THE REINTERPRETATION OF THE "MAXWELL EQUATIONS"

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ABSTRACT

This publication contains a mathematical approach for a reinterpretation of the "Maxwell equations" under the assumption of a magnetic field density. The basis for this is Faraday's unipolar induction, which has proven itself in practice, in combination with the calculation rules of vector analysis. The theoretical approach here is the assumption, according to Paul Dirac, that there is a magnetic field density.

In this publication, the "Maxwell equations" are recalculated in their entirety. It is shown that both the temporal change in the magnetic field and the temporal change in the electric field can each be derived from a second-order tensor (matrix), which can be interpreted as a spatial field distortion tensor. Likewise, both the magnetic field density and the electric field density are derived from the unipolar induction, according to Faraday. The magnetic field density results from the fact that the $\operatorname{div}\vec{B}$ is equal to the $(\mathrm{Sp})\operatorname{grad}\vec{B}$.

In addition to the two field distortion tensors $\operatorname{grad}\vec{B}$ and $\operatorname{grad}\vec{D}$, the velocity gradient $\operatorname{grad}\vec{v}$, which can also be derived from Faraday's unipolar induction, plays an important role in the interpretation of spatially distorted fields.

1. INTRODUCTION

The "Maxwell equations" were defined in their present form in a simplified way by Oliver Heaviside (1850-1925). Since vector mathematics was still in its infancy at that time, the "Maxwell equations" were simplified by Oliver Heaviside using the methods of differential calculus and integral calculus of the time. He assumed that no magnetic field density existed. This was later questioned by Paul Dirac, through a theoretical consideration. Therefore, this elaboration deals with the reinterpretation of the "Maxwell equations", under the mathematical requirement of a magnetic field density and with the help of vector analysis. The basis for this is the unipolar induction according to Faraday.

2. IDEAS AND METHODS

2.1 IDEA FOR REINTERPRETATION OF THE "MAXWELL EQUATIONS"

The basic idea for the reinterpretation of the "Maxwell equations" is based on the discovery of magnetic "quasi-monopoles" that cause a magnetic field density. These were demonstrated in the following experiments:

1. Castelnovo, Moessner und Sondhi, 2009, Helmholz-Zentrum Berlin, Formation of "quasi-monopoles" through neutron diffraction of a dysprosium titanate crystal.

2. 2010, Paul-Scherrer-Institut, Formation of "quasi-monopoles" through synchronous radiation.

3. 2013, Technische Universitäten Dresden und München, Formation of "quasi-monopoles" when mining Skyrmion crystals.

4. David Hall und Mikko Möttönen, 2014, University of Amherst und Universität Aalto, Formation of "quasi-monopoles" in a ferromagnetic Bose-Einstein condensate.

Starting from the unipolar induction according to Faraday (equation 2.1.1) and the associated analogous equation (equation 2.1.2), the "Maxwell equations" can now be derived and reformulated under the mathematical requirement of a magnetic field density and with the help of vector analysis become.
All physical and mathematical descriptions used in this elaboration are listed below.

$\vec{E}$ = electric field strength
$\vec{v}$ = velocity
$\vec{B}$ = magnetic flux density
$\vec{H}$ = magnetic field strength
$\vec{D}$ = electrical flux density

$\times$ = Cross product

$\vec{s}$ = distance

t = time

ρ_{el} = electrical space charge density

ρ_m = magnetic space charge density

j = electric current density

j_m = magnetic current density

δ = Delta

rot = rotation/curl

div = divergence

grad = gradient

Faradys unipolar induction:

$$\vec{E} = \vec{v} \times \vec{B} \tag{2.1.1}$$

Unipolar induction for magnetic fields:

$$\vec{H} = -(\vec{v} \times \vec{D}) \tag{2.1.2}$$

2.2 BASICS OF VECTOR CALCULATION

In order to be able to derive the set of equations of the “Maxwell equations” from vector calculation, the basics of vector calculation used for this are described in this chapter.
First, three meta-vectors $\vec{a}$, $\vec{b}$ and $\vec{c}$ are introduced at this point. The three meta-vectors will be used in the following basic mathematical description. In Equation 2.2.1, these three meta-vectors are used to map the cross product.

$$\vec{c} = \vec{a} \times \vec{b} \tag{2.2.1}$$

In equation 2.2.1, the rot-operator is now used on both sides of the equation. This results in equation 2.2.2.

$$\text{rot } \vec{c} = \text{rot } (\vec{a} \times \vec{b}) \tag{2.2.2}$$

Now the right side of equation 2.2.2 is rewritten according to the calculation rules of vector calculation. This results in equation 2.2.3.

$$\text{rot}\,\vec{c} = \text{rot}(\vec{a}\times\vec{b}) = (\text{grad}\,\vec{a})\ \vec{b} - (\text{grad}\,\vec{b})\ \vec{a} + \vec{a}\ \text{div}\,\vec{b} - \vec{b}\ \text{div}\,\vec{a} \qquad (2.2.3)$$

Two vector gradients (grad) and two vector divergences (div) now appear on the right-hand side of equation 2.2.3.

If a minus sign is now applied to all sides of Equation 2.2.3, this Equation changes to Equation 2.2.4.

$$\text{rot}(-\vec{a}\times\vec{b}) = -\,\text{rot}(\vec{a}\times\vec{b}) = -(\text{grad}\,\vec{a})\ \vec{b} + (\text{grad}\,\vec{b})\ \vec{a} - \vec{a}\ \text{div}\,\vec{b} + \vec{b}\ \text{div}\,\vec{a} \qquad (2.2.4)$$

The two equations 2.2.3 and 2.2.4 are analogous to the equations 2.1.1 and 2.1.2.

2.3 UNIPOLAR INDUCTION FOR DESCRIBING ELECTRIC AND MAGNETIC FIELDS

The rot operator is applied to equations 2.1.1 and 2.1.2 according to the calculation rules from equation 2.2.2. Taking Equations 2.2.3 and 2.2.4 into account, the two expressions from Equations 2.3.1 and 2.3.2 arise.

$$\text{rot}\,\vec{E} = \text{rot}(\vec{v} \times \vec{B}) \qquad (2.3.1)$$

$$\text{rot}\,\vec{H} = -\text{rot}(\vec{v} \times \vec{D}) \qquad (2.3.2)$$

In a next step, the right-hand side from equations 2.3.1 and 2.3.2 is rearranged according to the calculation rules from equations 2.2.3 and 2.2.4. This results in the expressions from equations 2.3.3 and 2.3.4.

$$\text{rot}\,\vec{E} = (\text{grad}\,\vec{v})\ \vec{B} - (\text{grad}\,\vec{B})\vec{v} + \vec{v}\ \text{div}\,\vec{B} - \vec{B}\ \text{div}\ \vec{v} \qquad (2.3.3)$$

$$\text{rot}\,\vec{H} = -((\text{grad}\,\vec{v})\ \vec{D} - (\text{grad}\,\vec{D})\vec{v} + \vec{v}\ \text{div}\,\vec{D} - \vec{D}\ \text{div}\ \vec{v}) \qquad (2.3.4)$$

Equation 2.3.4 is further simplified, resulting in equation 2.3.5.

$$\text{rot}\,\vec{H} = -(\text{grad}\,\vec{v})\ \vec{D} + (\text{grad}\,\vec{D})\vec{v} - \vec{v}\ \text{div}\,\vec{D} + \vec{D}\ \text{div}\ \vec{v} \qquad (2.3.5)$$

In principle, Equations 2.3.3 and 2.3.5 can already be described as a reinterpretation of the "Maxwell equations", since these describe a large part of the electrodynamics. For better understanding, the "Maxwell equations" are derived from equations 2.3.3 and 2.3.5 in the next chapters.

2.4 DERIVATION OF THE "MAXWELL EQUATIONS"

In the following chapters, the well-known "Maxwell equations" are derived from Equations 2.3.3 and 2.3.5 in order to create the conditions for being able to reinterpret and reformulate precisely those "Maxwell equations".
The derivation is based on the physical assumption that there is no magnetic field density, as given by the interpretation according to Heaviside. Here, too, it is assumed that no distortions occur in the velocity vector field, in the magnetic field, or in the electric field. As a result, the $(\text{grad}\ \vec{v})$ and the $(\text{div}\ \vec{v})$ have no influence on the overall result. Furthermore, the two expressions $\vec{v}\,(\text{grad}\ \vec{B})$ and $\vec{v}\,(\text{grad}\ \vec{D})$ become $\frac{\delta \vec{B}}{\delta t}$ and $\frac{\delta \vec{D}}{\delta t}$.

2.4.1 "MAXWELL EQUATIONS"

From the prerequisites formulated in chapter 2.4, the simplified forms of the "Maxwell equations" can now be listed by equations 2.4.1, 2.4.2, 2.4.3 and 2.4.4.

Gaussian law:

$$\text{div}\,\vec{D} = -\rho_{el} \tag{2.4.1}$$

Gaussian law for magnetic fields:

$$\text{div}\,\vec{B} = 0 \tag{2.4.2}$$

Induction law:

$$\text{rot}\,\vec{E} = -\frac{\delta \vec{B}}{\delta t} \tag{2.4.3}$$

Flooding law:

$$\text{rot}\,\vec{H} = \frac{\delta \vec{D}}{\delta t} + \vec{j} \tag{2.4.4}$$

The following chapters explain how equations 2.4.1, 2.4.2, 2.4.3 and 2.4.4 can be derived from equations 2.3.3 and 2.3.5 under the assumptions from chapter 2.4.

2.4.2 DERIVATION OF GAUSS' LAW FOR MAGNETIC FIELDS AND THE LAW OF INDUCTION

In this chapter, both Gauss's law for magnetic fields and the law of induction are derived from equation 2.3.3, under the assumptions from chapter 2.4.

$$\text{rot}\,\vec{E} = \left(\text{grad}\,\vec{v}\right)\,\vec{B} - \left(\text{grad}\,\vec{B}\right)\vec{v} + \vec{v}\,\text{div}\,\vec{B} - \vec{B}\,\text{div}\,\vec{v} \tag{2.3.3}$$

First, the individual components from Equation 2.3.3 are considered under certain assumptions. Assuming a homogeneous velocity vector field, $\left(\text{grad}\,\vec{v}\right)$ and $\left(\text{div}\,\vec{v}\right)$ have no influence on the overall result and therefore assume the value 0. The $\left(\text{div}\,\vec{B}\right)$ also assumes the value 0, assuming that there is no magnetic field density. Equations 2.4.5, 2.4.6 and 2.4.2 follow from this. Equation 2.4.2 describes Gauss' law for magnetic fields.

$$\left(\text{grad}\,\vec{v}\right) = 0 \tag{2.4.5}$$

$$\left(\text{div}\,\vec{v}\right) = 0 \tag{2.4.6}$$

Gaußsches Gesetz für magnetische Felder:

$$\text{div}\,\vec{B} = 0 \tag{2.4.2}$$

Under the assumptions from Equations 2.4.5, 2.4.6 and 2.4.2, Equation 2.3.3 can now be simplified to Equation 2.4.7.

$$\text{rot}\,\vec{E} = \left(\text{grad}\,\vec{v}\right)\,\vec{B} - \left(\text{grad}\,\vec{B}\right)\vec{v} + \vec{v}\,\text{div}\,\vec{B} - \vec{B}\,\text{div}\,\vec{v} \tag{2.3.3}$$

$$\text{rot}\,\vec{E} = 0\cdot\vec{B} - \left(\text{grad}\,\vec{B}\right)\vec{v} + \vec{v}\cdot 0 - \vec{B}\cdot 0 \tag{2.4.7}$$

If the terms that do not contribute to the overall result in Equation 2.4.7 are now eliminated, the overall expression from Equation 2.4.7 can be further simplified. Equation 2.4.8 results from this.

$$\text{rot}\,\vec{E} = -\left(\text{grad}\,\vec{B}\right)\vec{v} \tag{2.4.8}$$

$\left(\text{grad}\,\vec{B}\right)\vec{v}$ from equation 2.4.8 can be rewritten in column notation. The changed notation is shown in Equation 2.4.9.

$$-\left(\text{grad}\,\vec{B}\right)\cdot\left(\vec{v}\right) = -\begin{pmatrix} \frac{\delta B_x}{\delta x} & \frac{\delta B_x}{\delta y} & \frac{\delta B_x}{\delta z} \\ \frac{\delta B_y}{\delta x} & \frac{\delta B_y}{\delta y} & \frac{\delta B_y}{\delta z} \\ \frac{\delta B_z}{\delta x} & \frac{\delta B_z}{\delta y} & \frac{\delta B_z}{\delta z} \end{pmatrix} \cdot \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} \tag{2.4.9}$$

If, in Equation 2.4.9, the velocity vector $\vec{v}$ is offset against $\left(\text{grad}\,\vec{B}\right)$, Equation 2.4.10 results.

$$-\left(\text{grad}\,\vec{B}\right)\cdot\left(\vec{v}\right) = -\begin{pmatrix} \frac{\delta B_x}{\delta x}\cdot v_x + \frac{\delta B_x}{\delta y}\cdot v_y + \frac{\delta B_x}{\delta z}\cdot v_z \\ \frac{\delta B_y}{\delta x}\cdot v_x + \frac{\delta B_y}{\delta y}\cdot v_y + \frac{\delta B_y}{\delta z}\cdot v_z \\ \frac{\delta B_z}{\delta x}\cdot v_x + \frac{\delta B_z}{\delta y}\cdot v_y + \frac{\delta B_z}{\delta z}\cdot v_z \end{pmatrix} = -\vec{x}_{(\text{grad}\,\vec{B})\,\vec{v}} \tag{2.4.10}$$

The velocity vector $\vec{v}$ can now be rewritten as $\frac{\delta \vec{s}}{\delta t}$. Equation 2.4.11 shows this relationship.

$$\vec{v} = \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} = \frac{\delta \vec{s}}{\delta t} = \begin{pmatrix} \frac{\delta x}{\delta t} \\ \frac{\delta y}{\delta t} \\ \frac{\delta z}{\delta t} \end{pmatrix} \tag{2.4.11}$$

Substituting the modified expression from Equation 2.4.11 into Equation 2.4.10 gives Equation 2.4.12.

$$-\left(\operatorname{grad}\vec{B}\right)\cdot\left(\vec{v}\right) = -\begin{pmatrix} \frac{\delta B_x}{\delta x}\cdot\frac{\delta x}{\delta t}+\frac{\delta B_x}{\delta y}\cdot\frac{\delta y}{\delta t}+\frac{\delta B_x}{\delta z}\cdot\frac{\delta z}{\delta t} \\ \frac{\delta B_y}{\delta x}\cdot\frac{\delta x}{\delta t}+\frac{\delta B_y}{\delta y}\cdot\frac{\delta y}{\delta t}+\frac{\delta B_y}{\delta z}\cdot\frac{\delta z}{\delta t} \\ \frac{\delta B_z}{\delta x}\cdot\frac{\delta x}{\delta t}+\frac{\delta B_z}{\delta y}\cdot\frac{\delta y}{\delta t}+\frac{\delta B_z}{\delta z}\cdot\frac{\delta z}{\delta t} \end{pmatrix} \tag{2.4.12}$$

Assuming a distortion-free magnetic field, the magnetic flux density $\vec{B}$ can only change in the respective effective direction. This simplifies the expression from equation 2.4.12 to equation 2.4.13.

$$-\left(\operatorname{grad}\vec{B}\right)\cdot\left(\vec{v}\right) = -\begin{pmatrix} \frac{\delta B_x}{\boldsymbol{\delta x}}\cdot\frac{\boldsymbol{\delta x}}{\delta t}+0+0 \\ 0+\frac{\delta B_y}{\boldsymbol{\delta y}}\cdot\frac{\boldsymbol{\delta y}}{\delta t}+0 \\ 0+0+\frac{\delta B_z}{\boldsymbol{\delta z}}\cdot\frac{\boldsymbol{\delta z}}{\delta t} \end{pmatrix} \tag{2.4.13}$$

Now δx , δy and , δz in Equation 2.4.13 can be reduced and the overall expression from Equation 2.4.14 results.

$$-\left(\operatorname{grad}\vec{B}\right)\cdot\left(\vec{v}\right) = -\begin{pmatrix} \frac{\delta B_x}{\delta t} \\ \frac{\delta B_y}{\delta t} \\ \frac{\delta B_z}{\delta t} \end{pmatrix} = -\frac{\delta\vec{B}}{\delta t} \tag{2.4.14}$$

Equation 2.4.14 depicts part of the law of induction. If Equation 2.4.14 is now inserted into Equation 2.4.8, Equation 2.4.15 results.

$$\operatorname{rot}\vec{E} = -\left(\operatorname{grad}\vec{B}\right)\cdot\vec{v} = -\frac{\delta\vec{B}}{\delta t} \tag{2.4.15}$$

Equation 2.4.15 can now be simplified to equation 2.4.3, resulting in the law of induction according to Heaviside.

law of induction:

$$\text{rot}\,\vec{E} = -\frac{\delta \vec{B}}{\delta t} \tag{2.4.3}$$

At this point, the note is inserted that the trace of the magnetic flux density gradient, i.e. $(\text{Sp})(\text{grad}\,\vec{B})$, corresponds to the divergence of the magnetic flux density, i.e. $\text{div}\,\vec{B}$. From this mathematical requirement arises the fact that if the $\text{div}\,\vec{B}$ is equated to 0, as required by Gauss' law for magnetic fields (equation 2.4.2), then the $(\text{Sp})(\text{grad}\,\vec{B})$ must also be equated to 0. However, since the $(\text{Sp})(\text{grad}\,\vec{B})$ consists of the individual components that ultimately become the expression $\frac{\delta \vec{B}}{\delta t}$ in the law of induction (equation 2.4.3), the question arises, which values do the individual components of the expression $\frac{\delta \vec{B}}{\delta t}$ assume under these conditions? And what is the physical result of this conclusion? From chapter 2.5 these questions will be dealt with.

2.4.3 DERIVATION OF GAUSS' LAW AND FLOOD LAW

In analogy to chapter 2.4.2, in this chapter, from equation 2.3.5, both Gauss's law and the law of flooding are derived.

$$\text{rot}\,\vec{H} = -(\text{grad}\,\vec{v})\;\vec{D} + (\text{grad}\,\vec{D})\vec{v} - \vec{v}\;\text{div}\,\vec{D} + \vec{D}\;\text{div}\,\vec{v} \tag{2.3.5}$$

As in chapter 2.4.2, it is also assumed in this chapter that neither the velocity vector field $\vec{v}$ nor the vector field of the electric flux density $\vec{D}$ experience any distortion. This means that the $(\text{grad}\;\vec{v})$ and the $(\text{div}\;\vec{v})$ have no influence on the overall result. Unlike in Chapter 2.4.2, however, the field divergence, i.e. $(\text{div}\;\vec{D})$, makes a contribution to the overall result. This results in the requirement that, unlike the magnetic field, there is a field density here. These physical assumptions are shown in Equations 2.4.5, 2.4.6 and 2.4.1. Equation 2.4.1 describes Gauss' law.

$$(\text{grad}\;\vec{v}) = 0 \tag{2.4.5}$$

$$(\text{div}\;\vec{v}) = 0 \tag{2.4.6}$$

Gauss' law:

$$\operatorname{div}\vec{D} = -\rho_{el} \qquad (2.4.1)$$

Under the assumptions of Equations 2.4.5, 2.4.6 and 2.4.1, Equation 2.3.5 can now be simplified to Equation 2.4.16.

$$\operatorname{rot}\vec{H} = -(\operatorname{grad}\vec{v})\ \vec{D} + (\operatorname{grad}\vec{D})\vec{v} - \vec{v}\ \operatorname{div}\vec{D} + \vec{D}\ \operatorname{div}\vec{v} \qquad (2.3.5)$$

$$\operatorname{rot}\vec{H} = -0\cdot\vec{D} + (\operatorname{grad}\vec{D})\vec{v} - \vec{v}\ \operatorname{div}\vec{D} + \vec{D}\ \cdot 0 \qquad (2.4.16)$$

If the terms that do not contribute to the overall result are now eliminated, equation 2.4.16 can be further simplified. The result is equation 2.4.17.

$$\operatorname{rot}\vec{H} = (\operatorname{grad}\vec{D})\vec{v} - \vec{v}\ \operatorname{div}\vec{D} \qquad (2.4.17)$$

The term $(\operatorname{grad}\vec{D})\vec{v}$, from Equation 2.4.17, can be rewritten in the form of Equation 2.4.18.

$$(\operatorname{grad}\vec{D})\cdot(\vec{v}) = \begin{pmatrix} \frac{\delta D_x}{\delta x} & \frac{\delta D_x}{\delta y} & \frac{\delta D_x}{\delta z} \\ \frac{\delta D_y}{\delta x} & \frac{\delta D_y}{\delta y} & \frac{\delta D_y}{\delta z} \\ \frac{\delta D_z}{\delta x} & \frac{\delta D_z}{\delta y} & \frac{\delta D_z}{\delta z} \end{pmatrix} \cdot \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} \qquad (2.4.18)$$

If, in Equation 2.4.18, the velocity vector $\vec{v}$ is offset against $(\operatorname{grad}\vec{D})$, Equation 2.4.19 results.

$$(\operatorname{grad}\vec{D})\cdot(\vec{v}) = \begin{pmatrix} \frac{\delta D_x}{\delta x}\cdot v_x + \frac{\delta D_x}{\delta y}\cdot v_y + \frac{\delta D_x}{\delta z}\cdot v_z \\ \frac{\delta D_y}{\delta x}\cdot v_x + \frac{\delta D_y}{\delta y}\cdot v_y + \frac{\delta D_y}{\delta z}\cdot v_z \\ \frac{\delta D_z}{\delta x}\cdot v_x + \frac{\delta D_z}{\delta y}\cdot v_y + \frac{\delta D_z}{\delta z}\cdot v_z \end{pmatrix} = \vec{x}_{(\operatorname{grad}\vec{D})\vec{v}} \qquad (2.4.19)$$

The velocity vector $\vec{v}$ can be rewritten as $\frac{\delta \vec{s}}{\delta t}$ according to Equation 2.4.11. This fact results in Equation 2.4.20 from Equation 2.4.19.

$$\vec{v} = \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} = \frac{\delta \vec{s}}{\delta t} = \begin{pmatrix} \frac{\delta x}{\delta t} \\ \frac{\delta y}{\delta t} \\ \frac{\delta z}{\delta t} \end{pmatrix} \tag{2.4.11}$$

$$\left(\operatorname{grad} \vec{D}\right) \cdot \left(\vec{v}\right) = \begin{pmatrix} \frac{\delta D_x}{\delta x} \cdot \frac{\delta x}{\delta t} + \frac{\delta D_x}{\delta y} \cdot \frac{\delta y}{\delta t} + \frac{\delta D_x}{\delta z} \cdot \frac{\delta z}{\delta t} \\ \frac{\delta D_y}{\delta x} \cdot \frac{\delta x}{\delta t} + \frac{\delta D_y}{\delta y} \cdot \frac{\delta y}{\delta t} + \frac{\delta D_y}{\delta z} \cdot \frac{\delta z}{\delta t} \\ \frac{\delta D_z}{\delta x} \cdot \frac{\delta x}{\delta t} + \frac{\delta D_z}{\delta y} \cdot \frac{\delta y}{\delta t} + \frac{\delta D_z}{\delta z} \cdot \frac{\delta z}{\delta t} \end{pmatrix} \tag{2.4.20}$$

Assuming that the electric field effect only changes in the respective effective direction, i.e. a distortion-free electric flux density field is assumed, the expression from Equation 2.4.20 changes to Equation 2.4.21.

$$\left(\operatorname{grad} \vec{D}\right) \cdot \left(\vec{v}\right) = \begin{pmatrix} \frac{\delta D_x}{\boldsymbol{\delta x}} \cdot \frac{\boldsymbol{\delta x}}{\delta t} + 0 + 0 \\ 0 + \frac{\delta D_y}{\boldsymbol{\delta y}} \cdot \frac{\boldsymbol{\delta y}}{\delta t} + 0 \\ 0 + 0 + \frac{\delta D_z}{\boldsymbol{\delta z}} \cdot \frac{\boldsymbol{\delta z}}{\delta t} \end{pmatrix} \tag{2.4.21}$$

Now the components δx, δy and δz can be reduced from Equation 2.4.21 and Equation 2.4.22 emerges.

$$\left(\operatorname{grad} \vec{D}\right) \cdot \left(\vec{v}\right) = \begin{pmatrix} \frac{\delta D_x}{\delta t} \\ \frac{\delta D_y}{\delta t} \\ \frac{\delta D_z}{\delta t} \end{pmatrix} = \frac{\delta \vec{D}}{\delta t} \tag{2.4.22}$$

Equation 2.4.22 depicts part of the flux law, namely $\frac{\delta \vec{D}}{\delta t}$, and can later be used in equation 2.4.4.

flooding law:

$$\mathrm{rot}\,\vec{H} \;=\; \frac{\boldsymbol{\delta \vec{D}}}{\boldsymbol{\delta t}} \;+\; \vec{j} \tag{2.4.4}$$

If the relationships from Equations 2.4.1 and 2.4.22 are now inserted into Equation 2.4.17, Equation 2.4.23 results.

$$\mathrm{div}\,\vec{D} \;=\; -\boldsymbol{\rho}_{el} \tag{2.4.1}$$

$$\left(\mathrm{grad}\,\vec{D}\right) \cdot \left(\vec{v}\right) = \begin{pmatrix} \frac{\delta D_x}{\delta t} \\ \frac{\delta D_y}{\delta t} \\ \frac{\delta D_z}{\delta t} \end{pmatrix} = \frac{\boldsymbol{\delta \vec{D}}}{\boldsymbol{\delta t}} \tag{2.4.22}$$

$$\mathrm{rot}\,\vec{H} \;=\; \left(\mathrm{grad}\,\vec{D}\right)\vec{v} \;-\; \vec{v}\;\,\mathrm{div}\,\vec{D} \tag{2.4.17}$$

$$\mathrm{rot}\,\vec{H} \;=\; \left(\mathrm{grad}\,\vec{D}\right)\vec{v} \;-\; \vec{v}\;\,\mathrm{div}\,\vec{D} \;=\; \frac{\boldsymbol{\delta \vec{D}}}{\boldsymbol{\delta t}} \;-\; \vec{v} \cdot \left(-\boldsymbol{\rho}_{el}\right) \tag{2.4.23}$$

The velocity vector $\vec{v}$ multiplied by the electrical space charge density $-\rho_{el}$, i.e. $\vec{v} \cdot \left(-\rho_{el}\right)$, results in the electrical current density $-\vec{j}$. This relationship is shown in equation 2.4.24.

$$-\boldsymbol{\vec{j}} \;=\; \vec{v} \cdot \left(-\rho_{el}\right) \tag{2.4.24}$$

If Equation 2.4.24 is used together with Equation 2.4.22 into Equation 2.4.23, the simplified variant of the flooding law in Equation 2.4.4 arises.

flooding law:

$$\text{rot}\,\vec{H} = \frac{\delta \vec{D}}{\delta t} + \vec{j} \qquad (2.4.4)$$

The difference between the law of induction (equation 2.4.3) and the flooding law (equation 2.4.4) is that the flooding law includes an electric current density $\vec{j}$. The problems that arise from the general assumption that there is no magnetic current density $\vec{j}_m$ in the law of induction will be examined in the following chapters in the reinterpretation of the "Maxwell equations".

2.5 THE REINTERPRETATION OF THE “MAXWELL EQUATIONS”

In order to be able to reinterpret the "Maxwell equations", the framework conditions are first redefined. The first condition is that it cannot be ruled out that both the vector field of the velocity $\vec{v}$ and the two vector fields of the magnetic flux density $\vec{B}$ and the electric flux density $\vec{D}$ can be subject to deformation or distortion. Accordingly, the velocity gradient $\text{grad}(\vec{v})$ cannot be equated with 0. In addition, the two field gradients $\text{grad}(\vec{B})$ and $\text{grad}(\vec{D})$ cannot be simplified as in Chapters 2.4.3 and 2.4.4. All three the $\text{div}(\vec{v})$ and the $\text{div}(\vec{B})$ and the $\text{div}(\vec{D})$ are dependent on the Spur (Sp) of the respective associated gradient. From a mathematical point of view, equations 2.5.1, 2.5.2 and 2.5.3 result from these framework conditions.

Equations 2.3.3 and 2.3.5 are the starting point for the reinterpretation of the “Maxwell equations”.

$$\text{rot}\,\vec{E} = (\text{grad}\,\vec{v})\,\vec{B} - (\text{grad}\,\vec{B})\vec{v} + \vec{v}\,\text{div}\,\vec{B} - \vec{B}\,\text{div}\,\vec{v} \qquad (2.3.3)$$

$$\text{rot}\,\vec{H} = -(\text{grad}\,\vec{v})\,\vec{D} + (\text{grad}\,\vec{D})\vec{v} - \vec{v}\,\text{div}\,\vec{D} + \vec{D}\,\text{div}\,\vec{v} \qquad (2.3.5)$$

$$(\text{Sp})(\text{grad}\,\vec{v}) = \text{div}(\vec{v}) \qquad (2.5.1)$$

$$(\text{Sp})(\text{grad}\,\vec{B}) = \text{div}(\vec{B}) \qquad (2.5.2)$$

$$(\text{Sp})(\text{grad}\,\vec{D}) = \text{div}(\vec{D}) \qquad (2.5.3)$$

The velocity gradient $\operatorname{grad}(\vec{v})$ makes a contribution to the overall result of equations 2.3.3 and 2.3.5 when substances are deformed, i.e. wherever the velocity vector field $\vec{v}$ is not homogeneous, in the form given in equation 2.5.4 is shown.

$$(\operatorname{grad}\vec{v}) = \begin{pmatrix} \frac{\delta v_x}{\delta x} & \frac{\delta v_x}{\delta y} & \frac{\delta v_x}{\delta z} \\ \frac{\delta v_y}{\delta x} & \frac{\delta v_y}{\delta y} & \frac{\delta v_y}{\delta z} \\ \frac{\delta v_z}{\delta x} & \frac{\delta v_z}{\delta y} & \frac{\delta v_z}{\delta z} \end{pmatrix} \tag{2.5.4}$$

In Equation 2.3.3 as well as in Equation 2.3.5, the velocity gradient $\operatorname{grad}(\vec{v})$ is multiplied by the respective field magnitude vector. For Equation 2.3.3 this is $\vec{B}$ and for Equation 2.3.5 this is $\vec{D}$. For the second term from Equation 2.3.3, Equation 2.5.5 can therefore be written. Equation 2.5.6 can be written analogously for the second term from Equation 2.3.5.

$$\operatorname{rot}\vec{E} = (\mathbf{grad}\,\vec{\boldsymbol{v}})\ \vec{\boldsymbol{B}} - (\operatorname{grad}\vec{B})\vec{v} + \vec{v}\ \operatorname{div}\vec{B} - \vec{B}\ \operatorname{div}\vec{v} \tag{2.3.3}$$

$$(\mathbf{grad}\,\vec{\boldsymbol{v}}) \cdot (\vec{\boldsymbol{B}}) = \begin{pmatrix} \frac{\delta v_x}{\delta x} & \frac{\delta v_x}{\delta y} & \frac{\delta v_x}{\delta z} \\ \frac{\delta v_y}{\delta x} & \frac{\delta v_y}{\delta y} & \frac{\delta v_y}{\delta z} \\ \frac{\delta v_z}{\delta x} & \frac{\delta v_z}{\delta y} & \frac{\delta v_z}{\delta z} \end{pmatrix} \cdot \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} \tag{2.5.5}$$

$$\operatorname{rot}\vec{H} = -(\mathbf{grad}\,\vec{\boldsymbol{v}})\ \vec{\boldsymbol{D}} + (\operatorname{grad}\vec{D})\vec{v} - \vec{v}\ \operatorname{div}\vec{D} + \vec{D}\ \operatorname{div}\vec{v} \tag{2.3.5}$$

$$(\mathbf{grad}\,\vec{\boldsymbol{v}}) \cdot (\vec{\boldsymbol{D}}) = \begin{pmatrix} \frac{\delta v_x}{\delta x} & \frac{\delta v_x}{\delta y} & \frac{\delta v_x}{\delta z} \\ \frac{\delta v_y}{\delta x} & \frac{\delta v_y}{\delta y} & \frac{\delta v_y}{\delta z} \\ \frac{\delta v_z}{\delta x} & \frac{\delta v_z}{\delta y} & \frac{\delta v_z}{\delta z} \end{pmatrix} \cdot \begin{pmatrix} D_x \\ D_y \\ D_z \end{pmatrix} \tag{2.5.6}$$

If the velocity gradient $\operatorname{grad}(\vec{v})$ is now offset against the respective field vector, equation 2.5.5 results in the expression from equation 2.5.7 and equation 2.5.6 results in equation 2.5.8.

$$\left(\text{grad }\vec{v}\right)\cdot\left(\vec{B}\right)=\begin{pmatrix}\frac{\delta v_x}{\delta x}\cdot B_x+\frac{\delta v_x}{\delta y}\cdot B_y+\frac{\delta v_x}{\delta z}\cdot B_z\\ \frac{\delta v_y}{\delta x}\cdot B_x+\frac{\delta v_y}{\delta y}\cdot B_y+\frac{\delta v_y}{\delta z}\cdot B_z\\ \frac{\delta v_z}{\delta x}\cdot B_x+\frac{\delta v_z}{\delta y}\cdot B_y+\frac{\delta v_z}{\delta z}\cdot B_z\end{pmatrix}=\vec{x}_{(\text{grad }\vec{v})\vec{B}} \qquad (2.5.7)$$

$$-\left(\text{grad }\vec{v}\right)\cdot\left(\vec{D}\right)=-\begin{pmatrix}\frac{\delta v_x}{\delta x}\cdot D_x+\frac{\delta v_x}{\delta y}\cdot D_y+\frac{\delta v_x}{\delta z}\cdot D_z\\ \frac{\delta v_y}{\delta x}\cdot D_x+\frac{\delta v_y}{\delta y}\cdot D_y+\frac{\delta v_y}{\delta z}\cdot D_z\\ \frac{\delta v_z}{\delta x}\cdot D_x+\frac{\delta v_z}{\delta y}\cdot D_y+\frac{\delta v_z}{\delta z}\cdot D_z\end{pmatrix}=-\vec{x}_{(grad\ \vec{v})\vec{D}} \qquad (2.5.8)$$

Under the assumption of Equation 2.5.1, Equation 2.5.4 yields a statement about the divergence of the velocity vector $\text{div}\,\vec{v}$. This results in Equation 2.5.9.

$$(\text{Sp})(\text{grad}\,\vec{v})=\mathbf{div}\,\boldsymbol{\vec{v}} \qquad (2.5.1)$$

$$(\text{grad}\,\vec{v})=\begin{pmatrix}\boldsymbol{\frac{\delta v_x}{\delta x}} & \frac{\delta v_x}{\delta y} & \frac{\delta v_x}{\delta z}\\ \frac{\delta v_y}{\delta x} & \boldsymbol{\frac{\delta v_y}{\delta y}} & \frac{\delta v_y}{\delta z}\\ \frac{\delta v_z}{\delta x} & \frac{\delta v_z}{\delta y} & \boldsymbol{\frac{\delta v_z}{\delta z}}\end{pmatrix} \qquad (2.5.4)$$

$$(\text{Sp})(\text{grad}\,\vec{v})=\mathbf{div}\,\boldsymbol{\vec{v}}=\boldsymbol{\frac{\delta v_x}{\delta x}}+\boldsymbol{\frac{\delta v_y}{\delta y}}+\boldsymbol{\frac{\delta v_z}{\delta z}} \qquad (2.5.9)$$

If Equation 2.5.9 is now multiplied by the respective field vector $\vec{B}$ or $\vec{D}$, Equation 2.5.10 arises for the fifth term from Equation 2.3.3 and Equation 2.5.11 arises for the fifth term from Equation 2.3.5.

$$\text{rot}\,\vec{E}=(\text{grad}\,\vec{v})\ \vec{B}-(\text{grad}\,\vec{B})\vec{v}+\vec{v}\ \text{div}\,\vec{B}-\boldsymbol{\vec{B}}\ \mathbf{div}\,\boldsymbol{\vec{v}} \qquad (2.3.3)$$

$$-\boldsymbol{\vec{B}}\ \mathbf{div}\ \boldsymbol{\vec{v}} = -\begin{pmatrix} B_x(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ B_y(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ B_z(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \end{pmatrix} = -\vec{x}_{\vec{B}\,\mathrm{div}\,\vec{v}} \qquad (2.5.10)$$

$$\mathrm{rot}\,\vec{H} = -(\mathrm{grad}\,\vec{v})\ \vec{D} + (\mathrm{grad}\,\vec{D})\vec{v} - \vec{v}\ \mathrm{div}\,\vec{D} + \boldsymbol{\vec{D}}\ \mathbf{div}\,\boldsymbol{\vec{v}} \qquad (2.3.5)$$

$$\boldsymbol{\vec{D}}\ \mathbf{div}\ \boldsymbol{\vec{v}} = \begin{pmatrix} D_x(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ D_y(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ D_z(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \end{pmatrix} = \vec{x}_{\vec{D}\,\mathrm{div}\,\vec{v}} \qquad (2.5.11)$$

The mathematical requirement from Equation 2.5.3 results in an electric field density from $\mathrm{div}\,\vec{D}$. This relationship is shown in Equation 2.5.12.

$$(\mathrm{Sp})(\mathrm{grad}\,\vec{D}) = \mathbf{div}\,\boldsymbol{\vec{D}} \qquad (2.5.3)$$

$$(\mathrm{Sp})(\mathrm{grad}\,\vec{D}) = \mathbf{div}\,\boldsymbol{\vec{D}} = \frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z} \qquad (2.5.12)$$

In order to get the fourth term from Equation 2.3.5, the expression $\mathrm{div}\,\vec{D}$ from Equation 2.5.12 must now be multiplied by the velocity vector $\vec{v}$. The result is the electric current density $-\vec{j}$. This fact is shown in Equation 2.5.13.

$$\mathrm{rot}\,\vec{H} = -(\mathrm{grad}\,\vec{v})\ \vec{D} + (\mathrm{grad}\,\vec{D})\vec{v} - \boldsymbol{\vec{v}}\ \mathbf{div}\,\boldsymbol{\vec{D}} + \vec{D}\ \mathrm{div}\,\vec{v} \qquad (2.3.5)$$

$$\boldsymbol{\vec{v}}\ \mathbf{div}\ \boldsymbol{\vec{D}} = \begin{pmatrix} v_x(\frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}) \\ v_y(\frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}) \\ v_z(\frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}) \end{pmatrix} = -\boldsymbol{\vec{j}} \qquad (2.5.13)$$

Since in Equation 2.5.13 only the field vector $\vec{D}$ has to be replaced by the field vector $\vec{B}$ in order to obtain a mathematically correct statement, it must also follow that there is a magnetic current density $-j_m$.

2.5.1 THE MAGNETIC FIELD DENSITY

In this chapter, the magnetic field density is treated separately because it is the core of this elaboration. It is shown here why the divergence of the magnetic flux density $\operatorname{div}\vec{B}$, which can be interpreted as just that magnetic field density, can only be equated with 0 from a mathematical point of view under certain circumstances.
From the mathematical requirement of equation 2.5.14 it follows that the divergence of the magnetic flux density $\operatorname{div}\vec{B}$ is directly related to the gradient of the magnetic flux density $\operatorname{grad}\vec{B}$, as can be seen in combination with equation 2.4.9. The sum of the diagonals, from top left to bottom right, of the magnetic flux density gradient $\operatorname{grad}\vec{B}$ represents the divergence of the magnetic flux density $\operatorname{div}\vec{B}$. This sum is called $(\mathrm{Sp})(\operatorname{grad}\vec{B})$. This affects the following matrix elements of the $\operatorname{grad}\vec{B}$: $\frac{\delta B_x}{\delta x}$, $\frac{\delta B_y}{\delta y}$ and $\frac{\delta B_z}{\delta z}$. According to the "Maxwell equations", the sum of these three elements must therefore be 0, as can be seen from Equation 2.5.14. However, since these three elements are an important part of Equation 2.5.15, the following problem arises. Either $\frac{\delta \vec{B}}{\delta t}$ or the sum of the individual elements $\frac{\delta B_x}{\delta x}$, $\frac{\delta B_y}{\delta y}$ and $\frac{\delta B_z}{\delta z}$ must become 0. Both are a contradiction to the law of induction. The reason for this is that the result, which emerges from the law of induction, is neither 0 nor the sum of its individual elements must be 0.

$$(\mathrm{Sp})(\operatorname{grad}\vec{B}) = \operatorname{div}(\vec{B}) = \frac{\boldsymbol{\delta B_x}}{\boldsymbol{\delta x}} + \frac{\boldsymbol{\delta B_y}}{\boldsymbol{\delta y}} + \frac{\boldsymbol{\delta B_z}}{\boldsymbol{\delta z}} = 0 \qquad (2.5.14)$$

$$-(\operatorname{grad}\vec{B}) \cdot (\vec{v}) = -\begin{pmatrix} \frac{\boldsymbol{\delta B_x}}{\boldsymbol{\delta x}} & \frac{\delta B_x}{\delta y} & \frac{\delta B_x}{\delta z} \\ \frac{\delta B_y}{\delta x} & \frac{\boldsymbol{\delta B_y}}{\boldsymbol{\delta y}} & \frac{\delta B_y}{\delta z} \\ \frac{\delta B_z}{\delta x} & \frac{\delta B_z}{\delta y} & \frac{\boldsymbol{\delta B_z}}{\boldsymbol{\delta z}} \end{pmatrix} \cdot \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} \qquad (2.4.9)$$

$$-\begin{pmatrix} \frac{\boldsymbol{\delta B_x}}{\boldsymbol{\delta x}} \cdot \frac{\delta x}{\delta t} \\ \frac{\boldsymbol{\delta B_y}}{\boldsymbol{\delta y}} \cdot \frac{\delta y}{\delta t} \\ \frac{\boldsymbol{\delta B_z}}{\boldsymbol{\delta z}} \cdot \frac{\delta z}{\delta t} \end{pmatrix} = -\frac{\delta \vec{B}}{\delta t} \tag{2.5.15}$$

The contradiction to the law of induction just formulated is shown in equations 2.5.16, 2.5.17, 2.5.18 and 2.5.19.

$$\frac{\delta \vec{B}}{\delta t} = 0 \tag{2.5.16}$$

$$(\mathrm{Sp})(\mathrm{grad}\,\vec{B}) = \mathrm{div}(\vec{B}) = -\frac{\delta B_x}{\delta x} = -\frac{\delta B_y}{\delta y} - \frac{\delta B_z}{\delta z} = 0 \tag{2.5.17}$$

$$(\mathrm{Sp})(\mathrm{grad}\,\vec{B}) = \mathrm{div}(\vec{B}) = -\frac{\delta B_y}{\delta y} = -\frac{\delta B_x}{\delta x} - \frac{\delta B_z}{\delta z} = 0 \tag{2.5.18}$$

$$(\mathrm{Sp})(\mathrm{grad}\,\vec{B}) = \mathrm{div}(\vec{B}) = -\frac{\delta B_z}{\delta z} = -\frac{\delta B_y}{\delta y} - \frac{\delta B_x}{\delta x} = 0 \tag{2.5.19}$$

The detailed description of the problem is as follows: Either $\frac{\delta \vec{B}}{\delta t}$ is set equal to 0 (equation 2.5.16) or in the theoretical movement of a point particle through a magnetic flux density $\vec{B}$, there is, in three-dimensional space, a dimensional direction of movement in which the flux density changes positively and two-dimensional directions of movement, which together describe a negative change in the magnetic flux density. This is evident from equations 2.5.17, 2.5.18, 2.5.19. However, the condition for this is that the sum of all three magnetic flux density changes in the three possible dimensional directions of movement results in 0. The resulting idea of the magnetic flux density $\vec{B}$ and, ultimately, the idea of a magnetic field does not correspond to the current physical idea of the magnetic field and the empirical values that result from practical inventions, such as the three-phase generator.
A solution to this problem results from an approach by Paul Dirac that there is a magnetic current density $-\vec{j}_m$. The calculation of this magnetic field density is shown in Equation 2.5.20, which is analogous to Equation 2.5.13. Since Equation 2.5.13 already describes the

electric current density $-\vec{j}$, only the field vector $\vec{D}$ has to be replaced by the field vector $\vec{B}$ there in order to derive Equation 2.5.20 from it.

$$\vec{v}\ \mathrm{div}\ \vec{\boldsymbol{D}} = \begin{pmatrix} v_x(\frac{\delta \boldsymbol{D}_x}{\delta x} + \frac{\delta \boldsymbol{D}_y}{\delta y} + \frac{\delta \boldsymbol{D}_z}{\delta z}) \\ v_y(\frac{\delta \boldsymbol{D}_x}{\delta x} + \frac{\delta \boldsymbol{D}_y}{\delta y} + \frac{\delta \boldsymbol{D}_z}{\delta z}) \\ v_z(\frac{\delta \boldsymbol{D}_x}{\delta x} + \frac{\delta \boldsymbol{D}_y}{\delta y} + \frac{\delta \boldsymbol{D}_z}{\delta z}) \end{pmatrix} = -\vec{\boldsymbol{j}} \qquad (2.5.13)$$

$$\vec{v}\ \mathrm{div}\ \vec{\boldsymbol{B}} = \begin{pmatrix} v_x(\frac{\delta \boldsymbol{B}_x}{\delta x} + \frac{\delta \boldsymbol{B}_y}{\delta y} + \frac{\delta \boldsymbol{B}_z}{\delta z}) \\ v_y(\frac{\delta \boldsymbol{B}_x}{\delta x} + \frac{\delta \boldsymbol{B}_y}{\delta y} + \frac{\delta \boldsymbol{B}_z}{\delta z}) \\ v_z(\frac{\delta \boldsymbol{B}_x}{\delta x} + \frac{\delta \boldsymbol{B}_y}{\delta y} + \frac{\delta \boldsymbol{B}_z}{\delta z}) \end{pmatrix} = -\vec{\boldsymbol{j}}_{\boldsymbol{m}} \qquad (2.5.20)$$

Equation 2.5.20 shows that at least one of the three expressions $\frac{\delta B_x}{\delta x}$, $\frac{\delta B_y}{\delta y}$ or $\frac{\delta B_z}{\delta z}$ must have a value so that the magnetic current density $-\vec{j}_m$ can also have a value. This also has a direct impact on equation 2.5.15. Because at least one of the three expressions listed has a value, the expression $\frac{\delta \vec{B}}{\delta t}$ now also has a value.

$$-\begin{pmatrix} \frac{\boldsymbol{\delta B_x}}{\boldsymbol{\delta x}} \cdot \frac{\delta x}{\delta t} \\ \frac{\boldsymbol{\delta B_y}}{\boldsymbol{\delta y}} \cdot \frac{\delta y}{\delta t} \\ \frac{\boldsymbol{\delta B_z}}{\boldsymbol{\delta z}} \cdot \frac{\delta z}{\delta t} \end{pmatrix} = -\frac{\boldsymbol{\delta \vec{B}}}{\boldsymbol{\delta t}} \qquad (2.5.15)$$

From this it follows that the expression $\frac{\delta \vec{B}}{\delta t}$ is always associated with a magnetic field density $\mathrm{div}\,\vec{B}$, with the exception of equations 2.5.17, 2.5.18 and 2.5.19. In addition, a magnetic current density $-j_m$ also requires a magnetic charge $-\rho_m$, which results from the magnetic field density $\mathrm{div}\,\vec{B}$. Analogously to Equation 2.4.24, in which the electric current density $-j$ is described, the assumption from Equation 2.5.21 can now also be made. A magnetic current density $-j_m$ is described therein.

$$-\vec{\boldsymbol{j}} = \vec{v} \cdot (-\rho_{el}) \qquad (2.4.24)$$

$$-\vec{\boldsymbol{j}}_{\boldsymbol{m}} = \vec{v} \cdot (-\boldsymbol{\rho}_{\boldsymbol{m}}) \qquad (2.5.21)$$

$$\vec{v}\ \mathbf{div}\ \vec{\boldsymbol{B}} = \begin{pmatrix} v_x(\frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z}) \\ v_y(\frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z}) \\ v_z(\frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z}) \end{pmatrix} = -\vec{j}_m \qquad (2.5.20)$$

Equation 2.5.21 in combination with Equation 2.5.20 shows that the magnetic field density $\operatorname{div}\vec{B}$ cannot have the value 0, but instead has the value $-\rho_m$. It follows that Equation 2.5.14 can only be interpreted as a special case of Equation 2.5.22.

$$(\mathrm{Sp})(\operatorname{grad}\vec{B}) = \operatorname{div}(\vec{B}) = \frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z} = \mathbf{0} \qquad (2.5.14)$$

$$(\mathrm{Sp})(\operatorname{grad}\vec{B}) = \operatorname{div}(\vec{B}) = \frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z} = (-\boldsymbol{\rho}_{\boldsymbol{m}}) \qquad (2.5.22)$$

Equation 2.5.22 can now also be converted into equation 2.5.23.

$$\operatorname{div}(\vec{B}) = -\rho_m \qquad (2.5.23)$$

Since a magnetic field density also results in the possibility of calculating certain field configurations, the "Maxwell equations" are reformulated in the following chapter.

2.5.2 REFORMULATION OF THE “MAXWELL EQUATIONS”

First, Equations 2.3.3 and 2.3.5 are written again, since these two equations depict the fundamental statements for the reformulation of the “Maxwell Equations”.

$$\mathrm{rot}\,\vec{E} \;=\; \left(\mathrm{grad}\,\vec{v}\right)\;\vec{B} \;-\; \left(\mathrm{grad}\,\vec{B}\right)\vec{v} \;+\; \vec{v}\;\mathrm{div}\,\vec{B} \;-\; \vec{B}\;\mathrm{div}\;\vec{v} \qquad (2.3.3)$$

$$\mathrm{rot}\,\vec{H} \;=\; -\left(\mathrm{grad}\,\vec{v}\right)\;\vec{D} \;+\; \left(\mathrm{grad}\,\vec{D}\right)\vec{v} \;-\; \vec{v}\;\mathrm{div}\,\vec{D} \;+\; \vec{D}\;\mathrm{div}\;\vec{v} \qquad (2.3.5)$$

Equations 2.4.10, 2.4.19, 2.5.7, 2.5.8, 2.5.10, 2.5.11, 2.5.13 and 2.5.20 are now written one below the other for better clarity. The reason for this is that, in a next step, these equations are substituted as individual components in equations 2.3.3 and 2.3.5. This set of equations has general validity, since it can also be used under the assumption that both the velocity vector field $\vec{v}$ and the two vector fields of the magnetic flux density $\vec{B}$ and the electric flux density $\vec{D}$ can be subject to deformation. In addition, in equation 2.5.20, the mathematical requirement from chapter 2.5.1 is fulfilled that there is a magnetic field density.

$$-\left(\mathrm{grad}\,\vec{B}\right)\cdot\left(\vec{v}\right) = -\begin{pmatrix} \frac{\delta B_x}{\delta x}\cdot v_x + \frac{\delta B_x}{\delta y}\cdot v_y + \frac{\delta B_x}{\delta z}\cdot v_z \\ \frac{\delta B_y}{\delta x}\cdot v_x + \frac{\delta B_y}{\delta y}\cdot v_y + \frac{\delta B_y}{\delta z}\cdot v_z \\ \frac{\delta B_z}{\delta x}\cdot v_x + \frac{\delta B_z}{\delta y}\cdot v_y + \frac{\delta B_z}{\delta z}\cdot v_z \end{pmatrix} = -\vec{x}_{(\mathrm{grad}\,\vec{B})\,\vec{v}} \qquad (2.4.10)$$

$$\left(\mathrm{grad}\,\vec{D}\right)\cdot\left(\vec{v}\right) = \begin{pmatrix} \frac{\delta D_x}{\delta x}\cdot v_x + \frac{\delta D_x}{\delta y}\cdot v_y + \frac{\delta D_x}{\delta z}\cdot v_z \\ \frac{\delta D_y}{\delta x}\cdot v_x + \frac{\delta D_y}{\delta y}\cdot v_y + \frac{\delta D_y}{\delta z}\cdot v_z \\ \frac{\delta D_z}{\delta x}\cdot v_x + \frac{\delta D_z}{\delta y}\cdot v_y + \frac{\delta D_z}{\delta z}\cdot v_z \end{pmatrix} = \vec{x}_{(\mathrm{grad}\,\vec{D})\,\vec{v}} \qquad (2.4.19)$$

$$\left(\mathrm{grad}\;\vec{v}\right)\cdot\left(\vec{B}\right) = \begin{pmatrix} \frac{\delta v_x}{\delta x}\cdot B_x + \frac{\delta v_x}{\delta y}\cdot B_y + \frac{\delta v_x}{\delta z}\cdot B_z \\ \frac{\delta v_y}{\delta x}\cdot B_x + \frac{\delta v_y}{\delta y}\cdot B_y + \frac{\delta v_y}{\delta z}\cdot B_z \\ \frac{\delta v_z}{\delta x}\cdot B_x + \frac{\delta v_z}{\delta y}\cdot B_y + \frac{\delta v_z}{\delta z}\cdot B_z \end{pmatrix} = \vec{x}_{(\mathrm{grad}\,\vec{v})\,\vec{B}} \qquad (2.5.7)$$

$$-(\text{grad}\ \vec{v}) \cdot (\vec{D}) = -\begin{pmatrix} \frac{\delta v_x}{\delta x} \cdot D_x + \frac{\delta v_x}{\delta y} \cdot D_y + \frac{\delta v_x}{\delta z} \cdot D_z \\ \frac{\delta v_y}{\delta x} \cdot D_x + \frac{\delta v_y}{\delta y} \cdot D_y + \frac{\delta v_y}{\delta z} \cdot D_z \\ \frac{\delta v_z}{\delta x} \cdot D_x + \frac{\delta v_z}{\delta y} \cdot D_y + \frac{\delta v_z}{\delta z} \cdot D_z \end{pmatrix} = -\vec{x}_{(grad\ \vec{v})\vec{D}} \quad (2.5.8)$$

$$-\vec{B}\ \text{div}\ \vec{v} = -\begin{pmatrix} B_x(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ B_y(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ B_z(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \end{pmatrix} = -\vec{x}_{\vec{B}\,\text{div}\,\vec{v}} \quad (2.5.10)$$

$$\vec{D}\ \text{div}\ \vec{v} = \begin{pmatrix} D_x(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ D_y(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \\ D_z(\frac{\delta v_x}{\delta x} + \frac{\delta v_y}{\delta y} + \frac{\delta v_z}{\delta z}) \end{pmatrix} = \vec{x}_{\vec{D}\,\text{div}\,\vec{v}} \quad (2.5.11)$$

$$\vec{v}\ \text{div}\ \vec{D} = \begin{pmatrix} v_x(\frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}) \\ v_y(\frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}) \\ v_z(\frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}) \end{pmatrix} = (-\vec{j}) \quad (2.5.13)$$

$$\vec{v}\ \text{div}\ \vec{B} = \begin{pmatrix} v_x(\frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z}) \\ v_y(\frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z}) \\ v_z(\frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z}) \end{pmatrix} = (-\vec{j}_m) \quad (2.5.20)$$

Equations 2.4.10, 2.4.19, 2.5.7, 2.5.8, 2.5.10, 2.5.11, 2.5.13 and 2.5.20 are now substituted into Equations 2.3.3 and 2.3.5. The result is Equations 2.5.33 and 2.5.34. Equations 2.5.35 and 2.5.36 show another result.

$$\operatorname{rot}\vec{E} = (\operatorname{grad}\vec{v})\ \vec{B} - (\operatorname{grad}\vec{B})\vec{v} + \vec{v}\ \operatorname{div}\vec{B} - \vec{B}\ \operatorname{div}\vec{v} \qquad (2.3.3)$$

$$\operatorname{rot}\vec{E} = \vec{x}_{(\operatorname{grad}\vec{v})\vec{B}} - \vec{x}_{(\operatorname{grad}\vec{B})\vec{v}} + (-\vec{j}_m) - \vec{x}_{\vec{B}\operatorname{div}\vec{v}} \qquad (2.5.33)$$

$$\operatorname{rot}\vec{H} = -(\operatorname{grad}\vec{v})\ \vec{D} + (\operatorname{grad}\vec{D})\vec{v} - \vec{v}\ \operatorname{div}\vec{D} + \vec{D}\ \operatorname{div}\vec{v} \qquad (2.3.5)$$

$$\operatorname{rot}\vec{H} = -\vec{x}_{(\operatorname{grad}\vec{v})\vec{D}} + \vec{x}_{(\operatorname{grad}\vec{D})\vec{v}} - (-\vec{j}) + \vec{x}_{\vec{D}\operatorname{div}\vec{v}} \qquad (2.5.34)$$

$$\vec{v}\ \operatorname{div}(\vec{D}) = (-\vec{j}) \qquad (2.5.35)$$

$$\vec{v}\ \operatorname{div}(\vec{B}) = (-\vec{j}_m) \qquad (2.5.36)$$

Equations 2.5.33, 2.5.34, 2.5.35 and 2.5.36 therefore represent the simplified reformulation of the "Maxwell equations". Equation 2.5.36 is the mathematical-physical expression of a magnetic current density.

3. DISCUSSION

1. It remains to be discussed whether the expression from Equation 2.4.2 ($\operatorname{div}(\vec{B}) = 0$) is physically admissible, since the mathematical requirement consists of Equation 2.5.2 ($(\mathrm{Sp})(\operatorname{grad}\vec{B}) = \operatorname{div}(\vec{B})$). And if $\operatorname{div}(\vec{B}) = 0$ is feasible, what does this mean for equation 2.5.14?

$$(\mathrm{Sp})(\operatorname{grad}\vec{B}) = \operatorname{div}(\vec{B}) = \frac{\delta B_x}{\delta x} + \frac{\delta B_y}{\delta y} + \frac{\delta B_z}{\delta z} = 0 \qquad (2.5.14)$$

2. Which effects would a possible distortion of the velocity vector field $\vec{v}$ have on the velocity gradient $\operatorname{grad}\vec{v}$ and what are the consequences for the $\operatorname{rot}\vec{D}$ and the $\operatorname{rot}\vec{B}$?

3. What effects would a possible distortion of the two flux density vector fields, the magnetic flux density $\vec{B}$ and the electric flux density $\vec{D}$, have on their field gradients $\operatorname{grad}\vec{B}$ and $\operatorname{grad}\vec{D}$? What follows from this for the $\operatorname{rot}\vec{D}$ and the $\operatorname{rot}\vec{B}$?

4. How do questions 1 through 3 affect Equations 2.4.10, 2.4.19, 2.5.7, and 2.5.8?

$$-(\mathrm{grad}\,\vec{B})\cdot(\vec{v}) = -\begin{pmatrix} \frac{\delta B_x}{\delta x}\cdot v_x + \frac{\delta B_x}{\delta y}\cdot v_y + \frac{\delta B_x}{\delta z}\cdot v_z \\ \frac{\delta B_y}{\delta x}\cdot v_x + \frac{\delta B_y}{\delta y}\cdot v_y + \frac{\delta B_y}{\delta z}\cdot v_z \\ \frac{\delta B_z}{\delta x}\cdot v_x + \frac{\delta B_z}{\delta y}\cdot v_y + \frac{\delta B_z}{\delta z}\cdot v_z \end{pmatrix} = -\vec{x}_{(\mathrm{grad}\,\vec{B})\vec{v}} \qquad (2.4.10)$$

$$(\mathrm{grad}\,\vec{D})\cdot(\vec{v}) = \begin{pmatrix} \frac{\delta D_x}{\delta x}\cdot v_x + \frac{\delta D_x}{\delta y}\cdot v_y + \frac{\delta D_x}{\delta z}\cdot v_z \\ \frac{\delta D_y}{\delta x}\cdot v_x + \frac{\delta D_y}{\delta y}\cdot v_y + \frac{\delta D_y}{\delta z}\cdot v_z \\ \frac{\delta D_z}{\delta x}\cdot v_x + \frac{\delta D_z}{\delta y}\cdot v_y + \frac{\delta D_z}{\delta z}\cdot v_z \end{pmatrix} = \vec{x}_{(\mathrm{grad}\,\vec{D})\vec{v}} \qquad (2.4.19)$$

$$(\mathrm{grad}\;\vec{v})\cdot(\vec{B}) = \begin{pmatrix} \frac{\delta v_x}{\delta x}\cdot B_x + \frac{\delta v_x}{\delta y}\cdot B_y + \frac{\delta v_x}{\delta z}\cdot B_z \\ \frac{\delta v_y}{\delta x}\cdot B_x + \frac{\delta v_y}{\delta y}\cdot B_y + \frac{\delta v_y}{\delta z}\cdot B_z \\ \frac{\delta v_z}{\delta x}\cdot B_x + \frac{\delta v_z}{\delta y}\cdot B_y + \frac{\delta v_z}{\delta z}\cdot B_z \end{pmatrix} = \vec{x}_{(\mathrm{grad}\,\vec{v})\vec{B}} \qquad (2.5.7)$$

$$-(\mathrm{grad}\;\vec{v})\cdot(\vec{D}) = -\begin{pmatrix} \frac{\delta v_x}{\delta x}\cdot D_x + \frac{\delta v_x}{\delta y}\cdot D_y + \frac{\delta v_x}{\delta z}\cdot D_z \\ \frac{\delta v_y}{\delta x}\cdot D_x + \frac{\delta v_y}{\delta y}\cdot D_y + \frac{\delta v_y}{\delta z}\cdot D_z \\ \frac{\delta v_z}{\delta x}\cdot D_x + \frac{\delta v_z}{\delta y}\cdot D_y + \frac{\delta v_z}{\delta z}\cdot D_z \end{pmatrix} = -\vec{x}_{(grad\,\vec{v})\vec{D}} \qquad (2.5.8)$$

5. What effect does equation 2.5.36 have on the electromagnetic wave equation?

$$\vec{v}\;\mathrm{div}(\vec{B}) = -\vec{j}_m \qquad (2.5.36)$$

6. Under what circumstances does the velocity vector field $\vec{v}$ and the two vector fields, the magnetic flux density $\vec{B}$ and the electric flux density $\vec{D}$, deform?

4. CONCLUSION

Under the mathematical requirement of Equation 2.5.2 ($(\mathrm{Sp})(\mathrm{grad}\,\vec{B}) = \mathrm{div}(\vec{B})$), the physical requirement of Equation 2.4.2 ($\mathrm{div}(\vec{B}) = 0$) is valid only provided that the $(\mathrm{Sp})(\mathrm{grad}\,\vec{B}) = 0$ is. This means that either the physical conception of the magnetic field has to be reinterpreted or the assumption from Equation 2.4.2 ($\mathrm{div}(\vec{B}) = 0$) is fundamentally wrong.
By reinterpreting the "Maxwell equations" from equations 2.5.33, 2.5.34, 2.5.35 and 2.5.36, a mathematically and physically consistent approach was achieved for the calculation of electric and magnetic fields. In addition, in these equations, the distortions of the field quantities used in the equations were taken into account. A direct analogy between electric and magnetic fields was also derived mathematically. This analogy leads to the fact that the magnetic field density becomes a mathematical-physical requirement when $(\mathrm{Sp})(\mathrm{grad}\,\vec{B}) \neq 0$ is. It remains to be discussed under what circumstances this does not happen. It also remains to be discussed what influence the equations 2.5.33, 2.5.34, 2.5.35 and 2.5.36 have on other equations that are based on the "Maxwell equations" and what technical possibilities result from them.

5. CONFLICTS OF INTEREST

The author (s) declares that there is no conflict of interest relating to the publication of this article.

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