ELECTROMAGNETIC INDUCTION WITHOUT MAGNETIC FIELD

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ABSTRACT

By the simple experiment described here, the existence of a time or space variation of a magnetic field in a conductor fragment, is not a necessary prerequisite for the induction of an electric potential. Thus, in general the perceived Faraday-Maxwell flux law is not valid in the following described experiment.

1. Introduction

In generator systems, one commonly takes into consideration the "Lorentz-force" named after Hendrik Anton Lorentz (1853-1928), as the driving force for conductor current. The engineer explains it by the "Left-Hand-Rule," that is, for the formula (1) to be correctly utilized, the vectors **F, v** and **B** must be orthogonal [1].

$$\mathbf{F} = Q\,(\mathbf{E} + \mathbf{v} \times \mathbf{B}) \qquad (1)$$

The empirically established Faraday induction law says that when the magnetic flux within a closed curve is varied in time, the flux change is proportional to the induced voltage. In order to calculate the induced voltage, one must first calculate the magnetic flux density **B** and the magnetic flux ϕ.

$$\phi = \int \mathbf{B} \cdot d\mathbf{A} \qquad (2)$$

Under a time variation of the magnetic flux one has the following:

$$\frac{\partial \phi}{\partial t} = \frac{\partial}{\partial t}\int \mathbf{B} \cdot d\mathbf{A} \qquad (3)$$

This induced voltage along a curve can also be described as a line integral:

$$U_{ind} = \oint \mathbf{E} \cdot d\mathbf{s} \qquad (4)$$

In view of Lenz's Law, there then results the induced voltage (Electromotive force - EMF- or "back"-voltage). This variant of induction voltage is also described as "back"- voltage of rest (Ruhe) [2]:

$$U_{ind} = -N \cdot \frac{\partial \phi}{\partial t}\,, \qquad (5)$$

where N = number of coils spread over the region with surface area **A**.

Analogously, there exists a "back" voltage EMF from movement, an alternate derivation from the induction laws:

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$$U_{ind} = -Z \cdot L \cdot (\mathbf{B} \times \mathbf{v}) \, , \quad (6)$$

where Z = number of conductors, L = conductor length perpendicular to **B** and **v**, and v = velocity of the conductor motion. Equations (5) and (6) are chiefly used in operation. We have shown only two particular cases of a much generalized situation. These general situations are brought about in the "Hooper-Monstein Experiment" [3, 4, 5, 6, 7] (see Fig. 1, which was taken from [7]).

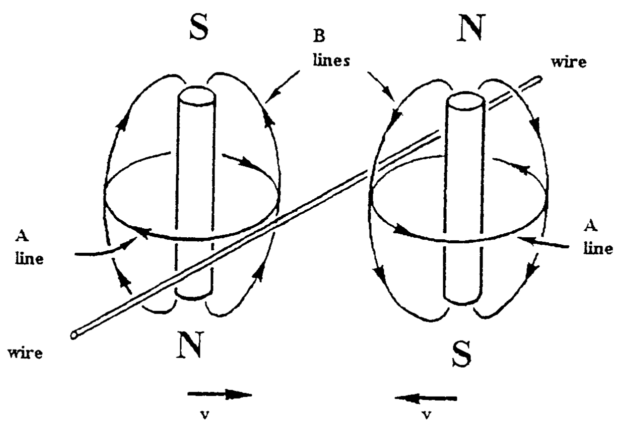

Fig. 1

EXPERIMENT

At equal distances from and perpendicular to a wire with an active length of 150 mm are arranged two identical permanent magnets each with a pole surface flux density of around 50 mT. The magnets are aligned so that opposite poles are facing directly across from each other. As a result of this positioning, where the wire is at the center the total magnetic field intensity is zero. The two drawn field lines which symbolize the display of the magnetic fields indicate two opposite arrow directions in the proximity of the wire. A simple check of this can be made with a Hall-Sonde (probe). The velocity **v** of each magnet as well as the wire, in an indicated direction are detected by an individual pulse (stepping) motor. The external control for four stepping motors is provided automatically by a PC (computer) with external hardware, seen below in Fig. 2.

The complete detailed mechanical structure with cradles (Schlitten), motors, stock, mounts, etc., was realized in this instance and provided to order by my friend Hans Peter Benz. My share was limited to the control PC, the control software, as well as the circuits and the analysis (interpretation).

Region of movement

With this convenience of operation is brought the possibility of many types of motion combinations and variants of moving the wire and magnets near to each other. For all the movements of interest in our experiment, where the wire is in the center, the magnetic flux density is zero and stays (remains) at zero. For all the following tests, velocity v is constant and held at 2.64 mm/sec. This is the same for all tests. This particular velocity is chosen due to the maximum elementary frequency derived for the step-motors on the one hand, and on the other hand from the maximum possible traversed path (Verfahrweg) Δ s.

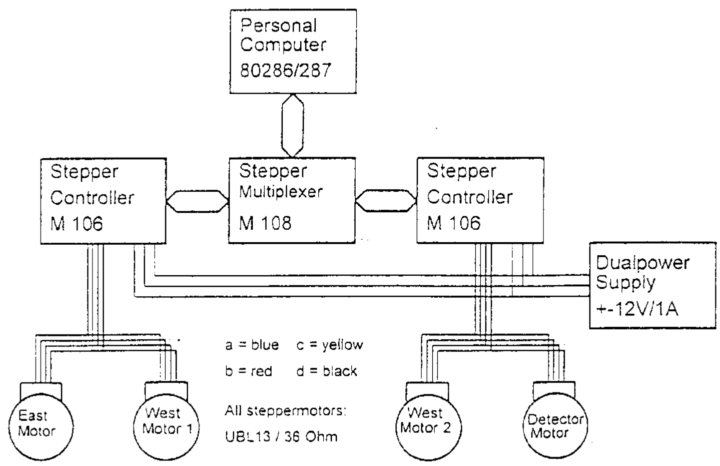

Fig. 2 Control System

The traversed path Δ s results from the maximum number of position-steps, np = 240 multiplied by the total amount (Betrag) of position-steps δ s. A single position-step δ s = 0.022 mm results inevitably from the (motor) gearbox (Spindeltriebe) and the number of active windings on the linear step-motors. The maximum possible measured path with respect to the traversed path $\Delta s = np \times \delta s$ is around 7.92 mm. This traversed path is carried out in each of the tests from the "left" and/or from the "right" magnets and/or from the wire. One example of the variants carried out are compared in the Table I.

Measuring Instruments

The actual measuring instrument in this experiment is a sufficiently sensitive XY-recorder with a range of 5 mV per 100 mm y-variance (Auslenkung). The x-axis is realized on a local appliance (gerateinternen) deflection oscillator with a range of 3 seconds per 100 mm x-variance (Auslenkung). The wire can be electrically cut-off (abgetrennt) and be replaced with a calibrated wiring. This calibration circuit is accomplished with a battery and realized with an exterior ohmic (ohmschen) voltage divider and produces a constant potential of around 1 mV. The circuit wire schematics is given next in Fig. 3. Additionally, the polarity of the calibration circuit is inverted (reversed). For highest sensitivity, there is not a single wire but a frame-winding coil (Rahmenwicklung) with n = 250 turns utilized. The values given in Table Fig. 4 can then certainly be traced back (zuruckgerechnen) to a single wire. There were three tests conducted.

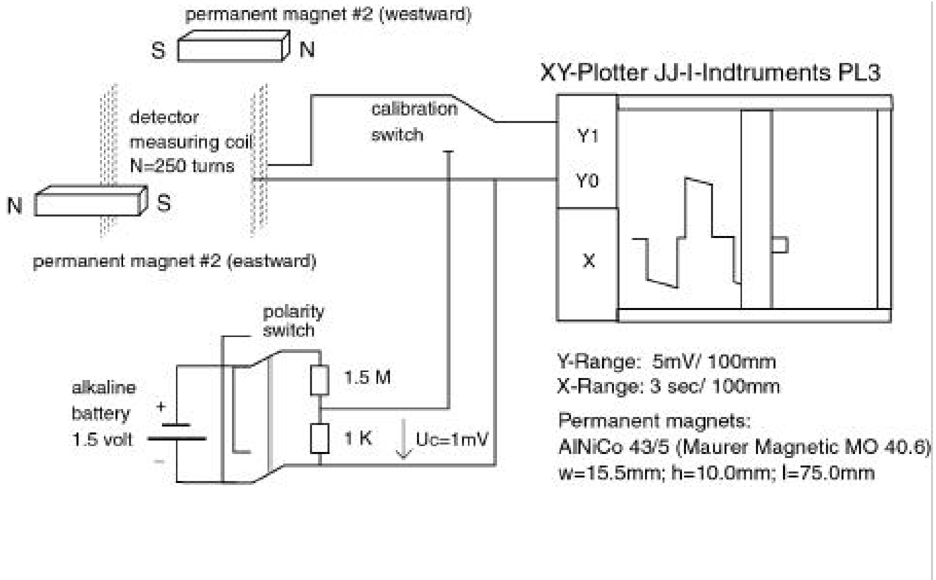

Fig. 3 Measuring Systems

(East) Magnet Moved

In the first test only one of the two magnets is moved towards the wire, while both the other magnet and the wire are stationary. This is the "normal" case, where the induction law in its familiar form holds in approximation, since in this case $B \neq 0$. By having the magnet approach the wire, **B** increases non-linearly. Along the wire the average magnetic flux density **B** is about .8 mT, measured with a Hall-Sonde KSY10. This permits the expected induced voltage in the wire to be assessed by the calculation: $/U/ = BLv = (0.8\text{ mT})\ (15\text{ cm})\ (2.64\text{ mm/sec}) = .3\ \mu V$. This is naturally much too small a value, since the actual part of the magnetic fluxes of both permanent magnets is already mutually compensated. Measured voltages are 1.2 µV, 1.6 µV, in case movement is from the east towards the west, and 1.3 µV, 1.8 µV in case the movement is from the west towards the east.

Both Magnets Moved

In the second test, both magnets are simultaneously moved toward the wire, and' after a short pause, they are moved away from the wire. Both magnets have exactly the same velocity **v** and brought back through the path s. In the center, the resultant (total) magnetic field is exactly zero. Thus, according to the equations (5) and (6), no voltage is induced. Then $B = 0$ mT as well as $\phi = 0$ Vs; these are at every time and each point on the wire equal to zero. In actual fact, in this case the measured voltage is **double** that of the first test, namely 2.4 µV, 3.6 µV. This is a glaring travesty (krasse Verletzung) for decades in the interest of finding a correct induction law! This test shows quite clearly, that the induction law in the form

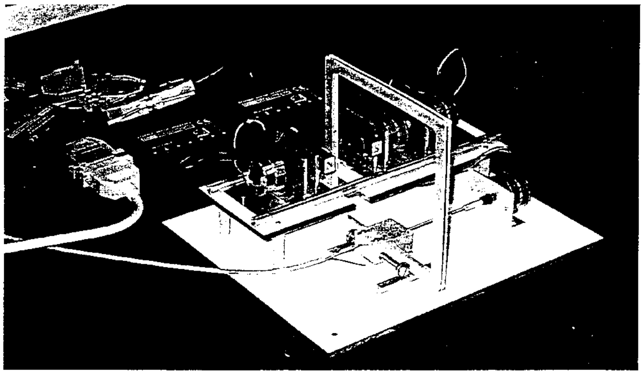

Fig. 4

that everyone knows cannot be correct. It also shows that the magnetic flux density **B** is not responsible for the induced voltage. On the contrary, it is namely the magnetic vector potential **A** which is not zero in the above described situation, but is doubled (indicated in Fig. 1 through the vector-arrow "A" line).

(West) Magnet and Wire Moved

A further interesting variant is the third part of the experiment. Here the left (Eastern) Magnet remains stationary, and is not moved. The right (Western) magnet is then moved with double velocity to the right towards the wire. Simultaneously, the wire itself is moved with velocity v to the left in the direction toward the stationary magnet. The distance between wire and magnets remains the same at all times. This combination (verbunden) is again a compensation of the magnetic fluxes at each position of the wire at each time. Here as well, the induction formulas (5) and (6) fail to account for the double voltage of 2.6 μV, 3.6 μV, similar to the results in Test 2. In this case, the relativity of motion plays no role in the final result, whether the wire or the magnets are moved.

MEASUREMENT RESULTS

All voltages maintained are average values in most tests. The accuracy (Messunsicherheit) of measurement of voltage is ± 0.12 μV for all part of the experiment. In both columns to the right on the outside of Table Fig. 4, two voltage values U and U' are each given. Namely that at the beginning (U) and that at the end (U') of the traversed path Δ s. Since the magnetic vector potential is space-dependent (taken radially from the outside), which also amounts to (via a constant linear velocity) a space-dependent induction voltage. Together with the above tests conducted, 10 further variants were carried out. They are not shown here since they do not change the final result. It is a fact and remains so that the magnetic vector potential **A** and not the magnetic flux density is the basis for the induced voltage.

Table I

Parameter ⇨	Rotational Speed v = 2.64mm/sec ± 0.01mm/sec			Magnetic Flux	Voltage ± 0,12 μV Measurement coil L=15 cm	
Test # ▼	Magnet (Left)	Detector measure-ment coil (Ctr.)	Magnet (Right)	Permanent Magnet	at Beginning x_0	at End $x_0 + \Delta s$
0	0	0	0	w/o Magnet	0,0μV = 0	0,0μV = 0
1a	v	0	0	$B \neq 0$	1,2μV = U	1,6μV = U'
1b	0	0	v	$B \neq 0$	1,3μV = U	1,8μV = U'
2	v	0	v	B = 0	2,4μV = 2U	3,6μV = 2U'
3	0	v	2v	B = 0	2,6μV = 2U	3,6μV = 2U'

INDUCTION VIA CHANGE OF THE MAGNETIC VECTOR POTENTIAL

A correct formula for calculating the induced voltage thus does not proceed from the magnetic flux **B**, but must be derived from the magnetic vector potential **A** as well as its time and spatial derivatives must be taken into consideration. The situation where the magnetic vector potential changes in time leads to an electric field intensity, which different authors [5] have described as "motional-transformer electric intensity".

$$\mathbf{E}_{mtr} = \frac{-\partial \boldsymbol{A}}{\partial \boldsymbol{t}} \tag{7}$$

Thus the induced voltage can be determined by a line integral over the conductor curve. When, for instance, the velocity **v** of the magnets is linear, then equation (7) can be formulated as:

$$\mathbf{E}_{mtr} = -(\mathbf{v} \cdot \mathit{grad}\,) \cdot \mathbf{A} \quad \text{or}$$
$$\mathbf{E}_{mtr} = -(\mathbf{v} \cdot \nabla) \cdot \mathbf{A} \tag{8}$$

In the case where the magnets are stationary and the wire moves another outcome results for the induced field intensity. In [5] this field intensity is described in distinction as "motional electric intensity".

$$\mathbf{E}_{mot} = \mathbf{v} \times \mathit{rot}\,\mathbf{A} \quad \text{or}$$
$$\mathbf{E}_{mot} = \mathbf{v} \times (\nabla \times \mathbf{A}) \tag{9}$$

Combining both of the above equations to obtain the "global" electric field intensity we get:

$$\mathbf{E}_{global} = \mathbf{E}_{mot} + \mathbf{E}_{mtr} \tag{10}$$
$$\mathbf{E}_{global} = \mathbf{v} \times (\nabla \times \mathbf{A}) - (\mathbf{v} \cdot \nabla) \cdot \mathbf{A}$$

Therefore, now we can calculate the effective induced voltage in the circuit:

$$U_{ind} = N \cdot \oint [\mathbf{v} \times (\nabla \times \mathbf{A}) - (\mathbf{v} \cdot \nabla) \cdot \mathbf{A}] \cdot d\mathbf{s} \tag{11}$$

(N = number of coil windings)

In many physics books the magnetic flux **B** is established as real and the magnetic vector potential is considered as purely a mathematical artifice. On the basis of the current experiments one must turn this statement around. The magnetic field intensity is pure fiction and **A** is real.

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