I have nowhere called the undulatory *theory* of light an hypothesis; I have called the undulatory *conception* (Vorstellung) of light an hypothesis. I have nowhere said that "it is the *sinnliche Wahrnehmung* which changes the *Hypothese* to the *Naturgesetz*." Perception, as was seen in the case of photographs of light-waves obtained by Prof. Wiener, makes hypothesis a matter of fact. To call this fact a law, has never come into my mind.

I have nowhere stated Galilei's law of inertia to be a law of nature; I have declared it to be a postulate laid down on the basis of rich empirical materials (ein auf grundreichen empirischen Materials aufgestelltes Postulat, p. 169). Newton's law of gravitation and the principle of energy are typical examples of natural laws. The law of inertia belongs to the "axiomata sive leges motus" of Newton, and in this respect I have compared the law of inertia to the axioms of geometry, and, considering the rich experience of *to-day*, I have spoken as of an *appearance* of obviousness and immediateness (von einem *Scheine* des Einleuchtenden und Unmittelbaren, p. 168). How little I really think the law of inertia to be so obvious and immediate (so einleuchtend und so unmittelbar), my reviewer might also have learned from pages 74–76 of my book. In a postulate, as well as in a law of nature, immediate perception is entirely out of the question.

These few examples will suffice to show that my reviewer, perhaps owing to some difficulties in understanding the German language, has constructed certain ideas which, in fact, do not exist at all, and are, by no means, advocated by myself. As it is, I do not feel obliged to enter into a discussion of his other remarks, in which he, at least, quotes from my book correctly.

PAUL VOLKMANN.

University of Königsberg, January 18.

FOR our *Principle of Inertia* the Germans use two expressions, *Tragheitsprincip* and *Tragheitsgesetz*. Dr. Volkmann in his work almost invariably adopts the latter, and even speaks of the principle of inertia as *das physikalische Gesetz der Trägheit*. If a physical law be not a law of nature, Dr. Volkmann ought to have carefully distinguished between a *Naturgesetz* and a *physikalisches Gesetz*. I am sorry, however, to have given him more credit for logical consistency than he desires to lay claim to. The law of inertia describes how an insensible particle would move relatively to certain "fixed axes" under certain purely conceptual, not physically realisable conditions. The law of gravitation describes how two insensible particles would move relatively to certain "fixed axes" under certain purely conceptual, not physically realisable conditions. If Dr. Volkmann wishes to draw a distinction between the two, and calls the latter alone a law of nature, then my opinion of his *Erkenntnistheoretische Grundzüge* is now lower than it was when I wrote my notice of it. Dr. Volkmann refers me to pp. 74–76 of his work to illustrate that he did not consider the law of inertia *so einleuchtend und so unmittelbar*, yet those are precisely the pages from which I cited in my review the motion of the railway train, which Dr. Volkmann considers can illustrate the law of inertia, an example which I hold to be most illusory. It is especially dangerous to the young student, and most misleading in popular lectures like Dr. Volkmann's *Allgemein wissenschaftliche Vorträge*.

Dr. Volkmann tells us that Wiener's researches have changed the undulatory conception (*Vorstellung*) of light into *eine vollendete Thatsache*, it has now ceased to be an hypothesis. How a conception can become a physical fact by any amount of research, I fail to understand; although I do grasp how the contents of that conception may by new discoveries be found to adequately describe our physical sensations. But when the contents of the conception are found to adequately describe our sensations, then it seems to me that the orderly account of those contents, which we term theory, ceases to be hypothesis, and becomes a law of nature. If Wiener's work makes the undulatory conception an adequate account of sensation, then it converts the undulatory theory into a law of nature. But Dr. Volkmann tells us this is not what he has said. Perhaps the undulatory theory, now that the undulatory conception has become *eine vollendete Thatsache*, still remains a theory, or is a postulate, or a physical law, or something else in Dr. Volkmann's classification. I certainly do not sufficiently grasp Dr. Volkmann's *Grundzüge* to be able to classify it.

Lastly, I hope my "understanding of the German language" has misled me; otherwise I should say that Dr. Volkmann's present interpretation of what he has written on p. 168 "appears" to me disingenuous. What he has written there runs:—

"Wir befinden uns dem Tragheitsgesetz gegenüber heute vielleicht in ähnlicher Lage wie der Geometer seinen Axiomen gegenüber, dem es gerade darum so schwer fallt, an seinen elementaren Satzen erkenntnistheoretische Studien anzustellen, weil der Inhalt dieser Satze so einleuchtend, so unmittelbar zugänglich ist. So scheint dem Physiker heute das Tragheitsgesetz so einleuchtend, so unmittelbar, dass es als Axiom vorgetragen zu werden pflegt. Aber es gab eine Zeit, wo der Inhalt des Trägheitsgesetzes dem menschlichen Geiste durchaus nicht so unmittelbar zugänglich erschien, und dies werden wir uns zu vergegenwartigen haben, um die Bedeutung der Galileischen Forschung noch heute würdigen zu können."

I take this to mean that the law of inertia appears obvious to the physicist of to-day, but at the time of its discovery it was not at all an obvious conception. Dr. Volkmann says that in this passage he has spoken *von einem Scheine des Einleuchtenden und Unmittelbaren*. He has certainly used the verb *scheinen*, but when I say, for example, that twice two makes four *appears* to me a direct and obvious truth, I certainly do not mean to indicate that the directness and obviousness are *specious*. I must apologise to Dr. Volkmann for having misunderstood this subtlety of the German language.

It is perhaps necessary to add that Dr. Volkmann is raising a verbal controversy which has nothing to do with our radical difference of view. For me a law of nature is purely a product of the human intellect; it is a formula which describes in the briefest terms yet discovered as wide a range as possible of the motions we attribute to atoms, particles, molecules, ether, &c., which kinetic *concepts* form parts of the entirely *conceptual* model by aid of which we describe the sequences of our physical sensations. For Dr. Volkmann the law of nature is something existing *ausser uns* (p. 56) in some manner kept in harmony with the *Denknothwendigkeiten in uns*. Presumably the law lies in the *Dinge an sich*, for it would be impossible to find a law like that of gravitation in the contents of our physical sensations. It is at this point that the older view of the physical sciences, as something quite different from *descriptive* sciences, runs us aground on the metaphysical mudbank.

KARL PEARSON.

Durham Degrees in Science.

JUST two remarks in answer to the Rev. Henry Palin Gurney's letter in your last issue.

He admits by his silence my main contention, viz.—that the nature of the M.Sc. degree at Durham has been radically changed owing to the recent action of the University in granting the degree by vote of Convocation.

I did not insinuate in my letter that "these gentlemen had no qualification for the honour."

It is impossible for me to know the necessary qualifications for the degree other than those published by the University in their Calendar. It was sufficient for me that the latter were ignored.

X.

February 6.

ON THE CONDUCTIVE EFFECT PRODUCED IN AIR BY RÖNTGEN RAYS AND BY ULTRA-VIOLET LIGHT.[1]

WE propose in this communication to describe results of experiments on the electrical effects of Röntgen rays and of ultra-violet light when shone on metals, or through air between two metals mutually insulated; and electrified to begin with, by previously producing a difference of potentials between platinum electrodes of an electrometer metallically connected with them. In some of our experiments this potential-difference was zero, and the initial ± electrifications of the opposed surfaces depended solely on difference of volta-electric quality between their opposed surfaces.

To investigate the effects of Röntgen rays, a hollow cylinder of unpolished aluminium connected to the

[1] A paper by Lord Kelvin, Dr. J. C. Beattie, and Dr. Smoluchowski de Smolan, read before the Royal Society of Edinburgh, February 1.

electrometer sheaths was used. Along the axis of this a metallic bar was placed, supported by its ends on small blocks of paraffin so situated as not to be shone on by the Röntgen rays. This insulated metal was connected by a copper wire to the insulated terminal of the electrometer. To protect it from inductive effects it was enclosed in a lead tube connected to the other terminal and to sheaths (see Diagram 1).

The Röntgen lamp was placed in a lead cylinder connected to sheaths. The rays passed into the tube of aluminium through a window in the lead cylinder, which could be screened or unscreened at will, as described in our former paper (*Proc. R.S.E.*, December 1896).

The course of the experiment was the same with each insulated metal. The metal was charged first positively, then negatively; the Röntgen rays were then shone on it through the aluminium cylinder surrounding it, and the electrometer readings taken at fixed intervals, until a steady reading on the electrometer was obtained. The point at which the electrometer reading remained steady with the rays acting we shall call the *rays-zero*.

Finally, the insulated metal was discharged by metallic connection in the electrometer, and re-insulated; the rays were again shone on it until the rays-zero was again reached.

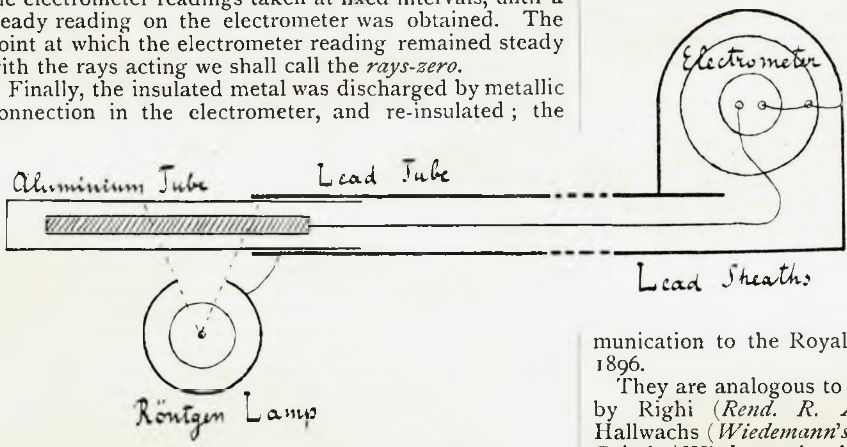

DIAGRAM 1.

The following figures, taken from the laboratory book, show the effect obtained in this way when the insulated metal was amalgamated zinc.

The zero with the electrometer quadrants in metallic connection we shall afterwards speak of as the *metallic zero*.

December 31, 1896, 5.56 p m.—Readings with one pair of electrometer quadrants insulated, and with Röntgen lamp acting.

− 72	scale divisions from metallic zero after	5 secs.
− 87	,, ,, ,, ,,	10 ,,
− 91	,, ,, ,, ,,	15 ,,
− 92	,, ,, ,, ,,	30 ,,
− 93	,, ,, ,, ,,	2 mins.

Afterwards steady.

Thus the difference between the rays-zero and the metallic zero is in this case − 93 scale divisions, or − 0·66 of a volt.

[Sensibility of electrometer 140 divs. per volt.]

This deviation from the metallic zero was not stopped by placing an aluminium screen over the window of the lead cylinder; on the other hand, it was stopped if a lead screen was used. If a positive or a negative charge was given to the insulated metal and the Röntgen rays were shone through the aluminium cylinder surrounding it, the discharge went on till the rays-zero was reached; only then was the electrometer reading steady.

In the following table, Column II. gives the potential differences of the rays-zero from the metallic zero for twelve different metals insulated within the unpolished aluminium cylinder as described above. Column III. gives the differences for two of the same metals in the interior, but with the surrounding aluminium cylinder altered by its inner surface being polished by emery paper.

I. Insulated metal.	II.	III.
Magnesium tape	− 0·671 of a volt	
Amalgamated zinc ...	− 0·66 ,, ,,	
Polished aluminium ...	− 0·465 ,, ,,	
Polished zinc	− 0·343 ,, ,,	
Unpolished aluminium	− 0·349 ,, ,,	... + 0·35 of a volt
Polished lead	− 0·257 ,, ,,	
Polished copper	+ 0·129 ,, ,,	
Polished iron nail ...	+ 0·182 ,, ,,	
Palladium wire	+ 0·255 ,, ,,	
Gold wire	+ 0·264 ,, ,,	... + 0·930 of a volt
Carbon	+ 0·429 ,, ,,	

It is to be noted that the preceding experiments tell us insufficiently as to what would happen had we shone the rays on an insulated metal surrounded by an absolutely identical metallic surface connected to sheaths. Another experiment towards answering this question will be described in a later part of our paper.

The preceding results of the action of Rontgen rays are very similar to, and wholly in accordance with, the results found by Mr. Erskine Murray, and described by him in a communication to the Royal Society of London, March 19, 1896.

They are analogous to those found for ultra-violet light by Righi (*Rend. R. Acc. dei Lincei*, 1888, 1889); Hallwachs (*Wiedemann's Annalen*, 34, 1888); Elster and Geitel (*Wiedemann's Annalen*, 38, 41, 1888); Branly (*Comptes rendus*, 1888, 1890), and others.

We have also made some experiments with ultra-violet light, in which this similarity is further brought out. The method we have employed is that of Righi.

A cage of brass wire gauze was made and connected to sheaths. Inside it the insulated metal was placed on a block of paraffin, and connected to the insulated terminal of the electrometer by a thin copper wire protected against inductive effects. The light from an arc lamp was then shone through the gauze so as to fall on the insulated metal perpendicular to its surfaces (see Diagram 2).

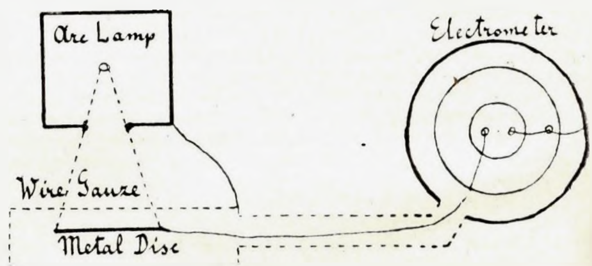

DIAGRAM 2.

The experiments were of the same nature as those with the Röntgen rays, except that wire gauze letting through the ultra-violet light was substituted for the non-perforated aluminium cylinder transparent to the Rontgen rays. The insulated metal disc was 2 cms. distant from the gauze of brass wire. The steady electrometer readings after the two pairs of quadrants were insulated and the ultra-violet light shining (which we shall hereafter refer to as the *ultra-violet-light-zero*) was observed.

The insulated metal was afterwards charged positively, and then negatively. The rate of discharge was observed till the ultra-violet-light-zero was reached.

With polished zinc as the insulated metal the following results were obtained.

The insulation was first tested. When no ultra-violet light was used it was found that the electrometer reading remained the same whether the two pairs of quadrants were in metallic connection or not. With the ultra-violet light shining the reading with the quadrants in metallic connection was the same as before, the readings with the quadrants disconnected were :—

January 14th, 3h. 41m. p.m.

– 25	sc. divs.	from metallic zero	after	15 secs.
– 45	,,	,,	,,	30 ,,
– 59	,,	,,	,,	45 ,,
– 67	,,	,,	,,	1 min.
– 80	,,	,,	,,	$1\frac{1}{2}$,,
– 89	,,	,,	,,	2 ,,
– 99	,,	,,	,,	3 ,,
– 101	,,	,,	,,	4 ,,

Afterwards steady.

[Sensibility of electrometer, 140 sc. divs. per volt.]

The difference thus found, between the metallic zero and the ultra-violet-light-zero, is –101 or –0·72 of a volt.

3h. 47m. Zinc charged positively to 219 scale divisions from the metallic zero.

Reading from metallic zero with ultra-violet light shining.—

	Time.
+ 124	after 15 secs.
+ 64	,, 30 ,,
+ 23	,, 45 ,,
– 13	,, 1 min.
– 55	,, $1\frac{1}{2}$,,
– 79	,, 2 ,,
– 93	,, $2\frac{1}{2}$,,
– 100	,, $3\frac{1}{2}$,,
– 103	,, 4 ,,

Afterwards steady.

3h. 55m. Zinc charged negatively to 238 scale divisions from metallic zero :—

– 177	sc. divs.	from metallic zero	after	15 secs.
– 149	,,	,,	,,	30 ,,
– 132	,,	,,	,,	45 ,,
– 124	,,	,,	,,	1 min.
– 113	,,	,,	,,	2 ,,
– 111	,,	,,	,,	3 ,,

Afterwards steady.

The following table shows the steady potential differences in the electrometer due to the conductive effect of ultra-violet light in our apparatus between the brass wire gauze and plates of various other metals.

Insulated metal :—

Polished zinc	–0·75 of a volt.
Polished aluminium ...	–0·66 ,,
German silver	–0·19 ,,
Gilded brass	+0·04 ,,
Polished copper ...	+0·12 ,,
Oxidised copper ...	+1·02 ,,

The copper was oxidised by being held in a Bunsen flame.

In the case of polished zinc, polished aluminium, polished copper, and oxidised copper, both positive and negative charges were discharged at the same rate, if we reckon the charge of the insulated metal from its ultra-violet-light-zero. The rates of reaching the ultra-violet-light-zero were not observed for gilded brass and German silver.

It must again be noticed that our experiments do not tell us what would happen if an insulated metal, shone on by ultra-violet light, were surrounded by a metal of precisely the same quality of surface connected to sheaths.

So far we have mentioned only experiments in which the rays, whether Röntgen or ultra-violet, fell perpendicularly on the insulated metal. We have also made some experiments with the rays going parallel to the metal surfaces.

For this purpose a cardboard box 46 cms. long, 19 cms. square (see Diagram 3), lined, in the first instance, with tinfoil, connected to sheaths, was used. Inside this box an insulated disc of oxidised copper of 10 cms. diameter was supported in such a way as to allow of its being fixed at different distances from the tinfoil-coated end-wall of the box facing it.

The distance between the disc and the tinfoil was at first 4 cms. The arc lamp was distant about 20 cms. from the box. The light from it shone through a slit in the tinfoil covering the side of the box perpendicular to the surface of the oxidised copper. The slit was 4 cms. long, 1 cm. broad. Its length was first placed parallel to the copper surface, so that the light admitted by it shone in the space between the two metals in such a way as not to illuminate either directly. It was found (1) that the ultra-violet-light-zero did not deviate from the metallic zero when the sheet of light passed between the two metals; (2) that a negative charge given to the insulated oxidised copper was not discharged; and (3) that a positive charge was removed very slowly—about four scale divisions per minute from a charge of 197 scale divisions from the metallic zero.

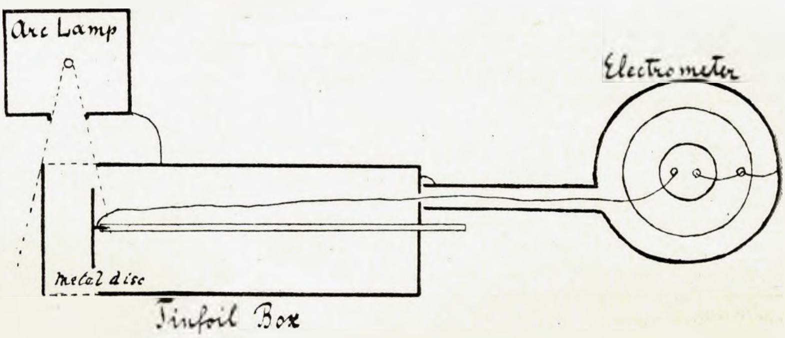

DIAGRAM 3.

When the length of the slit was placed perpendicular to the surface, so that a small portion of both metals, as well as the intervening air, was illuminated, it was found that the reading deviated about +1 scale division per minute from the metallic zero. The oxidised copper was charged positively; and negatively. Discharge took place at about four scale divisions per minute, from a charge of +202 scale divisions; and three scale divisions per minute from a charge of –246 scale divisions: the charge reckoned from the metallic zero in each case.

The slit was then so arranged as to allow the light to shine on the oxidised copper alone. In this case the deflection went towards an ultra-violet-light-zero at about +6 sc. divs. per minute; and both positive and negative charges were discharged, the negative much more quickly than the positive.

The ultra-violet light was now shone between the oxidised copper and the disinsulated tinfoil wall opposite to it, parallel to their surfaces so as to illuminate both. The difference between the metallic zero and the ultra-violet-light-zero was found to depend on the distance between the two surfaces. This will be seen from the following table :—

Jan. 28.	Ultra-violet-light-zero.	Distance between surfaces.	Time required to come to steady reading.
12.20 p.m.	+ 150 {sc. divs. from metallic zero}	4·3 cms.	4 mins.
2.0 ,,	+ 134 ,, ,,	3·0 ,,	9 ,,
2.10 ,,	+ 121 ,, ,,	2·0 ,,	5 ,,
2.20 ,,	+ 102 ,, ,,	1·0 ,,	5 ,,
2.40 ,,	+ 86 ,, ,,	0·6 ,,	5 ,,
2.50 ,,	+ 169 ,, ,,	4·0 ,,	10 ,,
3.0 ,,	+ 161 ,, ,,	5·0 ,,	5 ,,
3.20 ,,	+ 199 ,, ,,	7·0 ,,	5 ,,

[Sensibility of electrometer 140 sc. divs. per volt.]

The fact that in experiments (2) and (6) a longer time was required before a steady reading was obtained, probably depended on the way the light fell on the surfaces and on variations in intensity of the light.

In this table we see that the steady electrometer reading (which we have called the ultra-violet-light-zero) is largely influenced by the distance between the plates, being greater the greater the distance. This is a very remarkable result. It was first discovered by Righi, and very clearly described in papers of his to which we have referred. It may be contrasted with the non-difference of electrometer readings for different distances between the plates in a volta-zinc-copper and single fluid cell.

Added February 6. [We have also made an exactly similar series of experiments with Röntgen rays. The same insulated oxidised copper plate was placed inside the same tinfoil box, and the Röntgen rays shone in between the two metals so as to shine on both. The following results were obtained with the oxidised copper at different distances.

February 5, 11.30 a.m.

Rays-zero.	Distance between surfaces.
+ 23·5 sc. divs. from metallic zero ...	1·2 cms.
+ 25·0 ,, ,, ,, ...	2·2 ,,
+ 23·0 ,, ,, ,, ...	3·8 ,,
+ 23·0 ,, ,, ,, ...	6·0 ,,

We next removed the oxidised copper plate, and substituted a polished zinc disc. With it we obtained the following results.

Rays-zero.	Distance between surfaces.
− 82 sc. divs. from metallic zero ...	1 cm.
− 79 ,, ,, ,, ...	1·5 ,,
− 81 ,, ,, ,, ...	3·0 ,,
− 90 ,, ,, ,, ...	7·0 ,,
− 90 ,, ,, ,, ...	7·5 ,,

The steady reading of the rays-zero was very nearly reached in each case in about 15 secs., but the observation was continued for one or two minutes till we found the reading steady.

Thus we see that, as previously found by Mr. Erskine Murray, the rays-zero is independent, or nearly independent, of the distance between the opposed metallic surfaces.]

Towards realising the case of an insulated metal surrounded by metal of identical surface-quality connected to sheaths, we covered over the oxidised copper with tinfoil. The tinfoil wall facing it was very rough, and not so well polished. The insulated tinfoil was 4 cms. distant from the end of the box to which its surface was parallel.

When the ultra-violet light fell on the insulated metal alone through a slit, the ultra-violet-light-zero was + 53 scale divisions from the metallic zero. A charge given to it, whether positive or negative, was discharged slowly. After making these experiments, we again observed the difference of zeros, and found that now the ultra-violet-light reading was at the end of the first four minutes + 2 scale divisions from the metallic zero; at the end of the next four minutes it was − 8 scale divisions from it.

When the ultra-violet light fell on the disinsulated metal and not on the insulated, the insulated when charged retained its charge.

With the light shining on both through a window 7 cms. broad, 13 cms. high, both positive and negative charges given to the insulated metal were discharged, and the ultra-violet-light-zero deviated from the metallic zero by − 152 scale divisions.

This difference was reduced to about − 30 scale divisions when the experiments were repeated after the apparatus had been left to itself for a night.

To make similar experiments with the Röntgen rays, it was found necessary to cover the window near the lamp with tinfoil gauze connected to sheaths, and the window on the opposite side was covered with non-perforated tinfoil. In this way direct electrostatic induction was avoided. We had also a thin sheet aluminium window between the tinfoil gauze and the Röntgen lamp.

When the Röntgen rays fell on both insulated and disinsulated metal the rays-zero was − 5 scale divisions from the metallic zero, and both positive and negative charges fell to this zero in a few seconds.

With the rays shining only on the insulated metal the same small difference of zeros was obtained, and both positive and negative charges fell to the rays-zero, though much more slowly than before—in about four minutes.

With the Röntgen rays shining on the insulated tinfoil through the disinsulated tinfoil gauze, the rays-zero was − 9 scale divisions from the metallic zero, and both positive and negative charges were removed in about a minute.

On substituting an aluminium gauze for the tinfoil gauze, and sending rays through it on the insulated tinfoil, the rays-zero was + 25 scale divisions from the metallic zero.

Added February 6. With a polished zinc disc as the insulated metal, and with the same windows to the tinfoil box, the Röntgen rays were shed in between the insulated zinc and the opposite wall of tinfoil from a slit in a lead screen outside. This slit was 4 cms. long by 1 cm. broad. The distance between the two metals was 7 cms. The rays illuminated only part of the air space between the two, and also a part of the tinfoil covering the two windows.

The following are some of the results obtained:—

[Sensibility of electrometer 140 sc. divs. per volt.]

February 5, 1897. Zinc charged negatively to 285 scale divisions from the metallic zero.

Reading from metallic zero with Röntgen lamp acting:—

	Time.
− 276 scale divisions ...	after 1 min.
− 265 ,, ...	,, 2 ,,
− 255 ,, ...	,, 3 ,,
− 243 ,, ...	,, 4 ,,
− 227 ,, ...	,, 5 ,,
− 214 ,, ...	,, 6 ,,
− 184 ,, ...	,, 8 ,,

Discharge still continued.

The zinc was then discharged by metallic connection. The readings, with the Röntgen light shining, and the two pairs of electrometer quadrants again disconnected, were:—

− 4	sc. divs.	from metallic zero	after	$\frac{1}{2}$ min.
− 13	,,	,,	,,	$1\frac{1}{2}$,,
− 41	,,	,,	,,	$2\frac{1}{2}$,,
− 53·5	,,	,,	,,	$3\frac{1}{2}$,,
− 61	,,	,,	,,	$4\frac{1}{2}$,,
− 67	,,	,,	,,	$5\frac{1}{2}$,,
− 70·5	,,	,,	,,	$6\frac{1}{2}$,,
− 71·0	,,	,,	,,	7 ,,

The difference between the rays-zero and the metallic zero is thus found to be − 71 sc. divs., or − 0·5 of a volt. Immediately after this experiment, we removed the lead window and allowed the Röntgen light to shine on both metals, still 7 cms. apart. We then found the difference of zeros to be − 89 sc. divs., or − 0·64 of a volt; but instead of seven minutes, scarcely a quarter of a minute was taken to reach the rays-zero after the metallic connection was broken. These results are substantially in accordance with Erskine Murray's §§ 9 of his paper already referred to.

KELVIN.
J. C. BEATTIE.
SMOLUCHOWSKI DE SMOLAN.

THE EFFECT OF MAGNETISATION ON THE NATURE OF LIGHT EMITTED BY A SUBSTANCE.[1]

IN consequence of my measurements of Kerr's magneto-optical phenomena, the thought occurred to me whether the period of the light emitted by a flame might be altered when the flame was acted upon by magnetic force. It has turned out that such an action really occurs. I introduced into an oxyhydrogen flame, placed between the poles of a Ruhmkorff's electromagnet, a filament of asbestos soaked in common salt. The light of the flame was examined with a Rowland's grating. Whenever the circuit was closed both D lines were seen to widen.

Since one might attribute the widening to the known effects of the magnetic field upon the flame, which would cause an alteration in the density and temperature of the sodium vapour, I had resort to a method of experimentation which is much more free from objection.

Sodium was strongly heated in a tube of biscuit porcelain, such as Pringsheim used in his interesting investigations upon the radiations of gases. The tube was closed at both ends by plane parallel glass plates, whose effective area was 1 cm. The tube was placed horizontally between the poles, at right angles to the lines of force. The light of an arc lamp was sent through. The absorption spectrum showed both D lines. The tube was continuously rotated round its axis to avoid temperature variations. Excitation of the magnet caused immediate widening of the lines. It thus appears very probable that the period of sodium light is altered in the magnetic field. It is remarkable that Faraday, as early as 1862, had made the first recorded experiment in this direction, with the incomplete resources of that period, but with a negative result (Maxwell, "Collected Works," vol. ii. p. 790).

It has been already stated what, in general, was the origin of my own research on the magnetisation of the lines in the spectrum. The possibility of an alteration of period was first suggested to me by the consideration of the accelerating and retarding forces between the atoms and Maxwell's molecular vortices; later came an example suggested by Lord Kelvin, of the combination of a quickly rotating system and a double pendulum. However, a true explanation appears to me to be afforded by the theory of electric phenomena propounded by Prof. Lorentz.

In this theory, it is considered that, in all bodies, there occur small molecular elements charged with electricity, and that all electrical processes are to be referred to the equilibrium or motion of these "ions." It seems to me that in the magnetic field the forces directly acting on the ions suffice for the explanation of the phenomena.

Prof. Lorentz, to whom I communicated my idea, was good enough to show me how the motion of the ions might be calculated, and further suggested that if my application of the theory be correct there would follow these further consequences: that the light from the edges of the widened lines should be circularly polarised when the direction of vision lay along the lines of force; further, that the magnitude of the effect would lead to the determination of the ratio of the electric charge the ion bears to its mass. We may designate the ratio e/m. I have since found by means of a quarter-wave length plate and an analyser, that the edges of the magnetically-widened lines are really circularly polarised when the line of sight coincides in direction with the lines of force. An altogether rough measurement gives 10^7 as the order of magnitude of the ratio e/m when e is expressed in electromagnetic units.

On the contrary, if one looks at the flame in a direction at right angles to the lines of force, then the edges of the broadened sodium lines appear plane polarised, in accordance with theory. Thus there is here direct evidence of the existence of ions.

This investigation was conducted in the Physical Institute of Leyden University, and will shortly appear in the "Communications of the Leyden University."

I return my best thanks to Prof. K. Onnes for the interest he has shown in my work. P. ZEEMAN.

Amsterdam.

[1] Translated by Arthur Stanton from the *Proceedings* of the Physical Society of Berlin.

NOTES.

THE Council of the Royal Society have invited Prof. C. S. Sherrington, F.R.S., Professor of Physiology in University College, Liverpool, to deliver the Croonian Lecture on April 1, the subject being "The Spinal Cord and Reflex Actions."

TUESDAY'S *Gazette* contains the formal intimation that the dignity of a Baron of the United Kingdom has been granted to Sir Joseph Lister, Baronet, President of the Royal Society, by the title of Baron Lister, of Lyme Regis, in the county of Dorset.

PROF. DR. RUDOLF VIRCHOW has been elected president of the German Anthropological Society for the year 1897.

IT is expected that Prof. Barnard will attend the meeting of the Royal Astronomical Society to-morrow, February 12, to receive the gold medal which has been awarded him for his numerous contributions to astronomy. Sir Robert Ball has been nominated as the new president of the Society.

THE Council of the Royal Meteorological Society have arranged to hold, from March 16 to 19, in commemoration of the diamond jubilee of H.M. the Queen, an exhibition of meteorological instruments in use in 1837 and in 1897, and of diagrams, drawings, and photographs illustrative of the advances which have been made.

THE Government of the Colony of the Cape of Good Hope has undertaken an investigation of the marine fauna of the South African coast, with reference both to economic value and scientific interest. A small marine station will probably be erected on False Bay, and a suitable steam vessel of about 150 tons is now being built for this purpose. It is confidently hoped that results of some scientific value may be obtained from the exploration of this little-known coast, and more especially of the Agulhas Bank. We are requested to state that the services of specialists are invited to work up the material that may be procured, under the following arrangements. Specimens will be forwarded as procured, and, on receipt of manuscript and drawings, each piece of work will be published without delay in a uniform style, so as to form ultimately a complete record of the Cape marine fauna. Authors' copies will be forwarded as soon as published, and a certain circulation will be guaranteed. No money remuneration is offered, but duplicate specimens may be retained by the authors. Unique specimens it is intended to be handed over to the South African Museum in Cape Town. Further information will be supplied to those interested in th work, on application to J. D. F. Gilchrist, Marine Biologist to Cape Government Agricultural Department, Cape Town.