Citation:

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polytopes of k import in the first are the same as those of $n-k-1$ import in the second; so k' has to be equal to $n-k-1$, i.e. we have $k+k'=n-1$. So we get

$$e_k \, e_{n-1} \, A = e_{n-k-1} \, e_{n-1} \, A',$$

i.e.: If we apply respectively to $e_{n-1} A$ and $e_{n-1} A'$ any two *reciprocal* operations e_k and e_{n-k-1} the result is the same but the imports are reciprocal.

This simple general theorem accounts for the equality of all the pairs of polytopes (and nets) indicated in the tables added to the memoir quoted.

Hever, Kent, England. September, 1910.

Physics. — *"An improved semicircular electromagnet."* II. By Prof. H. E. J. G. du Bois. (Communication from the Bosscha-Laboratory.)

Recently I described a new type of semicircular electromagnet together with some results obtained with it.[1]) In the present paper I beg to communicate a few more measurements; and also its adaptation to special purposes, which lately have come to prominent notice.

Influence of polar windings. The reproduction given previously exhibited the windings as split into two divisions by a rectangular flange: *a.* polar windings, which are in the neighbourhood of the pole-pieces, the efficiency of which can be increased by supplementary loose polar coils; *b.* circuital windings round the other parts of the magnetic circuit. A second instrument was wound and connected in a somewhat different way; the field was determined again under different circumstances by means of a ballistic moving-coil galvanometer; this was standardised by means of a normal solenoid, and the proportionality of the readings ascertained. A small test-coil was made with a diameter of 3 m.m. and a thickness of 0,3 m.m.; the thickness of the bare copper wire used was 0,025 m.m., silk-covered 0,07 m.m.; it was wound in collodium. The equivalent area of the 45 windings was 1,544 cm^2., determined by comparison with a slightly smaller normal coil of 1,530 cm^2., measured geometrically. The results are given in the subjoined table:

[1]) H. du Bois. These Proc. 18 p. 189, 1909.

End planes	3,6 mm.		6 mm.	
Polar distance	Field (Kilogauss) with: *a*) 135 K. A. T.	*a, b*) 255 K.A.T.	Field (Kilogauss) with: *a*) 135 K. A. T.	*a, b*) 255 K. A.T.
0 mm.	—	—	53,3	53,9
0,5 »	54,9	55,4	51,3	51,9
1,0 »	51,3	51,9	49,3	50
1,5 »	48,9	49,7	47,3	48,1
2,0 »	46,5	47,4	45,8	46,6

These values are a little higher still than those previously given; the first limiting values have again been linearly extrapolated, and they are all considerably greater than is calculable from a saturation-value of about 1710 C. G. S. [1]) according to the usual formulae. This fact, of advantage from an empirical point of view, is difficult to explain as yet. Sub *a*) we find the fields measured with polar windings only (135 kiloampère-turns); sub *a, b*) those obtained with polar and circuital windings (255 K. A. T,). Hence it is convincingly shown, as might be foreseen, that the influence of the former greatly preponderates; under certain circumstances the share of the latter amounts to only one per cent of the whole field; in other cases, however, it is greater. Yet for various reasons it does not seem desirable to omit these inferior windings altogether, as has been the general custom with designers of the Rühmkorff type.

For the investigation of this problem — also of importance with a view to the economical construction of field-magnets in general — under better defined circumstances, a complete ring-electro-magnet was used, provided with 12 separate coils according to Fig. 1. They were connected in various ways, but always so that two coils, numbered alike, symmetrical with respect to the air-slit, were excited at the same time. It appears from a great number of field-curves — as a function of the kiloampère-turns — that up to $^1/_2$ or $^2/_3$ saturation the azimuth of the coils remains indifferent, as has been generally supposed. The more, however, the iron becomes saturated, the more the action of the coils near the air-slit begins to preponderate, so that their influence is determined by the order of the

[1]) E. Gumlich. Elektrotechn. Zeitschr. **30**, p. 1096, 1909. P. Weiss, Journ. de Phys. (4) **9**. p. 373, 1910. Comp. also B. Beattie and H. Gerrard, the Electrician, **64** p.p. 750, 811, 1910.

numbers in Fig. 1. This is in accordance with KIRCHHOFF's saturation-law; P. WEISS also drew attention to this fact. On the other hand J. HOPKINSON did not postulate such a difference in his well-known theory of the magnetic circuit; in spite of this such views have also been gradually introduced into electrical practice. As dynamos and motors were more and more saturated and the air-slits became narrower — the value of the induction sometimes reaches 20000 C. G. S. — the field-windings were moved as near as possible to the armature-space; this tendency is finally checked by the fact that a given number of accumulated windings has a higher resistance than when they are uniformly distributed, so that their periphery on an average is evidently smaller.

Gradient-pole-pieces are used for investigations in a non-uniform field; this is the opportunity to describe the arrangement, alluded to in a previous communication [1]). The test-piece takes up a position in the equatorial plane such that both $\mathfrak{H}_x$ as well as the transverse gradient $\partial \mathfrak{H}_x/\partial y$, and also the product $\mathfrak{H}_x \partial \mathfrak{H}_x/\partial y$ retain values as great as possible; this product determines the attraction or repulsion exerted. Besides this chief condition, some practical requirements concerning the necessary space etc. must be fulfilled. The calculation of an optimum would be exceedingly difficult, and even if feasible, might prove more laborious than the empirical method, by which the configuration represented in Fig. 2 was developed after much experience. The axes of the polar pieces form an angle of 25°; the pole-tops are provided with conic cores slightly rounded and just protruding. The field was determined by means of a standardised spherical test-coil of diameter 3 mm. Inside the smaller angle (direction $+y$) the maximum of $\mathfrak{H}_x \partial \mathfrak{H}_x/\partial y$ in general lies further away and is flatter than in the opposed direction $(-y)$; as the axial angle increases the maximum moves away from the origin A towards $+y$; the distance between the pole-tops and the strength of the current have less influence on its position.

In Fig. 3 some curves have been traced referring to this, and corresponding to the configuration of Fig. 2; the abscissae $\pm y$ represent the distances from the origin on a ten-fold scale. The ordinates of I represent the field $\mathfrak{H}_x$ in kilogauss (right-hand scale) those of II the value of $\mathfrak{H}_x \partial \mathfrak{H}_x/\partial y$ in millions of C.G.S. units (left-hand scale). This experiment was made with a distance between the pole-tops of 0,3 cm. and 50 kiloampère-turns. So it appears possible to

1) H. DU BOIS and KŌTARŌ HONDA, These Proc. 18, p. 596, 1910. Cf. P. CURIE, Ann. Chim. & Phys. (7) 5 p 295, 1895; Oeuvres p. 237, Paris 1908.

make use of a non-uniform field of more than 25 kilogauss with a perfectly sufficient gradient. Now the pole-tops may be insulated from the shoes e.g. by means of horn-discs, or by surrounding them with a somewhat pliable leather case, so that e.g. immersion in liquid air can take place; thus we can easily work within a temperature range of — 200° to + 200°. In addition a similar arrangement was made for pyromagnetic investigations at high temperatures up to 1300°, in which case the available field amounted to only 15 kilogauss on account of the larger space required.

Oblique-vision pole-pieces. By EGOROFF and GEORGIEWSKY, and afterwards by RIGHI the ZEEMAN-effect was investigated in directions forming an arbitrary angle ϑ with the direction of the field [1]). The last-mentioned physicist already pointed out the necessity of special electromagnets for this purpose, and could observe within a range $42° < \vartheta < 90°$ with the aid of pointed conical polar-pieces and coils. When recently this problem again came under consideration in connection with the spectrum of the solar spots, it was treated theoretically by LORENTZ, experimentally by ZEEMAN and WINAWER [2]). They extended the interval from 90° to 26°; with such pointed polar-pieces, however, the field is very much weakened; with the aid of glass prisms inserted within the polar-pieces [3]) it was also possible to observe with one single smaller angle $\vartheta = 16°$. In consequence of a conversation with Prof. ZEEMAN I have lately tried to design an arrangement which allows of gradually varying the angle of observation ϑ from 0° to 90°.

Within the range $0° < \vartheta < 45°$ the rays must pass inside the iron; these small angles are of the greatest importance because the critical angle ϑ_1 of LORENTZ will probably always lie within this interval for a strong field. The pole-tops Q_1 and Q_2 (Fig. 4) as usual have a half vertex angle of 55° gradually increasing to 57°; they are kept separate by a strong, unmagnetic mounting V, which is provided with openings. At the back they are spherical and ground into the hollow cups of the pole-shoes P_1 and P_2, whose half vertex-angle amounts to 59°. The bore B had the shape of an excentrical rect-

[1]) N. EGOROFF & N. GEORGIEWSKY. Compt. Rend. **124** p. 949, 1897. A. RIGHI, Mem. accad. Bologna (5) **8** p. 277 (Fig. 3.) 1899. Cf. A. COTTON, le Phénom. ZEEMAN, "Scientia" No. 5. p. 48, 74, Paris 1899.

[2]) H. A. LORENTZ, These Proc. **12** p. 321, 1909. P. ZEEMAN & B. WINAWER, These Proc. **12** p. 584; **13** p. 35, 1910.

[3]) For this artifice proposed by WERTHEIM SALOMONSON the use of a magneto-optically inactive ceriteborosilicate crown-glass may prove efficient; cf. H. DU BOIS & G. J. ELIAS, Verh. D. phys. Ges. **11** p. 710., 1909.

angular pyramid, which fits round the conical beam as determined by the usual conic prolongation of the bores B' in pole-shoe and further core. Now it appears sufficiently clear from Fig. 4, how we can arbitrarily change the angle between the field-axis $x'x'$ and the direction of the light xx and read it on the divided circle C. For a definite polar distance the conical faces as well as the segments of the two pole-tops are concentric — and so also those of the pole-shoes; for other distances these spherical surfaces can always be made to coincide by a slight lateral shifting of the cores carrying the cup-shaped pole-shoes.

This arrangement proved satisfactory; the subjoined table gives some measurements of the field (in kilogauss), firstly before boring and

Polar distance	2 mm.		4 mm.		6 mm.	
ϑ	without bore	with bore	without bore	with bore	without bore	with bore
0 °	41,2	29,2	35,3	28,2	31,3	26,4
25°	—	26,2	—	25,5	—	23,9
45°	33 9	21,6	28,2	21,2	24,0	19,5

secondly after the boring had been made; the diameter of the end-planes was 6 mm.; the measurements were always made with 122 kiloampère-turns. So when ϑ increases from 0° to 25°, the field decreases by about 3, between 0° and 45° by about 7 kilogauss. For unbored tops no deviation of the field was found from the direction normal to the end-planes, which, indeed, agrees with a known property of lines of force. After the boring, however, the field is somewhat strained, so that ϑ is a few degrees greater than the angle between $x'x'$ and xx; the difference diminished as ϑ became greater, and disappeared at 45°; then the well-known counteracting influence of the polar windings just balanced the deviation caused by the borings.

Lately Corbino [1]) described an optical method of photographing the distribution of the iso-dynamics in such cases by means of the birefringency in Bravais-iron. However, it is not necessary to use the round bores assumed by him on account of the straining of the field; slit apertures should, no doubt, always be used. This is also possible in the case in question: for so far as one observes at a definite

[1]) O. M. Corbino. Phys. Zeitschr. **11**, p. 521, 1910.

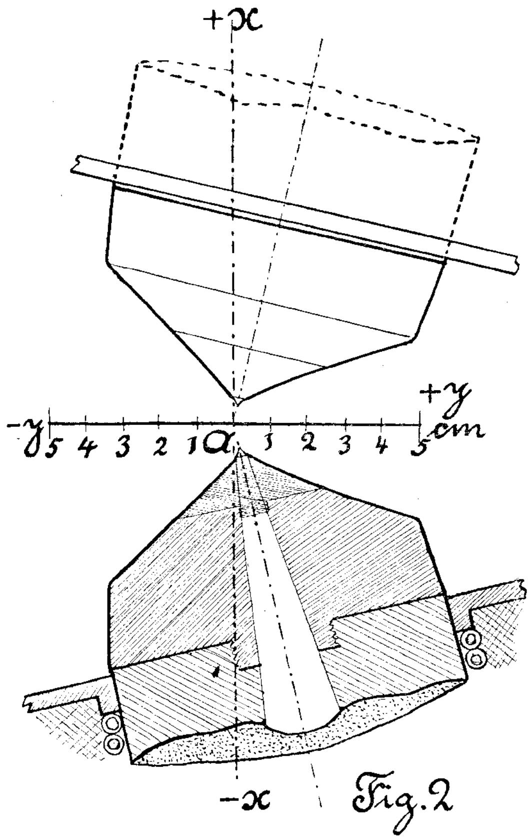

Fig. 2

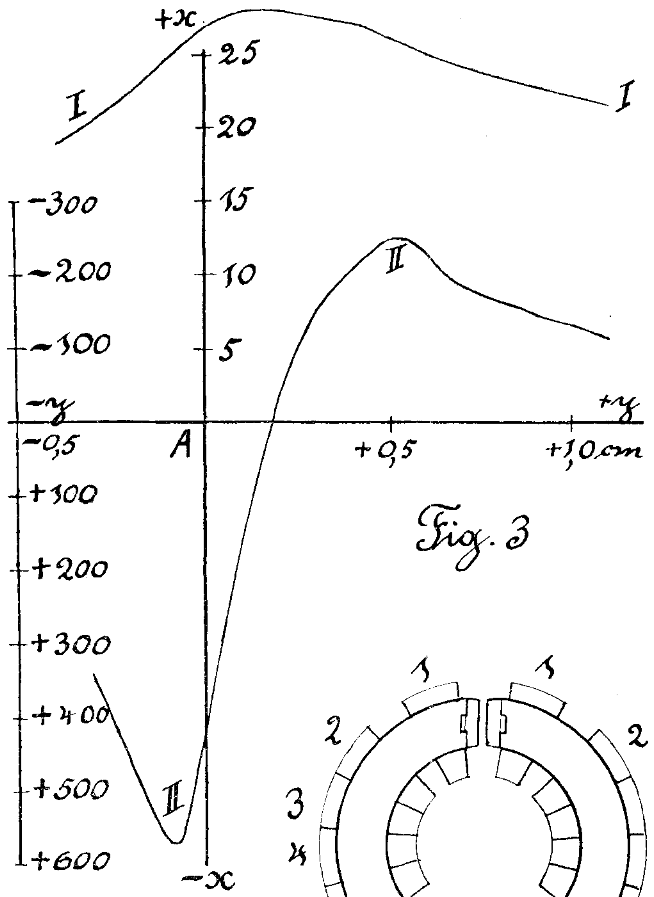

Fig. 3

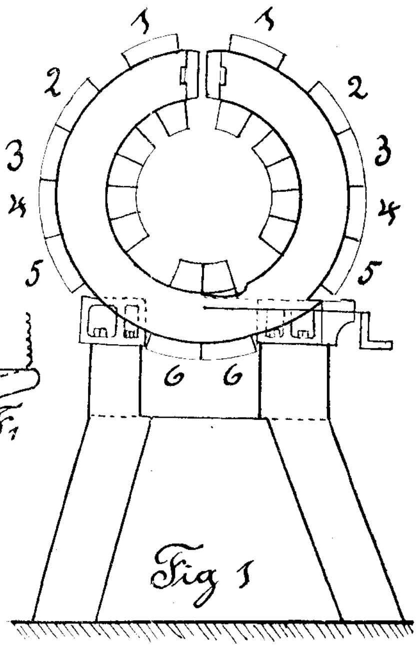

Fig. 1

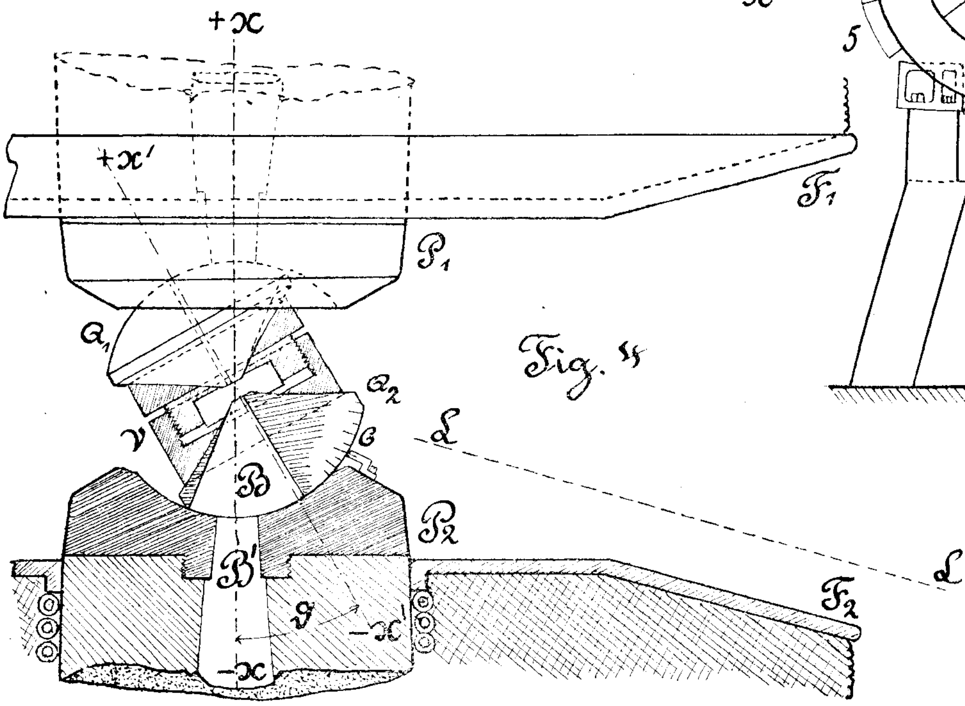

Fig. 4

angle ϑ it will be advisable to fill up the superfluous parts of the bores B with a set of loose wedge-shaped cores; then the field can be only slightly weakened and strained.

Angles $45° < \vartheta < 90°$ are easier to realise, because the course of the light remains outside of the pole-pieces, the half vertex-angle of which must, however, be smaller than ϑ. If this were the case, we might e. g. already go to 45° in Fig. 4, the line of vision LL going alongside the truncated pole-flange F_2. For this work the ball-frame with the divided circle, on which the whole electromagne rests, proves convenient; it was, in fact first used by RIGHI (loc. cit.) for similar purposes.

With the arrangement described Dr. ELIAS investigated the oblique emission-effect for some spark-spectra [1]). It may also prove serviceable in other cases, e. g. for the KERR-effect.

If we now consider Fig. 4 as normal section of pole-tops, bounded by truncated bi-planes and cylinders, we have a configuration that may be useful e. g. for string-galvanometers, for the observation of the transversal bi-refringency and for similar cases. We can, in addition, prove that the normal optimum-value of the bi-plane angle amounts to $2 \times 45°$ in this case, instead of to $2 \times 54°44'$ for the cone vertex. I am greatly indebted to Mr. MORRIS OWEN for the measurement of the magnetic fields.

Physics. — "*On the* ZEEMAN-*effect for emission-lines in a direction oblique with regard to the lines of force.*" By Dr. G. J. ELIAS. (Communicated by Prof. H. E. J. G. DU BOIS)

The modifications to which emission and absorption lines are subjected in a magnetic field, have been studied up to now chiefly in two special cases, namely those for which the direction of the magnetic field coincides with the direction of the rays of light, and those for which it is normal to it.

The theory of the phenomenon for the case that the rays of light form an arbitrary angle with the direction of the magnetic field, was developed by LORENTZ [2]).

Experiments of ZEEMAN and WINAWER [3]) refer to the modifications to which the absorption lines of natrium vapour are subjected in a magnetic field with oblique passage of the light.

1) Comp. the subjoined communication.

2) H. A. LORENTZ, These Proc. 12 p. 321; 1909.

3) P. ZEEMAN and B. WINAWER, These Proc. 12 p. 584. 1909; 13 p. 35. 1910