Open access • Journal Article • DOI:10.1080/14786448108627092

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Published on: 01 Sep 1881 - Philosophical Magazine Series 1 (Taylor & Francis Group)

Topics: Ebonite

Philosophical Magazine Series 5

ISSN: 1941-5982 (Print) 1941-5990 (Online) Journal homepage: http://www.tandfonline.com/loi/tphm16

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To cite this article: W.E. Ayrton & John Perry (1881) XXIV. Note on the index of refraction of ebonite , Philosophical Magazine Series 5, 12:74, 196-199, DOI: 10.1080/14786448108627092

To link to this article: http://dx.doi.org/10.1080/14786448108627092

Published online: 17 May 2010.

33. It follows that the relation of art. 27 may be represented by some case of

$$\pm 3(I \pm J) \pm (U-2) + 2 = 0;$$

and when this single condition is fulfilled, the biordinal can be linked with a terordinal whereof the factors in both numerator and denominator are in arithmetical progression. The values of the arbitrary or indeterminate quantities A and E will, of course, have to be properly assigned.

34. Returning to art. 21, we get a second and a third set of relations, viz.

$$A = \tfrac{1}{2} + \sqrt{\tfrac{1}{4} - L}, \quad E = \tfrac{1}{2},$$

and

$$A = \tfrac{1}{2}, \quad E = \tfrac{1}{2} + \sqrt{\tfrac{1}{4} - N};$$

and in either case we have

$$(\Omega - 1)^2 = \omega^2.$$

35. Taking the second set ($E = \frac{1}{2}$), we see that $\Omega - 1 = \omega$, and that $(5)_2$ leaves N free. But it would seem that the four conditions cannot be fulfilled unless L, M, N be connected by at least two relations. This last remark applies also to the third set ($A = \frac{1}{2}$), wherein $\Omega - 1 = -\omega$, and $(4)_2$ leaves L free.

36. In the fourth set ($A, E = \frac{1}{2}$) we have both L and N left free and $\Omega - 1, \omega = 0$. And if we take the radicals positively, $(1)_2$ and $(2)_2$ are each satisfied by $b = 0$ or by $U = -2$. Thus, bearing in mind Boole's transformations, we may say that when U is an even integer, the biordinal can be linked with a terordinal of the form described in art. 33. This last result is confirmed by, and confirms, another process by which I have arrived at it, and (compare Proc. L. M. S. vol. xiii. pp. 67–68), combined with what is otherwise known, leads to the conclusion that when, of the three expressions I, U, J, one is $4(i \pm \frac{1}{3})$, i being an integer, and the remaining two are unevenly even integers, then the biordinal is finitely soluble.

2 Sandringham Gardens, Ealing,
July 25, 1881.

XXIV. *Note on the Index of Refraction of Ebonite.* *By* W. E. Ayrton *and* John Perry*.

IN a note communicated to the Royal Society (printed in 'Nature,' No. 596, vol. xxiii. March 31, 1881), we described how, by using a selenium cell, lent us by Mr. Bidwell, and a

* Communicated by the Physical Society, having been read at the Meeting on June 25, 1881.

pair of delicate Bell's telephones, we had succeeded in showing, 1st, that there was refraction when intermittent radiation from the oxyhydrogen light passed through an ebonite prism; and, 2ndly, that the index of refraction of that ebonite was approximately 1·7.

Exceedingly great care had to be taken, in consequence of the feebleness of the sounds given out by the telephones; and, from the nature of the experiment, we obtained the index of refraction for that narrow band of rays which experienced least absorption.

Shortly after these results were published, Prof. Fitzgerald, of Dublin, suggested, in conversation, the possibility of checking them by measuring the polarizing angle of light reflected from ebonite, on the assumption that the refracted ray is at right angles to the reflected one when giving maximum polarization. Subsequently Dr. Jellett was so kind as to make these experiments, the results of which Prof. Fitzgerald permits us to quote. The mean index of refraction for ebonite thus obtained, on Fresnel's theory, was 1·611.

Later on we repeated our selenium experiments, replacing the intermittent oxyhydrogen light with an intermittent electric light, and increasing the electromotive force in the selenium telephone-circuit to about 60 volts. A confirmation of our former result was obtained; but, although we were able to take greater precautions to ensure accuracy, we obtained no more than a confirmation; and from the difficulty of hearing the weak sounds in the telephones, we felt that the index of refraction thus measured might be as much as 1·8 or as small as 1·6.

In the course of these experiments, however, it was noticed that visible red rays were certainly refracted; and consequently we proceeded to make measurements according to ordinary optical methods, using the apparatus shown in the figure. L (fig. 1) is a fairly powerful electric light produced by a Gramme machine; C is a glass lens giving a parallel beam of light, part of which passes through the slit, S, $\frac{1}{20}$ inch wide, and falls on the edge of the ebonite prism P. F is a frame holding tissue-paper, which can be moved about P as centre, and which carries an index, I, pointing to the graduations on the circle, as seen in fig. 2. There was a fine vertical line in the middle of the tissue-paper; and HG, forming about one third of the paper, was well blackened. First this screen was moved into such a position that the edge of the prism threw a black shadow which was bounded by the fine central line, and between that line and the blackened portion H G was a thin band of white light. In fact a narrow beam from the slit fell

Fig. 1.

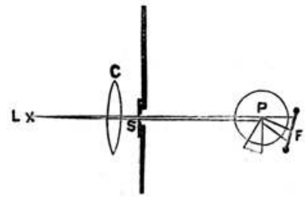
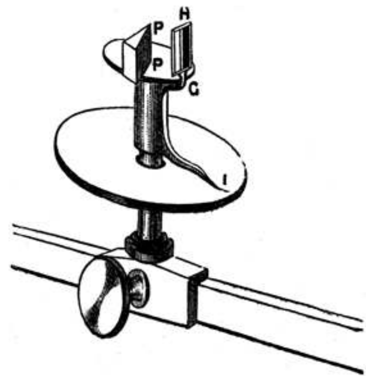


Fig. 2.



on the edge of the prism; and half was stopped by the prism, the other half going on. The index-reading in this position was taken; and now the screen was moved round until a red spectrum was seen. At the least-refrangible end this spectrum terminated nearly abruptly, as the ordinary visible spectrum usually does; and this end was made to coincide with the central line in the screen, and the index-reading taken when, after moving the prism itself, it was supposed that we had minimum deviation. The index-reading was also taken in the same way for the most-refrangible end of the visible spectrum; but as this did not die away at all abruptly, and as the whole spectrum was very faint, the second set of measurements merely gives a rough idea of the amount of spectrum that was visible. The mean of a number of observations made by different observers, and the results of which were closely in accord, gave 1·66 as the index of refraction for the well-defined least-refrangible end, and 1·9 as the average result for the badly-defined most-refrangible end.

As the slit in the metal diaphragm used with the selenium experiments had to be much wider than that employed with the simple light-experiments, we cannot of course tell what exact part of the spectrum produced the sound: probably it was at about the least-refrangible end of the visible spectrum; but it may have been the dark rays just beyond.

Summing up the results of the various experiments, we have for the index of refraction of certain specimens of ebonite:—

Ebonite prism, selenium, and telephones . . about	1·7
Measurement of polarizing angle by reflection ,,	1·611
Least refracted end of visible spectrum produced by ebonite lens having an angle of $28^{\circ}{\cdot}5$. about	1·66

In a paper by Captain Abney and Colonel Festing, recently read before the Physical Society and printed in the Philosophical Magazine for June, on the Transmission of Radiation through Ebonite, reference is made to our original experiments; and the authors say that, judging from the figure accompanying our Note, they should think that the thickness of the ebonite prism traversed by the intermittent beam must have been about one fourth of an inch. We are afraid that that figure is liable to give this misconception; in drawing it we were merely paying attention to the directions of the incident and refracted beam, and not to the actual thickness of the ebonite, which was in fact very small indeed where the intermittent beam passed through it.

XXV. *On Instruments for Measuring and Recording Earthquake-Motions.* *By* Thomas Gray, *B.Sc., F.R.S.E.**

[Plate III.]

I. *Rolling-Sphere Seismograph.*

THE instrument which I have called a rolling-sphere seismograph will be readily understood from the accompanying sectional drawing (fig. 1). A sphere of lead, iron, or any other heavy substance rests on a flat plate, B, made truly plane and furnished with three levelling-screws, L. An arm, A, fixed to the base, B, is so formed that a circular ring fixed to its end is held in a horizontal position with its centre vertically above the highest point of the sphere. This ring carries a species of spring universal joint, consisting of four very light bent springs, *j*, arranged at right angles to one another and meeting in a small round disk, *b*, at the centre. The lower end of the lever, *l*, passes through this ring *b*, and is fixed to it at such a point that its lower end, which is rounded, just fits a small hole in the top of the sphere S. Between S and *b* a small sphere, *s*, is fixed to the lever *l*, and is so proportioned that the lever *l*, when pushed at *b*, tends to rotate around a point a little above its lower end, thus diminishing the push on the sphere S. The springs *j* serve to allow the lever *l* to turn in any direction, and are made so light that they can only make the ball roll with a very long period. When thus proportioned they serve the purpose of a universal joint, and at the same time give a little stability to the parts, thus preventing the plate P, if it be put in motion, from causing the ball to roll over. The lever *l* is a rod of bamboo which is at the same time

* Communicated by the Author.