discrepancy factor $\Sigma||F_{obs}|-|F_{calc}||/\Sigma|F_{obs}|$ was 9.4 percent for the initial parameters and 5.9 percent for the final ones.

The results show conclusively that the arrangement of hydrogen atoms is ordered. The hydrogen atoms are situated 1.07A from oxygen atoms O_1, nearly along the hydrogen bonds. The length of the phosphorus-to-hydroxyl-oxygen link is 1.56A, while that of the other P—O link is slightly shorter, 1.53A. The length of the hydrogen bond, O—H$\cdots$O, is 2.50A. All of these distances are close to those existing in the tetragonal room-temperature modification, where the hydrogen atoms are probably disordered.[6]

Some of the parameters for oxygen derived here differ by small but possibly significant amounts from those given by x-ray diffraction.[2] Should these differences prove to be real, they may indicate that some of the atomic nuclei are displaced away from the centroids of the extranuclear-electron clouds. Such displacements might play a significant role in the ferroelectric behavior of this crystal.

* Work performed at the Oak Ridge National Laboratory under the auspices of the U. S. Atomic Energy Commission.
† Research participant, Oak Ridge Institute of Nuclear Studies, summer of 1952.
[1] J. Waser and V. Schomaker, Revs. Modern Phys. 25, 671 (1953).
[2] B. C. Fraser and R. Pepinsky, Acta Cryst. 6, 273 (1953).
[3] A. D. Booth, Proc. Roy. Soc. (London) A188, 77 (1946).
[4] Because of overlapping peaks, the (hhl) projection cannot yield all the atomic parameters independently. Throughout this treatment, the assumption was made that $x+y$ for O_1 is equal to $y-x$ for O_2, in agreement with the x-ray result (reference 2) and that $x+y$ for H has the same value. The latter assumption places H in a plane parallel to c passing through the hydrogen-bonded oxygen atoms.
[5] Shoemaker, Donohue, Schomaker, and Corey, J. Am. Chem. Soc. 72, 2328 (1950).
[6] Peterson, Levy, and Simonsen, J. Chem. Phys. 21, 2084 (1953); G. E. Bacon and R. S. Pease, Proc. Roy Soc. (London) A220, 397 (1953).

Theory of the Galvanomagnetic Effects in n-Germanium

S. MEIBOOM AND B. ABELES
Weizmann Institute of Science, Rehovot, Israel
(Received December 21, 1953)

SEITZ[1] has computed the galvanomagnetic constants of germanium, assuming spherical energy surfaces in momentum space and a relaxation time with cubic symmetry. His results, however, do not fit the published experimental data.[2,3] Shockley[4] has suggested that the energy surfaces may be degenerate, but has not presented any explicit calculations.

We have carried through calculations for n-type germanium, based on the following assumptions: (1) The relaxation time is given by $\tau = L/\sqrt{E}$, where E is the energy and L a constant. (2) The energy as function of momentum (**P**) has a number of minima; electrons near each of these minima contribute to the conductivity; and the energy surfaces, near the minima, can be approximated by quadratic functions of **P**.

For brevity, we shall refer to these quadratic functions as ellipsoids. The ellipsoids must be arranged in the Brillouin zone so as to obtain the cubical symmetry of the germanium crystal. We have considered the two simplest models which fulfill this requirement: (a) three rotational ellipsoids, with rotational axes perpendicular to each other; (b) four rotational ellipsoids, with their rotational axes along the body diagonals of a cube.

Model (a) may result when the energy minima are situated at the center of the small faces, and model (b), when they are situated on the large faces, of the first Brillouin zone of the face-centered cubic lattice.[5]

Our calculations are based on the series expansion of the distribution function [e.g., Wilson,[6] Eq. (8.551.3)]. This equation is written in tensor form; terms in H^3 and higher are neglected. On our assumptions, the integrals giving the current [Wilson, Eq. (8.551.4)] can then be computed for each ellipsoid. The total current I is obtained by summing over all the ellipsoids. By inversion, we obtain an expression for E, as function of I and H, in which the coefficients are the galvanomagnetic constants. It was found that the experimental results for n-germanium cannot

be explained on the basis of model (a). Calculations based on this model result in zero longitudinal magnetoresistance effect in the (100) direction. However, a good fit can be obtained, using model (b). The only parameter appearing in the results is the ratio K of the effective masses, $K>1$ corresponding to prolate energy ellipsoids and $0<K<1$ to oblate. The results are:

$$R_H = (3\pi/8)[3K(K+2)/(2K+1)^2](1/nec),$$

$$L_{(100)} = (8/3\pi)R_H{}^2\sigma^2(2K+1)(K-1)^2/K(K+2)^2,$$

$$T_{(100)(010)} = (1/3\pi)R_H{}^2\sigma^2[K^2(16-3\pi)+K(16-6\pi)+4]/K(K+2),$$

$$L_{(110)} = (1/2)L_{(100)},$$

$$T_{(110)(1\bar{1}0)} = (1/2)L_{(100)}+T_{(100)(010)},$$

$$T_{(110)(001)} = T_{(100)(010)},$$

where the Hall coefficient is denoted by R_H; the conductivity by σ; the number of electrons in the conduction band by n; the

TABLE I. Comparison of theoretical and experimental magnetoresistance coefficients (in gauss^{-2}).

Coefficient	Calc[a]	Exp[b]
$L_{(100)}$	$1.91\cdot10^{-9}$	$1.92\cdot10^{-9}$
$T_{(100)(010)}$	0.91	0.90
$T_{(110)(001)}$	0.91	1.03
$T_{(110)(1\bar{1}0)}$	1.86	1.68
$L_{(110)}$	0.95	0.99

[a] Calculated for $K=20$; values for R_H and σ as found by Pearson and Suhl (reference 3) for their n-germanium sample at 300°K.
[b] Measurements of Pearson and Suhl on above sample.

longitudinal magnetoresistance coefficient by $L_{(ikl)}$ (the indices giving the crystallographic direction of I and H); and the transverse coefficient by $T_{(ikl)(mnp)}$ (the first set of indices giving the direction of I, and the second set, the direction of H).

Table I shows that the values obtained from these equations for $K=20$ compare closely with the measurements of Pearson and Suhl.[3]

In the equation for R_H, the numerical coefficient gives the ratio of Hall- to drift-mobility. Inserting $K=20$, the value of $0.79(3\pi/8)$ is obtained for this ratio.

Calculations were also made for the sample measured by Pearson and Suhl at 77°K. Agreement was somewhat less satisfactory. However, a better fit can be obtained by taking impurity scattering into account.

[1] F. Seitz, Phys. Rev. 79, 372 (1950).
[2] I. Esterman and A. Foner, Phys. Rev. 79, 365 (1950).
[3] G. L. Pearson and H. Suhl, Phys. Rev. 83, 768 (1951).
[4] W. Shockley, Phys. Rev. 78, 173 (1950).
[5] L. Brillouin, *Wave Propagation in Periodic Structures* (McGraw-Hill Book Company, Inc., New York, 1946), Fig. 37.11.
[6] A. H. Wilson, *The Theory of Metals* (Cambridge University Press, Cambridge, 1953), second edition.

Origin of Retrograde Motion of Arc Cathode Spots

A. E. ROBSON AND A. VON ENGEL
Clarendon Laboratory, Oxford, England
(Received December 29, 1953)

MINORSKY discovered that if a transverse magnetic field acts on the cathode region of a mercury arc, under certain conditions the cathode spot will move contrary to Ampere's rule.[1] The positive column necessarily remains attached to the spot but is always deflected in the Ampere direction. If the pressure is sufficiently low, the motion is retrograde, but changes to the Ampere direction if the pressure exceeds a critical value which is the greater the lower the current and the stronger the magnetic field. Hitherto no explanation of this effect has carried great conviction.[2] We believe that it can be understood as a classical electrodynamic problem.

Using a tube similar to Gallagher's, at a vapor pressure of ≈ 20 mm Hg and a current of ≈ 10 amp, we observed for moderate