3D spaces, which yields 3D closed structures. There are then parts in common with 2D, 1D and zero dimension (points). General topology indicates the origin of time, which should be treated as an assembly of sections Si of open sets (Poincaré sections).

Due to fuzzy dimensions generated by fractality, the general part of a pair of open sets W_q and W_l with different dimensions q and l also accumulate points of open space. For instance, it is impossible to put a pot onto a sheet without changing the shape of the 2D sheet into a 3D packet. Only a 2D slice of the pot can be a part of a sheet. Therefore, infinitely many slices, *i.e.* a new subset of sections with dimensionality from 0 to 3, ensure the raw universe in its timeless form.

Providing the empty set $\varnothing$ with mathematical operations $\in$, $\cup$ and $\cap$ as combination rules, and also the ability of complementary (∁) we obtain a magma (*i.e.* fusion with a binary operation) of empty sets: Magma is a union of elements $(\varnothing)$ that act as the initiator polygon, and complementary (∁) acting as the rule of construction; *i.e.*, the magma is the generator of the final structure. This allowed the formulation of the following **Bounias' theorem** [21]:

The magma $\varnothing^{\varnothing}=\{\varnothing,\complement\}$ *constructed with the empty hyperset and the axiom of availability is a fractal lattice.*

Writing $\varnothing^{\varnothing}$ denotes the magma (*i.e.* the binary operation) and it reflects the set of all self-mappings of $\varnothing$. The space, constructed with the empty set cells of the magma $\varnothing^{\varnothing}$, is a Boolean lattice, and this lattice is provided with a topology of discrete space. A lattice of tessellation balls has been called a tessellattice, and hence the magma of empty hyperset becomes a fractal tessellattice.

Introduction of the lattice of empty sets, *i.e.* the tessellattice, ensures the existence of a physical-like space.

So real physical space can be presented in the form of a mathematical lattice of empty sets: the tessellattice is regularly ordered such that the packing has no gaps between two or more empty topological balls. Such tessellattice accounts for the existence of relativistic space and the quantum void (vacuum) because:

- the conception of distance and the conception of time are defined and
- such space includes a quantum void, because the mosaic/tessellation space introduces a discrete topology with quantum scales and, moreover, it does not have "solid objects" that would appear as real matter.

The tessellattice with these characters has properties of a degenerate physical space. The sequence of mappings from one structural state to the other of an elementary cell of the tessellattice generates an oscillation of the cell's volume along the arrow of physical time.

4.1. Mass

If a transformation of a cell under the influence of some iteration similarity that overcomes conservation of homeomorphism is occurring, we will have the cell deformed under a peculiar fractal law. For instance, for N similar figures with the ratio of similarity $1/\rho$ the Bouligand exponent (e) is given by expression

$$N\cdot\left(\frac{1}{\rho}\right)^{\mathrm{e}}=1 \tag{7}$$

and the cell of an image changes its dimension from D to $\mathrm{D}' = -\ln N/\ln\rho = \mathrm{e} > 1$. A change of the dimension means an acquisition of properties of "solid" objects, *i.e.* the creation of matter. Figure 2 demonstrates the appearance of a solid object in a degenerate lattice when the transformation is driven by a fractal iteration. It should be noted that this is a volumetric fractal transformation of the cell. The volume of a topological ball in the tessellation can also fractally expand in the same way as it fractally decreases (Figure 2). The fractally decreased volume of a cell means the emergence of a lepton and the fractally inflated volume of the cell designates the emergence of a quark.

Thus the universe can be treated as a tessellattice composed of a huge number of cells, or topological balls. This universe is empty until matter appears, as shown in Figure 2; namely, a volumetric fractal deformation of the particled cell means the emergence of mass in it [2] [13] [22] [24]:

$$m = CV^{\deg}/V^{\mathrm{deform}}\left(\mathrm{e}_v-1\right)_{\mathrm{e}_v>1} \tag{8}$$

where $V^{\deg}$ is the initial volume of a degenerate cell, V^{deform} is the volume of fractally deformed cell, e is the Bouligand coefficient and (e − 1) is the gain in dimensionality given by the fractal iteration as ascribed to the volumetric changes of the ball.

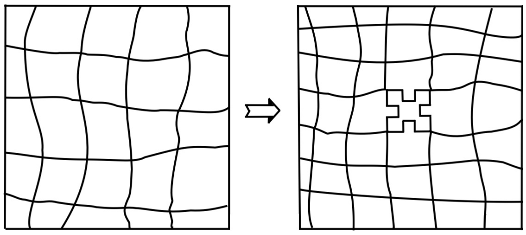

Figure 2. Only fractal transformation of a cell generates the appearance of a particle. The size of a cell can be related to Planck's length ~10^{-35} m.

From a pure mathematical point of view, we can allow that volumetric fractals can not only be concentrated in one ball (*i.e.* a cell), but can also be distributed by a number of surrounding cells. Physically this symbolises that the particle mass in principle can be disseminated around the particle itself. This is possible for a moving particle—due to its friction on the surrounding opposing cells the particle can gradually lose fragments of its mass. Note this situation can be reversed if we endow the spatial substrate—the tessellation—with elastic properties, *i.e.* the tessellattice pushes disseminated volumetric fractals back to the single cell in which they reassembled.

Thus, this is the movement of a particle with periodic decay of its mass. Such a motion was described in detail [2], and it represents a submicroscopic mechanics beyond the rough description given by the quantum mechanical formalism.

4.2. Charge

The second property of matter is its electric charge. The creation of matter designates the appearance of two particles with opposite charges, positive and negative. But where is a charge in a cell of the tessellattice? The notion of charge arises as a fractal quantum of the cell surface [2] [22]-[26]. Namely, the surface of a cell deformed by volume fractals can be additionally covered with a surface fractal structure. Therefore, the notion of the electric charge is reduced to a spherical surface covered with spikes (**Figure 3**).

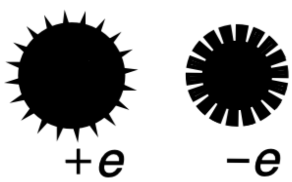

Figure 3. Profile of the quantum of surface fractal on a cell, which forms the electric charge $+e$ and $-e$.

Of course, a local deformation in the tessellattice like the ones shown in **Figure 3**, must be shielded in the tessellattice (as shown in **Figure 1**). Hence the tessellattice forms a deformation coat around the created charged particle, which is organised of the inertial sub-coat and electro-polarised sub-coat [2], which manifest themselves via the fine structure constant (3).

Thus, a charged electron with a size of around 10^{-35} m is surrounded by polarised cells up to a distance of $r_e \sim 10^{-15}$ m.

Shielding of the electric charge involves the induction of the opposite polarisation of the surrounding cells (**Figure 4**), the magnitude of which gradually weakens, reaching a minimum threshold value at the boundary of the electric coat, *i.e.* at the distance r_e.

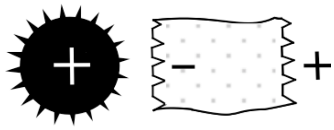

Figure 4. Electric charge induces a polarisation in the surrounding cells.

Now we can consider the motion of such a charge taking into account the interaction of the charge with the surrounded polarised cells.

5. Description of the Charge and Its Movement

First of all, we have to introduce basic electromagnetic notions. An electric charge induces an electric field in the environment. So, let us introduce an electric field. Each spike in the surface (**Figure 5**) can be considered as a scalar potential and then its gradient can be interpreted as an electric field: $\boldsymbol{E} = -\nabla\varphi$ [2] [25]. If spikes are oriented outward we may talk about the positive charge, if spikes are oriented inward—this could be the negative charge. Thus, fractal transfigurations of the ball's surface, the surface fractal defect ΔS, will consist of exclusively unidirectional surface fractals $\sigma_n^{(\mathrm{out})}$ or $\sigma_n^{(\mathrm{in})}$. Such a "chestnut" model of the electric charge with a huge number of spikes protrudes outside or inside the particulate ball's surface and is sustainable and it can be considered as the quantum of the surface fractal.

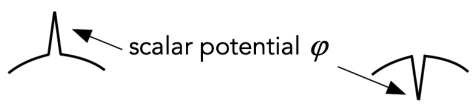

Figure 5. Visualisation of the potential φ. The outward-facing spike generates a positive electrical charge and the inward-facing spike generates a negative electrical charge.

When such a charged particle starts to move, squeezing between the polarised cells, the coat states also migrate. The moving particled cell imposes its coat, *i.e.* ambient cells adapt to the particled cell in each point of its path.

A particle moving in a substrate experiences friction and the particle velocity slows down. In the tessellattice a moving particle must rub against oncoming cells, or in other words it interacts with these cells. Owing to this interaction, the particle emits a cloud of excitations named *inertons*, which transfer the particle's mass and velocity, and the particle gradually loses its speed down to zero and after that the elastic tessellattice returns inertons back to the particle and adsorbing them the particle acquires its mass and speed again, and so on. Note that these excitations migrate in the tessellattice by hopping from cell to cell.

Thus, this is a periodical motion in which the moving particle emits and then absorbs its cloud of spatial excitations, *i.e.* inertons [2]. The particle's de Broglie wavelength λ plays the role of a spatial period: in an odd section $\lambda/2$ the particle emits inertons and finally stops; in the next even section $\lambda/2$ the space returns these inertons to the particle and the particle, absorbing inertons, restores its velocity. Thus, the particle, in odd sections equal to half its de Broglie wavelength $\lambda/2$, gradually loses its velocity and mass, which are transferred to the emitted inerton cloud.

The presence of the additional electric polarisation in the environment of the charged particle results in the overlapping of mass and electric properties in emitted inertons. In other words, the particle's inertons become also electrically polarised and hence the moving particle is accompanied by its proper inerton-photon cloud. Below we do not consider the mass component and will focus only on the electric component of the cloud, *i.e.* will consider so-called "virtual" photons joined to the charged particle.

At the motion, the surface of both the particled cell and its surrounding cells change in such a way that spikes also acquire motion, namely, they move slightly near their equilibrium positions, so that the radial symmetry changes to the curl symmetry (**Figure 6**). A spike, which we describe by the scalar potential φ, bends not as a one-dimensional line, but as a certain body. This means that such a bend should be described by the vector potential $\boldsymbol{A}$. So, we have two potentials, φ and $\boldsymbol{A}$, and the second one makes it possible to introduce one more field, which can be associated with magnetic induction $\boldsymbol{B} = \nabla \times \boldsymbol{A}$.

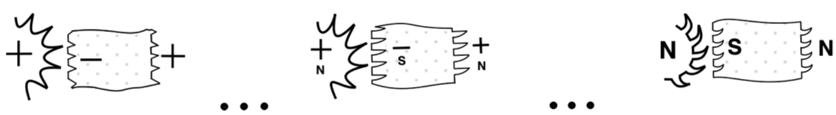

Figure 6. Motion of the charge through the tessellattice [26]: the initial state → intermediate state → the state at the end of the odd section of the particle's de Broglie wavelength, *i.e.* the particle surface becomes stretched, or tensed and it represents the source of the magnetic induction $\boldsymbol{B} = \nabla \times \boldsymbol{A}$. In other words, in the final point of de Broglie's wavelength λ the particle's charge e is transformed to the magnetic monopole g.

So, we have determined from first submicroscopic principles two potentials, φ and $\boldsymbol{A}$, which facilitates to introduce two physical fields, electric $\boldsymbol{E} = -\nabla\varphi$ and magnetic induction $\boldsymbol{B} = \nabla \times \boldsymbol{A}$, respectively. The origin of the electric field is spikes described by the scalar potential φ on the surface of the particled cell (*i.e.* the quantum of the surface fractal) and the origin of the magnetic field, or magnetic induction is the vector potential $\boldsymbol{A}$ generated by the bend movement of the spikes, *i.e.* the bend movement of the scalar potential.

The two measurable physical parameters $\boldsymbol{E}$ and $\boldsymbol{B}$ allow the comparison with two potentials φ and $\boldsymbol{A}$, respectively, which in turn have their subtle submicroscopic nature in the structure of the surface of the topological ball, as the primary element of the tessellattice.

Figure 7 demonstrates the profile of the particled cell, which shows that all spikes on the surface are twisted, or combed. Thus, in the moving particle, after it passes half the de Broglie wavelength $\lambda/2$, the following characteristics change: its velocity $\upsilon_0 \to 0$; its rest mass $m_0 \to 0$; its electric charge $e \to 0$. What remains for the particle? Its mass is transferred to a tension state Ξ and its electric charge (Figure 2) is transmitted to a magnetic monopole state $\boldsymbol{g}$ (Figure 7). Then, after passing the next (even) half of the de Broglie wavelength $\lambda/2$, the tessellattice returns the velocity and inerton-photon excitations to the particle, such that its parameters are restored to their original values: υ_0, m_0 and e.

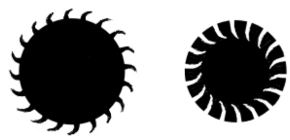

Figure 7. Profile of the combed surface fractals on a particled cell: spikes oriented outward represent the magnetic antimonopole (left), and spikes oriented inward illustrate the magnetic monopole (right).

Thus, we can see that a canonical particle carries both an electric and magnetic charge and these charges periodically replace each other, *i.e.* the charged particle is a dynamic dyon. The idea of the dyon was first expressed by Schwinger [27], but he considered constant fractal quantities of electric and magnetic charge that could be constantly present in the particle under consideration.

The section λ plays the role of the spatial period of oscillation of the particle's velocity, mass and charge. The inner reason for such a behaviour of these characteristics is the interaction of the particle with oncoming cells of the tessellattice, or in other words, this occurs owing to the continuous interaction of the particle with physical space.

The polarisation of cells shown in Figure 6 presents the successive states of a migrating photon. Initially the photon has a purely electric polarization, *i.e.* the spikes on its two opposite faces are normal to the surface, but after passing the section $\lambda/2$, the spikes become twisted, or cimbled, which signifies establishing the magnetic polarisation in the photon. After passing through the next, even section λ of its path, the primary electric polarisation is again established on the photon.

Now we can construct the Lagrangian that describes a moving photon [2]

$$L_{\text{photon}} = \frac{1}{2}\dot{\varphi}^2 + \frac{1}{2}\dot{\boldsymbol{A}}^2 + c\dot{\boldsymbol{A}} \cdot \nabla\varphi - \frac{c^2}{2}\left(\nabla \times \boldsymbol{A}\right)^2 \tag{9}$$

It is known that when the Lagrangian L includes in addition to variables φ

and $\boldsymbol{A}$ also $\nabla\times\boldsymbol{A}$, the Euler-Lagrange equations have the form

$$\frac{\partial}{\partial t}\left(\frac{\partial L}{\partial\dot{\varphi}}\right)-\frac{\partial L}{\partial\varphi}=0, \tag{10}$$

$$\frac{\partial}{\partial t}\left(\frac{\partial L}{\partial\dot{Q}}\right)-\frac{\delta L}{\delta Q}=0 \tag{11}$$

where the functional derivative $\delta L/\delta Q$ for $Q\equiv\nabla\varphi$ has the form

$$\frac{\delta L}{\delta Q}=\frac{\partial L}{\partial Q}-\frac{\partial}{\partial x}\frac{\partial L}{\left(\frac{\partial Q}{\partial x}\right)}-\frac{\partial}{\partial y}\frac{\partial L}{\left(\frac{\partial Q}{\partial y}\right)}-\frac{\partial}{\partial z}\frac{\partial L}{\left(\frac{\partial Q}{\partial z}\right)}. \tag{12}$$

However, when the variable $Q\equiv\nabla\times\boldsymbol{A}$, the functional derivative looks formally as below

$$\frac{\delta L}{\delta Q}=\frac{\partial L}{\partial Q}-\nabla\times\frac{\partial L}{\partial Q}. \tag{13}$$

So we arrive to the equations

$$\ddot{\varphi}+c\nabla\boldsymbol{A}=0, \tag{14}$$

$$\ddot{\boldsymbol{A}}+c\nabla\dot{\varphi}+c^2\nabla\times(\nabla\times\boldsymbol{A})=0 \tag{15}$$

From the Equations (14) and (15) we easily arrive at two conventional wave equations, which describe the behaviour of the potentials φ and $\boldsymbol{A}$, respectively, of the photon [2]

$$\ddot{\varphi}-c^2\nabla^2\varphi=0, \tag{16}$$

$$\ddot{\boldsymbol{A}}-c^2\nabla^2\boldsymbol{A}=0. \tag{17}$$

Now we can consider the motion of a charged particle that interacts with its own photons and also external free photons too. In the standard symbols the Lagrangian density can be written as follows

$$\mathcal{L}=\frac{\varepsilon_0}{2c^2}\dot{\varphi}^2+\frac{\varepsilon_0}{2}\dot{\boldsymbol{A}}^2+\varepsilon_0\dot{\boldsymbol{A}}\cdot\nabla\varphi-\frac{\varepsilon_0c^2}{2}(\nabla\times\boldsymbol{A})^2-\rho\cdot(\varphi_0-\varphi)+\boldsymbol{g}\cdot\boldsymbol{A} \tag{18}$$

where ρ is the charge density, φ_0 is the reference point of the potential φ because as in reality the difference of the potentials between two points is considered, $\boldsymbol{g}$ is the density of the magnetic monopole (which is introduced instead of a conventional expression $\boldsymbol{j}=\rho\boldsymbol{v}$, so that $\boldsymbol{g}=\rho\boldsymbol{v}$). The equations of motions, *i.e.*, the Euler-Lagrange equations for the potentials φ and $\boldsymbol{A}$ are as below

$$\frac{1}{c^2}\frac{\partial^2\varphi}{\partial t^2}-\nabla^2\varphi=\frac{\rho}{\varepsilon_0}, \tag{19}$$

$$\frac{1}{c^2}\frac{\partial^2\boldsymbol{A}}{\partial t^2}-\nabla^2\boldsymbol{A}=\mu_0\boldsymbol{g}. \tag{20}$$

These two equations are the d'Alambert's form of Maxwell's equations. Here, Equation (19) is the wave equation for the density of the electric charge and Equation (20) is the wave equation for the density of the magnetic monopole $\boldsymbol{g}$. The

Equations (19) and (20) reveal that Maxwell's equations are symmetric in the sense that their structure is the same for both electric and magnetic potentials, and that is how it should be—the electric field has its source in an electric charge, and the magnetic field has its source in a magnetic charge, which we call a monopole. The vector $\boldsymbol{E} = -\nabla\varphi$ is normal to the surface of the particle and the vector field $\boldsymbol{A}$ is tangential to the surface of the particle; that is, these two components are orthogonal, as they should be.

The outward-curving spikes on the particled cell as it moves can be interpreted as a magnetic N-monopole (north pole), and the inward-curving spikes can be interpreted as a magnetic S-monopole (south pole). The direction of the particle's rotation (*i.e.* its spin) determines the direction of its magnetic field, that is, the vector $\boldsymbol{A}$ (and correspondently the vector $\boldsymbol{B}$).

6. Discussion

We consider physical space as a tessellattice of primary topological balls and the size of a cell in the tessellattice is equal to the Planck length, ~10^{-35} m. An electric charge is formed on the surface of a topological ball, namely, it appears as a quantum of the surface fractal (**Figure 3**). The emerged charge polarises cells of the tessellattice up to a distance known as the Thomson's classical radius of electron, ~10^{-15} m.

The photon appears as an excitation of the tessellattice that moves like an inerton, *i.e.* hopping from cell to cell. A photon has no wave-particle duality in its motion. The diffraction phenomenon of photons is caused by the influence of the material from which the diffraction grating is made [2].

A photon carries electromagnetic polarisation, that is, in the same cell, outward and inward spikes are partially present on two opposite faces of the cell. The equations of motion of the polarisation of a photon are (16) and (17); they show that the motion of the potentials φ and $\boldsymbol{A}$ obeys a wave equation. These two potentials must move in antiphase: when the value of $|\varphi|$ decreases, then the value of $|\boldsymbol{A}|$ increases and vice versa. Nevertheless, for some reason all the books on electrodynamics claim that these two potentials fall and rise simultaneously, although such a statement violates the laws of conservation.

Figure 8 demonstrates how an electromagnetic wave propagates correctly. The magnetic component appears with a delay of an angle π/2 because the primary component is the electric field, as explained in the text above.

When a charge moves, it rubs against oncoming polarised cells of the tessellattice, such that spikes on the surface of the particled cell are combed. After travelling a distance equal to half de Broglie wavelength $\lambda/2$ ($i.e.$ $= h/(2m\upsilon)$) of the particle, the symmetry of spikes changes from radial to tangential, which means that the charge is transformed into a magnetic monopole. The tessellattice returns the photon cloud back to the particle restoring the particle's momentum and original fractal structure, *i.e.* its electric charge, which occurs within the next even section $\lambda/2$.

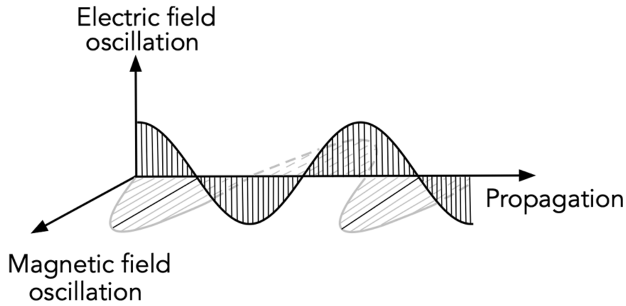

Figure 8. Electromagnetic wave propagation. The magnetic field is out of phase by π/2.

Therefore, when we want to describe the motion of a charged particle, we have to take into account the two opposite states of the particle: the electric charge and the magnetic monopole. During movement, one state passes into another and vice versa, and it is quite logical that the electric charge generates an electric field and the magnetic monopole induces a magnetic field, as evidenced by Maxwell's equations (19) and (20), which are based on the appropriate Lagrangian density (18).

The proposed Lagrangian density (18) is different from the standard Lagrangian density of the electromagnetic field used in the literature: it contains the variable $\dot{\varphi}$. It was absent from the conventional Lagrangian density because there was no understanding of the nature of the charge or of the internal physical processes that lead to Maxwell's equations. In classical electrodynamics, the problem balances by the augmented FitzGerald-Lorentz condition

$$\nabla \cdot \boldsymbol{A} + \frac{1}{c^2}\frac{\partial \varphi}{\partial t} = 0 \tag{21}$$

that introduces the missing derivative $\dot{\varphi}$ into Maxwell's equations.

The scalar φ and vector $\boldsymbol{A}$ potentials are transferred to two measurable fields—electric $\boldsymbol{E} = -\nabla\varphi$ and magnetic induction $\boldsymbol{B} = \nabla \times \boldsymbol{A}$, and Maxwell's equations written in the conventional form, which corresponds to the Equations (19) and (20), are

$$\nabla \cdot \boldsymbol{E} = \frac{\rho}{\varepsilon_0}, \tag{22}$$

$$\nabla \cdot \boldsymbol{B} = 0, \tag{23}$$

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}, \tag{24}$$

$$\nabla \times \boldsymbol{B} = \frac{1}{c^2}\frac{\partial \boldsymbol{E}}{\partial t} + \mu_0 \boldsymbol{g}. \tag{25}$$

Here, the dimensionality of the magnetic monopole $\boldsymbol{g}$ is [$\text{A}\cdot\text{m}^{-2}$], which is also corresponds to the dimensionality of the density of electric current.

Equations (19) and (20) are suitable for applications in particle physics, as well as Equations (22)-(25). The presence of a magnetic monopole $\boldsymbol{g}$ must be taken into account when considering the behaviour of a particle within its de Broglie wavelength λ, which is typical for particle physics. In the case of considering a particle on a long segment of its path, which significantly exceeds λ, one can use the standard approach, *i.e.* a current density $\boldsymbol{j}$ can be used instead of $\boldsymbol{g}$.

D'Alambert's form (19), (20) of the Maxwell equations has naturally been derived from first submicroscopic principles; it is symmetric with respect to the two existing charges—electric and magnetic, although the classical form written for fields $\boldsymbol{E}$ and $\boldsymbol{B}$, *i.e.* the equations (22)-(25), does not have symmetry.

Hypothetical magnetic stable charges and also magnetic currents have been searching by researchers for a long time. Maxwell [28] wrote about "imaginary magnetic matter within the element, of the kind which points north", which he denoted with the symbol m. Curie [29] speculated on possibility of isolated magnetic charges. Poincaré [30] considered the motion of a point electric charge in a field of possible magnetic monopole. Thomson [31] was also talking about a presumable magnetic pole.

With the emergence of quantum mechanics, researchers suggested some quantum versions of magnetic poles. Dirac [32] was the first to put forward his own mathematical version of a magnetic monopole considering it as a topologically stable particle, like a string, which had a multiple integer charge

$$g_{\mathrm{D}} = \frac{\hbar c}{2e} = \frac{e}{2\alpha} = 68.5e. \tag{26}$$

Later, researchers offered other versions of magnetic monopoles that should satisfy the so-called Grand Unified Theories. 't Hooft's [33] monopole became the most popular. It was arranged as a topological soliton similar to the Dirac monopole but without the string structure. 't Hooft's abstract construction was based on a speculative Yang-Mills theory with a gauge group *G*, coupled to a conjectural Higgs field, spontaneous symmetry breaking, etc. All these hypothetical theoretical models of the magnetic monopole, which base on fictional/romantic concepts of physical mathematics, have nothing to do with the structure of real space. As a result of such surreal views on the nature of things, numerous experiments, of course, failed to measure any figment of the imagination of the authors of such abstract theories.

Nevertheless, magnetic monopoles can be measured, and have been for a long time, because neutrinos and antineutrinos are such monopole states of the corresponding leptons [8].

It is important to emphasise that the proposed submicroscopic approach is entirely based on mathematical physics, no abstract notions are involved in the theory of space and particles in general. This approach describes particles and fields with parameters that are inherent in the particles themselves. This is a striking difference between the submicroscopic deterministic concept and descriptions within the framework of physical mathematics in which physical objects are reduced to dimensionless points endowed with characteristics, or their combinations, that are absent in these objects. For example, in conventional quantum mechanics there are two such abstract parameters—the wave ψ-function and the indefinite vacuum, while in particle theory, *i.e.* quantum chromodynamics, there are as many as 16 free parameters [8], although Morsch [34] notes that more than 20 parameters are required to describe the data of high-energy physics with remarkably accuracy. Furthermore, the gauge transformation used is devoid of any physical meaning [5] [14], especially considering the absence of colour charges, since quarks have only integer charges $\pm e$. In addition, the electroweak theory is completely false [10] [35], and the entire Standard Model in its current form, which does not provide for the structure of real space, is unable to explain and account for gravity, although this is easily done within the framework of the tessellattice [2] [36].

7. Conclusions

This paper shows how Maxwell's equations appear from first submicroscopic principles, where such basic notions as charge, electric field, and magnetic field are defined from postulates underlying the structure of real physical space, which is contemplated as a tessellattice of primary topological balls. Although current density is an important component of Maxwell's equations, which are used in traditional electrodynamics, it is not needed when we study the behaviour of charge in particle physics.

A moving charged particle interacts with the tessellattice, which reveals the subtle details of the particle's behaviour within the de Broglie wavelength $\lambda = h/(m\upsilon)$: it demonstrates the mode of action of a dynamical dyon which aggregate states oscillate between an electric charge and a magnetic monopole with the spatial period λ. Thus, in the case of particle physics, Maxwell's equations include the magnetic monopole as the source of the magnetic field in an explicit form. The monopole appears as a curl state of the moving charge.

The neutrino is the classical example of a stable frozen magnetic monopole g: it does not have charge but possesses a tiny initial mass; the neutrino carries only the magnetic monopole g and a volumetric tension Ξ [8].

The electric charge as a quantum of surface fractality of a cell of the tessellattice must be the same for leptons and quarks, since they originate from similar cells of the tessellattice, and the elementary charge can only be an integer. Both leptons and quarks obey the same Maxwell's equations, and photons, as carriers of the electromagnetic field, provide the interaction between these particles, and the spectrum of photons is continuous from the lowest frequency to the highest values reached at about 10^{28} Hz, which corresponds to 100 TeV and maybe more.

Finally, the revelation of the structure of Maxwell's equations at the submicroscopic level and the final determination of the origin and contexture of neutrinos indicate that particle physicists urgently need to abandon abstract physical mathematics and return to mathematical physics. That is, they need to get on the physical rails, or in other words, start studying real matter within the framework of real physics: it is necessary to determine the objects that physicists work with and take into account the structure of space, in the arena of which the processes of particle interaction and particle transformations occur, since space itself also participates in all these processes.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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