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A session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on January 21, 1971, in the Conference Hall of the P. N. Lebedev Physics Institute. The following papers were read at the session:

1. **S. I. Syrovatskiĭ**, Current Sheets in Cosmic and Laboratory Plasmas.
2. **G. S. Krinchik**, The Optics of Ferromagnets.

We publish here brief summaries of the papers presented.

S. I. Syrovatskiĭ. Current Sheets in Cosmic and Laboratory Plasmas

The dynamics of a plasma in a magnetic field, even in the hydrodynamic description, is incomparably richer, with respect to the diversity of the types of motion, than ordinary gas dynamics. This range of questions has not yet been studied well and we are sometimes in essence nonplussed by quite simple phenomena. The point is that the investigation of the general magnetohydrodynamic problem is extremely complicated and is usually considered in diverse approximations.

The weak-field approximation, in which the magnetic strains ($\sim H^2/8\pi$) are small compared to the kinetic (nkT) and dynamic ($\rho v^2/2$) pressure of the plasma, is often used. For example, the problems of the generation and intensification of a field by a magnetohydrodynamic dynamo process or by turbulence are considered in this approximation. However, from the point of view of dynamics, these problems are not outside the framework of ordinary gas dynamics since the inverse effect of the magnetic fields is neglected.

Specifically new effects arise in the opposite limiting case of strong fields ($H^2/8\pi \gg nkT, \rho v^2/2$), and this admits formally of quite a rigorous analysis, allows us to develop our intuition in this new range of problems, and yields a number of concrete results for the physics of laboratory and cosmic plasmas. The regions of applicability of this approximation are stellar and planetary atmospheres and high-current discharge laboratory plasmas.

We consider the plane two-dimensional problems, when the intensity of the magnetic field can be expressed in terms of a single component, $A(x, y, t)$, of the vector potential. In the zeroth approximation, the strong field is a potential field, i.e., $\Delta A = 0$ and A is a harmonic function, which allows us in determining the field from the prescribed external sources to use the formalism of the theory of functions of the complex variable. For the field thus found, the problem is completely solvable if we use the freezing-in condition ($dA/dt \equiv \partial A/\partial T + \mathbf{v} \cdot \nabla A = 0$) and the condition of transversality of the acceleration (i.e., of the absence of forces along the magnetic lines of force: $dv/dt \parallel \nabla A$). An exception to this are the singular neutral points of the magnetic field, at which $|H| = |\nabla A| = 0$ but the electric field $E = -\partial A/c\partial t \neq 0$; the equations are inconsistent at these points, i.e., the freezing-in equation cannot be satisfied.

The problem is solvable when the assumption is made that the singular neutral points generate regions of nonlinearity of the solution. It is shown that these regions should be cuts in the complex plane, i.e., current sheets in the plasma. A rule for drawing the cuts and a method for calculating the field outside the cuts are given.

The proposed method is applied to the case of an isolated neutral point (see Figs. 1 and 2), and the results of an experiment on the flow of a plasma in the neighborhood of a neutral line, performed by A. G. Frank and A. Z. Khodzhaev, are discussed

Possible applications to the physics of the Sun and the magnetosphere are indicated: the structure of the

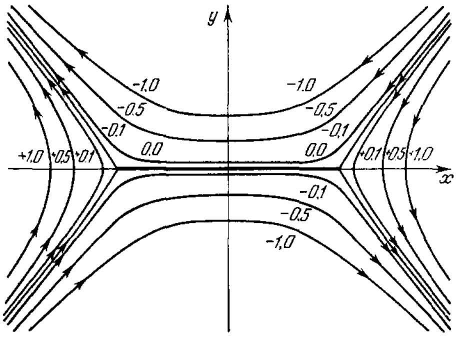

FIG. 1. Magnetic field in the neighborhood of a current sheet (heavy line) in the absence of reverse currents. The numbers indicate the values of the potential A on the corresponding lines of force. In this case the total current in the sheet is a maximum for a given width of the current sheet.

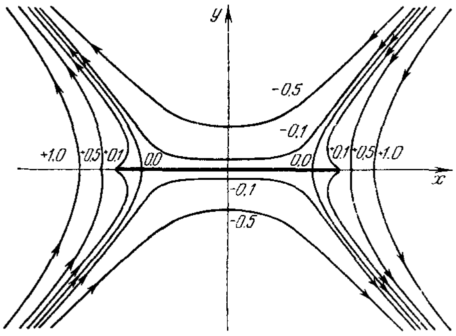

FIG. 2. Same as in Fig. 1, but in the presence of reverse currents. The total current is 0.2 of the maximum for a fixed width of the cut.

coronal rays and helmets on the Sun, the structure of the field during solar flares, and a two-dimensional model of the Earth's magnetosphere.

The main results of the work will be published in JETP.

G. S. Krinchik. The Optics of Ferromagnets.

Three concrete examples are used in the report to demonstrate the effectiveness of the application of optical methods in the investigation of ferromagnets.

1. The electron-structure model of ferromagnetic with a reverse level order. The foremost problem in the physics of ferromagnetism today is the problem of the quantitative determination of the band structure of ferromagnetic metals, of which ferromagnetic nickel is the most widely studied both experimentally and theoretically. The initial attempts were directed at the construction of an electron-structure model for nickel by analogy with copper. However, on the basis of a magneto-optical investigation of nickel[1], a model with a reverse order (with respect to copper) of the d- and p-bands at the L point in the Brillouin zone was proposed. The results of this model are: the characteristic frequencies of interband transitions, the disappearance of hole pockets at the L point, the appearance of a region of strong hybridization of the d- and p-bands in the vicinity of the Fermi level, a distinctive behavior of the hole pockets at the X point, etc. At the present time, the model with a reverse level order has been confirmed by direct theoretical calculations[2] and independent experiments[3] and is a generally accepted model.

2. Orientational magneto-optical effect. Since the orbital angular momenta in ferromagnetic d-metals are "quenched," while the orientation of the spin angular momentum—the saturation magnetization I—can be changed by an external magnetic field, the rotation of I leads to considerable (of the order of 0.1 eV) changes in the band structure of a ferromagnetic metal on account of the spin-orbit coupling. There arises, in principle, a possibility for observing this change through the interband transition frequencies by means of optical methods. The indicated magneto-optical effect, whereby the electronic structure of a ferromagnetic metal changes with rotation of I, was experimentally discovered in[4] and was called orientational magneto-optical effect (OME) in[5]. OME is the change in the intensity of reflected light which is quadratic in the component of the magnetization perpendicular to the incidence plane of the light[5]. Let us compare the OME, in order of magnitude, to the ordinary odd equitorial magneto-optical Kerr effect (EKE). It is shown in[6] that the OME is strongly anisotropic when the EKE is totally isotropic. The OME is characterized by a distinctive frequency dependence with multiple changes in sign, by a characteristic spin-orbital fine structure of the maxima, etc.[6]

Three types of changes in the band structure which can lead to orientational effects are considered in[7]. These are: 1) spin-orbital splitting of the degenerate d-bands in the vicinity of definite symmetry lines; 2) spin-orbital removal of the incidental degeneracy of intersecting bands; 3) the formation or disappearance of hole pockets under the action of the spin-orbit interaction. The third mechanism, although very strong, is exotic. A specific analysis shows that for a fixed frequency the interband transitions for changes of the type (2) occur in a considerably larger—with respect to volume—region of the Brillouin zone than for changes of the type 1). In the case of 1) this is approximately a sphere of volume $4\pi\delta^3/3$, while in the case 2), it is a toroid of volume $2\pi r\delta^2$, i.e., a ratio of volumes of the order of r/δ, where $r \gg \delta$. Therefore, the second mechanism is apparently the principal mechanism in the OME. The prospect of the OME for the study of the ferromagnetism of metals can also be characterized by the following example. In[7] a concrete interband transition of the type 2) is indicated, which is identified with an OME peak at $\hbar\omega \approx 0.4$ eV and for which the quantity $\hbar\omega$ is numerically equal to the exchange splitting of the 3d-band, independently of the details of the band structure. Thus, we obtain a direct method for a spectroscopic determination of the magnitude of the exchange splitting, as well as the possibility of studying the variation of this most important—for ferromagnets—quantity under the influence of diverse factors in metals and alloys.

3. The magnetic susceptibility of ferromagnets at optical frequencies. Magneto-optical methods were used in[8] to observe and measure for the first time the effect of magnetization by light of ferromagnetic dielectrics—from garnets—and of the ferromagnetic metal—iron. The magnetic susceptibility of these ferromagnets for circularly polarized light $\kappa_{\pm}^{\text{opt}}$ turned out to be equal to 10^{-4}—10^{-5}. For transparent ferromagnets this result did not give rise to doubts and was subsequently repeatedly confirmed, but for ferromagnetic metals one more measurement of $\kappa_{\pm}^{\text{opt}}$ [9] was made which resulted in overestimated values of $\kappa_{\pm}^{\text{opt}}$ (roughly by two orders of magnitude. The inaccuracy of[9] was recently demonstrated and the result obtained in[8b] confirmed in[10]. The question arises in connection with the possibility of the correct determination of $\kappa_{\pm}^{\text{opt}}$ as to what use this effect may be put. In transparent ferromagnets, we can, by measuring $\kappa_{\pm}^{\text{opt}}$, determine the g-factor of magneto-active ions[8a]. In ferromagnetic metals by measuring the function $\kappa_{\pm}^{\text{opt}}(\omega)$, we may hope to detect an exchange resonance—the optical mode of spin oscillations.[1a] It is proposed in[11] that the measurement of $\kappa_{\pm}^{\text{opt}}$ should be used to detect the exchange resonance in ferrites and the magnetic modes localized on impurities. In[12] the intensity of infrared-light scattering by spin waves, the concentration of which can be increased by several orders of magnitude by pumping, is calculated.

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[2] J. W. D. Connolly, Phys. Rev. 159, 415 (1967); E. I. Zornberg, Phys. Rev. 1B, 244 (1971).

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