About magnetism (review)

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Abstract: In this paper, the problem was considered contradictions magnetic Coulomb's law and the Bio-Savar-Laplass, and the question was raised about the physical sense of the magnetic vectors. The problem of finding the equilibrium described by the distribution of the surface and volume of stationary currents in a solid body. We analyzed the equilibrium state of a two-phase thermodynamic equilibrium system in the case of the classical theory of the two-fluid Gorter-Casimir, taking into account the magnetic field. It is expected that the results obtained in the course of research, can be used for further development of a modernized classical theory of superconductivity

1. Introduction

Despite huge progress in practical use of magnetism (from compasses to computer memory), the nature of this complex structure remains not clear till present. It is enough to mention a problem, the bound that still it is not possible to reduce to uniform physical and consistent model magnetic Coulomb's laws (permanent magnets) and Bio-Savar-Laplass (the field of direct currents) which are the cornerstone of phenomenological approach to magnetism. And though they describe in a resultant way the same material physical structure - the magnetic field, and the nature of this phenomenon common, however are not connected among themselves at all that very surprisingly (in any case this communication till today did not manage to be found). In work of authors [1] the modified set of equations of Maxwell is presented in the complex form. In it an attempt to three pairs of the free electric, polarized and magnetic density of charges and currents is made: \((\mathbf{j}_e, \mathbf{\rho}_e), (\mathbf{j}_p, \mathbf{\rho}_p), (\mathbf{j}_m, \mathbf{\rho}_m)\) to add the formal molecular current density which does not result in clear physical results \(\mathbf{j}_{mol}\) in a look that.

\[
\frac{\partial \mathbf{\rho}_{mol}}{\partial t} = -\mathbf{div}\mathbf{j}_{mol} = -\mathbf{divrot}\mathbf{M} = 0
\]

From our point of view one of the reason is the following circumstance. Law B.-S.-L. differentially in essence it cannot be checked. It is experimentally possible to check only an integral form. From mathematics it is well known that on value of a particular integral it is impossible to remove a type of an integrand. Therefore, most likely, it is impossible to be differential ratios the basis for the theory of magnetism. This circumstance indicates that, probably, the padding research with audit of basic concepts is required here.

Constitutive equations of a magnetostatics as a result of initial empirical laws and defining characteristics of permanent magnetic fields look as follows:

\[
\begin{align*}
\mathbf{rot}\mathbf{H} &= 0 \\
\mathbf{div}\mathbf{B} &= 0
\end{align*}
\]

Taking into account

\[
\frac{\mathbf{B}}{\mu_0} = \mathbf{H} + \mathbf{M} \quad \text{and} \quad \mathbf{j}_{mol} = \mathbf{rot M}
\]

easily the equations to which a magnetic induction submits
\[ \begin{align*}
\text{rot} \, \vec{B} &= \mu_0 \vec{j}_{\text{total}}, \\
\text{div} \, \vec{B} &= 0
\end{align*} \]

Here \( \vec{j}_{\text{total}} = \vec{j} + \vec{j}_{\text{mol}} \), from which follows that the single source of a magnetic field is the total electric current which is the sum of the routine current of conduction flowing in the environment estimated conducting, and molecular current. Let's notice that the similar form of record is convenient that in this case it is possible to consider current of superconducting electrons. This circumstance was taken into consideration at calculation of the surface currents of a superconducting sphere [2-4], a current distribution in the superconducting site of a cylindrical wire [5] and rigorous conclusion of a depth of penetration of a magnetic field in a superconductor (a constant London’s) [6].

For a magnetic intensity taking into account \( \rho_m = -\text{div} \vec{M} \) the system \[ \begin{align*}
\text{rot} \, \vec{H} &= \vec{j} \\
\text{div} \, \vec{H} &= \rho_m
\end{align*} \]

from which follows that sources of a magnetic field are the latent magnetic electricities and currents of conduction turns out.

Analyzing the received systems it is possible to try to formulate physical sense of magnetic vectors and as follows. What of this magnetic fields should be considered the true magnetic field of the magnetized exemplar? Often in the modern physical literature answer this question as follows. Magnetization of an exemplar, on Ampere’s hypothesis, is manifestation of the available intramolecular and intratomic electric currents, that is, eventually, is bound to magnetism of currents. Therefore the magnetic field of \( \vec{B} \) is the true magnetic field, it makes actual physical sense while the magnetic field of \( \vec{H} \) in an exemplar does not make physical sense. This formal mathematical field. Such categorical answer, apparently, is not right as from the atomic and molecular point of view, except magnetism of intramolecular and intratomic electric currents, there is a magnetism of spin magnetic electrical dipole moments of electrons and atomic kernels. The last, as we know, to magnetism of electric currents cannot be reduced, apparently. To answer a question of that, properly to define the true magnetic field in the magnetized material, it is necessary to leave, apparently, phenomenological approach and to be engaged in examination in each concrete situation of the microscopic atomic and molecular physical nature of a vector of magnetization of \( \vec{M} \). As it is represented, only thus it is possible to hope to understand the true physics of vectors \( \vec{H} \) and \( \vec{B} \).

2. Theoretical analysis

The thermodynamic hypothesis of Gibbs allowing to solve a problem by means of the magnetic principle of the virtual works was applied to finding of an equilibrium distribution of the surface and volume stationary currents in a continuous body in work [7]. The variation of a magnetic field energy was considered with the side conditions defining constancy of currents, two of which having differential character are necessary and sufficient for the solution of a task in case of the singly connected body. If the considered body doubly-connected (a torus, a thick ring) appears it is necessary still one-integral condition. In work it was shown what this condition at the same time providing a condition of uniqueness of the decision can be or constancy of current of the torus proceeding through a transverse section or a task of constant rate of a magnetic induction through a torus opening. At problem definition
the first option as more visual was chosen. The problem was solved with the help of a method of Lagrangian multiplicities.

The basic and a little unexpected result was that circumstance that an induction of a magnetic field and volume current in volume address in zero. I.e. the magnetic field together with currents is squeezed out on a surface. The free current has the surface character and for searching of its density the boundary value problem on finding of a certain multifunction is solved. The issue of a uniqueness is resolved as follows. It is shown that in case of the singly connected bodies except two mentioned above it is not necessary to impose any side conditions – the decision and so it appears the unique. The doubly-connected area requires a side condition in a look: or the task of integral current which uniquely determinates circulation of a magnetic displacement vector or is set a stream of a magnetic induction through a torus opening.

In work [8] it is shown that as such side condition it is also possible to record value of magnetic electrical dipole moment of an equilibrium distribution of currents. Considering that realization of the main result requires and enough only constancy of currents which can be reached, apparently, or an adjustable feeding device or considering Wednesday with a small ohmic resistance (in particular, superconducting structures), it was interesting to consider communication of the received results with Meyssner-Oksenfeld's effect and the equation London’s applied in the classical theory of superconductivity. The further research of the received results in of connection with the appeared analogy to made mention effect is executed in work [9]. The detailed analysis of the classical phenomenological theory of superconductivity London’s was for this purpose carried out and the incorrectness of a conclusion of a basic set of equations and unsubstantiality of the assumption of an irrotational flow of liquid of superconducting electrons was shown. On the basis of what the conclusion was drawn that for superconductors it is impossible to uniquely determinate a vector of a magnetic intensity as it is not clear how to divide superconducting current into current of conduction and current of magnetization.

Taking into account the results received for constants in time of currents in materials with big conduction the conclusion is drawn that currents and a magnetic field are squeezed out on a surface, i.e. there are only surface currents. The actually surface current just needs to be considered as the current flowing in thin, but terminating thickness a layer which and can be considered as a field depth of penetration. Thickness of a made mention layer was received proceeding from dimensional reasons. The result in received at the same time a case of different force systems coincided with thickness London’s that indicates consistency of an initial hypothesis.

Since, a phenomenological electrodynamics of superconductors is constructed on the basis of classical representations, and, despite outstanding successes in an explanation of this phenomenon, the partial classical theory demands essential specifications and improvements. Taking into account the received results it was important to analyse basic laws of an electrodynamics of liquid of superconducting electrons again. In work [10] are removed in a Si-system of a Poynting theorem (law of conservation of energy) and Abragam (law of conservation of momentum) for a true liquid of superconducting electrons. It was shown that an apparent density of a mechanical impulse in an immediate look is not included into the end
result, it is considered through a stress tensor. Let's notice that purely convective stream of an impulse which flows in volume together with electronic liquid is also considered.

Using concepts of a fluksoid and superpotential of work [11] it was established that the ratios connecting density of superconducting current in each point and vector potential of a constant magnetic field in case of the singly connected superconductors are prime record of the constitutive equations London’s. As fluksoid, being function, the bound to superconducting carriers, it is unambiguous along any selfcontained trajectory describing an opening there was opportunity for analogy to a case of wave functions of atomic electrons to accept a quantization rule of the Bohr – Sommerfeld and to demand that for each superconducting electron the condition was satisfied: \( \oint p_s \, dl = n h \) where \( p_s = e \Lambda j + e A = m \dot{v} + + e A \) a so-called "initial" impulse of a superconducting electron in an electromagnetic field.

I.e.: \( \oint e \Lambda j \, dl + \oint e A \, dl = \oint e \Lambda j \, dl + e \Psi = n h \), where \( \Psi \) – the complete magnetic flux. At the long distances from an opening exceeding a field depth of penetration the first item it is close to zero and we receive a quantization rule of a magnetic flux in superconductors: \( \Psi = \frac{n h}{e} \). Thus, the well-known condition of quantization for superconductors, as expected, can take place at a small, but terminating thickness of the surface layer.

Further the analysis of equilibrium standing of equilibrium system two-phase thermodynamic in case of the classical double-fluid theory of Gorter-Kazimir taking into account a magnetic field was carried out [12].

Rigorous mathematical conclusion of conditions of thermodynamic magnetic equilibrium is considered for the isolated system for that prime reason that for it the known thermodynamic principle of Gibbs allowing to find in general any equilibrium conditions in what – it is necessary physical and physical and chemical situations, in particular conditions of interphase equilibrium is fair. At the solution of an objective the method of Lagrangian multiplicities was used by analogy with the magnetic principle of the virtual works for the free currents [7].

Due to the aforesaid there was a need of the detailed analysis of quantum mechanical behavior of ensemble of electrons for wide temperature range, in particular, the further analysis of thermodynamic characteristics [13]. In this work an attempt of the detailed analysis of the specified properties was made, having taken as a basis the quantum mechanical description on the basis of operators of secondary quantization, how to do it for electric properties of a solid body at low temperatures.

Taking into account the previous researches conditions of a thermodynamic equilibrium of expression for thermodynamic potentials, entropies and thermal capacities in wide temperature range were removed. As it seems to us, it makes sense to apply the received results to further attempts of development of the upgraded classical theory of superconductivity.

The method of secondary (double) quantization was also applied in work [14] at a conclusion taking into account a perturbation theory in the second order of smallness of a diamagnetic constant of Landau.
Let’s note that authors in the quoted works (as far as possible) applied an international system of units (SI) though as it seems to us, in sections of physics of the directly bound to an electromagnetism, use of an absolute (Gaussian) force system as the last meets the modern expectations of the nature of the electromagnetic phenomena much more would be most expedient. Electric and magnetic fields are bound among themselves, moreover, they can be considered two symmetric characteristics of the same physical object. But at the same time dimensions of all sizes (strength and an induction of this field) different that in itself is already unnatural. For overcoming this discrepancy it is also necessary to enter simulated coefficients which discussion of physical sense continues and now. Especially, as it is visible, is shown by consideration of classical questions of magnetism, such as monopoles of Dirac or classical phenomenological theory of superconductivity. Probably, that these concepts are entered and discussed in books and articles on theoretical physics which qualified authors, as a rule, adhere to absolute system in which the received results look more naturally and therefore work with these sections in a Si-system constantly leads business to selection of necessary coefficients.

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