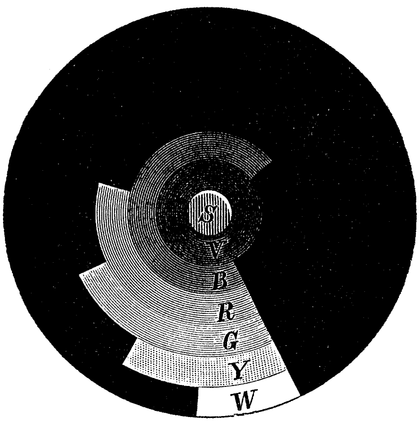
"On the Estimation of the Luminosity of Coloured Surfaces used for Colour Discs." By Sir WILLIAM DE W. ABNEY, K.C.B., F.R.S.

Received May 5,—Read May 31, 1900.

When a source of light is small, such as the points of an arc light, a candle, or lamp, it is comparatively easy to find the luminosity of any coloured surface which is illuminated by it, using the method which has been described in "Colour Photometry, Part II";* but when the source of light is a large surface, such as the sky, the method therein described is much more difficult to apply. Quite recently, when examining the question of providing suitable screens for producing the negatives required for three-colour photographic prints, it became necessary to devise a plan by which rings of different colours could be made of equal luminosity in ordinary daylight by rotating them with the proper proportions of black. The rings were concentric and rotated as a disc,

FIG. 1.



S is the nut of the spindle.
V is a violet disc (methyl violet).
B is a portion of a blue ring (French ultramarine).
R " " red ring (vermilion).
G " " green ring (emerald green).
Y " " yellow ring (chrome yellow).
W " " white ring.

see fig. 1, and the difficulty encountered was to ascertain what amount of black ought to form part of each ring.

In "Colour Photometry, Part III,"† it was shown that only one ray

* Abney and Festing, 'Phil. Trans.,' A, 1888.
† Abney and Festing, 'Phil. Trans.,' A, 1892.

of the spectrum, a greenish-yellow, progressed in luminosity at the same rate as white light. Thus, if part of a white screen were illuminated by this colour and another part by white light, and the luminosities were equal (say) to one candle, then if the two beams were equally diminished they would still match in luminosity until the light was so feeble that it ceased to stimulate the retina. Other rays lying not far from this ray, both on the red and green side of it, gave practically the same results. When, however, the red was compared with the white, each being made equal (say) to one candle, equal diminution of the beams did not show the luminosities as the same, the red becoming rapidly less luminous than the white. With the blue-green, the blue, and the violet the reverse was the case, the white becoming darker than the colour as the beams were equally diminished.

A more extended research which is nearly complete shows that the observations recorded in Part III of "Colour Photometry" are correct and can be applied to the problem which I wished to solve.

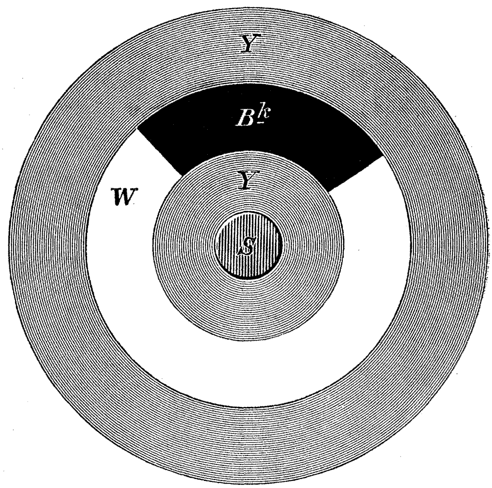
Further, it was shown in the same paper that colour disappeared from all rays of the spectrum long before (except in the case of the pure red) their light was extinguished, this last owing to the feeble stimulation of the retina. Naturally, as the colour began to disappear, the matching of the luminosity of the ray under consideration with that of white became easier to carry out.

These facts made it possible to devise a ready method to ascertain the luminosity of any colour. If we take two yellow discs, one (say) 8 inches in diameter and the other 4 inches, and between them sandwich a pair of interlaced black and white discs of 6 inches diameter, and rotate the four discs on a rotating machine at a speed which will make the black and white into a grey without scintillation, this grey can be made, by altering the proportion of black to white, to match the luminosity of the yellow. A very exact match can be obtained by observing the discs through a black transparent medium, such as the black obtained on a photographic plate after development with methol or amidol developers. The deposit may be so dense that the yellow colour may practically disappear, and the two dull greys may then be readily matched. The luminosity of the yellow in terms of the white is given by the angle which the white subtends when the small proportion of white reflected from the black annulus is added to it.

The same procedure may be adopted for a green colour and its luminosity be obtained. It may be stated that four or five observations for each colour should be made if great exactness is required.

When the luminosities of these two colours have been determined, 4-inch discs of them may be interlaced with a blue, and a grey formed, which can be matched with a grey formed of black and white as before.

FIG. 2.



YY are yellow discs.
B^k is a black disc.
W ,, white disc.
S is the nut of the spindle.

From the angles which the sectors of the colours subtend and of the black and white employed, the luminosity of the blue can be calculated. The luminosity of the blue being ascertained, a red disc may be interlaced with the green and the blue disc, and that of the red calculated. As a check a black and yellow disc may be interlaced and compared with the colour given with the red and green discs interlaced, one of the pairs of course being of greater diameter than the other.

To ascertain what degree of accuracy could be attained the following experiment is given in detail. The light used was the arc light, and the measurements as described above made.

It was found that the black reflected 3·33 per cent. of white light, and that when the luminosity of the yellow was matched the interlaced black and white discs occupied 82° and 278° respectively of the compound disc. This gave the yellow a luminosity of 78, white being 100. In a similar way the luminosity of emerald green was found to be 43. These two discs were interlaced with a dark blue disc and a grey formed which matched a grey formed by black and white. The following equation was obtained:—

Yellow.		Green.		Blue.		White.		Black.		White.
118	+	71	+	171	=	122	+	238	=	130

Yellow.

$$\text{The luminosity of } 118 = \frac{118}{360} \text{ of } 78 = 25{\cdot}6$$

Green.

$$\text{,, ,, } 71 = \frac{71}{360} \text{ of } 43 = 8{\cdot}5$$

White.

$$\text{,, ,, } 130 = \frac{130}{360} \text{ of } 100 = 36{\cdot}1.$$

Blue.

The luminosity of 171 is therefore represented by

$$36{\cdot}1 - (25{\cdot}6 + 8{\cdot}5) = 2.$$

The luminosity of the blue pigment is therefore

$$\frac{360}{171} \text{ of } 2 = 4{\cdot}2.$$

The luminosities of the three pigments were then compared with white by the method described in Part II of "Colour Photometry," and found to be

Yellow	77·7
Green	43·2
Blue	4·1

The luminosity of the blue only differs by that found by the new plan by 0·1, which is a very close approximation.

The red disc was then interlaced with the blue and the green, and a grey formed as before, and from calculation it was found that it had a luminosity of 32·5. Measuring it by the old plan, the luminosity came out as 32·7.

Having obtained the luminosity of the three standard colours, that of any other colour can be calculated by substituting for one of them a disc of such colour, and again making a grey and matching it with a grey formed by the black and white. It will be noticed that this method can be carried out in any light, whether candle light, electric light, or day light; but of course the luminosities of the colours will vary according to the quality and kind of light employed.

When the luminosities of the colours are determined, the angles which the segments of the annuluses in fig. 1 should subtend can be calculated after taking into account the luminosity of the black employed.

When the disc is rotated round S, each colour should be equally luminous, and if by means of an appropriate screen, placed in front of the lens, the image of the disc impresses the photographic plate in such

a manner as to make the density of each part of the negative the same on development, then all objects photographed with such a screen interposed on similar plates will be rendered in proper gradations of light and shade regardless of their colour or colours.

"The Diffusion of Ions produced in Air by the Action of a Radio-active Substance, Ultra-violet Light, and Point Discharges." By JOHN S. TOWNSEND, M.A., Clerk Maxwell Student, Cavendish Laboratory, Fellow of Trinity College, Cambridge. Communicated by Professor J. J. THOMSON, F.R.S. Received May 17,—Read June 14, 1900.

(Abstract)

The researches described in this paper form a continuation of those published on the Diffusion of Ions into Gases.* The latter paper gives the results of experiments made with ions produced in air, oxygen, hydrogen, and carbonic acid by the action of Röntgen rays. The gases in these experiments were at atmospheric pressure.

The present paper contains similar investigations for ions produced in air at various pressures by the action of a radio-active substance, and also determinations of the rate of diffusion of ions produced in air at atmospheric pressure by the action of ultra-violet light and point discharges.

The principle of the method consists in calculating the coefficient of diffusion from observations on the loss of conductivity of a gas as it passes along metal tubing. The experiments were arranged so that in all cases the loss of conductivity due to diffusion should be much greater than the loss due to other causes, so that it was not necessary to apply any corrections for losses arising from recombination or from the mutual repulsion of the ions.

The results of the experiments are given in the following tables. Tables I, II, III, and IV give the coefficients of diffusion, K, of positive and negative ions in dry and moist air at various pressures, P, the ionization being produced by the action of a radio-active substance. The temperature of the air during each experiment is given in the column Θ.

These tables show that in each case the rate of diffusion of ions into a gas is inversely proportional to the pressure of the gas.

The coefficients of diffusion at 772 mm. show a discrepancy from this law, which is somewhat greater than the probable error of the experiments, but we should not expect a closer agreement between the products P × K unless the temperature of the air was the same in

* 'Phil. Trans.,' A, vol. 193, pp. 129—158.

Fig. 1.

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R ,, ,, red ring (vermilion).
G ,, ,, green ring (emerald green).
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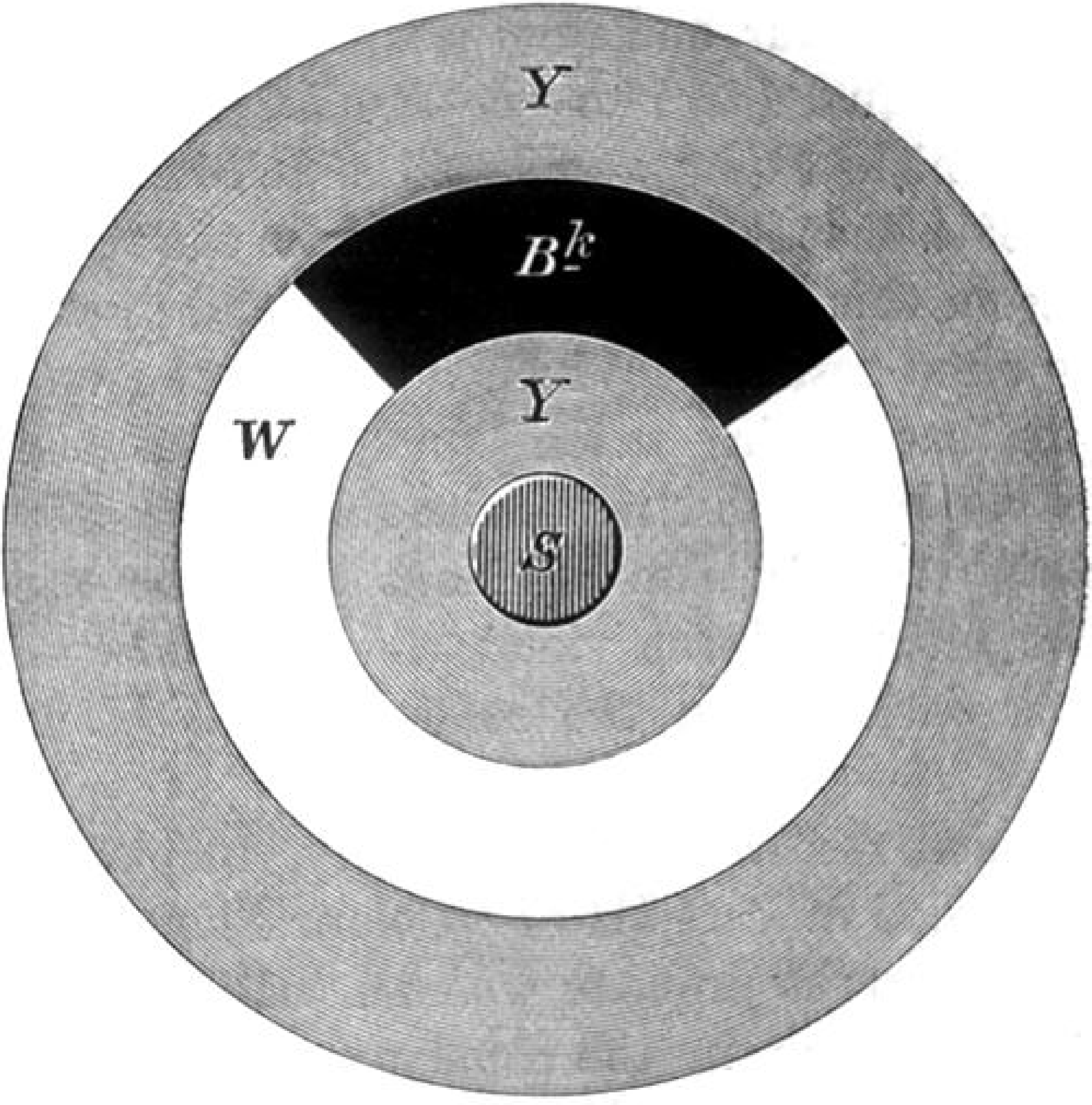
FIG. 2.



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