A charged space as the origin of sources, fields and potentials

Koen J. van Vlaenderen
The Institute for Basic Research
e-mail: nlx6461@nl.ibm.com

February 2, 2022

Abstract

The wave function $\psi$ is interpreted as charge density, or charge distribution, at each point in space. This is a physical interpretation of $\psi$. The notion of speed can be associated with $\psi$, which leads to the concept of conduction currents and (displacement) convection currents. The charge distribution is the origin of electrical and mechanical sources, potentials and fields. The notion of self potential is essential for defining electrical or mechanical sources. Maxwell’s equations are derived from the condition of charge conservation and mass conservation.

There are two methods of modelling the mass of a charge:

1. The mass of a charge is its electrostatic energy.

2. The mass of a charge is the energy of the Zero Point Field (ZPF) that interacts with the point charge.

It is shown that the two models are related by a simple energy equation for a particle at rest.

1 Introduction

An alternative study of microphysics, called Material Wave Theory (MTW), shows that the interpretation of $\psi$ as a physical wave is more realistic and more simple than the non-physical Copenhagen interpretation of $\psi$ representing only statistical qualities. The central conjecture of MTW is the notion of intrinsic potential energy of a particle. This intrinsic potential energy turns out to be electromagnetic field energy. Therefore, the wave nature of matter is closely related to electromagnetic energy. There are several other theories that attribute even more importance to electromagnetic phenomena.

Stochastic Electro-dynamics (SED) explains the statistical nature of micro-physics by a physical mechanism: quantum-like fluctuations of a random perturbing Zero Point Field. The inertia of a particle is described as a reaction force that is a consequence of the anisotropy of the ZPF in an accelerating frame of reference. This means that inertia and also gravity are secondary electromagnetic phenomena. The ZPF energy is described for the first time as an extra term in the Planck (or blackbody) function.

In the mass of a charge is considered equal to the electrostatic energy of the charge. An accelerating charge gives rise to a self force (Newton’s reaction force), because the speed of light is anisotropic around the accelerating charge. A local anisotropy of light speed is exactly a field of gravity.

In the linear momentum of a charged particle is described as a self induced magnetic potential that acts on the charge, and also rest-mass is considered here as the electrostatic energy.

Although these views have much in common (electrodynamics is essential in order to explain the wave nature of matter, or to explain inertia and gravity), it is not obvious how to integrate these theories into one consistent theory. First, the electrodynamics of electrons within MWT is further explored.
2 Classical Electrodynamics in MWT

Hofers central conjecture within MWT [1] is: the intrinsic energy of a particle consists of kinetic and potential energy. Quantum Physics states that the intrinsic energy of a particle is solely kinetic. This is not based on experiment, and the reasoning about the intrinsic nature of particles within the framework of Quantum Physics boils down to a logical circle [1]:

If a particles intrinsic energy is solely kinetic, the phase velocity of a de Broglie wave is not equal to the mechanical velocity of a particle. If phase velocity does not equal mechanical velocity, a free particle cannot exist of a single wave of specific frequency and it must be formalized as a Fourier integral over infinitely many partial waves. In this case any partial wave cannot be interpreted as a physical wave. Then the wave features of a partial wave cannot be related to physical qualities. If they cannot be related to physical qualities, then internal processes must remain unconsidered. And if internal processes remain unconsidered, then the intrinsic energy of a particle is solely kinetic energy.

Hofers conjecture is more simple and forces to describe the wave nature of particles in terms of physical qualities, instead of adopting the non-physical Hilbert space.

2.1 The de Broglly wave

First, the wave function \( \psi \) is treated as a real function, in stead of a complex function, and with physical meaning:

\[
\psi(\vec{r}, t) = \psi_0 \sin(k \cdot \vec{r} - \omega t) \tag{2.1}
\]

\[
\varrho(\vec{r}, t) = C \psi_0^2 \sin^2(k \cdot \vec{r} - \omega t) \tag{2.2}
\]

The function \( \varrho \) is the de Broglly wavefunction with dimension of mass-density. A de Broglly wave is a mass oscillation. The periodic change of kinetic energy requires the existence of an intrinsic potential energy with a density of \( \phi \). The particle velocity equals the phase velocity. By using an undefined constant \( C \), it is avoided to define the dimension of \( \psi \). In this paper, \( C=1 \), and \( \psi \) has the dimension of square root of mass-density. These definitions define mechanical properties of \( \psi \).

It is assumed that speed, \( \vec{u} \), can be associated with \( \psi \) en \( \varrho \) : \( \vec{p} = \varrho \vec{u} \) is the impulse density and \( w_{kin} = \frac{1}{2} \varrho u^2 \) is the kinetic energy density (\( u = |\vec{u}| \)). A material wave is a periodic transformation of intrinsic kinetic energy and intrinsic potential energy, such that the sum of both intrinsic energy densities is constant:

\[
\frac{1}{2} \varrho u^2 + \phi = \phi_0 = \text{constant} \tag{2.3}
\]

2.2 Electric and Magnetic Potentials

In Material Wave theory it is shown that the intrinsic potential is electromagnetic in nature. The definitions of the electric field and the magnetic field, in terms of the intrinsic moment and intrinsic potential, are as follows:

\[
\vec{E} = -\nabla \frac{1}{\rho} \phi + \frac{1}{2\rho} \frac{\partial \vec{p}}{\partial t} \tag{2.4}
\]

\[
\vec{B} = -\frac{1}{\rho} \nabla \times \vec{p} \tag{2.5}
\]

where \( \rho \) is a constant with the dimension of charge density to guarantee compatibility with electromagnetic units. By substituting \( \phi = \phi_0 - \frac{1}{2} \varrho u^2 \) and \( \vec{p} = \varrho \vec{u} \), the equations 2.4 and 2.5 become:

\[
\vec{E} = \nabla \frac{1}{\rho} \varrho u^2 + \frac{1}{2\rho} \frac{\partial (\varrho \vec{u})}{\partial t} \tag{2.6}
\]

\[
\vec{B} = -\frac{1}{\rho} \nabla \times (\varrho \vec{u}) \tag{2.7}
\]

If an electric potential and magnetic potential are defined as follows:

\[
\Phi = -\frac{\varrho}{2\rho} u^2 \quad \vec{A} = -\frac{\varrho}{2\rho} \vec{u} \tag{2.8}
\]

then it is obvious that the fields can be expressed in terms of the potentials in the usual way. The sources \( \rho_s \) and \( J_s \) can be expressed also in terms of the potentials \( \Phi \) and \( \vec{A} \).

\[
\vec{E} = -\nabla \Phi - \frac{\partial \vec{A}}{\partial t} \tag{2.9}
\]
\[ \vec{B} = \nabla \times \vec{A} \] (2.10) \[ \nabla \times \vec{B} = \nabla \times \nabla \times \vec{A} = \nabla (\nabla \cdot \vec{A}) - \nabla^2 \vec{A} \]

\[ \rho_s = \epsilon \left( \mu \frac{\partial^2 \Phi}{\partial t^2} - \nabla^2 \Phi \right) \] (2.11) \[ \mu \frac{\partial \vec{E}}{\partial t} + \left( \mu \frac{\partial^2 \vec{A}}{\partial t^2} - \nabla^2 \vec{A} \right) = \frac{\mu}{\epsilon} \frac{\partial \vec{E}}{\partial t} + \mu \vec{J}_s \] (2.12)

### 2.3 Maxwell’s equations

If mass is conserved and \( \epsilon \mu = \frac{1}{\rho} = \text{constant} \) then Maxwell’s equations are valid in MWT. Proof: starting with the mass continuity equation, the Lorentz gauge can be derived:

\[
0 = \nabla \cdot (\rho \vec{u}) + \frac{\partial \rho}{\partial t} = \nabla \cdot (\frac{\rho}{2 \rho} \frac{\partial (\vec{u} \vec{u})}{\partial t}) + \mu \epsilon \frac{\partial \vec{E}}{\partial t} \]

(2.13)

\[
0 = \nabla \cdot (\rho \vec{u}) + \frac{\partial \rho}{\partial t} = \nabla \cdot \vec{A} + \mu \epsilon \frac{\partial \vec{E}}{\partial t} \]

Maxwell’s equations follow from the definitions of fields and sources and the Lorentz gauge:

\[
\nabla \times \vec{B} = \nabla \times \left( - \nabla \Phi - \frac{\partial \vec{A}}{\partial t} \right) = - \frac{\partial (\nabla \times \vec{A})}{\partial t} = - \frac{\partial \vec{B}}{\partial t} \] (2.14)

\[
\nabla \cdot \vec{E} = \nabla \cdot \left( - \nabla \Phi - \frac{\partial \vec{A}}{\partial t} \right) = - \nabla^2 \Phi - \frac{\partial \vec{A}}{\partial t} \nabla \cdot \vec{A} = - \nabla^2 \Phi + \mu \epsilon \frac{\partial^2 \Phi}{\partial t^2} = \rho_s \] (2.15)

### 2.4 Field energy and Pointing vector

In case of \( \vec{u} = \text{constant} \) the expressions of field energy and pointing flow, in terms of \( \vec{g} \) and \( \vec{u} \), become:

\[
\frac{\mu}{2} H^2 = \frac{\mu}{2} \left( \frac{\vec{B}}{\mu} \cdot \frac{\vec{B}}{\mu} \right) = \frac{1}{2\mu} (\vec{g} \times \vec{u}) \cdot (\vec{g} \times \vec{u}) \] (2.20)

\[
\frac{\epsilon}{2} E^2 = \frac{\epsilon}{2} (\vec{B} \times \vec{u}) \cdot (\vec{B} \times \vec{u}) = \frac{\epsilon}{2} u^2 (\vec{B} \cdot \vec{B}) = \frac{1}{2\mu} |\vec{g} \times \vec{u}|^2 \] (2.21)
\[ \mathbf{E} \times \mathbf{H} = \frac{1}{\mu} (\mathbf{E} \times \mathbf{B}) = \frac{1}{\mu} (\mathbf{B} \times \mathbf{u}) \times \mathbf{B} \]
\[ = \frac{1}{\mu} \mathbf{B}^2 \mathbf{u} - \frac{1}{\mu} (\mathbf{B} \cdot \mathbf{u}) \times \mathbf{B} \]
\[ = \frac{1}{\mu} [\mathbf{g} \times \mathbf{u}]^2 \mathbf{u} = \left( \frac{\mu}{2} \mathbf{H}^2 + \frac{\epsilon}{2} \mathbf{E}^2 \right) \mathbf{u} \]  

(2.22)  

Equation (2.22) is Pointing’s Theorem in Material Wave Theory. Notice that if \( \mathbf{g} \times \mathbf{u} = 0 \) then the field energies are zero, and also the energy flow is zero. The mass gradient of the matter wave must have a non-zero component that is perpendicular to the direction of motion. Otherwise there is no intrinsic potential energy. Therefore the monochromatic plane particle wave (see equation 2.2) cannot be an adequate description of a matter wave with intrinsic kinetic energy and intrinsic electro-magnetic (potential) energy, because in this case \( \mathbf{g} \times \mathbf{u} = 0 \)!

3 Self induced potentials

At this point it is worthwhile to make a comparison with the notion of the self-induced magnetic potential of a charge [6]:

\[ m \mathbf{u} = q \mathbf{A} \quad \Rightarrow \quad \mathbf{A} = \frac{m}{q} \mathbf{u} = \frac{\rho}{\mu} \mathbf{u} \]  

(3.1)

This equation is the result of combining Newton’s laws with Maxwell’s equations, as follows: an applied force causes an elementary particle, with mass \( m \) and charge \( q \), to accelerate.

\[ \mathbf{F} = m \mathbf{a} = \frac{\partial (m \mathbf{u})}{\partial t} \]  

(3.2)

The term \( \frac{\partial \mathbf{A}}{\partial t} \) in equation (2.9) is caused by the applied force. If the particle is not accelerated then this term is zero. Therefore, \( -q \frac{\partial \mathbf{A}}{\partial t} \), which is an extra Coulomb force, is also Newton’s reaction force \( F' \).

\[ F = -F' \quad \Rightarrow \quad \frac{\partial (m \mathbf{u})}{\partial t} = \frac{\partial (q \mathbf{A})}{\partial t} \quad \Rightarrow \quad m \mathbf{u} = q \mathbf{A} \]  

(3.3)

A similar equation exists for the electric potential:

\[ mc^2 = q \Phi \quad \Rightarrow \quad \Phi = \frac{m}{q} c^2 = \frac{\rho}{\mu} \epsilon^2 \]  

(3.4)  

meaning the total energy of a charge is electrostatic. In equation (2.8) \( \rho \) is a constant, which is not the case in equation (3.3), where \( \rho \) is a scalar function. It is not clear why \( \rho \) is defined a constant, except for compatibility between units for mechanical quantities and variables for electromagnetical quantities.

The simplest view is to consider the self-induced potentials and the intrinsic potentials of MWT as equal, and to be called self potentials. This means that we have to replace the constant \( \rho \) for the scalar \( -\frac{1}{2} \rho \).

3.1 The electromagnetic self potentials

Since \( \psi \) has real physical interpretation, the following question comes to mind: is \( \rho \) a function of \( \psi \)?

If, for instance, \( \rho = \psi \), then space is filled with "charge", or even consists of "charge". This model is in agreement with notions like displacements currents or convection displacement currents [7]. Such a current has to exist beside conduction currents in order to solve a paradox in the Faraday-Maxwell theory. The definitions of the electric and magnetic potentials (in case \( -\frac{1}{2} \rho = \rho = \psi \)) becomes:

\[ \Phi = \frac{\rho}{\mu} \psi^2 \psi u^2 = \psi u^2 \]  

(3.5)

\[ \mathbf{A} = \frac{\rho}{\mu} \psi u = \psi \psi u = \psi \psi \]  

(3.6)

The definitions of electromagnetic sources and fields now become:

\[ \mathbf{E} = -\nabla \psi u^2 - \frac{\partial (\psi \psi u)}{\partial t} \]  

(3.7)

\[ \mathbf{B} = \nabla \times (\psi \psi u) \]  

(3.8)

\[ \rho_s = \epsilon \left( \frac{\mu}{\mu} \frac{\partial^2 (\psi u^2)}{\partial t^2} - \nabla^2 (\psi u^2) \right) \]  

(3.9)

\[ \mathbf{J}_s = \frac{1}{\mu} \left( \epsilon \frac{\partial^2 (\psi u^2)}{\partial t^2} - \nabla^2 (\psi u^2) \right) \]  

(3.10)

It would be unnatural to distinguish between \( \rho_s \) and \( \rho(= \psi) \):

\[ \psi = \epsilon \left( \frac{\mu}{\mu} \frac{\partial^2 (\psi u^2)}{\partial t^2} - \nabla^2 (\psi u^2) \right) \]  

(3.11)
\[ \psi \ddot{u} = \frac{1}{\mu} \left( \mu \frac{\partial^2 (\psi \ddot{u})}{\partial t^2} - \nabla^2 (\psi \ddot{u}) \right) \] (3.12)

If \( \psi \) satisfies equations 3.11 and 3.12 at some point in space, then \( \psi \) is a source at that particular point. Equations 3.11 and 3.12 are called the self-potential equations. They can be reformulated in terms of the potentials:

\[ \Phi = \frac{1}{\mu} \left( \mu \frac{\partial^2 \Phi}{\partial t^2} - \nabla^2 \Phi \right) \] (3.13)

\[ \vec{A} = \frac{1}{\mu} \left( \mu \frac{\partial^2 \vec{A}}{\partial t^2} - \nabla^2 \vec{A} \right) \] (3.14)

If charge is conserved and \( \mu \varepsilon = \frac{1}{\mu^2} = \text{constant} \), then Maxwell’s equations are valid. The proof is similar to the proof in section 2.3. First, the Lorentz gauge is derived from the charge continuity equation:

\[ 0 = \nabla \cdot (\psi \ddot{u}) + \frac{\partial \psi}{\partial t} \] (3.15)

(Etc...). Substitute \( \vec{g} = \nabla \psi \) and take \( \ddot{u} = \text{constant} \), then the EM fields are perpendicular to each other (see section 2.3). Also the same expressions for the energy densities and Pointing vector can be derived by substituting \( \vec{g} = \nabla \psi \) (see section 2.4).

Equation 2.3 \[ \frac{1}{2} \dot{\varepsilon} u^2 + \frac{\varepsilon}{2} E^2 + \frac{\mu}{2} H^2 = \rho \Phi \] (3.16) can be rewritten in terms of electric energy density, magnetic energy density and static electric energy density (which is the total energy):

\[ w = \psi^2 u^2 \quad \vec{p} = \psi^2 \ddot{u} \] (3.17)

\[ \vec{f} = \nabla w + \frac{\partial \vec{p}}{\partial t} \] (3.18)

\[ \vec{s} = \nabla \times \vec{p} \] (3.19)

3.2 The mechanical self potentials

In analogy with electromagnetic sources, fields and potentials, one can define mechanical sources, fields and potentials, simply by substituting \( \psi^2 \) for \( \psi \):

\[ w = \psi^2 u^2 \quad \vec{p} = \psi^2 \ddot{u} \] (3.17)

\[ \vec{f} = \nabla w + \frac{\partial \vec{p}}{\partial t} \] (3.18)

\[ \vec{s} = \nabla \times \vec{p} \] (3.19)

\[ \varrho_s = \epsilon_m \left( \mu_m \epsilon_m \frac{\partial^2 w}{\partial t^2} - \nabla^2 w \right) \] (3.20)

\[ \vec{p}_s = \frac{1}{\mu_m} \left( \mu_m \epsilon_m \frac{\partial^2 \vec{p}}{\partial t^2} - \nabla^2 \vec{p} \right) \] (3.21)

\( w \) and \( \vec{p} \) are the potential energy density and potential momentum density. The vector fields \( \vec{f} \) and \( \vec{s} \) are the force density field and angular momentum density field. An intrinsic angular momentum is also called spin, and therefore the symbol \( s \) is used. The constants \( \epsilon_m \) and \( \mu_m \) are the mechanical analogies of \( \epsilon \) and \( \mu \). The force density is zero if energy-momentum is conserved.

In case \( \epsilon_m \mu_m = \frac{1}{\mu^2} = \text{constant} \) then also for the mechanical fields the Maxwell’s equations apply:

\[ \nabla \times \vec{f} = -\frac{\partial \varrho_s}{\partial t} \] (3.22)

\[ \nabla \cdot \vec{f} = -\frac{\varrho_s}{\epsilon_m} \] (3.23)

\[ \nabla \times \vec{s} = -\epsilon_m \mu_m \frac{\partial \vec{f}}{\partial t} + \mu_m \vec{p}_s \] (3.24)

\[ \nabla \cdot \vec{s} = 0 \] (3.25)

Equation 3.22 expresses that the spin increases or decreases in case the rotation of force density is not zero. Equation 3.23 is the law of gravity in differential form. Equation 3.24 is the mechanical equivalent of Ampère’s law.

Next, it is unnatural to distinguish between \( \varrho_s \) and \( \varrho = \psi^2 \) and therefore we can speak also of the mechanical self potentials:

\[ w = \frac{1}{\mu_m} \left( \mu_m \epsilon_m \frac{\partial^2 w}{\partial t^2} - \nabla^2 w \right) \] (3.26)

\[ \vec{p} = \frac{1}{\mu_m} \left( \mu_m \epsilon_m \frac{\partial^2 \vec{p}}{\partial t^2} - \nabla^2 \vec{p} \right) \] (3.27)

Surprisingly, equation 3.16 can be derived by using the definition of the mechanical self potential:
\( (\epsilon_m = \epsilon, \mu_m = \mu, \epsilon_\mu = \frac{1}{\mu_\tau}, \bar{u} = \text{constant}) \)

\[
\frac{1}{2} \theta \bar{u}^2 = \frac{1}{2} \bar{w} = \frac{1}{2} \mu \left( \epsilon \mu \frac{\partial^2 \bar{w}}{\partial \varepsilon^2} - \nabla^2 \bar{w} \right)
\]

\[
= \frac{1}{2} \mu \left[ \epsilon \mu \frac{\partial^2 (\psi_u)}{\partial \varepsilon^2} \right] + \left[ \epsilon \mu \frac{\partial^2 (\psi_u)}{\partial \varepsilon^2} \right] + \frac{1}{2} \left[ -2 \bar{u} \bar{w} \nabla^2 (\psi_u) \right]
\]

\[
= \frac{1}{\mu} \left[ (\nabla \cdot (\psi \bar{u})) \right] - u^2 (\nabla \psi)^2 \right] + \frac{1}{\mu} \left[ (\nabla \cdot (\psi \bar{u})) \right] - u^2 \nabla (\psi_u)^2 \right] + \frac{1}{\mu} \left[ (\nabla \cdot (\psi_u))^2 \right] - (\nabla \psi)^2 u^2 \right] + \psi \Phi
\]

\[
= -\frac{1}{\mu} \left[ \nabla \cdot (\psi_u) \right] + \psi \Phi
\]

\[
= -\frac{1}{\mu} \left[ \nabla \cdot (\psi_u) \right] + \psi \Phi
\]

Especially, the definition of Coulomb is interesting. It seems that the spatial dimension of a charge is \( \frac{3}{2} \). This is a fractal dimension. One might interpret a charge as a point-like particle (without mass) that follows a trajectory with a fractal dimension of \( \frac{3}{2} \), within a closed volume.

5 Discussion

Equations 2.18 to 2.22 can be derived also from the relations of \( \nabla \times \bar{u} = 0 \) and \( \nabla \cdot \bar{u} = 0 \), instead of \( \bar{u} = \text{constant} \). A fractal trajectory within a closed volume is an example of \( \bar{u} \neq \text{constant}, \nabla \times \bar{u} = 0, \nabla \cdot \bar{u} = 0 \). A trajectory with a fractal dimension is in agreement with Stochastic Electro Dynamics, because SED assumes a massless parton to interact with the ZPF that has a broad spectrum.

Suppose, the massless parton has a speed \( |\bar{u}| = c \), then equation 3.16 becomes:

\[
\frac{1}{2} \epsilon c^2 + \frac{\mu}{2} E^2 + \frac{\mu}{2} H^2 = \rho \Phi
\]

Its total energy density is \( \epsilon c^2 = \rho \Phi \). This can only be understood by the notion of (intrinsic) self potentials, as introduced in this paper. If the closed and finite volume that confines the parton’s trajectory is motionless, then one speaks of rest-energy or rest-mass. This combines the different models, as described in the introduction, such that it yields one theory.

The charged field \( \psi \) does not show Coulomb interaction or gravity interaction between every two points. In other words: not all points in space are sources. Only those points in space that satisfy the self potential equations can show Coulomb interaction or gravity interaction. Thus, the charged space \( \psi \) is the origin of sources and (self) potentials.

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