Physics. — "*The effect of temperature and transverse magnetisation on the continuous-current resistance of crystallized antimony.*" By Dr. W. J. DE HAAS. Communication from the BOSSCHA-laboratory. (Communicated by Prof. DU BOIS).

(Communicated in the meeting of March 28, 1914).

Introduction. There exists an extensive literature on the effect of transverse magnetisation on the electric conductivity of different metals and metalloids. We may divide these into three groups i.e. 1. ferromagnetic, 2. paramagnetic, 3. diamagnetic substances. Other phenomena also suggest this grouping.

As to our effect, the substances mentioned in section 1 show distinctly measurable changes in the resistance. Those mentioned in sect. 2 however have been less investigated and until now give only exceedingly small effects [1]), the nature of which is very difficult to determine. In contrast with the HALL-effect, the ferromagnetic and diamagnetic substances show in our case a change in the resistance which is dependent on the direction of the field. For ferromagnetic substances a decrease and an increase of the resistance have been observed, while also the sign is dependent on the temperature [2]) at least for Swedish iron.

By far the most measurements have been made with conglomerates.

The diamagnetic substances on the contrary always show an increase of resistance with the temperature, not a change of this increase into a decrease. The curves, which represent the resistance as a function of the field have all the same character; sometimes the effect is very large. For example for bismuth in a field of 37 K.G. at $-190°$ C. $R'/R = 230$ [3]) and at hydrogen temperatures in a field of 17 K.G. $R'/R = 380$ [4]), while for graphite in a field of 40 K.G. and at the temperature of liquid hydrogen $R'/R = 130$ [5]). Until now the diamagnetic elements have been investigated; bismuth [6]), antimony [7]), carbon [8]) tellurium [9]) gold [10]), silver [11]), copper [12]), zinc [13]) lead [14]), cadmium [15]), mercury [16]).

1) L. GRUNMACH and F. WEIDERT, Ann d. Phys. **22**, p. 141, 1907.
2) H. KAMERLINGH ONNES and B. BECKMAN, Comm. Leiden. **12** N°. 132*a*, 1912.
3) H. DU BOIS and A. P. WILLS, Verh. d. D. Phys. Ges. **1**, p. 169, 1899.
4) H. KAMERLINGH ONNES, Comm Leiden, **12** N°. 129, 1912.
5) D. E. ROBERTS, Ann. d. Phys. **40**, p. 453, 1913
6) F. C. BLAKE, Ann. d. Phys. **28**, p. 449, 1909.
6) 10) 12) 16) H. KAMERLINGH ONNES and BENGT BECKMAN, Comm. Phys. Labor. Leiden **12** N°. 129, 130, 1912.
7) A. v. ETTINGSHAUSEN, Wien. Akad. Ber. **59**, p. 714, 1887.
PH. LENARD, Wied. Ann. **39**, p. 637, 1890.
10) 11) 12) 13) 14) 15) L. GRUNMACH and F. WEIDERT, loc. cit.
15) 13) 8) 16) 12) 10) 11) J. PATTERSON Phil. Mag. (6) **3**, p. 643, 1902.
9) 15) 13) 10) C. W. HEAPS, Phil. Mag. (6), **24**, p. 813, 1912, VI. **22**, p. 900. 1911.
8) 13) 15) S. C. LAWS, Phil. Mag. (6) **19**, p. 694, 1910.

A list of the literature on bismuth up till 1909 can be found in a paper by F. C. BLAKE [1]). Of the more recent experiments must be mentioned those of KAMERLINGH ONNES and BECKMAN [2]), who worked at temperatures down to — 258° C. Carbon has been investigated by ROBERTS, who also gives the literature.

There remains to be mentioned, that researches on crystallized specimens have been made in the Leyden laboratory on bismuth and by ROBERTS on graphite. These are very important, as the orientation of the principal axis has a great influence on the effect. It is principally from this side that we can expect some light on the otherwise unnecessarily complicated phenomena. However crystals have been investigated insufficiently. A method to obtain large metal crystals would certainly be of great use. So far reasonably large crystals have only been made with bismuth.

§ 1. Investigation of antimony.

We shall use the following notations.

R' Resistance in the field,

$R'//$ Resistance in the field, when the axis of the crystal is parallel to the field,

$R'_{\perp}$ The same with the axis perpendicular to the field,

R Resistance without a field, while the index at the foot indicates the temperature, at which the measurements have been made,

$\mathfrak{H}$ field.

Out of several antimony crystal conglomerates of MERCK the best specimens were selected; the material seemed to be very pure and according to the analysis contained less than $^1/_{10000}$ % iron. The pieces were split into thin plates along the basic planes, which were at the same time planes of perfect cleavage. These plates were then immersed in shellac and carefully polished into small rods. At both the ends of one of these rods (long 4 mm, broad 0.55 mm, thick 0.15 mm) two copperwires were soldered. These wires, were carefully insulated with shellac, and the two at one end were bent over the rod so that they came into the same direction as the other two. Then the whole, wires and rods, was slipped into a cylindrical glass tube of 0.8 mm diameter. The wires were then pulled through a brass capillary, in the end of which the tube was fitted. Perpendi-

1) F. C. BLAKE, Ann. d. Phys. 28, p. 449, 1909.

2) l. c.

cular to the brass capillary a needle was soldered. When the apparatus was mounted, so that it could be rotated, the needle passed a fixed scale, indicating in this way the orientation of the crystal axis in the field. The resistances were measured with a THOMSON bridge. As this method requires wire resistances small compared with the fixed resistance, in the arms of the bridge (110 ohms in each arm), the above mentioned wires, which were of necessity thin because the four of them had to pass through the glass and brass capillary, were kept as short as possible. When they had left the brass capillary they were soldered to very thick wires, leading to the bridge.

In the bridge a galvanometer of the type of DU BOIS and RUBENS was used. The magnet most used was a small half ring magnet of the newest type with water cooling. For some determinations a large model magnet was used. This new type enables a long series of measurements to be made without introducing an error due to rise of the temperature in the field.

For the resistance measurements at the temperature of liquid air the newly constructed vacuum cryoarmature on the immersion principle has been very useful [1]). In fact the combination of the strong fields up to 45 K.G. with low temperatures can easily be obtained; the field was only very slightly diminished by the gaps in the pole pieces in which the DEWAR vessel fitted. This strong field is partly due to the use of ferrocobalt for the pole pieces.

The magnetic field was measured by the usual ballistic method; nothing particular has to be remarked on this subject. For the estimation of the influence of the low temperatures on the field between the ferro-cobalt pieces the DEWAR vessel with the liquid air was quickly taken away and immediately afterwards the field was measured. This must be done very quickly, as the pole pieces become warm, while also the search coil cools down and at the lower temperature its area is smaller, (and just on this area is based the measurement of the field). Particularly the latter must be avoided as the coefficient of expansion of the material (a hard kind of colophonium) was not known. The coil had been compared previously with a carefully polished glass standard coil. [2]) The influence of the temperature on the field proved to be negligible.

The current through the magnet, was read on a precision instrument of SIEMENS and HALSKE. The resistance measurements were carried out at very short intervals. This was desirable to eliminate

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[1]) H. DU BOIS, Ann. der Physik. **42** p. 968, 1913.

[2]) See W. J. DE HAAS and P. DRAPIER, Ann. der Physik. **42**, p. 673, 1913.

the influence of fluctuations in the magnet current. The current was taken from the central Berlin lighting circuit net. The chief errors in the measurements were due to the temperature and to a less extent to the field measurement. An unfavourable circumstance is, that the effect is roughly proportional to the square of the field, so that an error in the field gets a double weight. When an accuracy of $^1/_2\,^0/_0$ is desired, the magnetic field must be known to $^1/_{000}$ and this accuracy is not so easily attained as is often supposed.

The purpose of this research was not to make very accurate measurements, but to see, whether in this case also the orientation of the crystal axis has a great influence. For graphite this has already been proved by D. E. ROBERTS (loc. cit.), for bismuth by VAN EVERDINGEN [1]) and LOWNDS [2]).

§ 2. *Temperature curve without field.* First the change of the resistance of antimony in the basic plane was investigated. The specific resistance was not determined because of the undefiniteness of the soldering places, which much diminishes the accuracy of the measurements. The different temperatures were reached on the principle of the HENNING [3]) cryostate. In a vacuum vessel with petroleum ether was put a tube, which was closed at the lower end. With a vacuum siphon this tube was filled with liquid air. This filling was not regulated automatically, but with the hand. The temperature was read on a pentane thermometer.

After some practice it was found that by good stirring the temperature could be kept sufficiently constant. Below $-140°$ the petroleum ether became thick, which made good stirring difficult and for this reason the lowest points were measured in the liquid air itself. At $-190°$ the curve $R/R_0 = (\theta)$ (fig. 1) does not yet show a point of inflexion. The greater the purity of the bismuth the lower the temperature at which the point of inflexion occurs and the weaker this point of inflexion. From this we may also conclude, that the antimony from MERCK was very pure [4]). From the observed values a formula $R = R_0(1 + \alpha\theta + \beta\theta)$ was calculated by the method of least squares.

Such a formula holds within this range of temperature. The formulae of NERNST, KAMERLINGH ONNES and WIEN have not been

[1]) E. VAN EVERDINGEN, Comm. Leiden, Nº. 26. 37. 40. 41. 42. 48. 53. 58. 61. 63. 72. Suppl. 2.

[2]) L. LOWNDS, Ann. der Phys. **6** p. 146, 1901; **9** p. 677, 1902.

[3]) F. HENNING, Zeitschr. f. Instrk. **33** p. 33, p. 1913.

[4]) F. C. BLAKE, loc. cit. Table I.

tied, partly because they do not refer to these low temperatures, partly because we have not, as far as they have been derived from the quantum theory, enough data, at least not for crystalline antimony.

Fig. 1 shows the curve R/R_0; except at $-32.9°$ it coincides very well with the experimental curve.

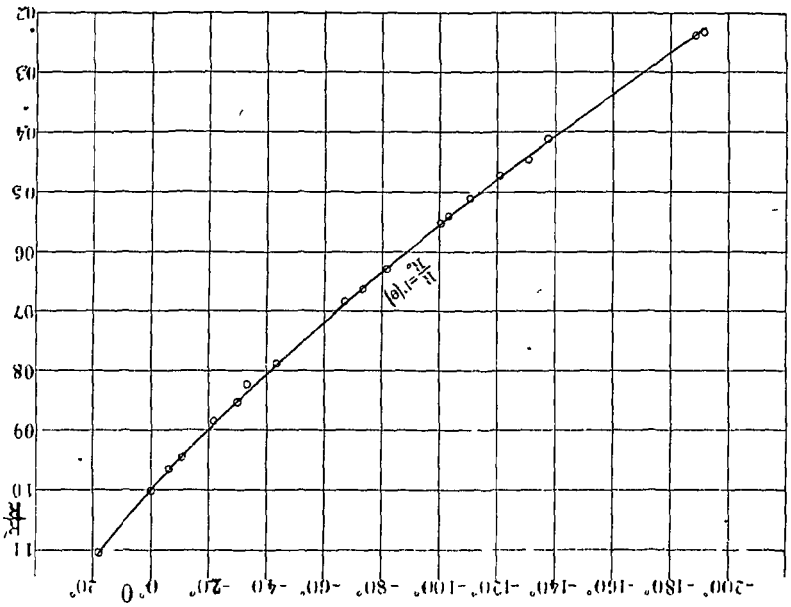

Fig. 1.

The values have been collected in table 1. The differences between the observed values and those calculated from the above mentioned formula with two coefficients are about 1%; it would be possible to get better agreement with a formula containing more coefficients but this was of no value since on account of the indefiniteness of the soldered joints an accuracy of 1% is as much as can be expected.

The values in table I have been calculated with the formula:

$$R = R_0 (1 + 0{,}005111\,\theta + 0{,}000005654\,\theta^2). \quad . \quad . \quad . \quad (1)$$

The linear coefficient of expansion is therefore somewhat greater in the basic plane than in other directions.

The "Recueil de Constantes Physiques" gives α 0,0039 [1]. This agrees with the measurements of EUCKEN and GEHLHOFF [2], who find for the electric conductivity of a cast stick of antimony at

$0°$	$-79°$	$-190°$
$2{,}565.10^4$	$3{,}568.10^4$	$9{,}56.10^4$

[1]) Recueil de Const. Phys. p. 584, 1913.

[2]) A. EUCKEN und G. GEHLHOFF, Verh. d. D. Phys. Gesellsch. **14**, p. 169, 1912.

TABLE 1.

θ C.	R/R_0 Observation	R/R_0 Calculation	O—C	%
18°	1.104	1.094	+ 0.01	+ 1%
0	1.000	1.000		
— 6.1	.962	.971	— .01	— 1
— 10.8	.942	.951	— .009	— 1
— 21.5	.883	.892$_5$	— .009	— 1
— 29.9	.851	.850	+ .001	+ 1/8
— 32.9	.822	.839	— .017	— 2
— 43.5	.787	.788	— .001	— 1/8
— 67	.684	.683	+ .001	+ 1/7
— 73	.663	.657	+ .006	+ 1/7
— 81	.626	.623	+ .003	+ 1/2
— 98.9	.545	.551	— .006	— 1
— 102.6	.537	.535	+ .002	+ 1/2
— 110	.507	.506	+ .001	+ 1/5
— 120.2	.470	.468	+ .002	+ 1/2
— 120.9	.473	.465	+ .008	+ 2
— 130	.443	.432	+ .011	+ 2
— 137	.408	.406	+ .002	+ 1/2
— 188	.235	.240	— .005	— 2
— 191	.228	.230	— .002	— 1

and with earlier experiments of VON BOSE and MATTHIESEN [1]) who found for the conductivity between 10° and 100°:

$$\lambda = 4{,}6172 - 0{,}018389\,\theta + 0{,}00004785\,\theta^2$$

§ 3. *Orientation curve.*

This was determined at 18° and about 23 K.G. The resistance of the crystal was measured with the axis normal and parellel to the

[1]) v. BOSE und MATHIESSEN, Pogg. Ann. **115**, p. 353, 1862.

field and in different positions between these two principal ones. The current for the measurements was always normal to the field, the direction of which is shown by the arrow in fig. 2. It was found (see fig. 2) that in the maximum and minimum positions, which were normal to each other, the values $\frac{R'-R}{R}$ did not differ much, much less than in the cases of graphite and bismuth. For these conductors in one of these principal positions I the effect is so much smaller than in the other one II, that ROBERTS [1]) thought it possible, that in position I there does not exist an effect at all. The small observed effect might be caused by an imperfect orienta-

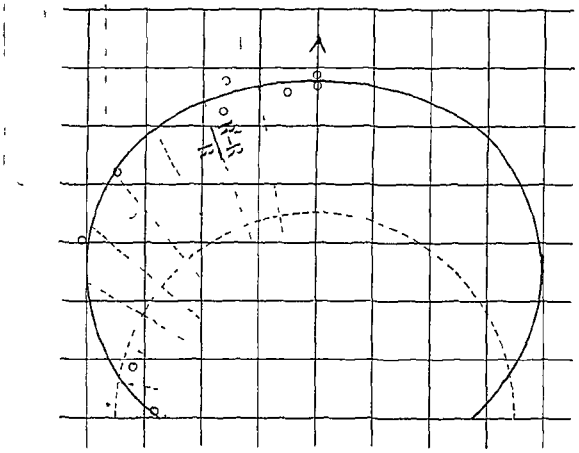

Fig. 2.

tion in the field. In this case a small component of the effect belonging to position II would be observed. For antimony the differences between the results in the positions I and II are so small, that this explanation seems not to hold. It is therefore probable, that metal crystals show for a definite direction of the current, normal both to the principal axis and to the field, two independent magnetic resistance changes, the one when the principal axis has the direction of the field, the other when it is normal to it. Other cases for intermediate positions can be reduced to these. The above observations, that for bismuth and graphite, i.e. for those crystals which show the greatest resistance change in the field, the difference between the resistance curves in the two principal positions is greatest, agree with a remark of C. W. HEAPS [2]). HEAPS, who worked with conglomerates, points out

[1]) D. E. ROBERTS, loc. cit. p. 469.

[2]) C. W. HEAPS Phil. Mag, VI **24** p. 815. 1912.

that those metals, which show the greatest resistance change also give the most different resistance curves in a tranverse and a longitudinal field. I hope to return to this point later. Fig 2 shows the orientation curve.

The full line represents the formula:

$$\left.\begin{aligned}\frac{R'_{18}-R_{18}}{R_{18}} = &[0{,}519-0{,}510\ sin\ 1{,}125\ (81-|\mathfrak{H}\ sin\ \varphi|)]\\ &+[0{,}167-0{,}1696\ sin\ 2{,}665\ (30-|\mathfrak{H}\ cos\ \varphi|)]\end{aligned}\right\}^{1)} \quad . \quad . \quad (2)$$

where φ is the angle between the direction of the field and the principal axis of the crystal.

To represent the resistance change in the field in one of the two principal directions, different types of formulae were tried. Finally certain considerations, which may be omitted here, led to the form $\frac{R'}{R} = a + b\ sin\ c\ (d-|\mathfrak{H}|)$ (3). Because of the connexion between the constants for the field $\mathfrak{H} = 0$, this formula has three constants. The above formula (2) is derived from (3) by resolving the $\mathfrak{H}$ under the sin.' into its components. As $R' - R$ is very small compared with R and as there were no special precautions taken with regard to the orientation, we may regard the agreement of the observed points ⊙ with the calculated ones as fairly satisfying.

§ 4. *Isothermal curves.* Fig 3.

As to these we may remark, that the quasi-linear part of the field curves is already reached at 30 KG. Of earlier investigations must be mentioned those of LENARD [2]), who used pressed antimony wire, 0.2 mm. thick. This highest field was 6.6 KG. where he found $\frac{R'}{R} = 1.012$ for a constant current; and also those of v. ETTINGSHAUSEN [3]), LEBRET [4]) and BARLOW [5]).

Fig. 3 shows the field curves for 18° and —188° in two principal directions. The formulae used are·

Table 2. $\frac{R'_{18^0}}{R_{18^0}} = 1.519 - 0.510\ \ sin\ 1.125\ (81 - |\mathfrak{H}_{//}|)$

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[1]) In this and in the other formula c is expressed in degrees.

[2]) PH. LENARD, Wied. Ann. **39**, p. 637, 1890.

[3]) A. v ETTINGSHAUSEN, Wien. Akad. Ber. **59**, p. 714, 1887.

[4]) A. LEBRET, Diss Leiden, 1895.

[5]) G. BARLOW. Ann d. Phys., **12**, p. 916, 1903.

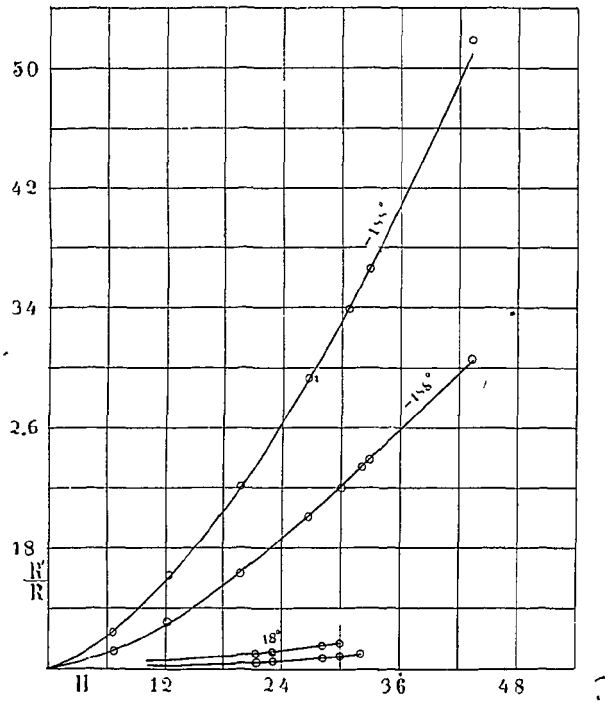

Fig. 3.

Table 3. $= 1.167 - 0\ 1696\ sin\ 2.665\ (30 - |\mathfrak{H}_\perp|)$

„ 4. $\frac{R'_{-185^0}}{R_{-188^0}} = 2.742 - 1.80\ sin\ 2.022\ (38.55 - |\mathfrak{H}_{//}|)$

„ 5. $= 10.08 - 0.965\ sin\ 1.069\ (74.90 - |\mathfrak{H}_\perp|)$.

TABLE 2.
Antim. resist. as a funct of θ and . axis // field.

$\mathfrak{H}$ Kilogauss	$\theta = 18°$	
	$\frac{R'}{R}(O)$	$\frac{R'}{R}(C)$
21.4	1.039	1.038
23.2	1.047	1 048
28.3	1.071[4]	1.072[5]
29.98	1.079	1.082
32.0	1.091	1.092

TABLE 3.
Antim. resist. as a funct. of θ and $\mathfrak{H}$. axis $\perp$ field.

$\mathfrak{H}$ Kilogauss	$\theta = 18°$	
	$\frac{R'}{R}(O)$	$\frac{R'}{R}(C)$
21.4	1.101	1.101[5]
23.2	1.114	1.114
28.3	1.154	1.155
29.98	1.167	1.167

The observed points have again been marked ⊙. In tabel 2, 3, 4, and 5 the numbers are given.

TABLE 4.
Antim. resist. as a funct. of θ and $\mathfrak{H}$.
axis // field.

$\mathfrak{H}$ Kilogauss	$\theta = -188°$	
	$\frac{R'}{R}(O)$	$\frac{R'}{R}(C)$
6.7	1.121	1.117
12.2	1.310	1.297
19.8	1.630	1.633
26.7	2 013	2.010
30.1	2.200	2.212
32.2	2.340	2 343
33.0	2 392	2.392
43.3	3.060	3.045

TABLE 5.
Antim. resist. as a funct. of θ and $\mathfrak{H}$.
axis $\perp$ field.

$\mathfrak{H}$ Kilogauss	$\theta = -188°$	
	$\frac{R'}{R}(O)$	$\frac{R'}{R}(C)$
6.6	1.239	1.238
12.4	1.620	1.607
19.8	2.210	2 192
26.7	2.937	2.920
30.9	3.396	3.401
33.0	3.664	3 666
43.3	5.195	5.105

In order to test formula (3) still further it has been applied to the observations of KAMERLINGH ONNES and BECKMAN.

The tables 6, 7, 8, 9 have been taken from Comm. N°. 129 and 130 Phys. Lab. Leiden. In the columns $\frac{R'}{R_0(O)}$ are given the observed values, while under $\frac{R'}{R_0(C)}$ are to be found the values calculated from the formula at the head of the table.

$$T = 15°. \quad \frac{R'}{R_0} = 68.4 - 68.76 \; sin \; 5.45 \; (15.05 - |\mathfrak{H}|)$$

$$T = 20.3°. \quad \frac{R'}{R_0} = 75.74 - 76.1 \; sin \; 5.09 \; (16.3 - |\mathfrak{H}|)$$

$$T = 72°. \quad \frac{R'}{R_0} = 134\,057 - 133.9 \; sin \; 2\,166 \; (40 - |\mathfrak{H}|)$$

$$T = 90°. \quad \frac{R'}{R_0} = 102.34 - 102\,15 \; sin \; 2.04 \; (42.15 - |\mathfrak{H}|)$$

TABEL 6.

Resistance of Bi_{dI} as a function of temperature and field.

$\mathfrak{H}$ Gauss	$T=15°$ K.			$T=20.3°$ K.		
	R'	$\frac{R'}{R_0(O)}$	$\frac{R'}{R_0(C)}$	R'	$\frac{R'}{R_0(O)}$	$\frac{R'}{R_0(C)}$
0	0.526	0.216	0.25	0.588	0.242	0.24
2760				11.5	4 73	4.74
3850	19.9	8.185	8.32			
5540	34.9	14.35	14.38	32.8	13.50	13.69
7370	55.9	23.00	22.48	54.7	22.50	21.44
9200	80.8	33.25	32.14	76.7	31.55	30.86
11850	116.4	47.90	47.82	113.2	46.55	46.47
13600	143.1	58.85	58.95	141.5	58.20	57.69
15670	175.6	72.25	72.45	172.	70.75	71.48
17080	199.3	82.00	81.18	196.5	80.85	81.00

TABLE 7.

Resistance of Bi_{dI} as a function of temperature and field.

$\mathfrak{H}$ Gauss	$T=72°$ K.			$T=90°$ K.		
	R'	$\frac{R'}{R_0(O)}$	$\frac{R'}{R_0(C)}$	R'	$\frac{R'}{R_0(O)}$	$\frac{R'}{R_0(C)}$
0	0.989	0.407	0.407	1.075	0.442	0.490
2760	4.68	1.926	1.919	3.92	1.613	1.54
5540	12.28	5.052	4 957	9.24	3.80	3.86
7370	19.10	7.86	7.66	14.20	5 84	5.82
9200	26.6	10.94	11.01	19.74	8.12	8.14
11850	41.2	16.95	16.92	29.82	12.27	12.34
13600	52.4	21.6	21.5	38.60	15.88	15.52
15670	67.2	27.65	27.57	48.05	19.77	19.68
17080	77.8	32.0	32.03	55.80	22.96	22.79

$$T = 170°. \quad \frac{R'}{R_0} = 10.47 - 10.08 \sin 2.46 (31.36 - |\mathfrak{H}|)$$

$$T = 290°. \quad \frac{R'}{R_0} = 1\ 657 - 0.749 \sin 4.5 (12 - |\mathfrak{H}|)$$

TABLE 8.

Resistance of Bi_{dl} as a function of temperature and field.

$\mathfrak{H}$ Gauss	$T = 170°$ K.			$T = 290°$ K.		
	R'	$\frac{R'}{R_0(O)}$	$\frac{R'}{R_0(C)}$	R'	$\frac{R'}{R_0(O)}$	$\frac{R'}{R_0(C)}$
0	1.570	0.646	0.630	2 570	1.057	1.051
2760	2.366	0.973	0.98	2.770	1.140	1.162
5540	3.657	1.504	1.47	3.110	1.280	1.294
7370	4.612	1.897	1.83	3.473	1 388	1 392
9200	5.613	2.310	2.25	3.635	1.495	1.494
11850	7.299	3.003	3.00	4.002	1.646	1.654
13600	8.506	3.500	3.51	4.248	1.746	1.750
15670	10.204	4.199	4.19	4.540	1.868	1.869
17080	11.412	4.695	4.69			

§ 5. *General remarks and conclusions.* Referring to the existing observations we may make some remarks on the electron theory of metals.

The sign of the HALL-effect shows, that the influence of the magnetic field on the so-called "free" electrons is a complicated phenomenon. The change of the resistance in the magnetic field can give us an insight into the mechanism of the electric current For it has been found, that the resistance change of a crystal depended only on the angle between the crystal axis and the field [1]), the angle between the directions of the field and of the current is of no importance, at least in a first approximation. From this we may conclude, that although the electrons may be "free" in passing from one molecule to the other, the influence of the field on these free paths and the resistance change caused by it, is negligible. Therefore theories as e.g. that of J. J. THOMSON, which try to calculate the phenomenon from the direct effect of the field on the "free" electrons cannot possibly give the right result.

[1]) D. E. ROBERTS, loc. cit. p. 468. Table II.

The field produces the change of resistance through its effect on the molecules and not on the "free" electrons (when these indeed exist) and it is natural to suppose that the field has also an orientating influence on diamagnetic molecules. From the magnetic double refraction COTTON and MOUTON have also concluded, that for diamagnetic substances too the field has a directing influence [1]). One can readily imagine, that anisotropic molecules have, in general, a greater magnetic moment than isotropic molecules; therefore, if the magnetic moment is already present before the field is excited, the field will have a stronger directing influence on anisotropic molecules. Similarly if we suppose, as is generally done, that diamagnetism is an induced phenomenon, we may assume that a bigger moment is produced in an anisotropic molecule than in an isotropic one. We may therefore conclude that the crystal system must have an influence on the phenomenon.

Now we find this to be really the case. All substances, which show a large or rather large resistance change, belong to the hexagonal system, while those which have a much smaller effect belong to the regular system.

Finally we may still remark, that those molecules, which have a large susceptibility and which are besides anisotropic will undergo the greatest influence of the magnetic field. And as the resistance change is caused by a directing effect, there must be a connection between susceptibility and resistance change. That this connection really exists is proved by the experiments. It is from this connexion that a large effect for graphite could be predicted [2]).

When we put the diamagnetic metals in a series in the order of the values of $(R'-R)/R$, beginning with the largest value, we have first:

Bismuth.
Graphite.
Antimony.
Then according to:

GRUNMACH	PATTERSON	HEAPS
Cadmium	Cadmium	Tellurium
Zinc	Zinc	Cadmium
Silver		Zinc
Gold	Gold	Gold
Copper	Copper	
Lead		

[1]) A. COTTON and H. MOUTON, Journal de Physique (5) 1 p. 40, 1911. P. LANGEVIN, le Radium 7 p. 249, 1910.

[2]) D. E. ROBERTS, loc. cit.

The definite series is: Bismuth Graphite Antimony Tellurium Cadmium Zinc Silver Gold Copper Lead.

Hexagonal are:	and regular:
Bismuth	Silver
Graphite	Gold
Antimony	Copper
Tellurium	Lead
Cadmium	
Zinc	

The order of the diamagnetic susceptibilities is according to MORRIS OWEN [1]):

	χ	
Bismuth	-1.40×10^{-6}	Hexagonal
Graphite [2])	-5	Hexagonal
Antimony	-0.815	Hexagonal
Tellurium	-0.303	Hexagonal
Cadmium	-0.185	Hexagonal
Zinc	-0.151	Hexagonal
Silver	-0.201	Regular
Gold	-0.152	Regular
Lead	-0.120	Regular
Copper	-0.085	Regular

The division into two crystallographic groups and a remarkable regularity in each of these groups are obvious.

CONCLUSION.

1. For all temperatures the resistance change of diamagnetic substances in the magnetic field can be represented by a formula of the form $R'/R = a - b \sin c(d + |\mathfrak{H}|)$.

2. The field has a directing influence on the diamagnetic metal molecules.

3. There exists a connexion between crystal system, resistance change and diamagnetic susceptibility.

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[1]) M. OWEN. Ann. d. Phys. **37**, p. 657, 1912.

[2]) As to the place of graphite one must take into account that different kinds of graphite differ greatly in properties. Further, no account is taken of the influence of temperature on the order in the series. All series are given for room temperature. It seems probable that in grouping at "corresponding" temperatures and "corresponding" states lead would also change its place.