Power interaction of the current systems, homopolar induction and the ponderomotive forces

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Abstract

The Maxwell equationsdo not contain of information about power interaction of the current carrying systems. In the classical electrodynamics for calculating such an interaction it is necessary to calculate magnetic field in the assigned region of space, and then, using a Lorentz force, to find the forces, which act on the moving charges. Obscure a question about that remains with this approach, to what are applied the reacting forces with respect to those forces, which act on the moving charges.

The concept of magnetic field arose to a considerable degree because of the observations of power interaction of the current carrying and magnetized systems. Experience with the iron shavings, which are erected near the magnet poles or around the annular turn with the current into the clear geometric figures, is especially significant. These figures served as occasion for the introduction of this concept as the lines of force of magnetic field. In accordance with third Newton's law with any power interaction there is always a equality of effective forces and opposition, and also always there are those elements of the system, to which these forces are applied. A large drawback in the concept of magnetic field is the fact that it does not give answer to that, counteracting forces are concretely applied to what, since. magnetic field comes out as the independent substance, with which occurs interaction of the moving charges.

Is experimentally known that the forces of interaction in the current carrying systems are applied to those conductors, whose moving charges create magnetic field. However, in the existing concept of power interaction of such systems the positively charged lattice, to which are applied the forces, does not participate in the formation of the forces of interaction. That that the positively charged ions take direct part in the power processes, speaks the fact that in the process of compressing the plasma in transit through it direct current (the so-called pinch effect) it occurs the compression also of ions.

Let us examine this question on the basis of the concept of scalar- vector potential [10-12]. We will consider that the scalar- vector potential of single charge is determined by relationship

$$\varphi'(r,v_\perp)=\frac{ech\frac{v_\perp}{c}}{4\pi\varepsilon r}=\varphi(r)ch\frac{v_\perp}{c},$$

and that the electric fields, created by this potential, act on all surrounding charges, including to the charges positively charged lattices.

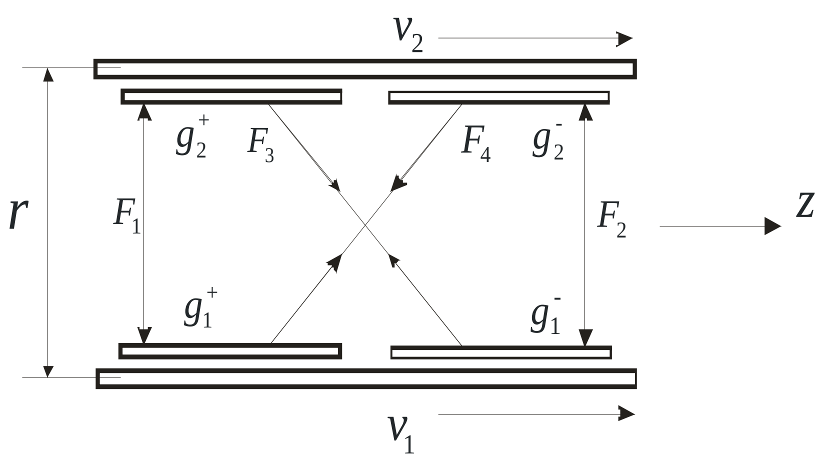

Fig. 1. Schematic of power interaction of the current carrying wires of two-wire circuit taking into account the positively charged lattice.

Let us examine from these positions power interaction between two parallel conductors (Fig. 1), along which flow the currents. We will consider that g_1^+, g_2^+ and g_1^-, g_2^- present the respectively fixed and moving charges, which fall per unit of the length of conductor.

The charges g_1^+, g_2^+ present the positively charged lattice in the lower and upper conductors. We will also consider that both conductors prior to the start of charges are electrically neutral. This means that in the conductors are two systems of the mutually inserted opposite charges with the specific density g_1^+, g_1^- and g_2^+, g_2^-, which neutralize each other. In Fig. 14 these systems for larger convenience in the examination of the forces of interaction are moved apart along the axis z. Subsystems with the negative charge (electrons) can move with the speeds v_1 and v_2. The force of interaction between the lower and upper conductors we will search for as the sum of four forces, whose designation is understandable from the figure. The repulsive forces F_1 and F_2 we will take with the minus sign, while the attracting force F_3 and F_4 we will take with the plus sign.

For the single section of the two-wire circuit of force, acting between the separate subsystems, will be written down

$$
\begin{aligned}
F_1 &= -\frac{g_1^+ g_2^+}{2\pi\varepsilon r}, \\
F_2 &= -\frac{g_1^- g_2^-}{2\pi\varepsilon r} ch\frac{v_1 - v_2}{c}, \\
F_3 &= +\frac{g_1^- g_2^+}{2\pi\varepsilon r} ch\frac{v_1}{c}, \\
F_4 &= +\frac{g_1^+ g_2^-}{2\pi\varepsilon r} ch\frac{v_2}{c}.
\end{aligned}
\qquad (1)
$$

Adding all force components, we will obtain the amount of the composite force, which falls per unit of the length of conductor,

$$F_{\Sigma} = \frac{g_1 g_2}{2\pi\varepsilon r}\left(ch\frac{v_1}{c} + ch\frac{v_2}{c} - ch\frac{v_1 - v_2}{c} - 1 \right). \qquad (2)$$

In this expression as g_1 and g_2 are undertaken the absolute values of charges, and the signs of forces are taken into account in the bracketed expression. Let us take only two first members of expansion in the series $ch\frac{v}{c}$, i.e., we will consider that $ch\frac{v}{c} \cong 1 + \frac{1}{2}\frac{v^2}{c^2}$. From relationship (2) we obtain

$$F_{\Sigma 1} = \frac{g_1 v_1 g_2 v_2}{2\pi\varepsilon c^2 r} = \frac{I_1 I_2}{2\pi\varepsilon c^2 r}, \qquad (3)$$

where g_1 and g_2 are undertaken the absolute values of specific charges, and v_1 and v_2 take with its signs.

Since the magnetic field of straight wire, along which flows the current I, we determine by the relationship

$$H = \frac{I}{2\pi r},$$

From relationship (2) we obtain

$$F_{\Sigma 1} = \frac{I_1 I_2}{2\pi\varepsilon c^2 r} = \frac{H_1 I_2}{\varepsilon c^2} = I_2 \mu H_1,$$

where H_1 - the magnetic field, created by lower conductor in the location of upper conductor.

It is analogous

$$F_{\Sigma 1} = I_1 \mu H_2,$$

where H_2 - the magnetic field, created by upper conductor in the region of the arrangement of lower conductor.

These relationships completely coincide with the results, obtained on the basis of the concept of magnetic field.

Relationship (3) represents the known rule of power interaction of the current carrying systems, but it is obtained not on the basis the introduction of phenomenological magnetic field, but on the basis of completely intelligible physical procedures. In the formation of the forces of interaction in this case the lattice takes direct part, which is not in the model of magnetic field. In the model examined are well visible the places of application of force. The obtained relationships coincide with the results, obtained on the basis of the concept of magnetic field and by the axiomatically introduced Lorentz force. In this case is undertaken only first member of expansion in the series $ch\frac{v}{c}$. For the speeds $v \sim c$ should be taken all terms of expansion. If we consider this circumstance, then the connection between the forces of interaction and the charge rates proves to be nonlinear. This, in particular it leads to the fact that the law of power interaction of the current carrying systems is asymmetric. With the identical values of currents, but with their different directions, the attracting forces and repulsion become unequal. Repulsive forces prove to be greater than attracting force. This difference is small and is determined by the expression

$$\Delta F = \frac{v^2}{2c^2}\frac{I_1 I_2}{2\pi\varepsilon c^2 \varepsilon},$$

but with the speeds of the charge carriers of close ones to the speed of light it can prove to be completely perceptible.

Let us remove the lattice of upper conductor (Fig. 1), after leaving only free electronic flux. In this case will disappear the forces F_1 and F_3, and this will indicate interaction of lower conductor with the flow of the free electrons, which move with the speed v_2 on the spot of the arrangement of upper conductor. In this case the value of the force of interaction is defined as:

$$F_\Sigma = \frac{g_1 g_2}{2\pi\varepsilon r}\left(ch\frac{v_2}{c} - ch\frac{v_1 - v_2}{c} \right). \qquad (4)$$

The Lorentz force assumes linear dependence between the force, which acts on the charge, which moves in the magnetic field, and his speed. However, in the obtained relationship the dependence of the amount of force from the speed of electronic flux will be nonlinear. From relationship (4) it is not difficult to see that with an increase in v_2 the deviation from the linear law increases, and in the case, when $v_2 >> v_1$, the force of interaction are approached zero. This is very meaningful result. Specifically, this phenomenon observed in their known experiments Thompson and Kaufmann, when they noted that with an increase in the velocity of electron beam it is more badly slanted by magnetic field. They connected the results of their observations with an increase in the mass of electron. As we see reason here another.

Let us note still one interesting result. From relationship (3), with an accuracy to quadratic terms, the force of interaction of electronic flux with the rectilinear conductor to determine according to the following dependence:

$$F_\Sigma = \frac{g_1 g_2}{2\pi\varepsilon r}\left(\frac{v_1 v_2}{c^2} - \frac{1}{2}\frac{v_1{}^2}{c^2} \right). \qquad (5)$$

From expression (5) follows that with the unidirectional electron motion in the conductor and in the electronic flux the force of interaction with the fulfillment of conditions $v_1 = \frac{1}{2} v_2$ is absent.

Since the speed of the electronic flux usually much higher than speed of current carriers in the conductor, the second term in the brackets in relationship (5) can be disregarded. Then, since

$$H_1 = \frac{g_1 v_1}{2\pi\varepsilon c^2 r}$$

we will obtain the magnetic field, created by lower conductor in the place of the motion of electronic flux:

$$F_\Sigma = \frac{g_1 g_2}{2\pi\varepsilon r} \frac{v_1 v_2}{c^2} = g_2 \mu v_2 H .$$

In this case, the obtained value of force exactly coincides with the value of Lorentz force.

Taking into account that

$$F_\Sigma = g_2 E = g_2 \mu v_2 H ,$$

it is possible to consider that on the charge, which moves in the magnetic field, acts the electric field E, directed normal to the direction of the motion of charge. This result also with an accuracy to of the quadratic terms $\frac{v^2}{c^2}$ completely coincides with the results of the concept of magnetic field and is determined Lorentz force.

As was already said, one of the important contradictions to the concept of magnetic field is the fact that two parallel beams of the like charges, which are moved with the identical speed in one direction, must be attracted. In this model there is no this contradiction already. If we consider that the charge rates in the upper and lower wire will be equal, and lattice is absent, i.e., to leave only electronic fluxes, then will remain only the repulsive force F_2.

Thus, the moving electronic flux interacts simultaneously both with the moving electrons in the lower wire and with its lattice, and the sum of these forces of interaction it is called Lorentz force.

Regularly does appear a question, and does create magnetic field most moving electron stream of in the absence compensating charges of lattice or positive ions in the plasma? The diagram examined shows that the effect of power interaction between the current carrying systems requires in the required order of the presence of the positively charged lattice. Therefore most moving electronic flux cannot create that effect, which is created during its motion in the positively charged lattice.

Let us demonstrate still one approach to the problem of power interaction of the current carrying systems. The statement of facts of the presence of forces between the current carrying systems indicates that there is some field of the scalar potential, whose gradient ensures the force indicated. But that this for the field? Relationship (3) gives only the value of force, but he does not speak about that, the gradient of what scalar potential ensures these forces. We will support with constants the currents I_1 and I_2, and let us begin to draw together or to move away conductors. The work, which in this case will be spent, and is that potential, whose gradient gives force. After integrating relationship (3) on r, we obtain the value of the energy:

$$W = \frac{I_1 I_2 \ln r}{2\pi\varepsilon c^2}.$$

This energy, depending on that to move away conductors from each other, or to draw together, can be positive or negative. When conductors move away, then energy is positive, and this means that, supporting current in the conductors with constant, generator returns energy. This phenomenon is the basis the work of all electric motors. If conductors converge, then work accomplish external forces, on the source, which supports in them the constancy of currents. This phenomenon is the basis the work of the mechanical generators of EMP.

Relationship for the energy can be rewritten and thus:

$$W = \frac{I_1 I_2 \ln r}{2\pi\varepsilon c^2} = I_2 A_{z1} = I_1 A_{z2},$$

where

$$A_{z1} = \frac{I_1 \ln r}{2\pi\varepsilon c^2}$$

is z- component of vector potential, created by lower conductor in the location of upper conductor, and

$$A_{z2} = \frac{I_2 \ln r}{2\pi\varepsilon c^2}$$

is z- component of vector potential, created by upper conductor in the location of lower conductor.

The approach examined demonstrates that large role, which the vector potential in questions of power interaction of the current carrying systems and conversion of electrical energy into the mechanical plays. This approach also clearly indicates that the Lorentz force is a consequence of interaction of the current carrying systems with the field of the vector potential, created by other current carrying systems. Important circumstance is the fact that the formation of vector potential is obliged to the dependence of scalar potential on the speed. This is clear from a physical point of view. The moving charges, in connection with the presence of the dependence of their scalar potential on the speed, create the scalar field, whose gradient gives force. But the creation of any force field requires expenditures of energy. These expenditures accomplishes generator, creating currents in the conductors. In this case in the surrounding space is created the special field, which interacts with other moving charges according to the special vector rules. In this case only scalar product of the charge rate and vector potential gives the potential, whose gradient gives the force, which acts on the moving charge. Thisis a Lorentz force.

In spite of simplicity and the obviousness of this approach, this simple mechanism up to now was not finally realized. For this reason the Lorentz force, until now, was introduced in the classical electrodynamics by axiomatic way.

Let us examine the still one case, when the single negative charge e moves with the speed v_2 in parallel to the conductor, along which with the speed v_1 move the electrons, whose specific density, that falls per unit of the length of wire, composes q_1^- (Fig.2). We will consider that the conductor prior to the beginning of electron motion was electrically neutral and the specific density of positive ions and electrons they were equal. The grain, which falls in the section dz of conductor with the current, in this case will compose q_1^-dz. The element of the effective force of the moving charge e on the element q_1^-dz will be determined by the relationship:

$$dF = \frac{eg_1 dz}{4\pi\varepsilon r^2}\left(\frac{v_{1n}v_{2n}}{c^2} - \frac{1}{2}\frac{{v_{1n}}^2}{c^2}\right),$$

where v_{1n} and v_{2n} - components of the corresponding speeds, normal to the radius, which connects the moving charge with the grain q_1^-dz. The speed of the electron motion v_{2n} is considerably more than the speed of the motion of charges in the conductor v_{2n}; therefore last term in the brackets in this relationship can be disregarded.

Since $v_{1n} = v_1 \sin\alpha$ and $v_{2n} = v_2 \sin\alpha$, and also, taking into account that $r_0 = r \sin\alpha$ and $dz = \dfrac{r_0 d\alpha}{\sin^2\alpha}$,

we obtain

$$dF = \frac{q_1 v_1 e v_2}{4\pi\varepsilon c^2 r_0} d\alpha .$$

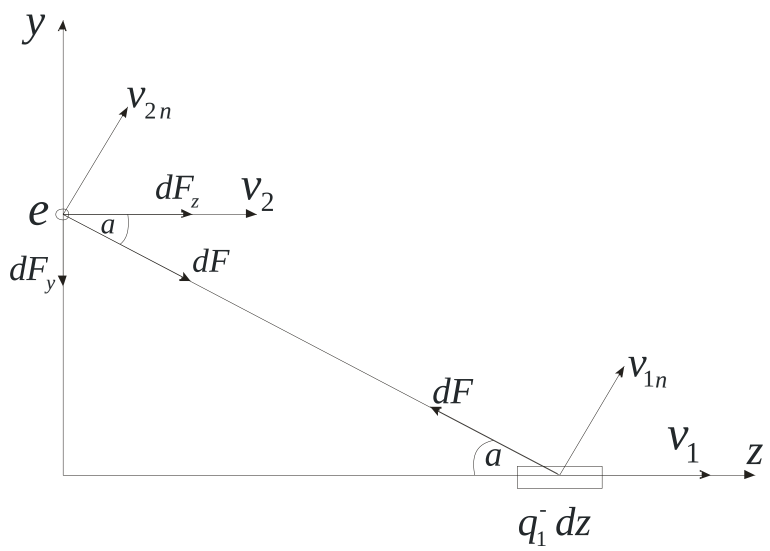

Fig. 2. The diagram of interaction of the moving point charge with the conductor, along which flows the current.

The obtained force corresponds to attraction. The element of this force, parallel r_0, will be written down as:

$$dF_y = \frac{q_1 v_1 e v_2}{4\pi\varepsilon c^2 r_0} \sin\alpha \, d\alpha \tag{6}$$

and the element of the force, normal to r_0 will be equal:

$$dF_x = \frac{q_1 v_1 e v_2}{4\pi\varepsilon c^2 r_0} \cos\alpha \, d\alpha . \tag{7}$$

After integrating relationship (6) and taking into account that the current, which flows by the lower conductor it is determined by the relationship

$I = q_1 v_1$, let us write down the force, which acts on the single moving charge e from the side of the right side of the wire:

$$F = \int_0^{\frac{\pi}{2}} \frac{Iev_2}{4\pi\varepsilon c^2 r_0} \sin\alpha \, d\alpha = \frac{Iev_2}{4\pi\varepsilon c^2 r_0}. \qquad (8)$$

If we consider interaction, also, with her left side of the wire, then the force, which acts in parallel r_0 will be doubled, and the forces, which act normal to r_0, they are compensated. Thus, the composite force, which acts on the charge, which moves in parallel to wire, will be written down:

$$F_\Sigma = \frac{Iev_2}{2\pi\varepsilon c^2 r_0}. \qquad (9)$$

Since the magnetic field, created by lower conductor with the current at the point of the presence of the moving charge, is determined by the relationship

$$H = \frac{I}{2\pi r_0},$$

and magnetic permeability $\mu = \frac{1}{\varepsilon c^2}$, then from relationship (8) we obtain

$$F_\Sigma = ev_2 \mu H$$

This force is exactly equal to the Lorentz force.

Now let us examine the case, when the charge moves between two limitless parallel plates, along which flows the specific current I, (Fig. 3). This current flows along the normal to the plane of figure. In this case the charge moves in parallel to the current, which flows in the plates.

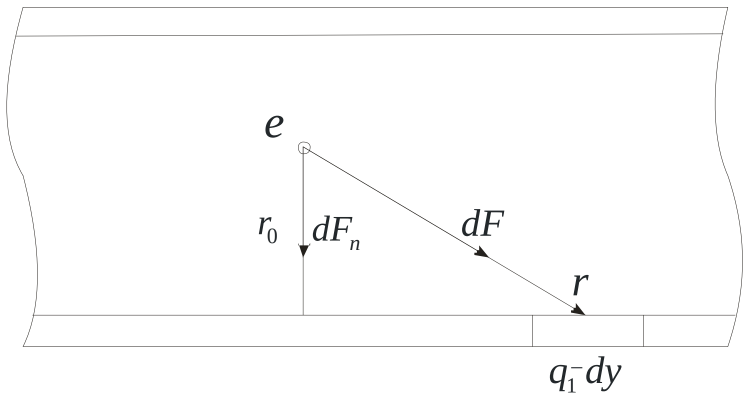

Fig.3. Diagram of interaction of the moving point charge with the currents, which flow along the parallel conducting plates.

Taking into account relationship (9), let us write down the element of the force, which acts on the moving charge from the side of the current element, which flows normal to the element, dy

$$dF = \frac{dz\ dy\ nv_1 q_2 v_2}{2\pi\varepsilon c^2 r}. \tag{10}$$

In this relationship dz is this thickness of the layer, along which the current flows, and n - electron density.

Let us rewrite relationship (10), taking into account that $dy = \frac{r_0 d\alpha}{\sin^2\alpha}$, $r = \frac{r_0}{\sin\alpha}$, and also that that $\frac{dF_n}{dF} = \sin\alpha$, where dF - element of force, directed in parallel r, and dF_n - element of force, directed normal to r_0:

$$dF_n = \frac{dz\ nv_1 g_2 v_2 d\alpha}{2\pi\varepsilon_0 c^2}.$$

After integrating this expression, we will obtain the total force, which acts on the moving charge from the side of one half-plane:

$$F = \int_0^{\frac{\pi}{2}} \frac{dz\ nv_1 g_2 v_2 d\alpha}{2\pi\varepsilon_0 c^2} = \frac{dz\ nv_1 g_2 v_2}{4\varepsilon_0 c^2}.$$

Taking into account that the fact that on the charge act the forces from the side of four half-planes (two from the side of lower plate two from the side of upper), finally we obtain:

$$F_{\Sigma} = \frac{g_2 v_2 H}{\varepsilon_0 c^2} = \mu g_2 v_2 H \ .$$

And again eventual result exactly coincided with the results of the concept of magnetic field.

Thus, the results, obtained taking into account the introduction of scalar-vector potential and concept of magnetic field, completely coincide, if we consider only quadratic members of the expansion of hyperbolic cosine in series. In the case of the calculation of the terms of the expansion of the higher orders, when the speeds of the motion of charges are great, this agreement it will not be and the connection between the force and the speed becomes nonlinear, and the concept of magnetic field will no longer give correct results.

By the merit of this method of examining interaction between the current carrying systems and the charges appears the fact that he indicates the concrete places of application of force, which act between their elements and moving charges, which is not in the concept of magnetic field. now it is possible to verify does work the mechanism of interaction of the current carrying systems in the case of the long line examined, along which is propagated electriccurent wave. The tension of the electric field between the planes of line is determined by the relationship:

$$E = \frac{g_{\square}}{\varepsilon_0}, \tag{11}$$

where $g_{\square}$ - the charge, which falls to the single square of the surface of long line.

The specific current, which falls per unit of the width of line, magnetic and electric field in it are connected with the relationship

$$I = g_{\square} v = H = \frac{E}{Z_0}. \qquad (12)$$

From this relationship we obtain

$$v = \frac{E}{g_{\square} Z_0}. \qquad (13)$$

Since the currents in the planes of line are directed in opposite directions, taking into account relationships (11 - 13), value of the repulsive force, falling to the single square surface, let us write down:

$$F_{\square} = \frac{g_{\square}{}^2 v^2}{2\varepsilon_0 c^2} = \frac{1}{2}\mu_0 H^2.$$

Thus, the concept of scalar- vector potential and in this case gives correct answer.

Let us examine the still one interesting consequence, which escapes from the given examination. If we as the planes of long line use an superconductor, then the magnetic field on its surface, equal to specific current, can be determined from the relationship:

$$H = nev\lambda, \qquad (14)$$

where $\lambda = \sqrt{\frac{m}{ne^2\mu}}$ - depth of penetration of magnetic field into the superconductor.

If we substitute the value of depth of penetration into relationship (14), then we will obtain the unexpected result:

$$H = v\sqrt{\frac{nm}{\mu}}.$$

Occurs that the magnetic field strength completely does not depend on the magnitude of the charge of current carriers, but it depends on their mass. Thus, the specific energy of magnetic pour on

$$W_H = \frac{1}{2}\mu H^2 = \frac{nmv^2}{2} \qquad (15)$$

is equal to specific kinetic the kinetic energy of charges. But magnetic field exists not only on its surface, also, in the skin-layer. Volume, occupied by magnetic fields, incommensurably larger than the volume of this layer. If we designate the length of the line, depicted in Fig. 4 as l, then the volume of skin-layer in the superconductive planes of line will compose $2lb\lambda$.

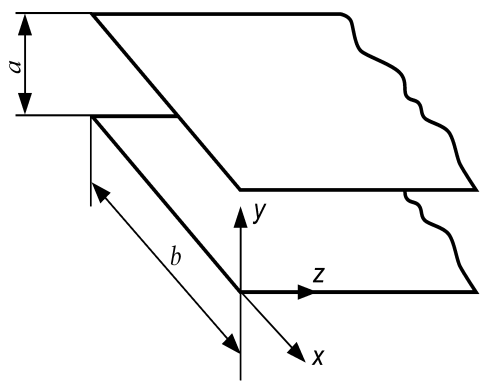

Fig. 4. Two-wire line consisting of two ideally conducting planes.

Energy of magnetic pour on in this volume we determine from the relationship:

$$W_{H,\lambda} = nmv^2 lb\lambda,$$

however, energy of magnetic pour on, accumulated between the planes of line, it will comprise:

$$W_{H,a} = \frac{nmv^2 lba}{2} = \frac{1}{2} lba\mu_0 H. \qquad (16)$$

If one considers that the depth of penetration of magnetic field in the superconductors composes several hundred angstroms, then with the macroscopic dimensions of line it is possible to consider that the total energy of magnetic pour on in it they determine by relationship (16).

Therefore, the formation of magnetic pour on H between the planes of line, which appear in connection with the motion of charges in the skin-layer, it requires the same expenditures of energy, as if entire volume of line was filled with the particles, which move with the speed v, whose density and mass compose respectively n and m.

Is obvious that the effective mass of electron in comparison with the mass of free electron grows in this case into $\frac{a}{2\lambda}$ of times. This is the consequence of the fact that the mechanical electron motion leads not only to the accumulation of their kinetic energy in the skin-layer, but in the line also occurs accumulation and potential energies, whose gradient gives the force, which acts on the conducting planes of line. Thus, becomes clear nature of such parameters as inductance and the effective mass of electron, which in this case depend, in essence, not from the mass of free electrons, but from the configuration of conductors, on which the electrons move.

homopolar induction was discovered by Farady more than 200 years ago, but also up to now the physical principles of the operation of some constructions of unipolar generators remain obscure. There were the attempts to explain the work of such generators by action on the moving charges of Lorentz force, but it turned out that there are such constructions, in which to explain their operating principle thus is impossible.

Beginning the study of the problem about the homopolar induction, it is necessary to clearly demarcate the concepts of a potential difference and electromotive force (EMF). The scalar potential of fixed charge is determined by the relationship

$$\varphi_0(r) = \frac{Q}{4\pi\varepsilon r},$$

where Q - magnitude of the charge, and ε - dielectric constant of medium.

Electric field is the gradient of the scalar potential

$$\vec{E} = -grad\ \varphi_0(r).$$

This field is potential, while this means that the work is not accomplished with the transfer of trial charge in this field along any locked trajectory, i.e. the condition is satisfied

$$\oint \vec{E}d\vec{l} = 0.$$

The electromotive force (EMF) is the scalar quantity, which characterizes the work of strange nonpotential forces in the locked conducting outline and is determined the work of these forces on the displacement of unit charge along the outline. In this case

$$\oint \vec{E}d\vec{l} = U,$$

where U is EMF, generated in this outline.

The EMF can be determined also in any section of the locked outline, in this case the work is determined by work EMF in this section and magnitude of the charge, moved in this section. Both potential difference and EMF are measured in volts.

In the usual electric generators EMF is generated in the locked fixed or moving outline, partly which appears the load, in which is separated the energy. A difference in the unipolar generator from such generators is the fact that in it the locked outline is composite: one part of this outline is fixed, and the second moves relative to the first. Galvanic contact between these parts is ensured with the aid of the feeder brushes. Both parts of the locked outline of unipolar generator their potential differences, which in the sum give complete EMF, are excited. If the discussion deals with the direct current, then EMF can be generated only in the locked outline.

The concept of scalar-vector potential, developed in the works [3,11,12,19], the dependence of the scalar potential of charge on its relative speed is assumed.

$$\varphi(v) = \varphi_0 ch \frac{v_\perp}{c}, \qquad (17)$$

where $v_\perp$ - normal component of charge rate to the vector, which connects the moving charge and observation point. Use of this concept gives the possibility not only to explain the work of all existing types of unipolar generators, but also to answer a question about the polarization of the moving magnet. We will consider that magnet it is possible to present in the form the framework, along which flows the current (Fig. 5).

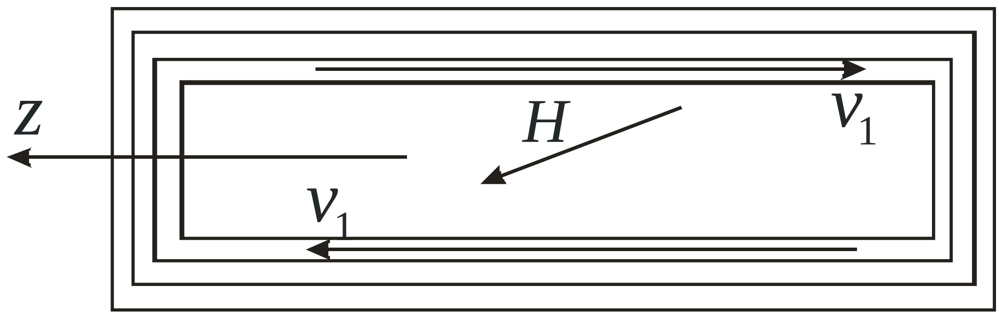

Fig. 5. Framework with the current.

In the conductor is located two subsystems of the mutually inserted charges: the ions of the positively charged lattice and electrons. These two subsystems neutralize each other, making conductor with neutral. When current flows along the conductor and conductor itself is fixed, then relative to fixed observer move only electrons.

In Fig. 5 the subsystems indicated are moved apart. Outer duct presents the positively charged rigid lattice, and internal outline presents the current of the moving electrons, which generate magnetic field.

If the framework with the current moves in the direction z, the like to relation to the fixed observer the electron velocity in the lower and upper section of the framework it changes differently: in the upper section it increases, while in the lower - it decreases. While the speed of lattice is identical and in the upper, and in the lower section and equal to the speed of the motion of the framework.

Let us examine the case, when there is a section of the conductor, along which flows the current (Fig.6). We will also consider that in the conductor are two subsystems of the mutually inserted charges of the positive lattice g^+ and free electrons g^-. For convenience in the examination in the figure these two subsystems are moved apart along the coordinate r.

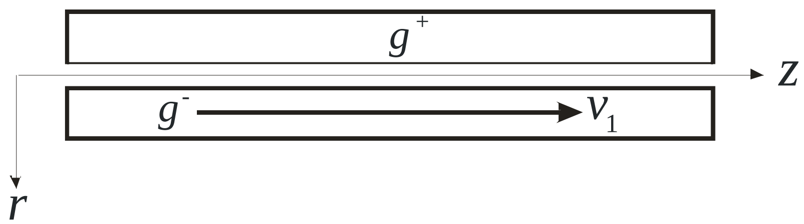

Fig. 6. Section is the conductor, along which flows the current.

The electric field, created by rigid lattice depending on the coordinate r, takes the form:

$$E^+ = \frac{g}{2\pi\varepsilon r} \quad , \tag{18}$$

where g - positive charge, which falls per unit of the length of conductor.

as in relationship (18.18) with the further consideration we will introduce only absolute values of the densities both of positive and negative charges, counting the absolute values of electrical pour on, which coincide in the direction for r by positive, and opposite to this direction - negative.

Using relationship (17), we obtain the values of electrical pour on, created by the electrons, which move in the conductor with the speed v_1

$$E^- = -\frac{g}{2\pi\varepsilon r} ch\frac{v_1}{c} \cong -\frac{g}{2\pi\varepsilon r}\left(1+\frac{1}{2}\frac{{v_1}^2}{c^2}\right). \qquad (19)$$

In this relationship only two first members of expansion in the series of hyperbolic cosine are undertaken.

Adding (18) and (19), we obtain the summary value of the electric field at a distance r from the axis of the conductor:

$$E = -\frac{g{v_1}^2}{2\pi\varepsilon c^2 r}.$$

This relationship indicates that around the conductor, along which move the electrons, is created the electric field, which corresponds to the negative charge of conductor. However, this field with those current densities, which can be provide ford in the normal conductors, has insignificant value, and discovered be it cannot with the aid of the existing measuring means. It can be discovered only with the use of the superconductors, where the current density can on many orders exceed currents in the normal metals [12].

Let us examine the case, when very section of the conductor, on which with the speed v_1 flow the electrons, moves in the opposite direction with speed v (Fig. 7).

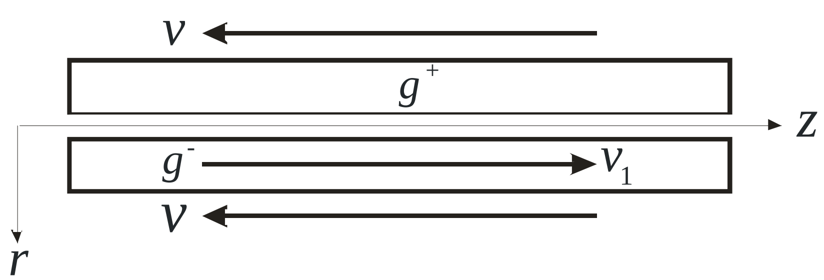

Fig. 7. Section of conductor with the current, which moves with the speed v.

In this case relationships (2) and (3) will take the form

$$E^{+}=\frac{g}{2\pi\varepsilon r}\left(1+\frac{1}{2}\frac{v^{2}}{c^{2}}\right) \tag{20}$$

$$E^{-}=-\frac{g}{2\pi\varepsilon r}\left(1+\frac{1}{2}\frac{(v_{1}-v)^{2}}{c^{2}}\right) \tag{21}$$

Adding (20) and (21), we obtain the summary field

$$E_{\Sigma}=\frac{g}{2\pi\varepsilon r}\left(\frac{v_{1}v}{c^{2}}-\frac{1}{2}\frac{v_{1}^{2}}{c^{2}}\right) \tag{22}$$

We will consider that the speed of the mechanical motion of conductor is considerably more than the drift velocity of electrons. Then in relationship (22) the second term in the brackets can be disregarded, and finally we obtain:

$$E\cong\frac{gv_{1}v}{2\pi\varepsilon c^{2}r}\,. \tag{23}$$

The obtained result means that around the moving conductor, along which flows the current, with respect to the fixed observer also is formed the electric field, but it is considerably greater than in the case of fixed conductor with the current. This field is equivalent to appearance on this conductor of the specific positive charge of the equal

$$g^{+}=\frac{gv_{1}v}{c^{2}}\ . \tag{24}$$

If in parallel with the conductor with the same speed moves the plate (it is shown in the lower part of Fig. 8), whose width is equal r_2-r_1, then between its edges will be observed a potential difference

$$U_{1}=-\int_{r_1}^{r_2}\frac{gv_{1}^{2}dr}{2\pi\varepsilon c^{2}r}=-\frac{gv_{1}^{2}}{2\pi\varepsilon c^{2}}\ln\frac{r_{2}}{r_{1}} \tag{125}$$

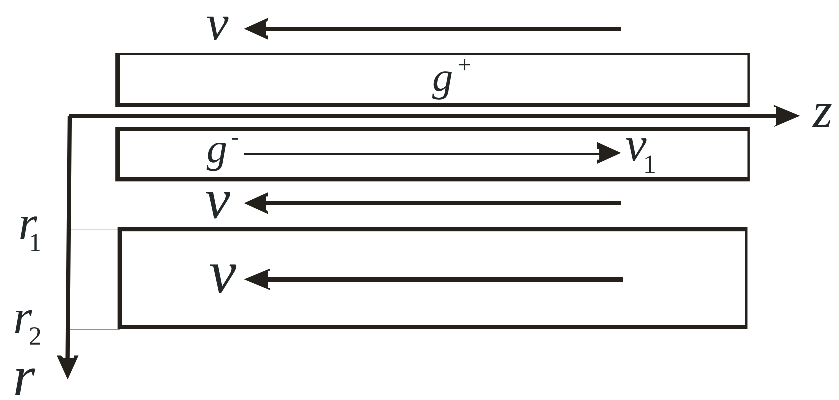

Fig. 20. The conducting plate moves with the same speed, as conductor.

However, a potential difference in the relation to the fixed observer between the points r_1 and r_2 we will obtain, after integrating equality (23)

$$U_2 = \frac{g v_1 v}{2\pi\varepsilon c^2} \ln \frac{r_2}{r_1}, \tag{26}$$

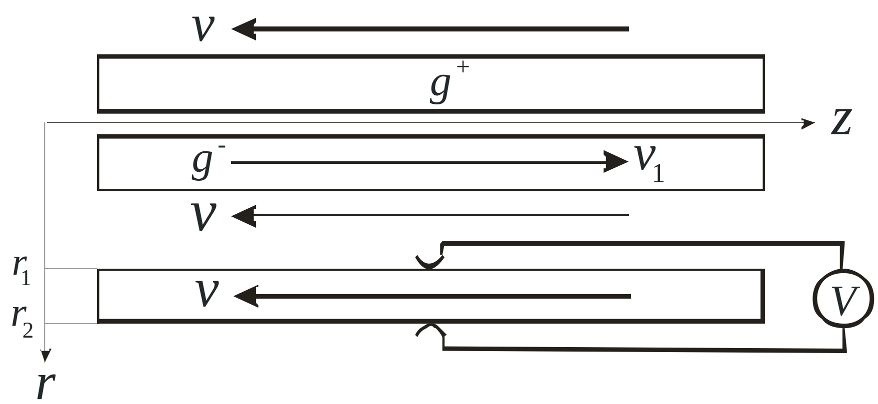

Fig. 9. To the conducting plate, which is moved together with the conductor, with the aid of the brushes the voltmeter is connected.

This potential difference will be observed between fixed contacts, which slide along the edges of plate and on the cross connection by their of that connecting (Fig. 9). In this case such cross connection is the circuit of voltmeter. The conducting plate, which is moved together with the conductor, presents together with the circuit of voltmeter the composite locked outline, in which will act EMF, which is been the sum of potential differences, which is located on the component parts of the outline. This potential difference will fix voltmeter. We will obtain its value, summing up expressions (25) and (26):

$$U_\Sigma = U_2 + U_1 = \left(\frac{g v_1 v}{2\pi\varepsilon c^2} - \frac{g v_1^2}{2\pi\varepsilon c^2} \right) \ln \frac{r_1}{r_2}. \qquad (27)$$

but since $v \quad v_1$, finally we considerably more than obtain

$$U_\Sigma \cong \frac{g v_1 v}{2\pi\varepsilon c^2} \ln \frac{r_1}{r_2} \qquad (28)$$

Is possible the conductor, along which flows the current, to roll up into the ring, after making from it a turn with the current, and to revolve this turn so that its speed would be equal v. In this case around this turn the electric field, which corresponds to the presence on the conductor of the ring of the specific charge, determined by relationship will appear (24).

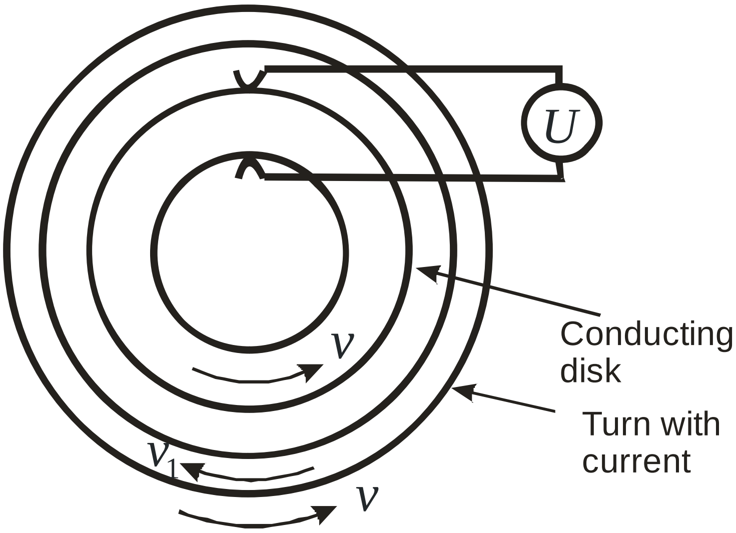

Fig. 10. Schematic of unipolar generator with the revolving turn with the current and the revolving conducting dick.

Let us roll up into the ring the conducting plate, after making from it a disk with the opening, and let us join to its generatrix feeder brushes, as shown in Fig. 10. If we with the identical speed revolve ring and disk, then on the condition that that the diameter of ring is considerably more than its width, on the brushes we will obtain EMF, determined by relationship (28).

Is examined the most contradictory version of the unipolar generator, the explanation of the operating principle of which in the literary sources previously was absent. With its examination it is not possible to use a concept of the Lorentz force, since and magnet and conducting ring revolve together with the identical speed.

The conducting dick and the revolving together with it magnet it is possible to combine in the united construction. For this should be carried out ring from the magnetic material and magnetized it in the axial direction. The continuous magnetized disk is the limiting case of this construction. With this EMF it is removed with the aid of the feeder brushes between the generatrix of disk and its axis. This construction presents the unipolar generator, which was proposed still by Faraday.

Different combinations of the revolving and fixed magnets and disks are possible.

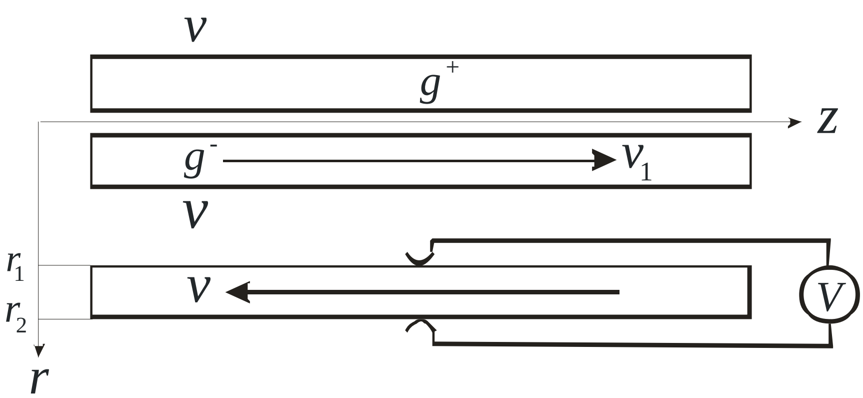

Fig. 11. The case, when the section of conductor with the current is fixed, and moves only the conducting plate.

The case with the fixed magnet and the revolving conducting disk is characterized by the diagram, depicted in Fig. 11.

In this case the following relationships are fulfilled:

The electric field, which acts on the electrons in the plate from the side of electrons, that move in the fixed annular turn, is determined by the relationship

$$E_1^- = -\frac{g}{2\pi\varepsilon r} ch\frac{v_1 - v}{c} = -\frac{g}{2\pi\varepsilon r}\left(1 + \frac{1}{2}\frac{(v_1 - v)^2}{c^2}\right),$$

and the electric field, which acts on the electrons in the disk, from the side of ions in the ring

$$E_2^+ = \frac{g}{2\pi\varepsilon r} ch\frac{v}{c} = \frac{g}{2\pi\varepsilon r}\left(1 + \frac{1}{2}\frac{v^2}{c^2}\right).$$

Therefore a potential difference between the edges of the revolving disk will comprise

$$U_1 = \frac{g}{2\pi\varepsilon}\left(\frac{v_1 v}{c^2} - \frac{1}{2}\frac{v_1^2}{c^2}\right)\ln\frac{r_2}{r_1}.$$

At the same time a potential difference between the brushes, which are fixed with respect to the reference system, will be determined by the relationship

$$U_2 = -\int_{r_1}^{r_2} \frac{g v_1^2 dr}{2\pi\varepsilon c^2 r} = -\frac{g v_1^2}{2\pi\varepsilon c^2}\ln\frac{r_2}{r_1} \ .$$

summarizing U_1 and U_2, we obtain value EMF in the composite outline of

$$U_\Sigma = \frac{g}{2\pi\varepsilon}\left(\frac{v_1 v}{c^2} - \frac{v_1^{\ 2}}{c^2}\right)\ln\frac{r_2}{r_1} \cong \frac{g v_1 v}{2\pi\varepsilon c^2}\ln\frac{r_2}{r_1} \ .$$

It is evident that this relationship coincides with relationship (28).

If we for the case examined roll up into the ring wire, and plate into the disk with the opening, then we will obtain the case, depicted in Fig. 12. Therefore there is no difference whatever between the case of the magnet, which revolves together with the disk and the magnet, which in the reference system of counting rests, and disk revolves is no. Specifically, this phenomenon did not find, until now, of explanation.

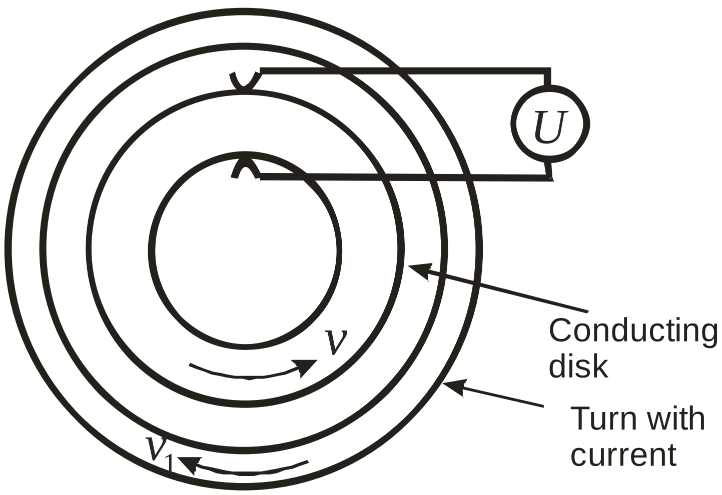

Fig. 12. Case of fixed magnet and revolving disk.

Now let us examine a question about what fields in the surrounding space it will direct the moving magnet, represented in Fig. 1 in the form the framework with the current. We will consider that the width of magnet is considerably lower than its length, and we will examine those fields, which will be generated near its average part without taking into account edge effects.

Let us at first examine a question about what electric fields the fixed framework with the current generates. We already said that the appearance of external static pour on around the conductors, along which flows the current, it is equivalent to appearance on these conductors of static charge. Therefore the it should be noted that indicated fields can be observed only when current into the framework is introduced by induction noncontact method. Otherwise electrical contact with the surrounding conductive bodies can lead to the overflow of the charges between the framework and these bodies, which will distort the results of experiment.

Let us examine a question about what electric fields must appear in the environment of the framework with the current, current into which is introduced by induction method. The middle part of the framework is represented in Fig. 13. Here electrons move with the speed v_1. At the point A the electric field will be they will be determined by the relationship

$$E_\Sigma = -\frac{g v_1^2}{2\pi\varepsilon c^2}\left(\frac{1}{r_1}+\frac{1}{r_2}\right). \qquad (29)$$

The same field will be observed, also, at the symmetrical point B.

If the framework moves in the direction of the axis z with the speed v, then upper conductor at the point A will create the electric field

$$E \cong \frac{g v_1 v}{2\pi\varepsilon c^2 r_1},$$

and lower conductor at the same point will create the will

$$E \cong -\frac{g v_1 v}{2\pi\varepsilon c^2 r_2}.$$

We will obtain summary field, after accumulating these two expressions

$$E_\Sigma \cong \frac{g v_1 v}{2\pi\varepsilon c^2}\left(\frac{1}{r_1}-\frac{1}{r_2}\right) \qquad (30)$$

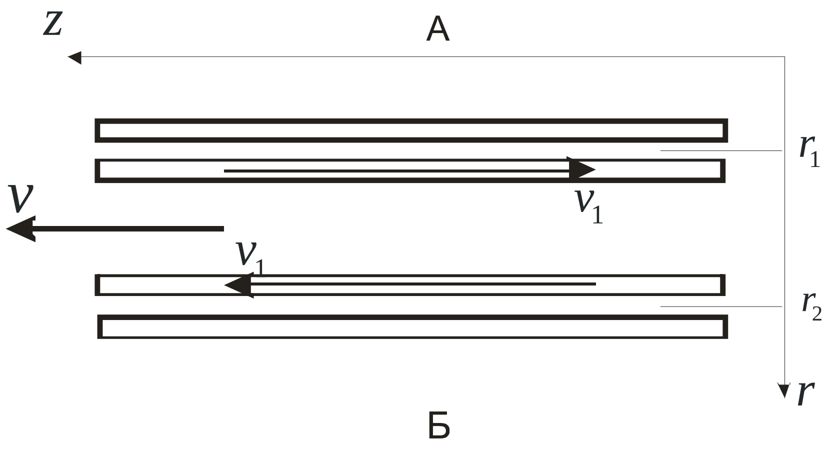

Fig. 13. Section of the moving framework with the current.

However, at the point В will be observed the same field only with the opposite sign.

Relationship (30) shows that with respect to the fixed observer the moving framework with the current creates electric field, in this case the impression of its polarization is created. However, observer, who moves together with the framework, will observe only the insignificant fields, determined by relationship (29).

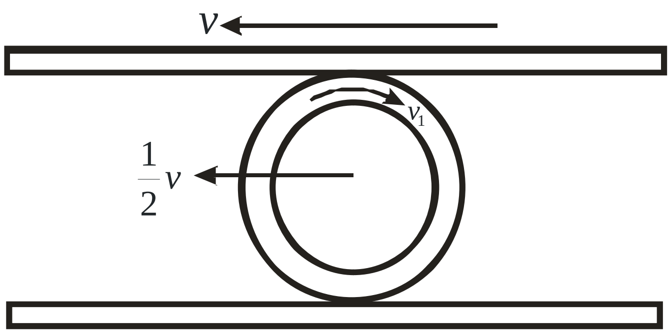

Fig. 14. Magnetized roller, which is rolled between two parallel planes.

Let us examine the new type of the unipolar generator, in which are used the magnetized rollers. In Fig. 14 is shown the magnetized conducting roller, which is rolled between two planes. We will consider that the lower conducting plane is fixed, and upper moves with the speed of v, making it necessary a roller to achieve simultaneously and progressive and rotary motion. Moreover, since the roller is magnetized, we will compare it, as before, with the turn, on which the electrons move with the speed v_1.

In this case the center of turn moves with the speed $\frac{1}{2}v$. The instantaneous speed of turn at the point of its contact with the lower plane is equal to zero, and at upper point it is equal v. Let us isolate in the upper part of the turn the small section dl. The speed of the positive charges of lattice in this section relative to fixed observer will be equal v, while the electron velocity will be equal $v - v_1$. This situation corresponds to the case, depicted in Fig. 6. The section indicated, flying near the fixed observer, who is located near the upper plate, will create the tension of electric field equal

$$E \cong \frac{g v_1 v}{2\pi\varepsilon c^2 r}.$$

The duration of the pulse of electric field will compose vdl.

For registering this single-pole pulse it is possible to use the diagram, represented in Fig. 14. This examination demonstrates only the principle of obtaining the pulse of electric field with the aid of the rolling turn. In actuality situation is more complex. All parts of the rolling turn as the components of charge rates, have different composing the speeds parallel to plates in the dependence from the distance to the upper plate. Therefore for finding the field at the assigned fixed point out of the roller necessary to integrate the components of all electrical pour on, created by both the moving charges and by moving lattice of all parts of the turn.

The diagram, given in Fig. 15 it is not unipolar generator, since the galvanic contact between the lower terminal of voltmeter and the upper point of the rolling roller is absent. This contact must be created for transforming this diagram into the unipolar generator.

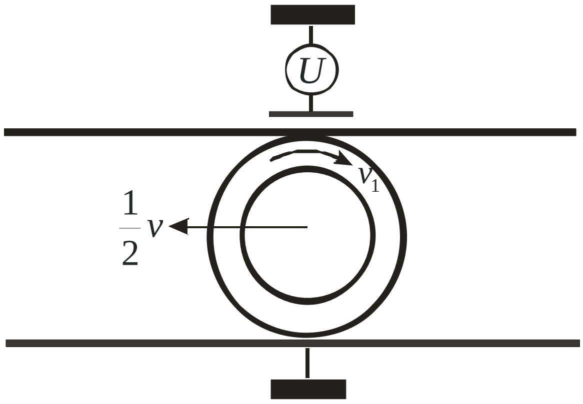

Fig. 15. Pulse-registering circuit of homopolar induction.

One of the possible diagrams of the creation of this contact simultaneously with all rollers, which are located in the bearing races, it is shown in Fig. 16.

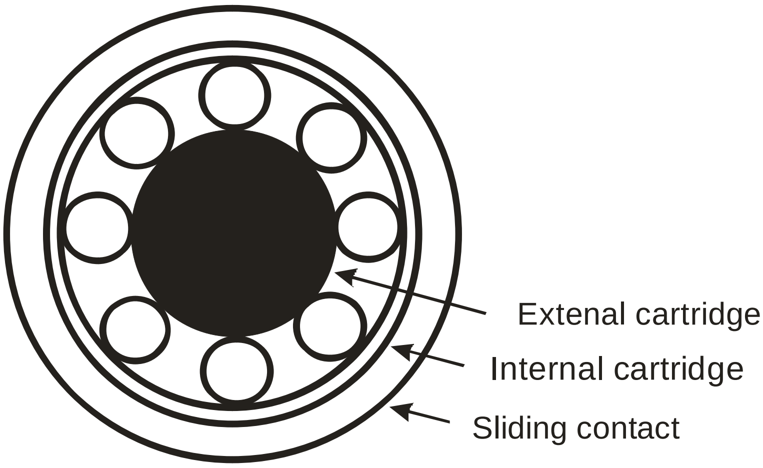

Fig. 16. Bearing with the magnetized rollers.

Bearing consists of the internal fixed conducting cartridge clip, external cartridge clip and sliding annular fixed contact. Internal cartridge clip can be both the continuous, as shown in figure and annular as in the usual bearing. External cartridge clip can be executed both of the conductor and from the dielectric. The fixed sliding contact, executed in the form of disk with the opening, must be prepared so that its internal annuli would not roll along the edge, but they slid immediately all rollers. If external cartridge clip was set into rotation, then each roller, presenting unitary unipolar generator, will generate in the fixed sliding contact a potential difference relative to internal cartridge clip. Longitudinal form of one of the possible constructions of this generator is shown in Fig. 17.

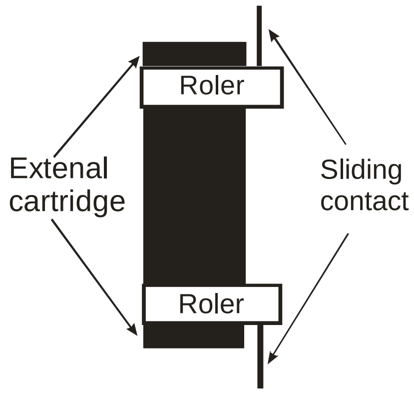

Fig. 17. The longitudinal section of unipolar generator with the magnetized rollers.

This model has only demonstration value, since. it is very difficult to reach this manufacturing precision in order to ensure the reliable sliding contact between the fixed slit ring terminal and all with that sliding on it by rollers.

More rational are the constructions, given in Fig. 18.

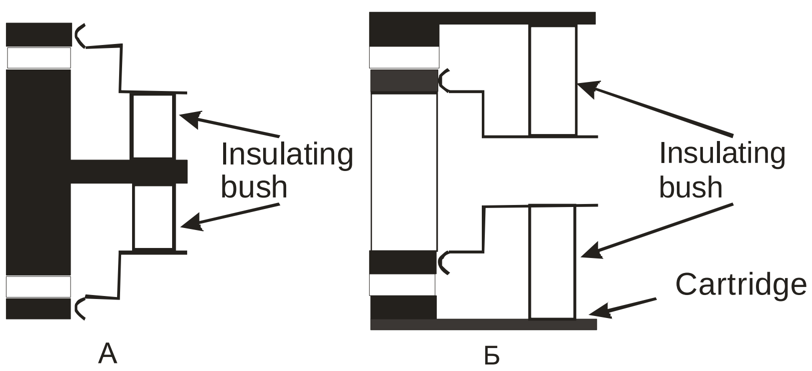

Fig. 18. Constructions of unipolar generator with the feeder brushes.

In both constructions are used roller bearings with the metallic cartridge clips and the magnetized rollers, EMF in which is removed with the aid of the brushes, which slide along the edge of cartridge clips. Then each roller, occurring opposite the sliding contact, will generate single-pole pulse EMF between the contact and the stationary part of the generator. In the construction A internal cartridge clip and the brushes, fastened to it on the insulating bushes, they are fixed, and external cartridge clip revolves. Constant stress EMF in this case appears between the central cartridge clip and the brushes. In the construction B internal cartridge clip, on the contrary, revolves, and spring cartridge clip with the brushes fastened to it, remains fixed. EMF in this case appears between the metallic cartridge clip, into which is pressed the bearing and by brushes. For an increase in the current, which they can ensure such generators should be increased a quantity of rollers and sliding contacts, after arranging them equidistantly on the perimeter of cartridge clip.