

Self-consistent Electrodynamics

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Abstract— Even though one usually calculates capacitor losses with a complex epsilon it still offends the principle of a constant speed of light. Maxwell's term $c^2 = 1/\epsilon \cdot \mu$ suggests a physically inexplicable complex speed. By such an offence against basic principles every physicist is asked to search and to repair the mistake in the textbooks. The contribution clearly explains how vortex losses occur instead of using the postulated and fictive imaginary part of the material constant epsilon. The theory better explains the function of a microwave oven, the welding of PVC foils or how capacitor losses occur. The responsible potential vortices can be derived without postulate them from the established laws of physics. Vortex losses can even be proven experimentally and are clearly shown. The potential vortex is substituted for the vector potential \mathbf{A} , which has controlled electrodynamics as "impurity factors" ever since its introduction. A unified theory of all interactions and physical phenomena is missing without potential vortices. This theory justifies the efforts and the rationale for rebuilding electrodynamics and in so doing effectively removes contradictions of the vector potential and loss theory. Consequences are discussed such as the discovery of magnetic monopoles by the German Helmholtz Center [1], the extended Poynting vector, and many more effects involved with the new approach of the potential vortex, that is replacing the vector potential in the dielectric.

1. INTRODUCTION

The error search leads over Poynting's theorem to the vector potential \mathbf{A} . At this point a new abyss opens. It shows quickly how and where the whole electrodynamics get entangled in contradictions. The vector potential \mathbf{A} assumes, as everybody knows that no magnetic monopoles exist. Mathematically expressed it should be

$$\operatorname{div} \mathbf{B} = \operatorname{div} \operatorname{rot} \mathbf{A} = 0. \quad (\text{Called the 3rd equation of Maxwell}). \quad (1)$$

On the 16th of October, 2009 sixteen authors reported in the magazine "*Science*" about the discovery of magnetic monopoles [1]. For the vector potential and all derivations constructing it, this new discovery means the final death blow from the mathematical-physical view. However, a new way must be found. A way to electrodynamics free of contradictions, without vector potential \mathbf{A} and without complex ϵ . Vortex physics offers such a way free from contradictions, with the derivation of potential vortices by a potential density vector \mathbf{b} which adequately substitutes for the outdated vector potential. Also the dielectrically losses, from now on as vortex losses of disintegrating potential vortices can be calculated in the electrodynamics free of contradiction without complex ϵ . Besides, \mathbf{b} is by no means postulated but is derived from approved physical legitimacies according to textbooks.

2. THE DISCOVERY OF THE LAW OF INDUCTION

In the choice of the approach the physicist is free as long as the approach is reasonable and well founded. In the case of **Maxwell's field equations** two experimentally determined regularities served as basis: On the one hand, **Ampère's law** and on the other hand the **law of induction of Faraday**. Maxwell, the mathematician, thereby gave the finishing touches for the formulations of both laws. He introduced the displacement current \mathbf{D} and completed Ampère's law accordingly, and doing so without a chance of being able to measure and prove the measure. Only after his death this was possible experimentally, what afterwards makes clear the abilities of this man. In the formulation of the law of induction, **Maxwell** was completely free because the **discoverer Michael Faraday** had done so without specifications. As a man of practice and of experiment the mathematical notation was less important for Faraday. For him the attempts with which he could show his discovery of the induction to everybody (e.g., his unipolar generator), stood in the foreground.

However, his 40 years younger friend and professor of mathematics Maxwell had something completely different in mind. He wanted to describe the light as an electromagnetic wave and doing so certainly the wave description of Laplace went through his mind, which in turn needs a second

time derivation of the field factor. Because Maxwell for this purpose needed two equations with each time a first derivation, he had to introduce the displacement current in Ampère’s law and had to choose an appropriate notation for the formulation of the law of induction to get to the wave equation. His light theory initially was very controversial. Maxwell faster found acknowledgement for bringing together the teachings of electricity and magnetism and the representation as something unified and belonging together [2] than for mathematically giving reasons for the principle discovered by Faraday. Nevertheless, questions should be asked.

If Maxwell has found the suitable formulation, if he has understood 100 percent correct his friend Michael Faraday’s discovery. If the discovery (1831) and the mathematical formulation (1862) stem from two different scientists, who in addition belong to different disciplines, thus it is not unusual for misunderstandings to occur. It will be helpful to work out the differences.

3. THE UNIPOLAR GENERATOR

If one turns an axially polarized magnet or a copper disc situated in a magnetic field, then perpendicular to the direction of motion and perpendicular to the magnetic field pointer a pointer of the electric field will occur, which everywhere points axially to the outside. In the case of this by **Michael Faraday**, he developed a **unipolar generator** — by means of a brush between the rotation axis and the circumference a voltage is picked off.

The mathematically correct relation

$$\mathbf{E} = \mathbf{v} \times \mathbf{B} \tag{2}$$

I call this the “*Faraday-law*”, despite the fact that it appears in this form in textbooks later in time [3]. The formulation usually is attributed to the mathematician **Hendrik Lorentz**, since it appears in the **Lorentz force** in exactly this form. Much more important than the mathematical formalism are the experimental results and the discovery by Faraday, for which the law concerning unipolar induction is named after him the “**Faraday-law**”.

Of course we must realize that the charge carriers at the time of the discovery hadn’t been discovered yet and the field concept couldn’t correspond to that of today. The field concept is an abstracter one, free of any quantization. That of course is also valid for the field concept advocated by Maxwell, which we now contrast with the “*Faraday-law*” (Figure 1). The second Maxwell equation, the law of induction (2), also is a mathematical description between the electric field strength **E** and the magnetic induction **B**. But this time the two aren’t linked by a relative velocity **v**.

In place stands the time derivation of **B**, with which a change in flux is necessary for an electric field strength to occur. As a consequence the Maxwell equation doesn’t provide a result in the static or quasi-stationary case. In such cases it is usual to fall back upon the unipolar induction according to Faraday (e.g., in the case of the Hall-probe, the picture tube, etc.). The falling back should only remain restricted to such cases, so the normally idea is used. The question then asked: “*Which restriction of the “Faraday-law” to stationary processes is made?*”

The vectors **E** and **B** can be subject to both spatial and temporal fluctuations. In that way the two formulations suddenly are in competition with each other and we are asked to explain the difference, as far as such a difference should be present.

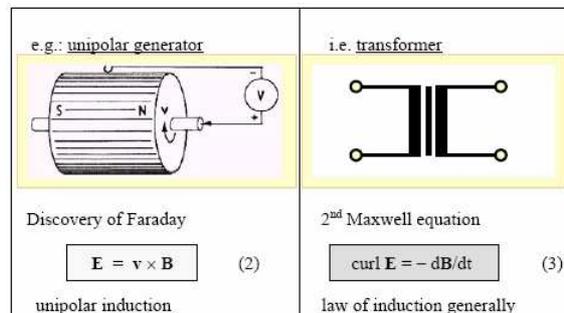
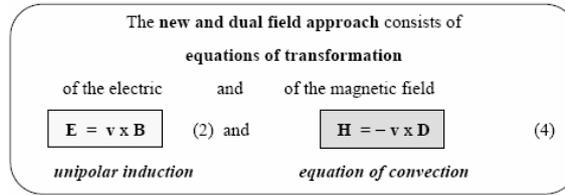


Figure 1: Two formulations for one law. As a mathematical relation between the vectors of the electric field strength **E** and the magnetic flux density **B**.



4. DIFFERENT INDUCTION LAWS

For instance, such a difference it is common practice to neglect the coupling between the fields at low frequencies. At high frequencies in the range of the electromagnetic field the \mathbf{E} - and the \mathbf{H} -field are mutually dependent. While at lower frequency and small field change the process of induction drops correspondingly according to Maxwell so that a neglect seems to be allowed. Under these conditions electric or magnetic field can be measured independently of each other. Usually it is proceeded as if the other field is not present at all.

That is not correct. A look at the “*Faraday-law*” and immediately it shows that even down to frequency zero both fields are always present. The field pointers however stand perpendicular to each other, so that the magnetic field pointer wraps around the pointer of the electric field in the form of a vortex ring. In this case the electric field strength is being measured and vice versa.

The closed-loop field lines are acting neutral to the outside; so is the normal used idea. However they need no attention. It should be examined more closely if this is sufficient as an explanation for the neglect of the not measurable closed-loop field lines or, if not after all, an effect arises from fields which are present in reality.

Another difference concerns the commutability of \mathbf{E} - and \mathbf{H} -field, as is shown by the Faraday-generator, how a magnetic field becomes an electric field and vice versa as a result of a relative velocity v . This directly influences the physical-philosophic question: “*What is meant by the electromagnetic field?*”

5. THE ELECTROMAGNETIC FIELD

The textbook opinion, based on the *Maxwell equations*, names the static field of the charge carriers as cause for the electric field, whereas moving ones cause the magnetic field [4, e.g.]. But that could not have been the idea of **Faraday**, to whom the existence of charge carriers was completely unknown. For his contemporaries, completely revolutionary abstract field concept, based on the works of the **Croatian Jesuit priest Bosovic** (1711–1778). In the case of the field it should less concern a physical quantity in the usual sense, than rather the “*experimental experience*” of an interaction according to his field description.

We should interpret the “*Faraday-law*” to the effect that we experience an electric field if we are moving with regard to a magnetic field with a relative velocity and vice versa. In the commutability of electric and magnetic field a duality between the two is expressed, which in the Maxwell formulation is lost as soon as charge carriers are brought into play. The question then becomes, “*Is the Maxwell field the special case of a particle free field?*” Much evidence points to the answer as “*yes*”, because, after all, a light ray can run through a particle free vacuum. As we see, fields can exist without particles but particles without fields are impossible! In conclusion, the field should have been there first as the cause for the particles. The Faraday description should form the basis from which all other regularities can be derived. What do the textbooks say to that?

6. CONTRADICTORY OPINIONS IN TEXTBOOKS

Obviously there exist two formulations for the law of induction (2 and 3), which more or less have equal rights. Science stands for the questions: “*Which mathematical description is the more efficient one? If one case is a special case of the other case, which description then is the more universal one?*” What Maxwell’s field equations tell us is sufficiently known so that derivations are unnecessary. Numerous textbooks are standing by, if results should be cited. Let us hence turn to the “*Faraday-law*” (2). Often one searches in vain for this law in schoolbooks. Only in more pretentious books one makes a find under the keyword unipolar induction. If one compares the number of pages which are spent on the law of induction according to Maxwell with the few pages for the unipolar induction, then one gets the impression that the later is only a unimportant special case for low frequencies. Prof. **Küpfmüller** (TU Darmstadt) speaks of a “*special form*”

of the law of induction” [4, p.228, Equation (22)], and cites as practical examples the induction in a brake disc and the Hall-effect. Afterwards Küpfmüller derives from the “*special form*” the “*general form*” of the law of induction according to Maxwell, a postulated generalization, which needs an explanation. But a reason is not given. Prof. **Bosse** (as successor of Küpfmüller at the TU Darmstadt) gives the same derivation, but for him the Maxwell-result is the special case and not the Faraday approach [5, p.58]! In addition he addresses the “*Faraday-law*” as an equation of transformation, points out the meaning, and the special interpretation. On the other hand he derives the law from the “*Lorentz force*”, completely in the style of Küpfmüller [4] and with that again takes part of its autonomy.

Prof. **Pohl** (University of Göttingen, Germany) looks at that differently. He inversely derives the “*Lorentz force*” from the “*Faraday-law*” [3, p.77]. We should follow this very convincing representation.

7. THE EQUATION OF CONVECTION

If Bosse [5] prompted term “*equation of transformation*” is justified or not is unimportant at first. That is a matter for discussion. If there should be talk about “*equations of transformation*”, then the dual formulation (to Equation (2)) belongs to it, and then it concerns a **pair of complementary equations** which describes the relations between the electric and the magnetic field. Written down according to the rules of duality there results an Equation (4), which occasionally is mentioned in some textbooks. While both equations in the books of **Pohl** [3, p.76 and 130] and of **Simonyi** [6, p.924] are written down side by side having equal rights and are compared with each other, **Grimsehl** [7, p.130] derives the dual regularity (4) with the help of the example of a thin, positively charged, and rotating metal ring. He speaks of “*equation of convection*” as moving charges produce a magnetic field and so-called convection currents. Doing so he refers to workings of **Röntgen** 1885, **Himstedt**, **Rowland** 1876, **Eichenwald** and many others. In his textbook **Pohl** also gives practical examples for both equations of transformation. He points out that one equation changes into the other one, if as a relative velocity \mathbf{v} the speed of light c should occur [3, p.77].

8. THE DERIVATION FROM TEXT BOOK PHYSICS

We now have found a field-theoretical approach with the equations of transformation, which in its dual formulation is clearly distinguished from the Maxwell approach. The reassuring conclusion is added: **The new field approach roots entirely in textbook physics**, and are the results from literature research. We can completely do **without postulates**.

As a starting-point and as approach serve the *equations of transformation* of the electromagnetic field, the “*Faraday-law*” of *unipolar induction* (3) and the according to the rules of duality formulated law called *equation of convection* (4).

$$\mathbf{E} = \mathbf{v} \times \mathbf{B} \quad (3)$$

and

$$\mathbf{H} = -\mathbf{v} \times \mathbf{D} \quad (4)$$

If we apply the curl to both sides of the equations:

$$\text{curl } \mathbf{E} = \text{curl}(\mathbf{v} \times \mathbf{B}), \quad (5)$$

$$\text{curl } \mathbf{H} = -\text{curl}(\mathbf{v} \times \mathbf{D}), \quad (6)$$

then according to known algorithms of vector analysis the curl of the cross product each time delivers the sum of four single terms [8]:

$$\text{curl } \mathbf{E} = (\mathbf{B} \text{grad})\mathbf{v} - (\mathbf{v} \text{grad})\mathbf{B} + \mathbf{v} \text{div } \mathbf{B} - \mathbf{B} \text{div } \mathbf{v} \quad (7)$$

$$\text{curl } \mathbf{H} = -[(\mathbf{D} \text{grad})\mathbf{v} - (\mathbf{v} \text{grad})\mathbf{D} + \mathbf{v} \text{div } \mathbf{D} - \mathbf{D} \text{div } \mathbf{v}] \quad (8)$$

Two of these again are zero for a non-accelerated relative motion in the x -direction with

$$\begin{aligned} \mathbf{v} &= dr/dt \\ \text{grad } \mathbf{v} &= 0 \\ \text{and div } \mathbf{v} &= 0 \end{aligned} \quad (9)$$

One term concerns the vector gradient $(\mathbf{v} \text{ grad}) \mathbf{B}$, which can be represented as a tensor. By writing down and solving the accompanying derivative matrix and giving consideration to the above determination of the \mathbf{v} -vector, the vector gradient becomes the simple time derivation of the field vector $\mathbf{B}(\mathbf{r}(t))$,

$$\begin{aligned} (\mathbf{v} \text{ grad}) \mathbf{B} &= \frac{d\mathbf{B}}{dt} \\ \text{and } (\mathbf{v} \text{ grad}) \mathbf{D} &= \frac{d\mathbf{D}}{dt} \end{aligned} \quad (10)$$

according to the rule:

$$\frac{d\mathbf{B}(\mathbf{r}(t))}{dt} = \frac{\partial \mathbf{B}(\mathbf{r} = \mathbf{r}(t))}{\partial \mathbf{r}} \cdot \frac{d\mathbf{r}(t)}{dt} = (\mathbf{v} \text{ grad}) \mathbf{B} \quad (11)$$

For the final not yet explained terms are written down the vectors \mathbf{b} and \mathbf{j} as abbreviation.

$$\text{curl } \mathbf{E} = -d\mathbf{B}/dt + \mathbf{v} \text{ div } \mathbf{B} = -d\mathbf{B}/dt - \mathbf{b} \quad (12)$$

$$\text{curl } \mathbf{H} = -d\mathbf{D}/dt + \mathbf{v} \text{ div } \mathbf{D} = -d\mathbf{D}/dt + \mathbf{j} \quad (13)$$

With Equation (13) we in this way immediately look at the well-known law of Ampère (1st Maxwell equation).

9. THE MAXWELL EQUATIONS AS A SPECIAL CASE

The result will be the **Maxwell equations**, if: the potential density

$$\mathbf{b} = -\mathbf{v} \text{ div } \mathbf{B} = 0, \quad (14)$$

(Equation (12) \equiv law of induction, if $\mathbf{b} = 0$ resp. $\text{div } \mathbf{B} = 0$), and the current density

$$\mathbf{j} = -\mathbf{v} \text{ div } \mathbf{D} = -\mathbf{v} \cdot \rho_{el}, \quad (15)$$

(Equation (13) \equiv Ampère's law, if $\mathbf{j} \equiv$ with \mathbf{v} moved neg. charge carriers; ρ_{el} = electric space charge density).

In addition the comparison of coefficients (15) delivers a useful explanation to the question, "What is meant by the current density \mathbf{j} "? It is a space charge density ρ_{el} consisting of negative charge carriers, which moves with the velocity \mathbf{v} , for instance through a conductor in the x -direction. The current density \mathbf{j} and the dual potential density \mathbf{b} mathematically seen at first are nothing but alternative vectors for an abbreviated notation. While for the current density \mathbf{j} the physical meaning already could be clarified from the comparison with the *law of Ampère*, the interpretation of the potential density \mathbf{b} is still due (14).

From the comparison of Equation (12) with the *law of induction* (Equation (3)) we merely infer, that according to the *Maxwell theory* that this term is assumed to be zero. But that is exactly the **Maxwell approximation** and the restriction with regard to the new and dual field approach, which takes root in Faraday.

10. THE MAXWELL APPROXIMATION

Also the duality gets lost with the argument that magnetic monopoles ($\text{div } \mathbf{B}$) in contrast to electric monopoles ($\text{div } \mathbf{D}$) do not exist and until today could evade every proof. It has not yet been searched for the vortices dual to eddy currents, which are expressed in the neglected term. Assuming a monopole concerns a special form of a field vortex, then immediately it is clear why the search for magnetic poles in the past had to be a dead end and their failure isn't good for a counterargument. The missing electric conductivity in a vacuum prevents current densities, eddy currents, and the formation of magnetic monopoles. Potential densities and potential-vortices however can occur. As a result, without exception, only electrically charged particles can be found in the vacuum.

Let us record: **Maxwell's field equations can directly be derived from the new dual field approach under a restrictive condition.** Under this condition the two approaches are equivalent and with that also error free. Both follow the textbooks and can, so to speak, be the textbook opinion. The restriction ($\mathbf{b} = 0$) surely is meaningful and reasonable in all those cases in which the Maxwell theory is successful. It only has an effect in the domain of electrodynamics. Here usually a vector potential \mathbf{A} is introduced and by means of the *calculation of a complex*