V.—PHYSICS.

Art. LIV.—*On the Screening of Electro-motive Force in the Fields produced by Leyden-jar Discharges.*

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[*Read before the Canterbury Philosophical Institute, 3rd November, 1897.*]

The apparatus used in these experiments was that used in the previous experiments on screening of magnetic force (described in "Wiedemann's Annalen," 1897, vol. 62, p. 145), the needle, however, being replaced by a small coil which was connected with another coil outside the coil of the primary circuit. In this second coil the detector needle[*] was placed.

The length of the coil placed inside the coil of the primary circuit was 6 cm., its internal diameter 1 cm. It had 22 windings. The length of the coil to which it was connected was 8 cm., its internal diameter 7 cm., and it had 31 turns.

In certain cases it was found that the reduction of deflection with the needle placed in direction *b* was greater than when it was placed in direction *a*.[†] When, however, the auxiliary coil was placed in a coil of fewer turns per centimetre, the greater reduction took place in direction *a*. The same thing occurs when the capacity of the primary circuit, or the spark-length, is decreased. It thus appears that the direction for which the effect is greater depends on the strength of field.

This anomaly may be explained by considering the demagnetizing action of the ends of the needle. If the field be strong a very considerable demagnetization is produced by the first semi-oscillation. The second semi-oscillation remagnetizes the outer layer, but is opposed by the demagnetizing action of the interior, which was unaffected by the first semi-oscillation. The weaker the field the greater will be the volume of this core unaffected by the first semi-oscillation, and the greater the demagnetizing action opposing remagnetization by the second semi-oscillation.

To test this explanation experiments were made with needles of different lengths. The demagnetizing action is

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[*] Rutherford, Trans. N.Z. Inst., 1894, vol. xxvii., p. 488.
[†] Erskine, "Wiedemann's Annalen," 1897, vol. 62, p. 145.

greater the shorter the needle. A needle of length 60 mm. was taken; the secondary coil was placed in the coil of 2 turns per centimetre of the primary circuit, and the needle in the exterior coil connected to the secondary coil. The reduction of deflection was 11 greater for direction *b* than for direction *a*. When the length was reduced to 50 mm. the excess in direction *b* was 9 scale divisions. With a length of 35 mm. the excess was only 3. With a length of 28 mm. the excess was 1 division in direction *a*, and with a length of 20 mm. 4 divisions in direction *a*.

As is to be expected, the screening of electro-motive force obeys the same laws as the screening of magnetic force. The values of the screening of electro-motive force for different capacities and spark-lengths in the primary circuit and for different thicknesses of screen are contained in the following tables.

Table I. gives the variation of the screening, with capacity, the spark-length remaining throughout 0·4 cm.

TABLE I.

Thickness of Screen.	Percentage Screening.					
	Direction *a*.			Direction *b*.		
	Capacity			Capacity		
	½.	1.	2.	½.	1.	2.
0·00111 cm.	59	44	35	71	68	55
0·00222 cm.	71	61	48	91	80	72
0·00333 cm.	81	75	69	100	90	89
0·00555 cm.	87	82	78	..	94	96
0·00888 cm.	94	88	85	..	100	100
0·01332 cm.	100	92	90	..	..	..

Table II. shows the screening for different spark-lengths, the condenser consisting of two jars arranged in parallel.

TABLE II.

Thickness of Screen.	Percentage Screening.					
	Direction *a*.			Direction *b*.		
	Spark-length =			Spark-length =		
	0·2 cm.	0·4 cm.	0·6 cm.	0·2 cm.	0·4 cm.	0·6 cm.
0·00111 cm.	34	35	31	54	55	53
0·00222 cm.	51	48	39	74	72	71
0·00333 cm.	69	69	63	86	89	85
0·00555 cm.	76	78	77	93	96	92
0·00888 cm.	83	85	83	..	..	..
0·01332 cm.	90	90	88	..	..	..

The percentage screening is given roughly by the formula $100\,(1-e^{-cx})$, where x is the thickness of the screen and c a constant. The values given by this formula are, however, too small when x is small, too great when x is great.

Tables III. and IV. compare the observed values of the screening with those given by the formula.

TABLE III.

Condenser, 1 jar; spark-length, 0·4 cm.

Thickness of Screen.	Percentage Screening.			
	Direction *a*.		Direction *b*.	
	Observed.	Calculated ($c=420$).	Observed.	Calculated ($c=840$).
0·00111 cm.	44	38	68	61
0·00222 cm.	61	61	80	85
0·00333 cm.	75	75	90	94
0·00555 cm.	82	90	94	99
0·00888 cm.	88	98	..	..

TABLE IV.

Condenser, 2 jars in parallel; spark-length, 0·4 cm.

Thickness of Screen.	Percentage Screening.			
	Direction *a*.		Direction *b*.	
	Observed.	Calculated ($c=350$).	Observed.	Calculated ($c=700$).
0·00111 cm.	35	32	55	54
0·00222 cm.	48	54	72	79
0·00333 cm.	69	69	89	90
0·00555 cm.	78	85	96	98
0·00888 cm.	85	95	..	..

It will be observed that the screening is in all cases much greater for direction *b* than for direction *a*, but that the difference is not so great as in the case of screening of magnetic force (*cf.* tables, pp. 149 and 150, "Wiedemann's Annalen," 1897, vol. 62). This difference between the two cases is an additional proof of the importance of the first term on the right-hand side of equation (3), p. 152, "Wiedemann's Annalen," 1897, vol. 62.

We may investigate the difference of the screening of electro-motive force for directions *a* and *b* as follows (letters with the suffix $_2$ refer to the secondary coil, those with the suffix $_s$ to the screen) :—

The current in the secondary circuit when no screen is interposed has the form

$$L_2=F_2e^{-\frac{R_2}{L_2}t}-G_2e^{-qt}\sin(pt+\theta+\eta_2).\quad \text{Equation 3 } \textit{loc. cit.}$$

As the secondary coil is small it will not affect appreciably the current in the screen, so when the screen is interposed the current in it will have the form

$$L_s=F_se^{-\frac{R_s}{L_s}t}-G_se^{-qt}\sin(pt+\theta+\eta_s).$$

If M_{12}, M_{2s} be the mutual inductances of the primary and secondary and secondary and screen respectively, then the current in the secondary is given by the equation

$$L_2\frac{dt_2}{dt}+R_2L_2+M_{12}\frac{dt_1}{dt}+M_{2s}\frac{dt_s}{dt}=0.$$

The solution is

$$L_2=ke^{-\frac{R_2}{L_2}t}-\frac{\frac{R_s}{L_s}F_s}{\frac{R_s}{L_s}-\frac{R_2}{L_2}}e^{-\frac{R_s}{L_s}t}-He^{-qt}\sin(pt+\theta+\eta_2)$$
$$+Ke^{-qt}\sin(pt+2\theta+\eta_2+\eta_s).$$

Now, the periodic terms may be combined, and L_2 takes the form

$$ke^{-\frac{R_2}{L_2}t}-fe^{-\frac{R_s}{L_s}t}-ge^{-qt}\sin(pt+\theta+\eta_2-\nu).$$

This shows that when the screen is interposed the phase difference between the secondary and primary currents approaches more nearly half a period, and since the initial value of the periodic terms is equal to the sum of the initial values of the other terms the periodic term is for small values of t relatively greater than before. Now, the effect of the non-periodic part of the current is to diminish the amplitude of the first and odd semi-oscillations of the secondary current, while it increases those of the second and even. Thus the screening of electro-motive force will be greater for direction b than for direction a.