Experimental Replication of Marinov's Siberian Coliu Device

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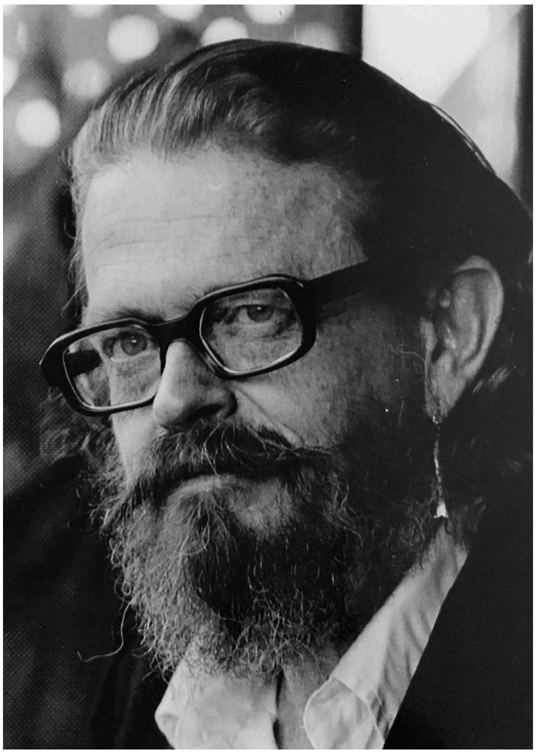
Dedicated to the memory of Stefan Marinov and James Paul Wesley. May history prove them right and bring them the recognition they deserve.



Abstract

This document contains a detailed analysis of the so-called Marinov motor (Siberian Coliu). The device, which has been carefully rebuilt, is unexplainable from the point of view of standard Maxwellian electromagnetism. Considerable effort has been applied to ensure that the experimental conditions leave no doubt on the presence of possible artifacts that may spoil the observed phenomena and mislead the unsuspecting scientist.

An explanation of the device is provided based on the alternative formulation of electrodynamics proposed by James Paul Wesley.

All ideas in this document are from James Paul Wesley and Stefan Marinov. The author has just collected them with the intention of bringing them to the scientific community.

Table of Contents

Index of Figures

Index of Tables

1. Biographical note

1.1. Brief biography of Stefan Marinov

Stephan Marinov was a physicist who devoted his life to two research fields: the restoration of absolute space time (refuting Einstein's theory of relativity) and the perfection of a perpetual motion machine. He made very important claims, such as having detected an anisotropy in the speed of light and having built an electromagnetic motor without back electromotive force. However, due to the controversial nature of his research, his personal situation (he was an illegal immigrant living outside of academic circles) and his eccentric personality; almost no one took his claims seriously.

Note to self: complete this section with information published by Marinov in his book series The Thorny Way of Truth.

1.2. Brief biografy of James Paul Wesley

Note to self: complete this section with information provided by Gabrielle. Include Popper's comment.

2. A new theory of classical electrodynamics

2.1. The skeleton in the closet of classical electrodynamics

I would like to start with an analogy. It is well known that frogs are sensitive to the time derivative of the temperature of the fluid in which they are immersed. If one wishes to boil a frog and throws it into boiling water; the frog will jump out of the pot. However, if the frog is placed in lukewarm water and the water is slowly heated; the frog will not leave the fluid until it dies. This behavior can be modeled by saying that a frog jump is triggered if the frog detects a temperature change larger than a certain threshold value. In other words, if T is the temperature and t is the time, a jump is triggered if:

$$\frac{dT}{dt} > k \tag{1}$$

Let us now consider a frog that walks on a metallic surface on which there exists a spatial temperature distribution that does not change with time. For example:

$$T(x) = mx + T_0 \tag{2}$$

If the frog walks on the hot surface with speed v, the frog will experience a temperature that varies over time, and this will happen despite the fact that the temperature of the surface does not actually change over time. In particular, the temperature that the frog will feel can be obtained by substituting x by vt:

$$T_{frog}(t) = mvt + T_0 \tag{3}$$

And the temperature variation:

$$\frac{dT_{frog}}{dt} = mv \tag{4}$$

So we can conclude that a jump will be triggered if the following inequality is satisfied:

$$v > \frac{k}{m} \tag{5}$$

The point of this little story is that a jump can be triggered by two different situations that the frog perceives as equivalent:

1. The temperature of the medium changing in time.
2. The frog moving through a medium in which the temperature does not change in time, provided that the movement is in a direction in which there exists a spatial temperature gradient.

Mathematically, this can be expressed as the addition of the two sources of temperature variation:

$$\frac{dT}{dt} = \frac{\partial T}{\partial t} + \left(\vec{v} \cdot \vec{\nabla}\right) T \tag{6}$$

The frog has no way of determining which of the two causes is responsible for the temperature increase that it is feeling, since its perception is only for the combined effect of the two sources.

Let's now consider a region of space in which there exists an electric potential and a magnetic vector potential:

$$\Phi = \Phi(x, y, z, t) \qquad \vec{A} = \vec{A}(x, y, z, t) \tag{7}$$

In particular, let the scalar potential be null and the magnetic vector potential be a function of position without any dependence on time:

$$\Phi = 0 \qquad \vec{A} = f(x, y, z)\vec{u}_x + g(x, y, z)\vec{u}_y + h(x, y, z)\vec{u}_z \tag{8}$$

The electric and magnetic field, according to Maxwell's equations, will be given by:

$$\vec{E} = -\vec{\nabla}\Phi - \frac{\partial \vec{A}}{\partial t} = 0 \qquad , \qquad \vec{B} = \vec{\nabla} \times \vec{A} \tag{9}$$

Let's focus on the electric field for now. If we consider a charged particle, with charge q, moving with speed:

$$\vec{v} = v_x(t)\vec{u}_x + v_y(t)\vec{u}_y + v_z(t)\vec{u}_z \tag{10}$$

The electric force it will experience will be given by:

$$\vec{F}_e = q\vec{E} = q\left(-\vec{\nabla}\Phi - \frac{\partial \vec{A}}{\partial t}\right) = 0 \tag{11}$$

The partial derivative has a profound implication. Notice that, even though the magnetic vector potential does not change with time, since it changes with space, the particle should feel a variation as it moves, just as happened with the frog of our previous analogy.

Is the particle more intelligent than the frog? For, if we are to believe in the equation, the particle apparently is able to know the origin of the time variation of the magnetic vector potential and only experiences a force if the variation is intrinsic to the field. This is against logic. To make it more clear, the contradiction is that the following two situations are equivalent from the point of view of a test charge:

1. Remaining at rest in an area of space in which there exists a magnetic vector potential that increases linearly with time.
2. Moving with constant speed in an area of space in which there exists a time-stationary magnetic vector potential that increases linearly with the direction of movement.

However, according to classical electrodynamics, in case 1 an electric force will arise while in case 2 no electric force will be felt. Two different outcomes for two equivalent scenarios are a contradiction.

2.2. Historical attempts to solve the problem

According to the logic discussed in the previous section, the partial derivative of the expression of the electric field should be substituted by a total derivative:

$$\vec{E} = -\vec{\nabla}\Phi - \frac{d\vec{A}}{dt} \tag{12}$$

This idea was already considered by Hertz [1], Phipps [] and Pinheiro [], who wrote:

$$\frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + \left(\vec{v}\cdot\vec{\nabla}\right)\vec{A} \tag{13}$$

Although this expression for the derivative makes electromagnetism galilean invariant, it encounters problems with many classical experiments such as Faraday's disk, for which it fails to predict the induced electromotive force.

It was James Paul Wesley who found the mistake, which is of mathematical origin. Wesley expounded his correction in a cryptic paper [] that I have deciphered for the comfort of the reader in the next lines. In summary, the mistake of Hertz, Phipps and Pinheiro lies in the fact that they considered an expression for the total derivative valid only for scalar fields. When the field has direction, as is the case with the magnetic vector potential, there is an additional source of time variation that must be accounted for.

2.3. The correct total time derivative of the magnetic vector potential

There is a missing term in equation (13) proposed by Hertz for the total derivative of the magnetic vector potential. To see why, following Wesley [], let's consider a charged particle q moving with uniform circular motion around the origin in the xy-plane with constant angular speed ω and radius b. The parametric equation of the trayectory of the particle is:

$$\vec{r}(t) = b\ cos(\omega t)\vec{u}_x + b\ sin(\omega t)\vec{u}_y \tag{14}$$

In the same region of space in which the particle is moving, there exists a constant magnetic vector potential of value:

$$\vec{A} = A_x\vec{u}_x + A_y\vec{u}_y \tag{15}$$

If we consider the particle *perception* to be associated with a moving Frenet-Serret frame, the particle experiences the magnetic vector potential as changing direction, even though the magnetic vector potential is constant.

The normal and tangent vectors to the particle are:

$$\vec{u}_\rho = cos(\omega t)\vec{u}_x + sin(\omega t)\vec{u}_y \quad , \quad \vec{u}_\phi = cos(\omega t)\vec{u}_y - sin(\omega t)\vec{u}_x \tag{16}$$

Wesley [] claimed that the particle feels its own normal and tangent vectors as stationary, while it perceives the laboratory frame as changing directions. Accordingly, the magnetic vector potential, which is constant in the laboratory frame, is perceived by the particle as changing direction, and the rate of change is given by:

$$\frac{d\vec{A}}{dt} = A_x\frac{d\vec{u}_x}{dt} + A_y\frac{d\vec{u}_y}{dt} \tag{17}$$

Let's compute these derivatives explicitely. The laboratory frame unit vectors can be expressed as a function of the normal and tangent vectors by solving from equation (16).

$$\vec{u}_x = cos(\omega t)\vec{u}_\rho - sin(\omega t)\vec{u}_\phi \quad , \quad \vec{u}_y = cos(\omega t)\vec{u}_\phi + sin(\omega t)\vec{u}_\rho \tag{18}$$

We can now compute the time derivatives by considering $\vec{u}_\rho$ and $\vec{u}_\phi$ as constant, as we have claimed that the particle perceives them. We have changed the signs too, as from the point of view of the particle the velocities of the unit vectors of the laboratory frame are negative.

$$\frac{d\vec{u}_x}{dt} = \omega\left[sin(\omega t)\vec{u}_\rho + cos(\omega t)\vec{u}_\phi\right] \quad , \quad \frac{d\vec{u}_y}{dt} = \omega\left[sin(\omega t)\vec{u}_\phi - cos(\omega t)\vec{u}_\rho\right] \tag{19}$$

We can now use this result in equation (17) to obtain:

$$\frac{d\vec{A}}{dt} = A_x\omega\left[sin(\omega t)\vec{u}_\rho + cos(\omega t)\vec{u}_\phi\right] + A_y\omega\left[sin(\omega t)\vec{u}_\phi - cos(\omega t)\vec{u}_\rho\right] \tag{20}$$

Rearranging terms, we obtain:

$$\frac{d\vec{A}}{dt} = \omega\left[A_x sin(\omega t) - A_y cos(\omega t)\right]\vec{u}_\rho + \omega\left[A_x cos(\omega t) + A_y sin(\omega t)\right]\vec{u}_\phi \tag{21}$$

It is easy to notice that the expressions inside the brackets correspond to the instantaneous tangential and normal components of the magnetic vector potential:

$$\frac{d\vec{A}}{dt} = \omega\left[A_\rho\vec{u}_\phi - A_\phi\vec{u}_\rho\right] \tag{22}$$

At first sight, this result that we have just obtained seems to be valid only for the special case of a particle moving with uniform circular motion around the origin. However, thanks to the theory of differential geometry of curves, the result can be easily generalized by considering that, at each instant, the particle is moving with angular velocity $\omega(t)$ around the center of the osculating circle of the trajectory. This calculation, which Wesley left for the reader, is presented in detail in the following lines:

Let's consider a charged particle q moving according to the parametric curve:

$$\vec{r}(t) = f(t)\vec{u}_x + g(t)\vec{u}_y + h(t)\vec{u}_z \tag{23}$$

The velocity of the particle at time t is given by:

$$\vec{v}(t) = \frac{d\vec{r}}{dt} = f'(t)\vec{u}_x + g'(t)\vec{u}_y + h'(t)\vec{u}_z \tag{24}$$

And the acceleration of the particle at time t is given by:

$$\vec{a}(t) = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}(t)}{dt^2} = f''(t)\vec{u}_x + g''(t)\vec{u}_y + h''(t)\vec{u}_z \tag{25}$$

The unit tangent vector of the Frenet-Serret frame at time t is given by:

$$\vec{u}_t(t) = \frac{\vec{v}(t)}{||\vec{v}(t)||} \tag{26}$$

And the unit normal vector of the Frenet-Serret frame at time t is given by:

$$\vec{u}_n(t) = \frac{[\vec{v}(t) \times \vec{a}(t)] \times \vec{v}(t)}{||\,[\vec{v}(t) \times \vec{a}(t)] \times \vec{v}(t)||} \tag{27}$$

The radius of the osculating circle to the curve at time t is:

$$R(t) = \frac{||\vec{v}(t)||^3}{||\vec{v}(t) \times \vec{a}(t)||} \tag{28}$$

And the angular velocity of the particle at a time t will be:

$$\omega(t) = \frac{||\vec{v}(t)||}{R(t)} = \frac{||\vec{v}(t) \times \vec{a}(t)||}{||\vec{v}(t)||^2} \tag{29}$$

Now, we can finally write the general form of equation (22). Note that the signs have been changed because $\vec{u}_n$ points from the position of the particle towards the center of the osculating circle, while $\vec{u}_\rho$ points from the center of the circle towards the position of the particle.

$$\frac{d\vec{A}}{dt} = \omega\left[\left(\vec{A}\cdot\vec{u}_t\right)\vec{u}_n - \left(\vec{A}\cdot\vec{u}_n\right)\vec{u}_t\right] \tag{30}$$

Equation (30) accounts for the perceived time variation of the magnetic vector potential caused by the change in the the movement of the particle. The total change, taking into account also the explicit time variation and the time variation felt by moving in a spatially varying field, can be written as:

$$\frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + \left(\vec{v}\cdot\vec{\nabla}\right)\vec{A} + \omega\left[\left(\vec{A}\cdot\vec{u}_t\right)\vec{u}_n - \left(\vec{A}\cdot\vec{u}_n\right)\vec{u}_t\right] \tag{31}$$

For the particular case in which the moving body is a continuous mass distribution and rotates around the origin of the laboratory frame of reference, the above equation can be written in a way that makes the symmetry more clear:

$$\frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + \left(\vec{v}\cdot\vec{\nabla}\right)\vec{A} + \left(\vec{A}\cdot\vec{\nabla}\right)\vec{v} \tag{32}$$

Finally, this last equation can be rewritten with the help of a well-known vector identity:

$$\frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + \vec{\nabla}\left(\vec{v}\cdot\vec{A}\right) - \vec{v}\times\left(\vec{\nabla}\times\vec{A}\right) - \vec{A}\times\left(\vec{\nabla}\times\vec{v}\right) \tag{33}$$

The last three equations (31, 32 and 33) are fully equivalent mathematically when the moving body is a continuous mass distribution rotating around the laboratory frame of reference, but for general use only equation (31) should be used.

2.4. Unipolar induction and Faraday's disk

Faraday's disk has puzzled physicists since its discovery. We will use equation 33 to predict the induced electromotive force. Let us consider a cylindrical magnet rotating around its z axis with angular velocity ω. Attached to the top of the magnet there is a conductive disk that rotates together with the magnet. The brushes of a voltmeter are connected to the center of the conductive disk and to the external radius of the disk. We are interested in the emf measured in the voltmeter.

Muller's experiments [] demonstrated that induction occurs locally in the conductive ring, and not in the wires of the voltmeter. If the permanent magnet has a remanent flux density of B_0 and we consider the magnetic field to be constant in the region of the conductive ring, as is usually done when studying Faraday's disk, the magnetic vector potential in cylindrical coordinates will be given by:

$$\vec{A} = \frac{B_0\rho}{2}\vec{u}_\phi \tag{34}$$

The velocity of the charges in the conductive ring, caused by the rotation of the ring, is the following.

$$\vec{v} = \omega\rho\vec{u}_\phi \tag{35}$$

We will now compute each term of equation 33. Since the magnetic vector potential has no dependence with the ϕ coordinate, rotating the permanent magnet around the z axis causes no change in the magnetic vector potential. Accordingly, $\partial\vec{A}/\partial t$ is null.

The second term is given by:

$$-\vec{\nabla}\left(\vec{v}\cdot\vec{A}\right) = -\vec{\nabla}\frac{\omega B_0\rho^2}{2} = -\omega B_0\rho\vec{u}_\rho \tag{36}$$

The third term is given by:

$$\vec{v}\times\left(\vec{\nabla}\times\vec{A}\right) = \omega B_0\rho\vec{u}_\rho \tag{37}$$

And finally the fourth term:

$$\vec{A}\times\left(\vec{\nabla}\times\vec{v}\right) = \omega B_0\rho\vec{u}_\rho \tag{38}$$

The total force per unit charge is thus given by the addition of the three acting terms:

$$\vec{E} = \omega B_0\rho\vec{u}_\rho + \omega B_0\rho\vec{u}_\rho - \omega B_0\rho\vec{u}_\rho = \omega B_0\rho\vec{u}_\rho \tag{39}$$

If we integrate this electric field along the radius, we obtain the emf that we were looking for, and that coincides with the well-known result for Faraday's disk.

$$emf = \int_0^R \omega B_0\rho d\rho = \frac{1}{2}\omega B_0 R^2 \tag{40}$$

The interesting thing about this is that we have obtained the correct result without using at any moment the *ad-hoc* created magnetic field or the expression of the Lorentz force. Rather, we have used only the electric field with the total derivative of the magnetic vector potential.

2.5. A particle moving in a constant magnetic field

Let's consider a region of space in which there exists a constant magnetic field in the z direction. The magnetic vector potential is given by the following expression, which the reader can check by computing its curl:

$$\vec{A} = \frac{B_0}{2}\left(x\vec{u}_y - y\vec{u}_x\right) \tag{41}$$

We are interested in the motion experienced by a charged particle that enters the region with initial velocity $v_0\vec{u}_x$. From experimental evidence, it is well known that the particle will describe a circular trayectory with the Lorentz's force acting as a central force. Its radius will be the so-called cyclotron radius, so if we can obtain this result from our theory, it should be a point favouring its consideration. An indeed, by seeing the result of the unipolar induction, it is easy to foresee that the theory of Wesley and Marinov will indeed provide the correct result this time as well.

Indeed, the situation is completely analogous. The particle enters the area with a speed aligned with the magnetic vector potential, so it will experience a central force. The radius will be given by the Lorent'z force, just as we saw with the unipolar induction example. However, just to show how the complete calculation would be done, I think it is valuable to include it here.

The particle position vector is given by:

$$\vec{r} = x\vec{u}_x + y\vec{u}_y + z\vec{u}_z \tag{42}$$

While its velocity is given by the following expression, where the dots are time derivatives:

$$\vec{v} = \dot{x}\vec{u}_x + \dot{y}\vec{u}_y + \dot{z}\vec{u}_z \tag{43}$$

An the acceleration is given by:

$$\vec{a} = \ddot{x}\vec{u}_x + \ddot{y}\vec{u}_y + \ddot{z}\vec{u}_z \tag{44}$$

To solve the motion of the particle, we will sum all the forces acting on the particle and write an ordinary differential equation by applying Newton's second law. In the absence of a scalar electric potential from static charges, all the force comes from the total derivative of the magnetic vector potential. According to equation (31), the total electric force per unit of test charge is given by:

$$\frac{-\vec{F}}{q} = \frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + \left(\vec{v}\cdot\vec{\nabla}\right)\vec{A} + \omega\left(\vec{A}\cdot\vec{u}_t\right)\vec{u}_n - \omega\left(\vec{A}\cdot\vec{u}_n\right)\vec{u}_t \tag{45}$$

Let us compute each force contribution term by term. The first contribution, $\partial\vec{A}/\partial t$, is clearly null, since the magnetic vector potential is constant in time.

The second contribution is given by:

$$\left(\vec{v}\cdot\vec{\nabla}\right)\vec{A} = \frac{B_0}{2}\left(-\dot{y}\vec{u}_x + \dot{x}\vec{u}_y\right) \tag{46}$$

For the third and fourth contributions, a strong heart is required to do the calculation. The angular velocity is given by equation (29).

$$\omega = \frac{\sqrt{(\dot{y}\ddot{z} - \dot{z}\ddot{y})^2 + (\dot{z}\ddot{x} - \dot{x}\ddot{z})^2 + (\dot{x}\ddot{y} - \dot{y}\ddot{x})^2}}{\dot{x}^2 + \dot{y}^2 + \dot{z}^2} \tag{47}$$

2.6. Force between current elements

Electrical conduction in solids is a very complex phenomenon, but macroscopically it can be modelled by means of current elements, which are unit charges moving at constant speeds i, with i being the electric current. Let us consider a current element situated at:

$$\vec{r}_0 = x_0\vec{u}_x + y_0\vec{u}_y + z_0\vec{u}_z \tag{48}$$

The current element points in the direction:

$$\vec{dl}_1 = a\vec{u}_x + b\vec{u}_y + c\vec{u}_z \qquad , \qquad a^2 + b^2 + c^2 = 1. \tag{49}$$

The second current element is situated at:

$$\vec{r} = x\vec{u}_x + y\vec{u}_y + z\vec{u}_z \tag{50}$$

And points in the direction:

$$\vec{dl}_2 = e\vec{u}_x + f\vec{u}_y + g\vec{u}_z \qquad , \qquad e^2 + f^2 + g^2 = 1. \tag{51}$$

According to Ampére's force law, the force that the second element will experience as a consequence of the first is given by:

$$d^2F_{21} = \frac{\mu_0}{4\pi} i_1 i_2 \frac{\vec{r} - \vec{r}_0}{|\vec{r} - \vec{r}_0|^3} \left[3 \left(\frac{\vec{r} - \vec{r}_0}{|\vec{r} - \vec{r}_0|} \cdot \vec{dl}_1 \right) \left(\frac{\vec{r} - \vec{r}_0}{|\vec{r} - \vec{r}_0|} \cdot \vec{dl}_2 \right) - 2 \left(\vec{dl}_1 \cdot \vec{dl}_2 \right) \right] \tag{52}$$

Ampére's original force law for solid current elements is nowadays seldom taught. When Ampére's force is integrated over a whole rigid current loop, the resulting total force coincides with Lorentz's force, so it is assumed that the force between individual current elements is also Lorentz's force. However, some wire deformations observed on railguns have attracted new interest to the topic from Graneau et al [], since many different expressions for the force between two individual current elements yield the same Lorentz's force when integrated over a closed current loop.

Since current always travels in closed loops, it is difficult to confirm experimentally what is the actual expression of the force between independent current elements. However, there exists a large body of experiments that tend to suggest that there is an additional repulsive force that acts between colinear current elements and can not be explained by Lorentz's force alone. Among these experiments, we have .

Interestingly, if we do the calculation with Wesley's formula, we obtain a result compatible with the experimental evidence. The magnetic vector potential created by current element 1 is:

$$\vec{A} = \frac{\mu_0 i_1}{4\pi\sqrt{(x - x_0)^2 + (y - y_0)^2 + (z - z0)^2}} \left(a\vec{u}_x + b\vec{u}_y + c\vec{u}_z \right) \tag{53}$$

To obtain the electric field felt by current element 2, we can apply equation (31):

$$-\vec{E} = \frac{d\vec{A}}{dt} = \frac{\partial \vec{A}}{\partial t} + \left(\vec{v} \cdot \vec{\nabla}\right) \vec{A} + \omega \left[\left(\vec{A} \cdot \vec{u}_t\right) \vec{u}_n - \left(\vec{A} \cdot \vec{u}_n\right) \vec{u}_t\right] \tag{54}$$

Since the first current element, acting as a source, is constant in time, we can disregard the partial derivative of the magnetic vector potential with respect to time. As for the term multiplied by ω, we should also disregard it: the model of current elements, used extensively to describe macroscopically the complexity of electrical conduction in diamagnetic materials, is based on each element moving in a straight line with constant speed. The drift velocity of the charge carriers is assumed to have no acceleration. We are thus left with:

$$-\vec{E} = \frac{d\vec{A}}{dt} = \left(\vec{v} \cdot \vec{\nabla}\right) \vec{A} \tag{55}$$

Now, making the substitution $q\vec{v} = i\vec{dl}$, we can obtain the infinitesimal force acting on current element 2:

$$\frac{-d^2F}{i_2} = \left(\vec{dl}_2 \cdot \vec{\nabla}\right) \vec{dA} \tag{56}$$

Since $\vec{dl}_2$ is just a constant vector, the above expression can be rewritten by means of a well-known vector identity:

$$\frac{d^2F}{i_2} = \vec{dl}_2 \times \left(\vec{\nabla} \times \vec{dA}\right) - \vec{\nabla}\left(\vec{dl}_2 \cdot \vec{dA}\right) \tag{57}$$

This last expression makes clear that we have Lorentz's force plus an additional term. However, this additional term is the gradient of a scalar field, so by definition it will dissapear when the force is integrated around a closed loop of current elements. This is exactly the situation that we were describing a few paragraphs before.

$$F_{Lorentz} = i_2 \oint \vec{dl}_2 \times \left(\vec{\nabla} \times \vec{A}\right) \tag{58}$$

However, between two isolated elements, before integrating over the whole loop, the force does not coincide with Lorentz's force, but rather is given by:

$$d^2F_{21} = \frac{\mu_0 i_1 i_2}{4\pi} \left[\frac{(\vec{r} - \vec{r}_0) \cdot \vec{dl}_2}{|\vec{r} - \vec{r}_0|^3}\right] \vec{dl}_1 \tag{59}$$

If two elements are colinear and separated by a distance h, they experience a repulsion force in the direction of colinearity, its magnitude given by:

$$F = \frac{\mu_0 i_1 i_2}{4\pi h^2} \tag{60}$$

This result is predicted by both the original Ampére's force law and by Wesley's theory, and explains many classical experiments that have puzzled phycisists for years; such as .

2.7. Electric interaction between two moving particles

Let us consider now two particles with charges q_1 and q_2. The position of the particles are given by the functions:

$$\vec{r}_1 = x_1\vec{u}_x + y_1\vec{u}_y + z_1\vec{u}_z \quad , \quad \vec{r}_2 = x_2\vec{u}_x + y_2\vec{u}_y + z_2\vec{u}_z \tag{61}$$

It is helpful to define some auxiliary variables:

$$\vec{R} = \vec{r}_2 - \vec{r}_1 \quad , \quad R = |\vec{R}| \tag{62}$$

$$\vec{v}_1 = \dot{\vec{r}}_1 = \frac{d\vec{r}_1}{dt} \quad , \quad \vec{v}_2 = \dot{\vec{r}}_2 = \frac{d\vec{r}_2}{dt} \quad , \quad \vec{V} = \vec{v}_2 - \vec{v}_1 \quad , \quad V = |\vec{V}| \tag{63}$$

$$\dot{R} = \frac{dR}{dt} = \frac{\vec{V}\cdot\vec{R}}{R} \tag{64}$$

We are interested in the force that particle 1 exerts on particle 2. Particle 1 creates both a scalar and a vector potential given by the following expressions, where the dots are time derivatives:

$$\Phi = \frac{q_1}{4\pi\epsilon_0\sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}} = \frac{q}{4\pi\epsilon_0 R} \tag{65}$$

$$\vec{A} = \frac{\mu_0 q_1\left(\dot{x}_1\vec{u}_x + \dot{y}_1\vec{u}_y + \dot{z}_1\vec{u}_z\right)}{4\pi\sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}} = \frac{\mu_0 q_1}{4\pi R}\vec{v}_1 \tag{66}$$

Now we can start computing the forces one by one. First, we have the gradient of the scalar potential:

$$\vec{\nabla}\Phi = \frac{q_1}{4\pi\epsilon_0 R^3}\vec{R} \tag{67}$$

Then we have the partial time derivative of the magnetic vector potential. To compute it, we will consider the coordinates of the second particle as fixed in time, since the magnetic vector potential is only concerned with the sources. The effects due to the motion of the second particle are taken into account in the total derivative.

$$\frac{\partial\vec{A}}{\partial t} = \frac{\mu_0 q_1}{4\pi R^3}\left[R^2\vec{a}_1 + \left(\vec{v}_1\cdot\vec{R}\right)\vec{v}_1\right] \tag{68}$$

3. Overview of Marinov's Device (Siberian Coliu)

We have shown so far a lot of different experimental evidence in support of the idea that the partial derivative of the magnetic vector potential should be substituted by a total derivative. This change has the advantage of logical consistency and simplification, since it avoids the recourse to the *ad-hoc* created magnetic field and Lorentz's force, and explains all electromagnetic phenomena just from the electric field.

However, as attractive as the idea may be, we have so far failed to present an *experimentum crucis*; that is, an experiment that is correctly predicted by just one of the two competing theories. Since we are talking about refuting no less than the classical theory of electrodynamics, the experiment should leave no room for doubt.

At this point is where Marinov's experimental genius perfectly complements Wesley's theoretical genius, for Marinov's device is that *experimentum crucis*. The device in question consists of a stationary toroidal permanent magnet that fully contains its own magnetic field. Now, in a plane perpendicular to the magnet, we spin a conductor and measure the induced voltage by means of sliding contacts.

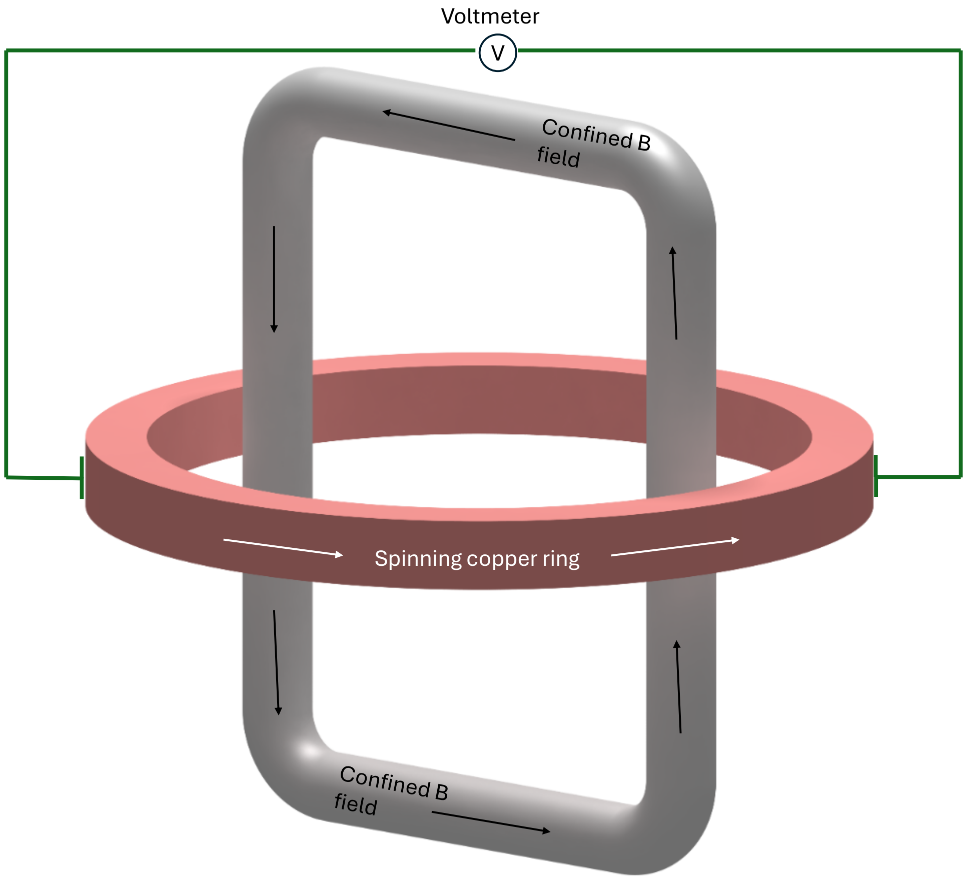


Figure 1: Concept of Marinov's device. A copper ring (shown in pink) rotates around a stationary toroidal permanent magnet (shown in grey) that contains its own magnetic flux. Two electric brushes (shown in green) are used as sliding contacts to touch the copper ring at fixed positions and measure the induced fem.

The copper ring moves in a region of space in which there is no magnetic field, since the field is confined inside the permanent magnet. For this reason, according to classical electrodynamics, no induced electromotive force is expected to be read in the voltmeter. However, as we shall see, the

permanent magnets creates a spatially varying magnetic vector potential, so the movement of the copper ring should create an electromotive force according to Wesley's theory.
There is one artifact that we have to be careful about: it is reasonable to believe that a small amount of magnetic flux could leak to the area of the copper ring. This leaked flux would be in the axial direction. When the ring is forced to rotate, the drift velocity of the electrons would be in the azimuthal direction, so a Lorentz force would appear causing a radial potential difference.

Due to the special arrangment of magnets, the leakage axial magnetic flux would have opposite sign at each brush. Accordingly, at one brush, the outer radius of the copper ring would become negatively charged while at the opposite brush the outer radius of the copper ring would become positively charged, explaining the measured voltage.

If the leaked flux in the axial direction has magnitude B_L and the copper ring has inner radius R_1 and outer radius R_2 and rotates with angular velocity ω, the electromotive force measured at the brushes would be given by the formula of unipolar induction (just like in Faraday's disk):

$$emf = 2\omega \int_{R_1}^{R_2} B_L \; r \; dr \tag{69}$$

The factor of 2 comes from the fact that there are two radial potential differences connected in series, one at each brush. Since the copper ring satisfies $R_2 - R_1 \ll R_1$, we can consider B_L as constant and pull it out of the integral, obtaining:

$$emf = 2\omega B \int_{R_1}^{R_2} \; r \; dr = \omega B \left(R_2^2 - R_1^2 \right) \tag{70}$$

Marinov's device can also be used as a motor instead of as a generator: when a current is supplied to the copper ring through the brushes, Marinov noted that the copper ring started rotating. However, the same undesirable artifact can take place in this situation: the supplied current is not purely azimuthal, since at the points of contact with the brushes there is a radial component.

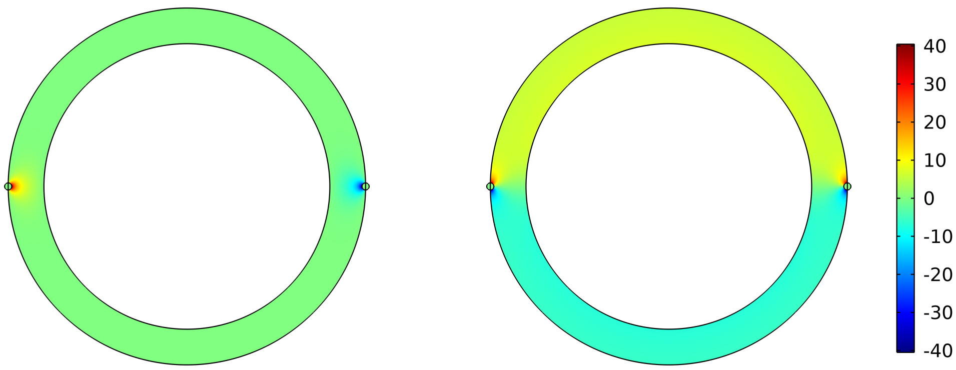


Figure 2: Radial (left) and azimuthal (right) components of the current shown as an example for an arbitrary copper ring. The result comes from solving first Poisson's equation for the voltage distribution, then computing its gradient to obtain the electric field, and finally multipliying by the conductivity to obtain the current. The units and actual values are scaled, since the example is arbitrary.

The reason for the presence of a radial component is that the current first enters perpendicularly at the points of contact with the brushes, and only after a small distance is transversed it is able to find the azimuthal trajectory.

As can be seen in the figure above, the radial component of the current has a different sign at each brush. This is obvious since the current is entering by one brush and leaving by another. Unfortunately, the leaked magnetic flux also has a different sign at each brush, allowing the possibility of a net torque caused by Lorentz's force.

Lorentz's force can thus be used to explain both the measured voltage when the device acts as generator and the net torque when the device acts as a motor. We do not know if Marinov noticed this fact, so our main priority is to discern which of the following two options is true:

1. All effects in Marinov's device are caused by Lorentz's force, which is present due to the leaked magnetic flux from the closed magnetic circuit. The device has no interest.
2. Some effects in Marinov's device can not be justified by Lorentz's force from the leaked magnetic flux, and other forces must be considered to explain the observed behavior.

To discern between the two options, we will follow two strategies: short-circuiting the radial dimension of the copper ring with the brushes and using a copper ring with a very small radial dimension ($R_2 - R_1 \approx 0.001\ mm$). Our aim, in the generator version, is to obtain an induced voltage several orders of magnitude bigger that the voltage explainable by Lorentz's force.

Leaving aside Marinov's claim of having observed a new electromagnetic force, that Wesley explained by his theory of the total derivative, Marinov made even more impressing claims for his device, namely:

1. When the device is used as a motor, there is no back electromotive force caused by Lenz's law. Rather, the only power consumption is the heat dissipated by Joule's effect.
2. When the device is used as a motor, angular momentum is not conserved. The stator does not experience the opposite torque of the rotor.
3. When the device is used as a generator, if the rotor is brought to a certain rotational speed by external means, and is then left to rotate by itself; the time required for its complete detention under friction is smaller when a larger current is drawn from the output brushes (anti-lenz effect).

We will check all these claims experimentally. But first, to be able to predict the results of Wesley's theory, we need to calculate the magnetic vector potential spatial distribution of our experimental device. To this goal we will devote the next section of this document.

4. Magnetic vector potential of Marinov's Device

4.1. Calculation by analytical means

Although we presented before the conceptual version of Marinov's device, the stator of the practical version is built in a slightly different way, with two cylindrical permanent magnets and two blocks of high magnetic permeability alloy to close the magnetic circuit as shown below.

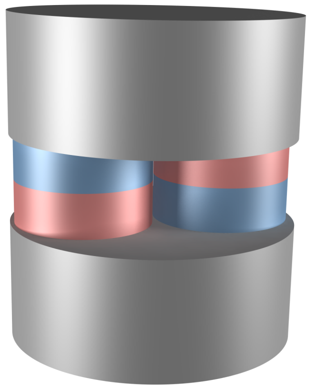


Figure 3: Marinov's stator with north poles of permanent magnets shown in red, south poles of permanent magnets shown in blue and high permeability alloy shown in gray.

4.1.1. Ideal approximation as infinitely long permanent magnets

The magnetic vector potential in the xy-plane (the horizontal plane that cuts both magnets in half) can be calculated by approximating the magnetic circuit as two infinitely long permanent magnets. This is valid as long as the magnetic flux outside the permanent magnets can be neglected against the magnetic flux inside them, as is the case in our experimental build. Accordingly, we can consider two infinitely long permanent magnets, M_1 and M_2, each of them with radius R, both oriented parallel to $\hat{z}$, one of them magnetized with remanent flux density $B_0\ \hat{z}$ and the other magnetized with remanent flux density $-B_0\ \hat{z}$. Magnet M_1 crosses the xy-plane at $x = 0,\ y = b$ while magnet M_2 crosses the xy-plane at $x = 0,\ y = -b$.

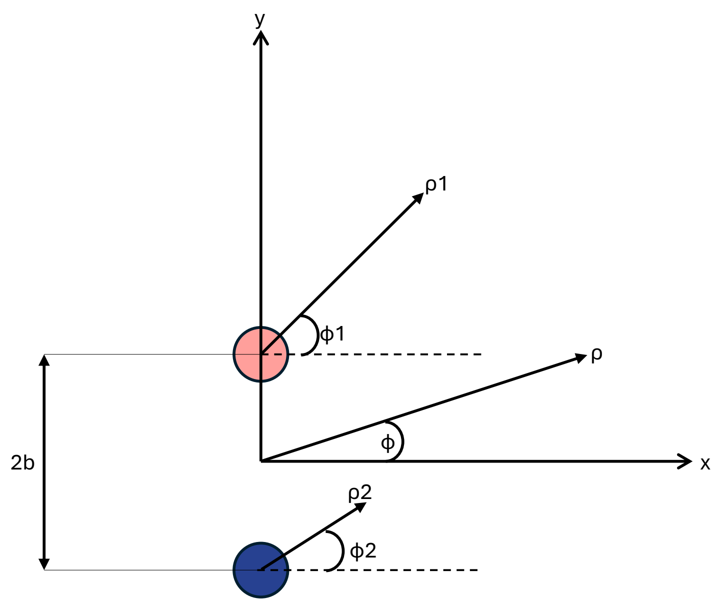


Figure 4: Idealization of the stator as two infinitely long permanent magnets.

Before solving this ideal situation, we will start with an even simpler case: the magnetic vector potential of a single infinitely long cylindrical permanent magnet of radius R and with its axis of revolution aligned with $\hat{z}$. After solving this simpler case, we will come back to the full problem.

4.1.2. Solution for a single ideal infinite cylindrical permanent magnet

Let's first consider the case of a single infinitely long cylindrical permanent magnet of radius R and remanent flux density $B_0\hat{z}$ and with its axis of revolution aligned with $\hat{z}$. After solving this simpler case, we will come back to the full problem.

The flux density outside the permanent magnet is null (because the length is infinite, just as with the case of an infinitely long solenoid) while the flux density inside it is just the remanent flux density, $B_0\hat{z}$, which is a parameter of the problem description.

If we consider a circle in the xy-plane with radius ρ, the following equation holds true for the magnetic vector potential (and for any well behaved vector field, as stated in Stoke's theorem):

$$\oint \vec{A} \cdot d\vec{l} = \iint \left(\vec{\nabla} \times \vec{A}\right) \cdot d\vec{S} \tag{71}$$

Now we can apply the definition of magnetic field, $\vec{B} = \vec{\nabla} \times \vec{A}$, to obtain:

$$\int \vec{A} \cdot d\vec{l} = \iint \vec{B} \cdot d\vec{S} = \Phi_{enc} \tag{72}$$

The above equation means that the circulation of the magnetic vector potential equals the enclosed magnetic flux, just like the circulation of the magnetic flux density equals the enclosed current. This allows us to write the following trivial proposal for a magnetic vector potential:

$$\vec{A} = \begin{cases} \frac{B_0\rho}{2}\,\hat{\phi} & \rho \leq R \\ \frac{B_0R^2}{2\rho}\,\hat{\phi} & \rho > R \end{cases} \tag{73}$$

We will do 4 checks on the proposed potential before deeming it valid:

1. The potential must be continuous.
2. The potential must be null at infinite distance from the source.
3. The divergence of the potential must be identically null.
4. The curl of the potential must be B_0 inside the magnet and null outside it.

The first check is trivial. It suffices to check the continuity at $\rho = R$, which indeed is verified. The second check is also trivial, since the magnetic vector potential decays as $1/\rho$. For checks 3 and 4, we must first remember the expression of $\vec{\nabla}$ in cylindrical coordinates:

$$\vec{\nabla} = \frac{\partial\left(\rho\cdot\right)}{\rho\partial\rho}\hat{\rho} + \frac{\partial\left(\right)}{\rho\partial\phi}\hat{\phi} + \frac{\partial\left(\right)}{\partial z}\hat{z} \tag{74}$$

Computing $\vec{\nabla} \cdot \vec{A}$ and $\vec{\nabla} \times \vec{A}$ in both regions of equation 73 allows us to satisfy checks 3 and 4 explicitely; so our proposed potential is accepted as valid.

Now that we know the magnetic vector potential of an infinitely long permanent magnet, we can apply trigonometry to solve the case described in figure 3. We will use the coordinate systems defined in figure 4.

4.1.3. Solution of the full problem

Figure 4 shows the xy plane. The red and blue colour represent the $\hat{z}$ component of the magnetic flux density $\vec{B}$, which is positive (red) inside one magnet, negative (blue) inside the other magnet and zero (white) everywhere else.

Any point of the xy-plane can be expressed using the centered cylindrical coordinates:

$$P = (\rho, \phi) \tag{75}$$

The distance ρ_1 from point P to the axis of the magnet M_1 situated at $y = b$ will be given by:

$$\rho_1 = \sqrt{(\rho cos\phi)^2 + (\rho sin\phi - b)^2} = \sqrt{\rho^2 + b^2 - 2b\rho sin\phi} \tag{76}$$

Similarly, the distance ρ_2 from point P to the axis of the magnet M_2 situated at $y = -b$ will be given by:

$$\rho_2 = \sqrt{(\rho cos\phi)^2 + (\rho sin\phi + b)^2} = \sqrt{\rho^2 + b^2 + 2b\rho sin\phi} \tag{77}$$

The angles in the coordinate system of each magnet can also be expressed in terms of the angle in the global coordinate system, according to:

$$\phi_1 = atan\left(\frac{\rho sin\phi - b}{\rho cos\phi}\right) \tag{78}$$

$$\phi_2 = atan\left(\frac{\rho sin\phi + b}{\rho cos\phi}\right) \tag{79}$$

If we directly apply equation 73, the magnetic vector potential outside the permanent magnets will be given by:

$$\vec{A} = \frac{B_0 R^2}{2\rho_1}\hat{\phi}_1 - \frac{B_0 R^2}{2\rho_2}\hat{\phi}_2 \tag{80}$$

Where the minus sign in the second term of the right side is due to the magnetic flux going in the $-\hat{z}$ direction inside the second magnet, and equation 73 has been applied.

Unfortunately, this expression is in terms of $\hat{\phi}_1$ and $\hat{\phi}_2$, and we need it in terms of $\hat{\rho}$ and $\hat{\phi}$. So now the task is expressing the unit vectors $\hat{\phi}_1$ and $\hat{\phi}_2$ as a function of the unit vectors $\hat{\rho}$ and $\hat{\phi}$. The coordinate transformation is as follows:

$$\begin{aligned}\vec{A} = &\left(\frac{B_0 R^2}{2\rho_1} sin\left(\phi - \phi_1\right) - \frac{B_0 R^2}{2\rho_2} sin\left(\phi - \phi_2\right)\right)\hat{\rho} + \\ &\left(\frac{B_0 R^2}{2\rho_1} cos\left(\phi - \phi_1\right) - \frac{B_0 R^2}{2\rho_2} cos\left(\phi - \phi_2\right)\right)\hat{\phi}\end{aligned} \tag{81}$$

With much algebraic manipulation it is possible to arrive to a simplified formula:

$$\vec{A} = \frac{B_0 R^2 b\left(\rho^2 - b^2\right) sin\phi}{\left(\rho^2 + b^2\right)^2 - 4b^2\rho^2 sin^2\phi}\hat{\phi} + \frac{B_0 R^2 b\left(\rho^2 + b^2\right) cos\phi}{\left(\rho^2 + b^2\right)^2 - 4b^2\rho^2 sin^2\phi}\hat{\rho} \tag{82}$$

The full simplification is not shown, but it is easy to check that the two equations (81 and 82) are identical by giving values to the variables or by plotting.

4.1.4. Solution of a particular case

If we consider our experimental device, we can implement equation 81 in a Matlab script (which also runs in Octave) to plot the magnetic vector potential as a function of the angle in the region of the conductive ring. We have used the convention of figure 4.

```
clear; clc; close all;
B0=1.44; % Remanent flux density of each magnet [T]
R=35; % Radius of each magnet [mm]
rho=73; % Radius of the conductive ring [mm]
b=35.3; % Half distance between the magnet centers [mm]
phi=linspace(0,2*pi,500); % Angles to evaluate [rad]
x1=rho*cos(phi); x2=x1;
y1=rho*sin(phi)-b; y2=rho*sin(phi)+b;
rho1=sqrt(x1.^2+y1.^2); rho2=sqrt(x2.^2+y2.^2);
phi1=atan2(y1,x1); phi2=atan2(y2,x2);
theta1=phi-phi1; theta2=phi-phi2;
Aphi1=B0*R^2./(2*rho1); Aphi2=B0*R^2./(2*rho2);
Aphi=Aphi1.*cos(theta1)-Aphi2.*cos(theta2);
Arho=Aphi1.*sin(theta1)-Aphi2.*sin(theta2);
plot(phi/pi,Arho,phi/pi,Aphi);
grid on; legend('Ar','Ap');
xlabel('Phi (pi rad)');
ylabel('Magnetic vector potential (Wb/km)');
```

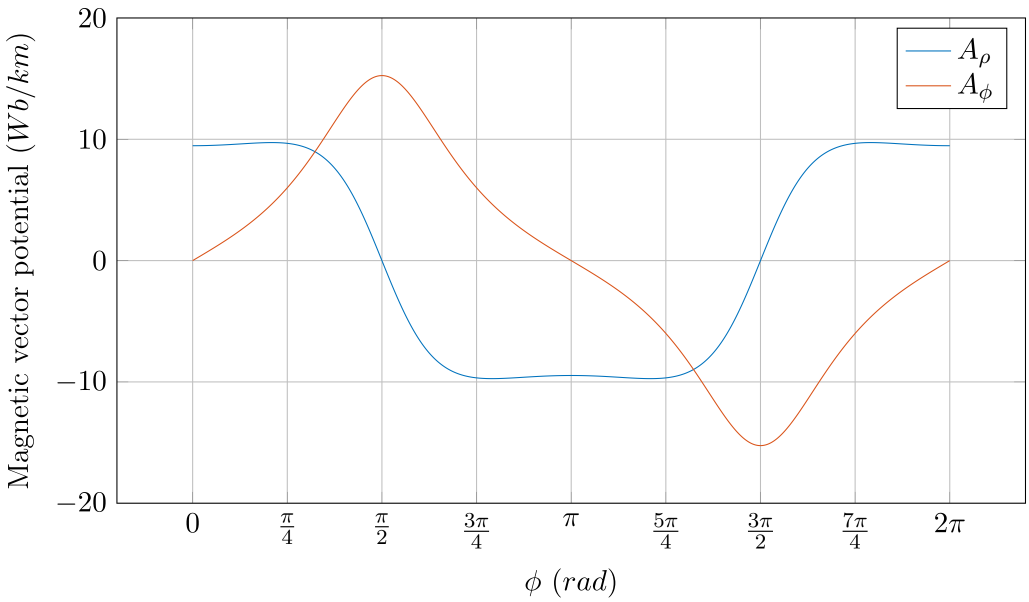


Figure 5: Magnetic vector potential in our experimental device, computed analytically.

While the above plot shows the magnetic vector potential as a function of the angle in the region of the conductive ring, we can get a better intuition of the shape of the potential by looking at a color plot of the xy-plane (the horizontal plane that cuts both magnets in half in figure 4) outside the magnets.

Please note that, in figure 6, only the areas outside the permanent magnets have been plotted, since we are not concerned with the magnetic vector potential inside the permanent magnets.

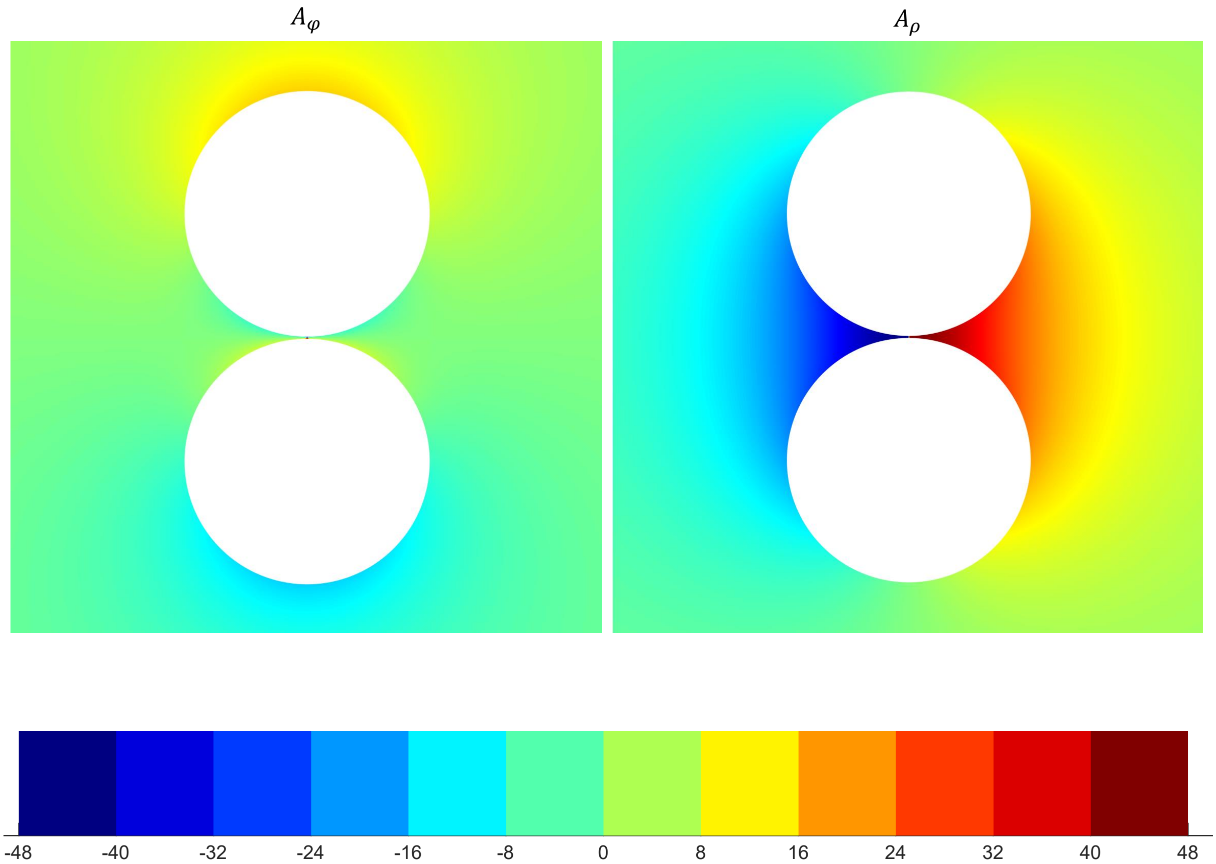


Figure 6: Color plot of the magnetic vector potential of our experimental build, computed analytically with equation 81 and expressed in Wb/km.

4.2. Calculation by finite elements

We have built a finite elements model of the stator of figure 3 in the software Comsol Multiphysics, obtaining the result shown in the following plot.

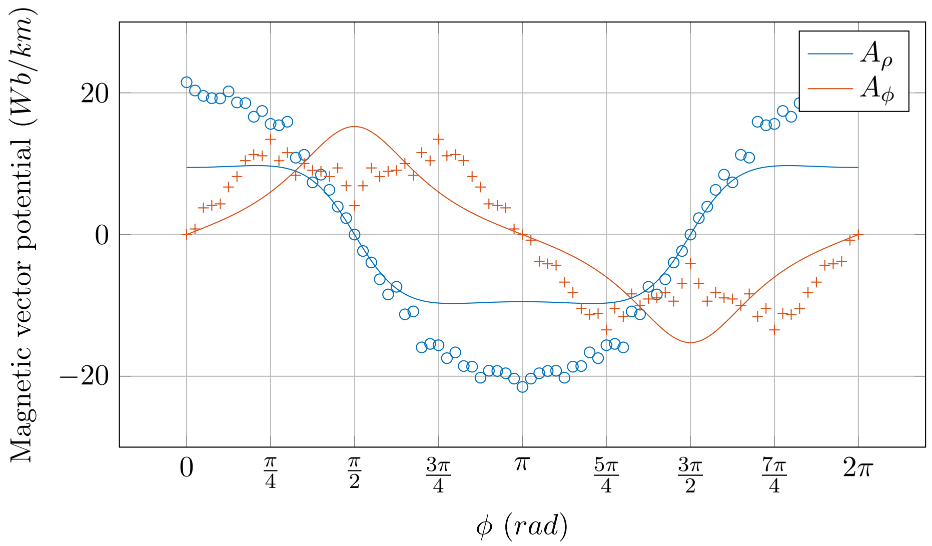


Figure 7: Magnetic vector potential in our experimental device, computed by fem. The continuous lines are the analytical solution of the ideal case, while the discrete points are obtained from the fem model.

As can be noticed, even though the order of magnitude and overall shape of the functions are the same, there are some discrepancies between the fem result and the analytical solution. However, we do not consider this a shortcoming of either solution, but rather we believe that the discrepancy is due to the departure from ideality that is taken into account in the fem model. According to this, the fem model is the actual correct solution to the problem.

These departures from the ideal case studied analytically would be, among others: the magnetic saturation of the steel blocks, the shape of the steel blocks, the magnetic flux leakage and the non-linear magnetic permeability.

The reader may be wondering why the plots give the magnetic vector potential at different azimuthal positions, but at just one radial position. The reason is that the radial dimension of the conductive ring is negligible. If R_1 and R_2 are, respectively, the inner and outer radius of the conductive ring; our experimental build satisfies:

$$R_2 - R_1 \approx 0.001 \ mm \tag{83}$$

Due to this feature we are able to assume that, for a given angular position, the magnetic vector potential does not change along the radial dimension of the conductive ring. This approximation, which we deem as fully valid, will be used extensively also in the next chapter.

5. Calculation of expected induced electromotive force

If the copper ring is forced to rotate by an external motor while the magnetic circuit is held fix, according to standard maxwellian electrodynamics, no emf should appear at the brushes. The magnetic field is zero (except for a small flux leakage, that we discussed in section 3). As for the standard electric field, it is given by:

$$E_\phi = -\nabla\Phi - \frac{\partial A_\phi}{\partial t} \tag{84}$$

There are no charged bodies and, since the the magnetic circuit is stationary, the partial time derivative of the magnetic vector potential is null in all space. The electric field is thus also null in the region of the copper ring, and no electromotive force is to be expected between the brushes. Now let's move on to Wesley's explanation: according to him, induction happens locally and is given by:

$$\frac{\vec{F}}{q} = \vec{E} = -\nabla\Phi - \frac{d\vec{A}}{dt} \tag{85}$$

The presence of a total time derivative, unlike Maxwell's partial derivative, gives rise to extra possibilites for causing induction, as we saw in section 2. The total derivative of a well-behaved vector field $\vec{A}$, as seen by a particle moving with velocity $\vec{v}$ relative to the source of the vector field, neglecting retarded effects by assuming small velocities, was shown in equation 33, reproduced below for the comfort of the reader:

$$\frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + \vec{\nabla}\left(\vec{v}\cdot\vec{A}\right) - \vec{v}\times\left(\vec{\nabla}\times\vec{A}\right) - \vec{A}\times\left(\vec{\nabla}\times\vec{v}\right) \tag{86}$$

According to section 4 equation 82, the magnetic vector potential in the area of the copper ring is:

$$\vec{A} = \frac{B_0R^2b\left(\rho^2-b^2\right)sin\phi}{\left(\rho^2+b^2\right)^2-4b^2\rho^2sin^2\phi}\hat{\phi} + \frac{B_0R^2b\left(\rho^2+b^2\right)cos\phi}{\left(\rho^2+b^2\right)^2-4b^2\rho^2sin^2\phi}\hat{\rho} = A_\rho\hat{\rho} + A_\phi\hat{\phi} \tag{87}$$

The velocity field of the copper ring, in cylindrical coordinates, will be given by:

$$\vec{v} = \omega\rho\vec{u}_\phi \tag{88}$$

Let's compute now the terms of equation (33) one by one: first, since the magnetic circuit is stationary, the partial derivative of the magnetic vector potential is null.

$$\frac{\partial\vec{A}}{\partial t} = 0 \tag{89}$$

The next term is given by:

$$\vec{\nabla}\left(\vec{v}\cdot\vec{A}\right) = \vec{\nabla}\left(\omega\rho A_\phi\right) = \left(\omega A_\phi + \omega\rho\frac{\partial A_\phi}{\partial\rho}\right)\vec{u}_\rho + \omega\frac{\partial A_\phi}{\partial\phi}\vec{u}_\phi \tag{90}$$

The next term is given by:

$$-\vec{v}\times\left(\vec{\nabla}\times\vec{A}\right) = 0 \tag{91}$$

The term is null because, as we saw, there is no magnetic field outside the permanent magnets; so the magnetic vector potential is curl-free. Indeed, this term represents Lorentz's force, and the whole experiment is arranged to avoid it.

And the final term is given by:

$$-\vec{A} \times \left(\vec{\nabla} \times \vec{v}\right) = 2\omega A_\rho \vec{u}_\phi - 2\omega A_\phi \vec{u}_\rho \tag{92}$$

Applying now equation (85), we can write the azimuthal component of the electric field as:

$$E_\phi = -\omega \left(\frac{\partial A_\phi}{\partial \phi} + 2A_\rho\right) \tag{93}$$

To obtain the emf between the two brushes, which are situated at radius ρ and angles ϕ_1 and ϕ_2, we must do the integral:

$$emf = -\rho \int_{\phi_1}^{\phi_2} E_\phi d\phi = \omega\rho\Delta A_\phi + 2\omega\rho \int_{\phi_1}^{\phi_2} A_\rho d\phi \tag{94}$$

6. Design and manufacture of Marinov's Motor

6.1. Magnetic circuit

The main component of the device is what Marinov called *Nikolaev's magnet*, a magnetic circuit with a completely self-contained magnetic flux.

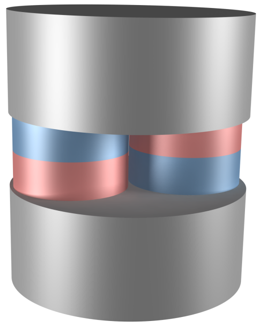


Figure 8: Closed magnetic circuit with north poles of permanent magnets shown in red, south poles of permanent magnets shown in blue and high permeability alloy shown in gray.

We have used two cylindrical neodymium magnets of 70 mm of diameter and 45 mm of height each; and two cylindrical blocks of soft steel of 140 mm of diameter and 60 mm of height each. In particular, the materials used have been neodymium magnetized to rating N52 and low-carbon steel type S355J2 [2]. The magnets have been bought in the following website (linked in october 2024): `https://www.superimanes.com/imanes-de-neodimio/discos/iman-neodimio-disco-70x45-mm`

The blocks of soft steel serve the purpose of closing the magnetic circuit by providing a low reluctance path that minimizes the flux leakage to the area of the copper ring. Due to the project being self-financed by the authors, we have been unable to buy a special alloy such as Permalloy, Mumetal or Supermalloy. If the experiment is repeated by an academic research team, we suggest that a special alloy with larger magnetic permeability should be used.

The assembling of the magnetic circuit has required the use of special tooling, since the extreme force of the magnets prevented their installation by hand. We have captured the assembling operation in video and made it available in the following address:
`https://www.superimanes.com/imanes-de-neodimio/discos/iman-neodimio-disco-70x45-mm`

6.2. Motor

The copper ring is spun by means of an external motor. In particular, we have used a squirrel cage monophasic induction motor provided by Adajusa under reference SY-56M1-2-B5. The rotation speed is 2740 rpm at 90W of power.

Figure 9: Squirrel cage motor for spinning the copper ring, provided by company Adajusa.

6.3. Conductive ring

For the conductive ring, our main concern has been making the radial dimension as small as possible to minimize the interaction between the conductive ring and the leaked magnetic flux. With this idea in mind, we have made a plastic part by 3D printing, and have attached to it a very thin layer of copper film.

7. Experimental results

All voltage measurements have been done with a precision voltmeter.

7.1. Control test

The first test we have done is spinning the copper ring without installing the magnetic circuit, and measuring the induced voltage. With this we intended to control two possible sources of parasitic induction: the coils inside the squirrel cage motor and the magnetic field of the Earth. The experiment, which has resulted in no significant voltage induction as expected, was recorded in video:

Our conclusion from the control test is that the

7.2. Azimuthal induced voltage test

Using a thin copper ring, we compare the radial induced fem with unipolar fem.

7.3. Radial induced voltage test

Using a thick copper ring, we compare the radial induced fem with unipolar fem.

7.4. Opposite torque test

Using the motor configuration, we hold the rotor stationary and observe the direction of motion of the permanent magnet. Then, we also hold the permanent magnet and observe the direction of motion of the brushes.

7.5. Power consumption

Using the motor configuration, we compare the power consumption of the motor with open and closed circuit. We also test for slow down time.

8. Quantum Mechanics

8.1. The Aharonov-Bohm effect: a quantum Marinov Motor

dasd

9. Retardation: from Coulomb's law to radiation

adad

10. Special Relativity

10.1. Galilean invariance of induction in classical electrodynamics

Induction is no doubt a phenomenon that has puzzled the most well-known physicists of history. In the famous *Feynman Lectures on Physics*, when discussing Faraday's flux rule:

$$\oint \vec{E} \cdot \vec{dl} = -\int_s \frac{\partial \vec{B}}{\partial t} \cdot \vec{dS} \tag{95}$$

Feynman writes []: "*So the flux rule (that the emf in a circuit is equal to the rate of change of the magnetic flux through the circuit) applies whether the flux changes because the field changes or because the circuit moves (or both). The two possibilities, circuit moves or field changes, are not distinguished in the statement of the rule. Yet in our explanation of the rule we have used two completely distinct laws for the two cases: $-\vec{v} \times \vec{B}$ for when the circuit moves, and $\vec{\nabla} \times \vec{E} = -\partial B/\partial t$ for field changes. We know of no other place in physics where such a simple and accurate general principle requires for its real understanding an analysis in terms of two different phenomena. Usually such a beautiful generalization is found to stem from a single deep underlying principle. Nevertheless, in this case there does not appear to be any such profound implication. We have to understand the rule as the combined effects of two quite separate phenomena. They are independent effects, but the emf around the loop of wire is always equal to the rate of change of magnetic flux through it.*"

Griffiths, in his equally famous book *Introduction to Electrodynamics* which is used worldwide by undergraduate university students, seems equally amazed by the apparent coincidence when he writes []:"*Maybe I am overly fastidious, but I find this confusing. There are really two totally different mechanisms underlying the changing flux rule, and to identify them both as Faraday's law is a little like saying that because identical twins look alike we ought to call them by the same name. In Faraday's first experiment it's the Lorentz force law at work; the emf is magnetic. But in the other two it's an electric field, induced by the changing magnetic field, that does the job. Viewed in this light, it is quite astonishing that all three processes yield the same formula for the emf.*"

Looking at this apparent coincidences, Einstein tried to find a deeper explanation. Here is what he wrote on the first page of his famous 1905 paper introducing the special theory of relativity []:"*It is known that Maxwell's electrodynamics, as usually understood at the present time, when applied to moving bodies, lead to assymetries which do not appear to be inherent in the phenomena. Take, for example, the reciprocal electrodynamic action of a magnet and a conductor. The observable phenomenon here depends only on the relative motion of the conductor and the magnet, whereas the customary view draws a sharp distinction between the two cases in which either one or the other of these bodies is in motion. For if the magnet is in motion and the conductor at rest, there arises in the neighbourhood of the magnet an electric field ... producing a current at the places where parts of the conductor are situated. But if the magnet is stationary and the conductor in motion, no electric field arises in the neighborhood of the magnet. In the conductor, however, we find an electromotive force ... which gives rise to electric currents of the same path and intensity as those of the former case. Examples of this sort, together with unsucessful attemps to discover any motion of the earth relative to the light medium, suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest.*"

According to the above discussion, it is safe to say that the strange assymetries of the classical theory of electromagnetic induction motivated the special theory of relativity. However, we have now been able to provide an alternative explanation that complies with logic and is backed by strong experimental evidence.

A major point for Wesley's theory is that it is Galilean invariant: in the absence of acceleration, the movement of the source and the test charge is completely interchangeable. Añadir aquí la explicación de Phipps.

10.2. The isotropy of the speed of light

The isotropy of the speed of light, the second pillar of special relativity, has today the status of religious dogma. Despite the fact that there exists a large number of experiments [] confirming a huge anisotropy in the speed of light (one part in 10^3), the isotropy of the speed of light continues to be taught without ever questioning it. And all due to a single experiment, the Michelson-Morley interferometer, which has been refuted countless times and interpreted wrongly. The experimental fact [] is that light moves at speed c with respect to the newtonian absolute space, If the Earth moves with velocity u, the measured velocity of light on Earth is given by the simple galilean addition of velocities, just as intuition dictates:

$$v = c - u \tag{96}$$

10.3. The Michelson-Morley experiment: a classical doppler effect

asdad

11. The end of Physics as a science

asdasd

12. Bibliography

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