XXIX. On the refractive index and specific inductive capacity of transparent insulating media

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To cite this article: J. Hopkinson D.Sc. F.R.S. (1882) XXIX. On the refractive index and specific inductive capacity of transparent insulating media , Philosophical Magazine Series 5, 13:81, 242-244, DOI: [10.1080/14786448208627177](https://doi.org/10.1080/14786448208627177)

To link to this article: <http://dx.doi.org/10.1080/14786448208627177>

Published online: 28 Apr 2009.

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We have

$$n = \frac{\sin i}{\sin r},$$

whence

$$\frac{dr}{dn} = - \frac{\sin^2 r}{\sin i \cos r},$$

whence

$$\phi + \frac{2t}{\cos r} \cdot \frac{dn}{d\lambda} = 0.$$

By Cauchy's formula we have

$$n = \alpha_1 + \frac{\alpha_2}{\lambda^2},$$

whence

$$\frac{dn}{d\lambda} = - \frac{2\alpha_2}{\lambda^3}.$$

Substituting, we have

$$n_0 \cos i - n \cos r = \frac{2\alpha_2}{\lambda^2 \cos r} = \frac{\frac{2\alpha_2}{\lambda^2} + n \cos^2 r}{\cos i \cos r};$$

or, finally,

$$n_0 = \frac{2(n - \alpha_1) + n \cos^2 r}{\cos i \cos r}. \quad \dots \dots \dots (8)$$

If the angle i is small, the value of n_0 will vary very little with i ; consequently there will be a large number of circles, all nearly achromatized. Under favourable circumstances as many as one hundred rings have been counted, using an ordinary lamp as source of light.

The difference of path of the two pencils which produce these rings in white light may exceed a thousand wave-lengths.

XXIX. *On the Refractive Index and Specific Inductive Capacity of Transparent Insulating Media.* By J. HOPKINSON, D.Sc., F.R.S.*

ONE of the deductions from Maxwell's electromagnetic theory of light is, that the specific inductive capacity of a medium is equal to the square of its refractive index. Another deduction is, that a body which is opaque to light, or, more generally, to radiant energy, should be a conductor of electricity. The first deduction appeared so clear an issue that many experimenters have put it to the test. The results

* Communicated by the Physical Society, having been read at the Meeting on February 25, 1882.

may be briefly summarized thus:—Some bodies (such, for example, as hydrocarbon oils* and paraffin-wax) agree with Maxwell's law so well that the coincidence cannot be attributed to chance, but certainly points to an element of truth in the theory: on the other hand, some bodies, such as glass† of various kinds, fluor-spar‡, Iceland spar‡, and the animal and vegetable oils§, have specific inductive capacities much greater than is indicated by their refractive indices.

How do these latter results really bear on Maxwell's theory? The facts are these. Taking the case of one substance as typical, the refractive indices of light flint-glass are very accurately known, the period of disturbance ranging from $\frac{1}{4.0 \times 10^{14}}$ second to $\frac{1}{7.6 \times 10^{14}}$ second; the specific inductive capacity is known to be about 6.7, the time of electrical disturbance being from $\frac{1}{17000}$ second to a few seconds. If from the observed refractive indices we deduce by a formula of extrapolation the refractive index for very long waves, we find that its square is about one third of 6.7. There can be no question about the accuracy of the observed refractive indices; and I have myself no doubt about the specific inductive capacity; but formulæ of extrapolation are always dangerous when used far from the actual observations. If Maxwell's theory is true, light flint-glass should be perfectly transparent to radiations having a wave-period of, let us say, $\frac{1}{17000}$ second; because this glass is sensibly a perfect electrical insulator, its refractive index for such waves should be about 2.6. Are there any facts to induce us to think such a thing possible? It is well known that in some cases strong selective absorption of light in the visible spectrum causes what is known as anomalous dispersion; that is to say, the body which presents such selective absorption of certain rays has a refractive index abnormally low for waves a little shorter than those absorbed, and an index abnormally high for waves a little longer than those absorbed||.

Light flint-glass is very transparent through the whole visible spectrum, but it is by no means transparent in the infra-red. If the absorption in the infra-red causes in light flint-glass anomalous dispersion, we should find a diminished refrac-

* Silow, Pogg. *Ann.* 1875, p. 382; 1876, p. 306. Hopkinson, Phil. Trans. 1881, part i. p. 371.

† 'Cavendish Researches,' edited by Clark Maxwell; Schiller, Pogg. *Ann.* 1874, p. 535; Wullner, *Sitz. k. bayer. Akad.* 1877, p. 1; Hopkinson, Phil. Trans. 1878, part i., 1881, part ii.

‡ Romich and Nowak, *Wiener Sitz.* Bd. lxx. part 2, p. 380.

§ Hopkinson, Phil. Trans. 1881, part ii.

|| 'Theory of Sound,' by Lord Rayleigh, vol. i. p. 125.

tive index in the red. We may say that we have a hint of this; for if we represent the refractive indices by the ordinates of a curve in which the squares of the reciprocals of the wave-lengths are abscissæ, this curve presents a point of inflection*. In the part corresponding to short waves it is concave upwards; in the part corresponding to long waves it is concave downwards: the curvature, however, is very slight. Does it not seem possible, looking at the matter from the purely optical point of view, that if we could examine the spectrum below the absorption in the infra-red, we should find the effect of anomalous dispersion, and that the refractive index of such long waves might even be so high as 2.6? To test this experimentally in a conclusive manner would probably not be easy. Perhaps the best chance of finding how these long waves are refracted would be to experiment on the rays from a thermopile to a freezing-mixture. Without an actual measurement of a refractive index below all strong absorption, it cannot be said that experiment is in contradiction to the Electromagnetic Theory of Light; for a strong absorption introduces a discontinuity into the spectrum which forbids us from using results on one side of that discontinuity to infer what they would be on the other side.

XXX. *Water-pipes that do not burst with Frost.* By C. VERNON BOYS, *Demonstrator of Physics, Normal School of Science, South Kensington*†.

DURING the severe weather of last winter, Mr. L. S. Powell proposed to me a scheme for preventing the possibility of water-pipes bursting through frost; and I have since learnt that Mr. Mangnall, of Manchester, independently hit upon the same idea. As far as I can remember, there were some letters in the 'Times' describing the use of india-rubber pipes containing air inserted in the service-pipes. This would obviously prevent pipes from bursting; for the pressure is of a nature that is relieved by a comparatively small expansion; and this the india-rubber tube allows to take place in the surrounding water when it collapses. There is, however, one serious objection to this, which is the possibility of the detachment of one end of the flexible tube, in which case a rush of water might cause it to accumulate in one place and obstruct the passage.

* Proceedings of Royal Society, 1877.

† Communicated by the Physical Society, having been read at the Meeting on November 12, 1881.