

December 12, 1895.

Sir JOSEPH LISTER, Bart., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

Pursuant to notice, Professor Albert Gaudry, Professor F. Kohlrausch, Professor S. P. Langley, Professor Sophus Lie, and Professor E. Metschnikoff were balloted for and elected Foreign Members of the Society.

The following Papers were read:—

- I. "On the Determination of the Indices of Refraction of various Substances for the Electric Ray. I. Index of Refraction of Sulphur." By Professor J. C. BOSE, B.A. (Cantab.), B.Sc. (Lond.). Communicated by LORD RAYLEIGH, Sec. R.S. Received October 20, 1895.

The indices of refraction of transparent substances have been determined by the usual optical methods. There is still a large number of substances like the various rocks, wood, brick, coal-tar, and others which are not transparent to light, so that their indices could not be obtained. These substances are, however, transparent to electric radiation; and the present investigation was undertaken to find a direct method of determining their indices with a sufficient amount of accuracy.

Even in the case of optically transparent substances, the indices are only known for the narrow range of light waves. For greater wave lengths, the index is inferred from Cauchy's formula. Professor Langley has, however, shown that this formula fails to give trustworthy results when applied to the dark radiations in the infra-red portion of the spectrum. It does not, therefore, seem at all likely that the above formula will give accurate results when applied to the electric radiation.

For the determination of the index for the electric ray, the prism method is unsuitable. In the well-known Hertz's experiment with the pitch prism, the deviation of the refracted rays extended from 11° to 34° . The approximate value of μ , = 1.69, obtained from this experiment, is probably higher than the true value by about 15 to 20 per cent.

For the accurate measurement of deviation, the effect produced by radiation on the receiver should undergo an abrupt variation. When the radiation passes from a dense to a light medium, at a certain critical angle of incidence, the radiation is totally reflected. From the critical angle the index of refraction is easily determined. The great advantage of this method lies in the fact that the transition from refraction to total reflection is very sudden.

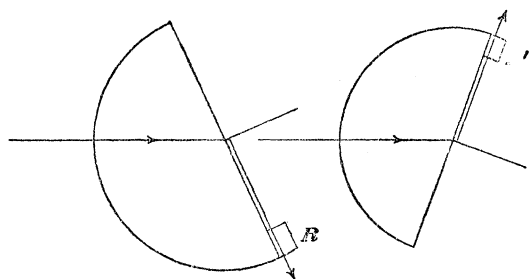
I have determined the μ of various substances for the electric ray, by the method of total reflection.

It will be seen from the results of the experiments, that this method is capable of giving very good results.

The refracting substance is cut out or cast in the form of a semi-cylinder, and mounted on the central table of a spectrometer; the electric ray is directed towards the centre of the spectrometer, and its direction is always kept fixed. It strikes the curved surface and passes into its mass without any deviation. It is then incident on the plane surface of the semi-cylinder, and is refracted into the air beyond.

The incident angle on the plane surface is increased or decreased by rotating the central table on which the cylinder rests. In practice, it is more convenient to commence the experiment with an angle of incidence greater than the critical angle, the incident ray being then

FIG. 1.



totally reflected. The angle of incidence is slowly decreased till the critical value is reached. At this point the ray is all at once refracted into the air, making an angle of 90° with the normal to the surface. If a receiver be fixed against the side of the semi-cylinder at R, it will now respond to the refracted radiation.

The platform on which the cylinder rests, carries the usual index. By alternately rotating the platform in one direction or the other, and observing the position of the index when the receiver just responds, the reading for the critical angle is obtained with great

accuracy. The receiver is now placed at R' , and the cylinder rotated in the opposite direction till total reflection again takes place. The difference between the first and second readings is evidently equal to twice the critical angle.

To utilise only the central rays, a metallic screen with a small central opening is placed against the plane face of the semi-cylinder. In order that all the rays should undergo total reflection simultaneously, it is necessary that the rays incident on the plane of separation of the two media should be parallel. This is effected by the cylinder itself. From the approximate value of μ found from a preliminary experiment, the focal distance of the semi-cylinder is roughly calculated. The spark-gap of the radiator is placed at this focus, and the rays thus rendered very near parallel. Each subsequent experiment gives a more accurate value of μ , and from the corrected value of the focal distance thus obtained, a more accurate adjustment is made for the next experiment.

Apparatus Used.

The apparatus used consists of an electric radiator emitting short waves, a large graduated circle provided with a central circular platform on which the refracting substance is placed, and a receiver, which responds to the electric radiation.

The Radiator.—I have given a detailed description of the electric radiator in my paper on polarisation of electric rays (*vide* Journal, Asiatic Society of Bengal, Part 2, No. 2, 1895). Electric oscillation is produced by sparking between two metallic beads and an interposed metallic sphere 1 cm. in diameter. By a single sudden break of the primary in a Ruhmkorff's coil, a flash of radiation is emitted. The spark gap is placed at one end of a brass tube 5 cm. in diameter. By a sliding arrangement, the length of the tube may be varied. The Ruhmkorff's coil is enclosed in a copper box.

The Circle.—The circle has a diameter of 45 cm., and is graduated into degrees, but one-fourth of a degree may be easily estimated. The circle, as a whole, may rotate round a vertical axis which passes through the centre of a massive stand. There is a raised circular platform at the centre of the circle on which the refracting substance is placed. This platform carries an index, and may be rotated independently of the large circle. When the platform index is clamped, the two circles rotate together.

The Refracting Substance.—For substances which can be cast, the molten mass is poured into a cylindrical mould with a thin partition in the middle. In this way two equal semi-cylinders are obtained at each casting. Substances like wood or stone are turned, and the cylinder sawn into two equal halves. In my experiments different sized cylinders were used. I have successfully used small ones with

a radius of 8 cm. only. But when the cost of the material is not prohibitive, it is advisable to use fairly large cylinders. The cylinders used in the following experiments were 27·4 cm. in diameter, and 10 cm. or more in height. For liquids, the cylindrical glass trough used has a diameter of 25 cm.

The tube of the radiator is fixed and points to the centre of the graduated circle. The vertical central line of the cylinder passes through the centre of the circular platform.

The Receiver.—The receiver is a modified form of the coherer. In a rectangular piece of ebonite a narrow groove is cut out. In this groove bits of coiled steel springs are arranged side by side, only one layer deep. In this way a linear receiver is constructed with a sensitive surface 2 cm. in length and 4 mm. in breadth. By means of a screw, the springs may be gradually compressed, reducing the resistance. The coherer is in a circuit with an aperiodic D'Arsonval galvanometer and a copper-iron cell. The galvanometer has a resistance of 300 ohms, and the voltaic cell has an E.M.F. of about 0·45 volt. A Daniell cell is sometimes used, with a resistance box as a shunt; the E.M.F. may thus be adjusted to suit the sensitiveness of the receiver. When the spiral spring coherer is freshly made, it is over sensitive. On the second day it settles down to a fair condition, though at first for about half an hour its action is rather unsteady. But afterwards the sensitiveness becomes fairly uniform. It will maintain this state under favourable conditions for nearly an hour; after which it begins to lose its sensitiveness. It must also be borne in mind that the sparking balls are also undergoing deterioration. The sensitiveness of the coherer may be partially restored by subjecting it to electric radiation at close quarters, and slightly raising the E.M.F. of the circuit. In this way it is sometimes possible to work continuously for about two hours; but greater weight should of course be given to the first sets of observations, which are taken at a time when the receiver is most sensitive.

It is superfluous to add that special precautions should be taken to guard against the disturbance due to stray radiations. The walls of the room, the table, even the person of the experimenter himself may act as reflectors, scattering the rays in all directions. I spent a considerable time in trying to find a substance that will act as a good absorber. Lamp black is useless, as it reflects copiously. Blotting paper soaked in water or copper sulphate solution does produce a certain amount of absorption; but even with these a certain amount of reflection is found to take place.

By proper screening, the disturbance due to stray radiations may, however, be got rid of. The radiating apparatus, with the exception of a tubular opening, is completely enclosed in a metallic box. The radiator tube extends right up to the refracting cylinder. The

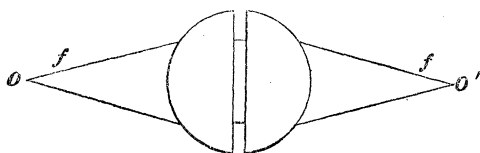
leading wires from the coherer are enclosed in a double coating of tin-foil.

Method of Experiment.

I first tried to determine the index of refraction of sulphur. The material used was ordinary commercial sulphur. A semi-cylinder was made, and the two positions for total reflection determined by the method which has already been described. The difference of readings found for the two positions varied from 69° to 71° and the value of the critical angle would from these experiments seem to lie between 34.5° and 35° . This approximate value for the critical angle having been obtained, the experiment was modified to secure a greater amount of accuracy.

Two equal semi-cylinders P and Q were taken and placed on the rotating table face to face, with an air film between. A metallic plate with a narrow rectangular opening was also interposed between

FIG. 2.

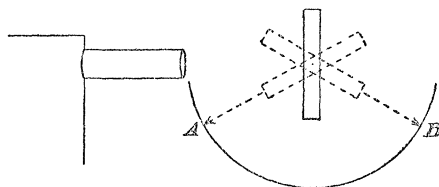


the semi-cylinders to serve as a diaphragm and cut off all but the central rays. When the spark gap is placed at O, the principal focus of P, the rays emerge parallel into the air film, and are then focussed by the second cylinder at an equal distance f on the other side.

The spark gap is placed at O, and the receiver at O', OO' being extremities of a diameter passing through the centre of the circle. The air film is for convenience placed parallel to the index.

The platform carrying the cylinders is now rotated, say to the left.

FIG. 3.



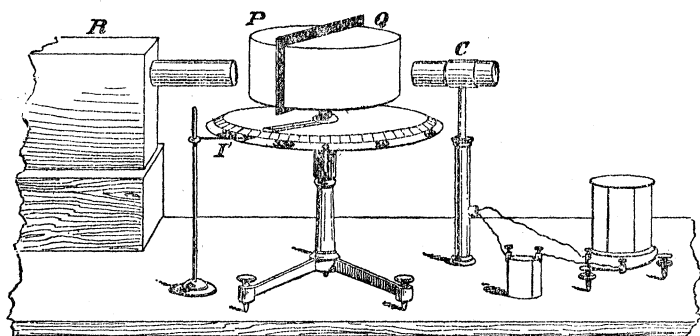
(The dotted lines represent the two positions of the air film for total reflection.)

The angle of incidence is thus gradually increased, till the rays just undergo total reflection. When this is the case the receiver ceases to respond. Let A be the corresponding reading of the platform index. A stationary index I' is now placed opposite the reading A of the graduated circle.

When the cylinder is rotated in the opposite direction a second reading B for the critical angle is obtained. It is obvious that, neglecting errors, $A-B$ is equal to twice the critical angle.

The platform index is now clamped and the circle as a whole is rotated till B comes opposite to the fixed index I' . The circle is now clamped, the platform arm unclamped, and the central table rotated till another reading C for the critical angle is obtained. Then, as in the previous case, $B-C = 2i$, where i is the critical angle. The circle as a whole is now rotated till C comes opposite the fixed index.

FIG. 4.



R, the Radiator; C, the Coherer.

Thus at each successive operation the circle is rotated past the fixed index through $2i$. The successive difference of readings of the circle in reference to the fixed outside index, thus gives a series of values of $2i$.

The result will be more accurate if we take the mean readings $\frac{1}{2}(A + B)$, $\frac{1}{2}(B + C)$, . . . , and take their differences. Successive readings are taken till the graduated circle is rotated as near as possible through 360° .

As has been said before, there are two semi-cylinders P and Q . In the first set of experiments P is turned towards the radiator, Q acting as a focussing lens. The circle at each successive operation moves in a *right-handed* direction.

In the second set of experiments Q is turned towards the radiator, P acting as the converging lens. Successive readings are taken as before, the circle now rotating in a *left-handed* direction.

It will be observed that the final results obtained from the two sets are freed from many of the unavoidable errors.

I give below the results of two sets of experiments each extending through eleven observations. The receiver was in an unusually good condition for nearly an hour, and during that time I took six observations with P to the front and six more with Q in the same position. As the receiver continued to remain in a fairly responsive condition I took five more for each set. As I have said already, greater weight should be given to the first two sets of six readings, as being taken under the most favourable conditions.

In the first two lines are given ten successive differences of the mean readings, taken with the cylinders P and Q.

P	71	70	70.5	70.5	70.5	70	69.5	69.5	69.5	70	= 701
Q	70	70	71	71	70	71	71	70	70	69.5	= 703.5
Mean										702.25	
$i = \frac{702.25}{2 \times 10} = 35.11, \mu = 1.738.$											

The following are the readings in degrees for the first six sets of observations with P or Q.

P.				
	<i>a.</i>	<i>b.</i>	Mean.	Difference.
1.....	216	144	188	71
2.....	144	74	109	70
3.....	74	4	39	70.5
4.....	(360)+4	293	328.5	70.5
5.....	293	223	258	70.5
6.....	223	152	187.5	
				352.5.... A.
Q.				
	<i>c.</i>	<i>d.</i>	Mean.	Difference.
1.....	308	360+18	343	70
2.....	18	88	53	70
3.....	88	158	123	71
4.....	158	230	194	71
5.....	230	300	265	70
6.....	300	360+10	335	
				352.0.... B.

Mean of A—B = 352.25.

$$i = \frac{352.25}{2 \times 5} = 35.22, \mu = 1.734.$$

If we take the differences between 1 and 4, 2 and 5, 3 and 6, we get the following four sets of values for a , b , c , and d .

Difference between	P.			Q.
	a .	b .	c .	d .
1 and 4	212	211	210	212
2 and 5	211	211	212	212
3 and 6	211	212	212	212
	<hr/> 634	<hr/> 634	<hr/> 634	<hr/> 636

Mean = 634·5.

$$i = \frac{634\cdot5}{6 \times 3} = 35\cdot25, \mu = 1\cdot733.$$

From the results given above it would appear that the index of refraction of sulphur is very near 1·73.

The method adopted thus seems to be capable of giving accurate results; no large quantity of material is required. The method is also well suited for liquids.

The determination of the indices of other solids and liquids are in progress. I shall give an account of these in a future communication.

- II. "Researches on the Structure, Organisation, and Classification of the Fossil Reptilia. Part X. On the complete Skeleton of an Anomodont Reptile (*Aristodesmus Rüttimeyeri*, Wiedersheim), from the Bunter Sandstone of Reichen, near Basel, giving new Evidence of the Relation of the Anomodontia to the Monotremata." By H. G. SEELEY, F.R.S.
Received November 7, 1895.

(Abstract.)

With the co-operation of the Trustees of the University Museum of Basel and Professor Rüttimeyer, the author has examined the fossil described by Dr. Robert Wiedersheim in 1878 as *Labyrinthodon Rüttimeyeri*. The bones are differently interpreted:—

The reputed humerus is the interclavicle.

The reputed scapula is the humerus.

The reputed supra-scapula is the left coracoid.

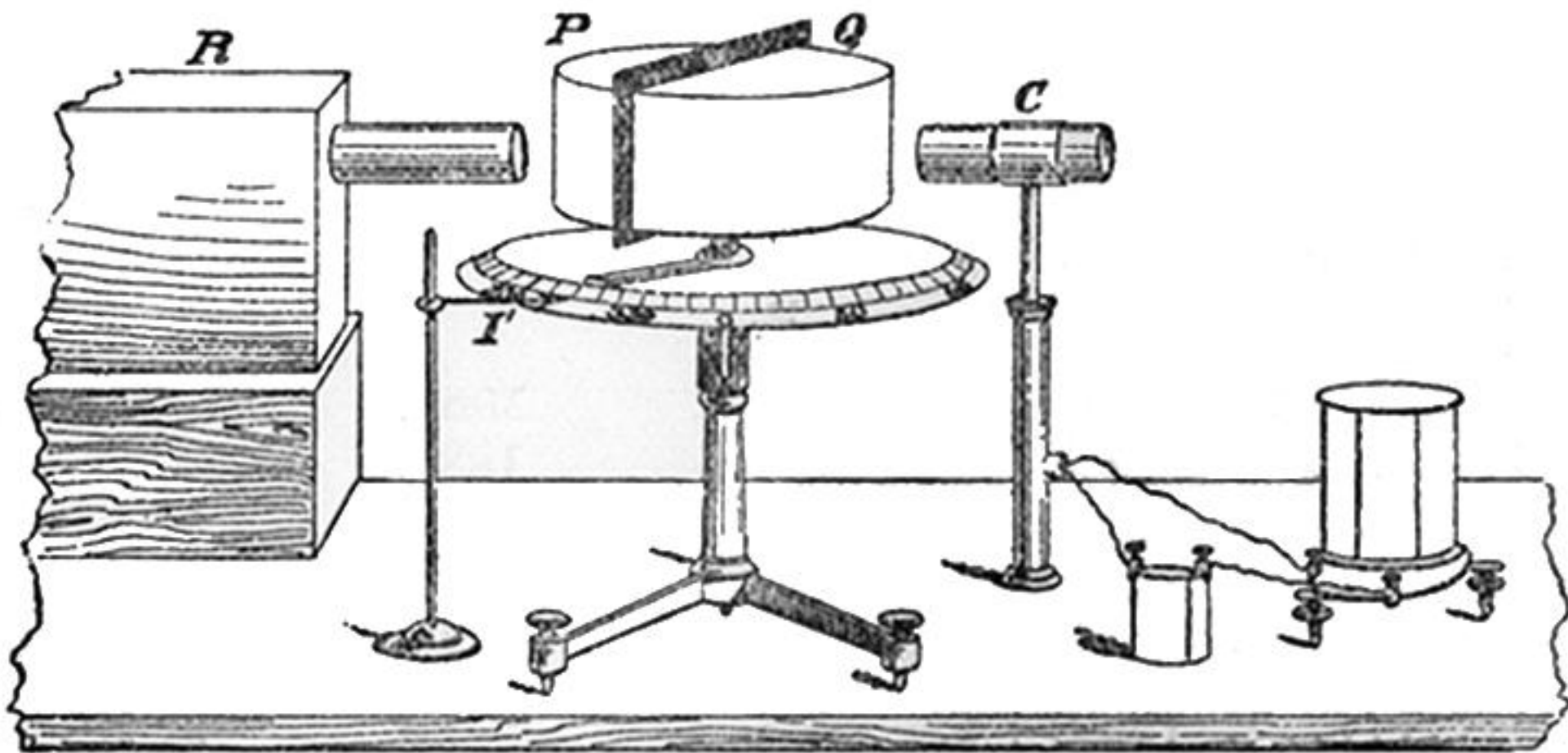
The reputed supra-scapula is the right scapula.

The reputed right and left coracoids are the pre-coracoid and coracoid of the right side.

The reputed clavicles are the ribs.

Five digits are identified in place of four in 1878.

FIG. 4.



R, the Radiator ; C, the Coherer.