

Again about the law of the Faraday induction

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This article discusses the law of Faraday

Soon to be carried out of 200 of years since into of 1831 to year Faraday opened his famous law of the induction, which is up to now one of the fundamental laws of the classical electrodynamics. But this law is up to now one of the contradictory, first of all for that reason, that from it are exceptions (for example, homopolar induction). Let us give on to this to the occasion the quotation from the sixth the volume of Feynman the lectures [1].” flow rule”, according to which EMP in the outline it is equal to the speed undertaken with the opposite sign, with which changes magnetic flux through the outline, when flow changes due to field change or when outline moves (or when it occurs and that and, etc). Two the possibility - “the outline moves” or “the field changes” - are not distinguished into to the formulation of the rule. Nevertheless, for explaining the rule in these two cases we used two completely different

laws: $[\vec{V} \times \vec{B}]$ for “moving outline” and $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ for “changing field”.

And further “We know in physics not one such example, if simple and precise general law required for its present understanding analysis in the terms of two different phenomena. Usually so beautiful of the generalization proves to be of outgoing from the united the deep that being basic the principle of. But in this case of any separately deep principle it is not evident” (end of the quotation).

But physics this is not grammar, and if from the law are exceptions, then law either is not accurate or not complete. When Faraday opened

his law, still were not known the Maxwell equations, were not known electromagnetic waves, those more were known the laws of the propagation of electromagnetic waves in the long lines. And now, when these equations and laws are known, came the time of the examination of the contradictions indicated. To there remains only be surprised, why the questions indicated, which lie practically on the surface, are up to now examined they were not examined.

Relationship, which presents the law of the Faraday induction, does not contain information about how arose fields in initial fixed IMS. They describe only laws governing the propagation and conversion pour on in the case of motion with respect to the already existing fields. let us demonstrate, as behaves relationship

$$\vec{E} = [\vec{v} \times \vec{B}] = \mu_0 [\vec{v} \times \vec{B}] \quad (1)$$

in practice.

Let us take long the solenoid (Fig. 1.), diameter which considerably less than its length let us introduce into its winding current.

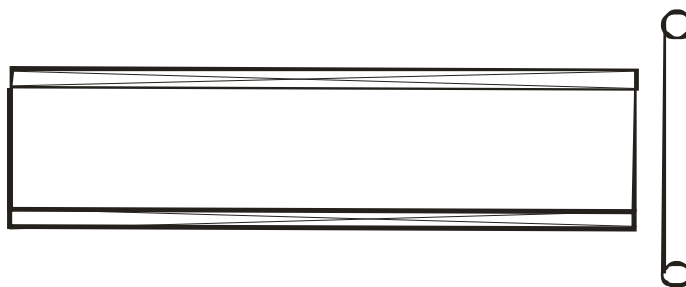


Fig. 1. Solenoid of from by the superconducting ring .

This inside the solenoid and at its ends will appear the lines of force of magnetic field..

Let us take of superconducting the ring and let us begin to dress its to the solenoid. If we look to the solenoid and the ring on top, then the magnetic fields of solenoid and currents in the solenoid and the ring will appear, as shown in Fig. 2.

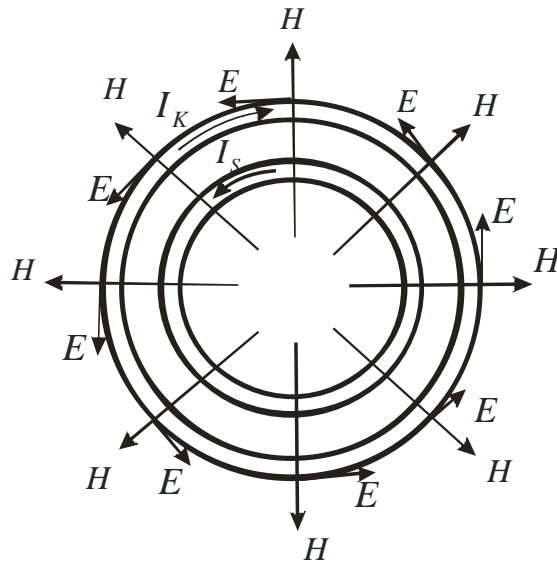


Fig. 2. Solenoid of of from of by the superconducting of ring of.

In the figure by radial vectors are designated the radial components of magnetic field near the upper edge of solenoid. If we lower ring some with the speed of \vec{v} , then to the charges in the ring will act electric field (1), which will accelerate charges in the Ger. It is clear that it is possible to attain this effect not only by dressing ring to the solenoid, but also sliding solenoid into the ring. With the reverse process electrical induction fields will be opposite sign, they will extinguish current in the ring, when it is completely taken from the solenoid.

Such to the procedure along the outline the ring will be induced the circulation the electrical the field

$$\oint \vec{E} d\vec{l} = \oint [\vec{v} \times \mu_0 \vec{H}] d\vec{l} .$$

If we ring open, and to connect to its ends voltmeter, thus will fix EMF, which is the result of the mechanical displacements of the extended turn. This the principle is used into all electromechanical the generators.

In law

$$\oint \vec{E} d\vec{l} = - \frac{d\Phi_B}{dt} = \mu_0 \int \frac{d\vec{H}}{dt} d\vec{s} \quad (2)$$

used complete time derivative. This means that for obtaining the circulation of electric field is not important the method of changing the magnetic flux,

i.e., magnetic flux can change both due to the motion of outline in the three-dimensional changing magnetic field and due to a local variation in the time.

In order of to pass from integral the relationships to by the local, as we already previously spoke, is introduced of vector of the potential the magnetic the field :

$$\Phi_B = \mu_0 \oint \vec{A}_H d\vec{l}$$

and further

$$\vec{E} = -\mu_0 \frac{\partial \vec{A}_H}{\partial t}$$

It should be noted that in some text books, for example in [1], vector potential is introduced with the aid of the relationship

$$\Phi_B = \oint \vec{A}_H d\vec{l} , \quad (3)$$

then

$$\vec{E} = -\frac{\partial \vec{A}_H}{\partial t} , \quad (4)$$

Again let us take long the solenoid and let us surround its by that extended by the turn (Fig. 3).

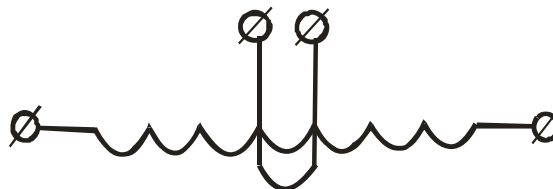


Fig. 3. Long the solenoid surrounded extended by the turn.

Since magnetic field inside the solenoid is defined by the relationship $H = nI$, where I - current in the solenoid, and n - a quantity of turns not the unit its length, magnetic flux inside the solenoid to be defined as

$$\Phi_B = \pi r_0^2 \mu_0 n I,$$

where r_0 - radius the solenoid.

Using the relationship (3), we obtain

$$\oint \vec{A}_H d\vec{l} = \pi r_0^2 \mu_0 n I,$$

from this relationship follows that at any point r out of the solenoid the absolute value of vector potential will be determined by the equality

$$A_H = \frac{\mu_0 n r_0^2 I}{2r}. \quad (5)$$

This indicates, that along the solenoid gird concentric the circle the circulation the vector of the potential. With this magnetic the field is located of only inside of the solenoid, and outside its there are no.

Using the relationships (4), we obtain electrical induction the field out the solenoid:

$$E = -\frac{\mu_0 n r_0^2}{2r} \frac{dI}{dt}. \quad (6)$$

Let us look, that apropos the diagram the formation of electrical pour on inductions around the long solenoid written in the work [1]. In the fifth the volume on page 286 is given the formula (14.27) for the vector the potential out the long the solenoid. Is evident, that it coincides from by the equality (5). Is discovered the sixth that and on page 21 we read: «You remember that if there is a long solenoid, along which flows the electric current, then the field \vec{B} exists inside it, but no outside the field whereas the set the vectors \vec{A} they circulate outside the solenoid (Fig.15.6)» (end of the quotation). In the figure is drawn the long solenoid, through cross section of which the lines force of magnetic induction are passed, and the concentric circles the circulation of vector potential are drawn around the solenoid. As in this case are obtained electrical induction fields we they already showed, after obtaining relationship (6). And this the point the

sight against to nature pour on the induction it has the place into all the existing textbooks. But of is accurate it?

If we to the solenoid connect of the source EMF U , then, as it was considered earlier, current in it will begin grow according to the linear law

$I = \frac{Ut}{L}$, where L - inductance of solenoid. Differentiate current on the

time and substituting it in equality (6), we obtain:

$$E = -\frac{\mu_0 nr_0^2 U}{2r L} .$$

This means that the voltage source is as soon as connected to the solenoid and the current in it beginnings grow according to the linear law, instantly around the solenoid it appears the circulation of electric field. This the fact causes the bewilderment. Moreover, with the calculation the energy, stored up in the solenoid, only magnetic fields are considered, and energy of electrical pour on, that arose thus mysterious, it is not considered. Consequently, these mysterious the field and energy not possess. Is certain, this the interpretation the appearance electrical pour on the induction around the solenoid not it is acceptable. This absurd result is connected with the fact that we they assumed that current in all turns of the solenoid, whatever it length had, it grows synchronously.

All this means that the Faraday induction law (2), recorded in the particular time derivatives in that version, as it is understood now, it is not accurate.

Currents cannot arise simultaneously in all turns of solenoid, but their appearance in that diagram, which is shown in the figure it begins at the beginning of solenoid, and this current wave is propagated on solenoid at a velocity, determined, including and by its linear inductance. And how was not short solenoid, this process will occur. In this consists the basic contradiction of the law of the Faraday induction.

[1] Фейнман Р., Лейтон Р., Сэндс М. Фейнмановские лекции по физике. М: Мир, 1977.