

On the Transmission of Radiation of Low Refrangibility through Ebonite

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the ratios of the wave-lengths; the lower ones the ratios of the amplitudes.

Typical curve of case I. . $\frac{27}{80}$
9 : 8

Typical curve of case II. . $\frac{27}{80}$
3 : 1

Typical curve of case III. $\frac{27}{80}$, or rather $\frac{1}{5} \times \frac{80}{79}$
9 : 2 10 : 1

POSTSCRIPT.—The curves shown in the Plates are all illustrations of the subject of this paper, with the exception of three sets; namely, the combinations of vibrations whose wave-lengths are nearly as 4 : 5, as 2 : 3, and as 2 : 5. These have been given for the sake of completeness in the collection of curves, and that readers may have the opportunity of seeing the nature of the difference between such curves as these, which may be said to belong to mistuned consonances of the form $h : k$, and our normal forms which belong to mistuned consonances of the form $h : 1$.

XXV. *On the Transmission of Radiation of Low Refrangibility through Ebonite.* By Capt. ABNEY, R.E., F.R.S., and Col. FESTING, R.E.*

WHEN Mr. Graham Bell described his interesting experiments with the photophone, we were much surprised to learn that an effect was produced when sheets of ebonite of small thickness were interposed between the apparatus and the source of radiation; and it became a matter of more than curiosity to us to know what was the cause of the phenomenon, since photographic manufacturers were commencing to use ebonite in the construction of the dark slides for the camera.

We think we can demonstrate, however, that the ordinary explanation of transmission of radiant energy can account for the phenomenon. Dr. Guthrie kindly furnished us with a sheet of ebonite, through which the action of a beam of

* Read April 9, 1881.

radiation on a selenium cell was most marked; and we accordingly first experimented with that. A photographic spectroscopic apparatus was employed, of the form we have already described in other papers¹; and the compound of silver was used which is sensitive to all parts of the spectrum. At first we employed only one prism, and used the sun as a source of illumination; and here it may be parenthetically remarked that on the evening when we made our first experiments the wind was blowing from the north-east, and there was a clear sky. Half the slit was covered up, a piece of ebonite placed in front of the other half, and a plate exposed to the action of the spectrum of the radiations (if any) coming through this thin layer of apparently opaque matter. An exposure of three minutes was given; the exposed half of the slit was then closed and the other half opened, and a spectrum taken through a solution of bichromate of potash $\frac{1}{10}$ inch thickness. This bichromate was used to prevent the too energetic action of the more refrangible rays, which illuminated the prism and would have caused a veil over the plate. Half a minute's exposure was given. The plate, on development, revealed that rays of very low refrangibility had passed through the ebonite, commencing at W.L. 12,000 and extending as far as W.L. 7500; the point of maximum intensity was situated at about 9000. The photographs were on a small scale, but sufficed to show the absorption of the ebonite. On the next day we had intended to repeat the experiments with two or three prisms; but the wind had shifted, and the solar spectrum was absorbed as far as about 9000, showing the presence of aqueous vapour. It was therefore useless to experiment further with the sun as a source of radiation; so we used the water of the positive pole of an electric light as a source. It will be seen that the spectrum through ebonite extends to about W.L. 15,000, and then terminates.

The next point to determine was as to the quality of the beam coming through the ebonite. This we determined as follows—first by placing a piece of ebonite in contact with the photographic plate and throwing an image of the points on it, and thus getting an impression, and then, by a simple arrangement, removing the ebonite to a distance of 1 foot, and allowing the beam to traverse it, and securing another image on a different plate. The photographs showed that the rays are

very much scattered in their passage through the ebonite, no distinct image being formed in the latter case, though it was sharp and defined in the former. The amount of scattering it seemed desirable to know. For this purpose the collimator of the spectroscope was used and no prism, the image of the slit $\frac{1}{20}$ inch wide was focused on the focusing-screen of a camera, and a piece of ebonite was placed in contact with the plate, and exposure made. This piece was removed and another piece inserted $2\frac{1}{2}$ inches in front of the plate, and another exposure given. The diffusion was most marked: a line $\frac{1}{20}$ inch broad was diffused over a space $\frac{1}{4}$ of an inch, most intense, of course, in the centre. By subsequent experiment it was shown that an exposure of three times the length of that given in the first case was necessary to cause the central portion of the band in the second case to correspond in intensity with that of the image of the slit in the first case. With two pieces of ebonite in contact with the plate six times the exposure was required to give the same intensity as with only one plate of ebonite intervening. Hence we may say that the coefficient of absorption of a plate of ebonite $\frac{1}{4}$ of an inch in thickness $= 1.8$; and a calculation will show that any rays which can penetrate through $\frac{1}{8}$ of an inch of ebonite will only have an intensity of $\frac{1}{1650000}$ that of the resultant beam, without deducting any thing for the scattering of light. In fact, with the electric light and a wide slit an hour's exposure produced no effect on the photographic plate when ebonite $\frac{1}{8}$ in. in thickness was placed before the slit. It must, however, be remembered that ebonite varies in quality; sometimes the outside alone is black, the inner portions resembling gutta percha in colour. With specimens of this sort a greater thickness could no doubt be traversed than $\frac{1}{8}$ inch. In such a case, however, we doubt if the substance would be true ebonite.

In a communication to 'Nature,' Messrs. Ayrton and Perry show how they determine the refractive index of ebonite by an arrangement with the telephone. They use a prism; and we should judge by the figure they give that the thickness of ebonite traversed must be about $\frac{1}{4}$ of an inch; so that the radiations transmitted must be very small. We may remark that the direction of a beam of light issuing from a prism formed of a turbid medium would not have its maximum in-

tensity in the true direction of refraction ; it would be slightly displaced. Mr. Preece, in a recent communication to the Royal Society, remarked that some ebonite he tried was as transparent as rock-salt ; and so it is if a thin-enough layer be taken ; and we think that it was the minute layer that was taken that caused this expression to be used. He also stated that another sample equally thin was perfectly opaque to radiation. Through his kindness we were able to experiment with the identical samples to which he refers. The "transparent" specimen behaved as that we have already described ; the opaque one showed that the radiations were more scattered in their passage through it. We may state that, by examining the thin ebonite with which we first experimented, we could see a trace of the sun's image through the material, and very faintly through two layers. The radiations of low refrangibility were evidently more copiously passed, since when an image of the sun formed by a lens was caused to fall on a piece of paper and a sheet of thin ebonite interposed, if the eye or hand was placed at the focus considerable warmth was felt.

It became interesting to know whether the ebonite was merely a mechanical mixture of sulphur and india rubber or a chemical combination. Placing a piece of stout india rubber, about the same thickness as the ebonite, before the slit of the spectroscope, and with an exposure of ten minutes, no vestige of an image was found on development of the plate. This was evidently owing to the great scattering of the rays by the substance. The india rubber being laid in contact with the plate, and an exposure made through it, showed that it was transparent to all rays from 10,000 to 5000. The absorption-spectrum therefore differed ; and it is evident that in ebonite the india rubber is chemically changed in composition.

The conclusion to be drawn is, that ebonite, when of small thickness, transmits to some extent the rays of low refrangibility.