GALVANO-MAGNETIC EFFECTS IN METALS WITH NEARLY EQUAL NUMBERS OF ELECTRONS AND HOLES

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A general theory of galvanomagnetic effects in metals, which explains the asymptotic behavior of the resistance tensor ρ_{ik} in high magnetic fields, is developed in reference 1. It has been shown that all metals (with closed Fermi surfaces) can be divided into two groups; one (Cu, Na, In, Al, . . .) with unequal number of electrons (n_1) and holes (n_2), and one (Bi, Be, Zn, Mg, . . .) with $n_1 + n_2$.*

Besides these limiting cases, we would expect approximate equality of the number of electrons and holes (i.e., $n_1 \approx n_2$) for a number of metals with small impurity content.[2] The relative difference $\Delta n/n$ ($\Delta n = n_1 - n_2$; $n = (n_1 + n_2)/2$) is a parameter which enables us to express the dependence of the resistance tensor on the magnetic field.

A calculation analogous to that described in reference 1 leads to the following results for the resistance ρ and the Hall constant R:

$$\rho \approx \rho' \frac{(H/H_1)^2}{1+\left(\frac{\Delta n}{n}\frac{H}{H_1}\right)^2}, \qquad H \gg H_1; \tag{1}$$

$$R \approx \frac{1}{nec}\frac{a+\frac{\Delta n}{n}(H/H_1)^2}{1+\left(\frac{\Delta n}{n}\frac{H}{H_1}\right)^2}, \qquad H \gg H_1; \tag{2}$$

$H_1 \sim m^*c/et_0$ (the notation is the same as in reference 1). The parameters ρ', H_1, and a depend on the angle between the magnetic field and the crystallographic axes, with a on the order of unity.

From (1) and (2) we obtain

$$\rho = \begin{cases} \rho'(H/H_1)^2 & (H_1 \ll H \ll H_1|n/\Delta n|) \\ \rho'(n/\Delta n)^2 & (H \gg H_1|n/\Delta n|) \end{cases}, \tag{3}$$

$$R = \begin{cases} \frac{a}{nec} + \frac{\Delta n}{n^2ec}(H/H_1)^2 & (H_1 \ll H \ll H_1|n/\Delta n|) \\ \frac{1}{\Delta nec} & (H \gg H_1|n/\Delta n|) \end{cases} \tag{4}$$

We note furthermore that the present results agree well with the experiments of Alekseevskii, Brandt, and Kostina[2] on bismuth with small concentrations of impurities. In fact, independently of the law of dispersion, the ratio $HE_y/E_x = H^2R/\rho$ (see reference 2) varies linearly with the square of the magnetic field, and the sign of the coefficient of H^2 is determined by the sign of Δn.

***Note added in proof (September 1, 1958). Recent results of I. M. Lifshitz and V. G. Peschanskii on the one hand, and of N. E. Alekseevskii and Iu. P. Gadukov on the other, show that the division of metals into two groups is very provisional.[1] Apparently many metals have open Fermi surfaces.**

[1] Lifshitz, Azbel', and Kaganov, J. Exptl. Theoret. Phys. (U.S.S.R.) **31**, 63 (1956), Soviet Phys. JETP **4**, 41 (1957).

[2] Alekseevski, Brandt, and Kostina, Dokl. Akad. Nauk SSSR **105**, 46 (1955).

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224

TRANSITION FROM THE ANTIFERROMAGNETIC INTO THE FERROMAGNETIC STATE IN $CoSO_4$

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We have investigated, jointly with Karasik,[1] the magnetic properties of anhydrous polycrystalline $CoSO_4$. We have established that this substance goes into an antiferromagnetic state near 15°K. In the present investigation we prepared single crystals of anhydrous $CoSO_4$ by weighing approximately 1.5 milligrams, using a procedure previously described.[2,3] The magnetic properties of these single crystals have been investigated at temperatures from 1.3 to 70°K. The crystals were obtained in bipyramidal form. The measurements were made along the axis joining the vertices of the pyramid (the c axis) and along axes that are coincident with the sides of the base