the compacting of the loose material. The moisture among it and the first snow that falls on its surface freeze. And thus a thoroughly compact moss is provided to resist snow-slips and to permit the water, from the melting snow when the thaw comes, to flow over it into the courses which feed the mountain torrents.

9. A careful examination of the deposits within this area, so far as they have any bearing on former Arctic conditions of climate and a glacial surface, begets the belief that the bulk of the phenomena may ultimately find their explanation in the recognition of two movements—one from the west, north-west, or north-north-west, inwards to the Ben Nevis range, and another, subsequently, outwards from Ben Nevis as a centre.

3. Remarks on Dielectric Strength. By Professor Chrystal.

The phenomena accompanying the disruptive discharge of electricity are, in the present state of electric science, among the most interesting known, because they are the least understood, and, so far as we know, the least concordant with our preconceived ideas. The simplest way of representing the facts is to imagine with Faraday that the non-conducting medium, or dielectric, between two charged conductors is the seat of mechanical stress, consisting of tension along, and pressure perpendicular to, the lines of force. The rupture of the dielectric may then be conceived as a phenomenon precisely analogous to the rupture of an elastic body under stress. We are thus led to the conclusion that the commencement of the rupture happens at that particular point where the tension first reaches a certain value, called the breaking tension or dielectric strength, which depends merely on the material of the dielectric, and on its physical condition at the time being. The main thing in any experiment on dielectric strength is to know the tension at the point where the rupture begins. According to Maxwell's rendering of Faraday's theory, the tension is $\frac{K}{8\pi}R^2$, where R is the resultant electric force and K the specific inductive capacity of the dielectric. If the dielectric be uniform, R will be a maximum at the surface of some conductor. If then σ be the surface density, since $KR = 4\pi\sigma$, we have at the point of rupture,

$$\tau = \frac{K}{8\pi} R^2 = \frac{2\pi}{K} \sigma^2;$$

and the discharge will begin at that point of some conductor of the system whose surface density first reaches the value $\sqrt{\frac{K\tau}{2\pi}}$.

In this view the beginning of disruptive discharge is conditioned solely by the nature of the dielectric in the immediate neighbourhood of a certain point on the surface of the discharging body, and by the electrical surface density at that point. This is, in the first instance, unquestionably the simplest and most scientific analysis of the phenomena, but it has not as yet, I think, been shown that it will account for all the observed facts. Experimenters have mainly themselves to blame for this; for they have in too many cases simply worked at random, and have consequently fallen among circumstances so complicated that a theoretical examination of their results is out of the question. Some, for instance, have apparently imagined that the breaking tension or dielectric strength of a medium could be inferred from the difference of potential required to produce a spark of given length between two bodies in it, no matter what their form or surroundings. The most casual observation of course proves the contrary. I am not aware whether any definite experiments have ever been made to show the influence of the *electrical condition* of surrounding conductors. The following extracts from notes of some experiments made last summer,* may perhaps be of some interest as illustrating this point. P and Q are

two rounded terminals between which the spark was taken. P was charged by means of a Holtz machine to a potential, which was measured by means of an electrometer, the method employed being a modification of that used by Dr. Macfarlane in his experiments

* With the valuable assistance of Dr. Macfarlane.

on disruptive discharge. R and S are two parallel metal discs faced with plates of glass *aa* and *bb*, to prevent discharge between them and P or Q. R can be raised to any required potential by charging the Leyden jar L. Q and S, the outer coating of L, and the other electrode of the Holtz machine, are all connected with the earth.

For a given distance PQ of 6 mm. or so, provided the distance, RS is not too small, the mere presence of R and S does not sensibly increase or diminish the difference of potential required to produce a spark between P and Q. But the case is very different if R be raised to a considerable potential, as will be seen by the following tables. In the columns headed P and R, the sign of the charge of these conductors is given; under V, the difference of potential (in an arbitrary unit) required to produce the spark; in the last column the difference between the two values of V.

P	R	V	Difference.	
+	–	129	– 20	PQ = 6 mm. RS = 25 mm.
+	0	149	...	
+	+	160	+ 27	
+	0	133	...	
+	+	142	+ 22	PQ = 3 mm. RS = 25 mm.
+	0	120	..	
+	–	107	– 25	
+	0	132	...	
–	+	140	– 30	PQ = 5·5 mm. RS = 25 mm.
–	0	170	...	
–	–	190	+ 20	
–	0	170	...	

A modification of the experiment was made by insulating S, and charging and discharging it along with R, with the following result:—

P	R	S	V	Difference.	
+	+	+	195	+ 56	} PQ = 7 mm. RS = 28 mm.
+	0	0	139	...	
+	+	0	163	+ 27	
+	0	0	136	...	

It appears very clearly from these experiments, that the presence of an independently charged body affects considerably the potential required to produce rupture. When the neighbouring body has a similar charge to the discharging one, a higher potential is required; and, when it has an opposite charge, a lower potential is required than when the neighbouring body is neutral or absent. The effect becomes smaller, *ceteris paribus*, when the distance PQ is diminished, and increases when the distance RS is diminished. If we bear in mind that it is the surface density at extremity of P, which determines the rupture, and not the difference of potential between P and Q merely, this result is precisely what we ought to expect.

If we assume that in the cases above quoted the charging of R and S affected the whole charge on P without sensibly altering its relative distribution, which must have been approximately true since the mere presence of R and S in the neutral state did not affect the discharge, then the surface density at every point of P will be proportional to its whole charge. Let p be the capacity of P depending almost entirely on the presence of Q; $-q$ the coefficient of induction between R and P, which is the same as that between S and P; V_0 the potential of P corresponding to rupture when R and S are at potential zero, V the corresponding value when R and S are at potentials U and U' respectively. Then we have, since the surface density at the point of rupture is the same in both cases, and therefore by our assumption the whole charges also the same,

$$pV_0 = pV - q(U + U') ,$$
$$V - V_0 = \frac{q}{p}(U + U') .$$

In the cases where R alone was charged we have

$$V - V_0 = \frac{q}{p} U.$$

When both R and S were charged to the same potential,

$$V - V_0 = 2\frac{q}{p} U.$$

These formulæ reproduce all the results quoted above; they further indicate that the differences are proportional to the potential of the disturbing body, as was found to be the case in some rough experiments which were tried to test this conclusion.

The fact that the presence of an oppositely charged body facilitates discharge from a conductor, suggests the curious conclusion that a spark may under certain circumstances be caused to pass between two bodies by merely bringing up near them a body oppositely charged to that on which the point of maximum surface density is to be found. This experiment was repeatedly tried with perfect success. P was gradually charged up until the electrometer indicated that it was near the potential of rupture. Then the machine was stopped and R suddenly charged oppositely to P by connecting it with a large Ledyen jar standing ready for the purpose. The result was to cause disruptive discharge between P and Q. A similar phenomenon no doubt sometimes occurs in nature. Suppose there were a positively charged thunder cloud at some distance from the earth, near, but not quite at, the point of discharging; the advent of another cloud negatively charged, but at a smaller height, might cause the lightning to pass down from the higher cloud to the earth.

Among the various circumstances that might affect the strength of a dielectric I thought, for reasons needless to relate, that it would be interesting to examine whether its magnetic state be material. With this view I arranged two spark terminals between the poles of a powerful electromagnet in different positions relatively to the lines of magnetic force and measured the difference of potential required to produce a spark when the magnet was excited and when it was not. The result was entirely negative. Although the magnetic force* employed went as high as 6000 absolute C. G. S. units, I

* For the rough measurement of the strength of the magnetic field I am indebted to Mr. Albert Campbell.

could detect no difference amounting to 1 per cent. which was about the uncertainty in my best experiments.

The earliest measurements in absolute units, from which the dielectric strength of air could be deduced, were those of Sir William Thomson (1860), who measured the electromotive force between two parallel plates required to produce a spark varying in length from .0025 cm. up to .15 cm. De La Rue and Müller (1877), Macfarlane (1878), and T. B. Baille (*Comptes Rendus*, Jan. 1882, pp. 38 and 130), have followed in his footsteps. The following table contains some selections from their results :—

Spark Lengths in Centimetres.	Potential Required to produce the spark in C. G. S. Electrostatic Units.				
	Thomson.	De La Rue and Müller.	Macfarlane.	Baille.	Water Electrometer.
.01	2.33	...	...	3.16	...
.05	7.28	7.69	7.48	8.71	...
.10	13.30	14.47	11.56	14.67	...
.30	...	34.44	25.56	35.35	...
.61	...	...	45.61	64.81	55.00

It will be seen that the agreement between the different experimenters is far from perfect. To those familiar with the manifold difficulties attending measurements of this kind, this is not surprising. I may mention that the result in the last column was obtained last summer by Dr. Macfarlane and myself, by means of a new form of absolute electrometer which I was led to devise during a course of experiments of which we hope to give an account hereafter. The instrument consists simply of an insulated plane disc, suspended parallel to a surface of water connected with the earth. When the disc is raised to a high potential, the water rises up and forms a plateau, whose height is measured by observing with a micrometer eyepiece the displacement of the image of a fixed point seen by reflection at the surface of the water. From this we can calculate at once the difference of potential between the disc and the water in absolute units. The instrument is very direct and ready in its ap-

plication, and promises well so far. If it continues to answer our expectations I shall take the liberty of laying a detailed description of it before the Society.

There is one point of great interest on which all these experimenters are agreed, viz., that the curve whose abscissæ is the spark length, and whose ordinate is the spark potential, is not a straight line as it ought to be by the ordinary electrostatic theory, combined with the notion of dielectric strength above explained, the air between the plates being assumed to be a *uniform* dielectric. There can be no question that at very short distances the falling off from this law is very great. I think that there has been a slight tendency to overstate the discrepancy for distances over .1 cm. Taking Baille's numbers, excluding all distances under .2 cm., I calculated by the method of least squares the formula of the form $V' = as + b$, which would best reproduce his observations. V' denotes calculated spark potential for s centimeters; V the observed spark potential. The formula found was

$$V' = 99.593s + 4.997 .$$

The following Table gives the comparison :—

s	V	V'	$V - V'$
.1	14.67	14.96	– .29
.2	25.51	24.92	+ .59
.3	35.35	34.88	+ .47
.4	44.77	44.83	– .06
.5	54.47	54.79	– .32
.6	63.82	64.75	– .93
.7	73.78	74.71	– .93
.8	84.86	84.67	+ .19
.9	94.72	94.63	+ .09
1.0	105.50	104.59	+ .91

The error nowhere exceeds 3 per cent., and if we consider the increased probability of error from leakage at the high potentials,

the arrangement of the negative signs in the middle of the difference column, indicating a slight curvature, may be said to be accounted for. I find a similar result on reducing some of Macfarlane's Tables in the same way, so that it would scarcely be unreasonable to say that for distances beyond .1 cm., the curve is straight within the limits of experimental error.

If this be allowed, there remains to be accounted for only the admitted curvature for distances under .1. Two explanations have been suggested, and others might be or perhaps may already have been advanced.

1. That the air in the immediate neighbourhood of a solid conductor is condensed, and therefore dielectrically stronger. This explanation, if I understand it aright, appears to me to fail altogether. For the beginning of rupture is conditioned by the strength of the layer next the conductor, and, even on this explanation, that would be the same at all distances, and the curve ought to be a straight line.

2. That there is a difference of potential between the conductor and the air. This hypothesis would still give a straight line although not passing through the origin, it would therefore still leave the curvature near the origin unexplained, which in the case of air at least is the main difficulty. Still this possible cause should not be lost sight of. It may be *part* of the explanation.

3. It might be that the air near the conductor is electrified, in which case the characteristic equation of the potential between the plates would become

$$\frac{d^2V}{dx^2} + 4\pi\rho = 0 .$$

Without entering into a discussion of this hypothesis in the meantime, I may mention that it is subject to the initial objection, that it seems difficult to reconcile it with the fact, proved by the best modern results, that there is nothing of the nature of slow conduction or even convective discharge through air at the atmospheric pressure, so long as the electromotive force does not surpass a certain limit.

4. There is yet another hypothesis which seems to me well worthy of examination, viz., that the *Specific Inductive Capacity* of the air, undergoes a rapid variation from the surface of a solid

outwards. The most natural assumption in the first instance would be that so long as the curvature of the surface is finite, K is a function simply of the distance from the surface, and independent of its curvature, that it starts with a value K_0 just at the surface, and very rapidly reaches a value K_1 , which it retains until the immediate neighbourhood of another solid is reached. The equation of the potential now becomes

$$\frac{d}{dx} \left(K \frac{dU}{dx} \right) = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

x being measured perpendicular to the two parallel plates, from the one at higher potential to the one at lower. We thus get

$$K \frac{dU}{dx} = A \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

where A is a constant.

Whence

$$U = A \int_s^x \frac{dx}{K},$$

and if V denotes the difference of potential between the plates, and s the distance between them,

$$V = -A \int_0^s \frac{dx}{K} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

The resultant force at the surface is

$$R = -\frac{A}{K_0} = -\frac{V}{K_0 \int_0^s \frac{dx}{K}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

If s be less than a certain distance (comparable with a millimetre, to judge by the experimental results) the integral $\int_0^s \frac{dx}{K}$ may be

broken up into two equal parts $\int_{\frac{s}{2}}^s \frac{dx}{K}$ and $\int_0^{\frac{s}{2}} \frac{dx}{K}$ each of

which is the same function of $\frac{s}{2}$, the whole is therefore some

function of s , so that we may write $\int_0^s \frac{dx}{K} = \frac{s}{K_0} f(s)$, where $K_0 f(s)$

has a value intermediate between K_0 and K_1 , we thus get

$$R = \frac{V}{s} f(s) \quad . \quad . \quad . \quad . \quad . \quad . \quad (5),$$

which is general enough to represent the experimental results for small distances.

Next let s be greater than a , where a is the distance from a conductor at which K ceases sensibly to vary, then,

$$\int_0^s \frac{dx}{K} = \int_{s-a}^s \frac{dx}{K} + \int_a^{s-a} \frac{dx}{K} + \int_0^a \frac{dx}{K}.$$

Here the first and last integrals are equal and constant, say each = $\frac{a}{K'}$, where K' is intermediate between K_0 and K_1 . In the second integral K is constant throughout, and equal to K_1 , we thus get

$$\int_0^s \frac{dx}{K} = \frac{2a}{K'} + \frac{s-2a}{K_1}.$$

Whence

$$R = \frac{V}{\frac{K_0}{K_1}s + 2\left(\frac{K_0}{K'} - \frac{K_0}{K_1}\right)a} \quad \dots \dots \dots (6),$$

or
$$V = R \left\{ \frac{K_0}{K_1}s + 2\left(\frac{K_0}{K'} - \frac{K_0}{K_1}\right)a \right\} \quad \dots \dots \dots (7).$$

This gives a straight line for distances greater than a , and accords with the interpretation which I am inclined to put upon the results of experiment.

This theory then would allow us to retain the notion of a definite dielectric strength for air, and at the same time to reproduce the results of experiment. The only question to be settled is whether the assumed variation of the specific inductive capacity actually exists. Equation (5) would of course allow us to find the nature of the variation, if any such existed. Since, in the case of air, by the unanimous testimony of experimenters, the intercept on the axis of V is positive, we must have $K_1 > K'$, and hence, since K' is intermediate to K_1 and K_0 , $K_1 > K_0$, *i.e.*, the specific inductive capacity of air in the neighbourhood of a conductor is less than in free air. This seems at first sight a somewhat startling conclusion; but on reflection I see nothing against it except perhaps prejudice. At all events it will scarcely be said that the kinetic theory of gases settles it immediately either way.

The above theory may at once be subjected to a very interesting

experimental test ; indeed, it is on this account mainly that I have ventured to bring it forward.

Let C denote the capacity per square centimetre of two parallel plates at a distance s apart. Then, since the surface density is given by

$$\sigma = \frac{K_0}{4\pi} R ,$$

we get by (4)

$$C = \frac{\sigma}{V} = \frac{1}{4\pi \int_0^s \frac{dx}{K}} \quad . \quad . \quad . \quad . \quad . \quad (8).$$

Hence, V being the *spark potential* corresponding to the same distance s , since by hypothesis R is always the same, being in fact

$\sqrt{\frac{8\pi\tau}{K_0}}$, we have

$$V = RK_0 \int_0^s \frac{dx}{K} ;$$

whence

$$CV = \frac{K_0 R}{4\pi} = \sqrt{\frac{K_0 \tau}{2\pi}} \\ = \text{constant}.$$

This reciprocal relation between the capacity and spark potential shows that the capacity of the plates for very small distances apart, ought, if the above theory be correct, to be much smaller than the value calculated by the usual assumption of a uniform dielectric, for experiment has already shown that the spark potential is very much greater. I have devised an arrangement for putting this conclusion to an experimental proof, and hope in the course of next summer to be able to lay the result before the Society.

There is one other point on which I should like to remark. However good the methods of Sir William Thomson may be, I think that little is to be gained by following them to the exclusion of others. It is clearly desirable to experiment with other forms of terminals for which the surface density can be calculated, and to examine whether the results can be explained in all cases by a common hypothesis. I think it might be possible by careful attention to insulation, to measure with some accuracy the potential at which disruptive discharge begins at the sharpest extremity of an

ellipsoid of given form, and from this to reduce a measure of the dielectric strength of air. Some curious problems of mathematical physics arise here in connection with the assumption of varying specific inductive capacity, which I can only mention in passing. I find on a certain rough assumption that ovary ellipsoids of reasonable dimensions ought to give practically measurable results, and propose to try the experiment.

With the same end in view I think it would be desirable to reduce the experiment of Baille and others with spheres, in cases where the surface density can be calculated, and to examine the values of the dielectric strength in these cases. Until this or something equivalent is done, it is clear that we have really no experimental ground for asserting the existence of such a constant as the dielectric strength of a medium, and therefore cannot take the very first step towards a physical theory of the disruptive discharge, which appears to me to be the next great advance to be made in the science of electricity.

4. Diagnoses plantarum novarum et imperfecte descriptarum Phanerogamarum Socotrensium; quas elaboravit Bayley Balfour, Scientiæ Doctor et in Universitate Glascuensi rerum botanicarum regius professor. Pars Prima.

Plena descriptio Botanices Socotrensis quantum nobis cognitæ, brevi tempore subjicietur Societati Regiæ Edinensis ut in suis Actis in lucem emittatur et divulgetur. Quoniam verum spatio certo temporis opus erit ut singulæ partes et minutiae Floræ tam abundantis et copiosæ plene elaborentur et perlustrentur, et quoniam perplures formæ endemicæ tam generum quam specierum in ea Flora comprehenduntur, oportet et congruit opportunis temporis intervallis, opere progrediente, breves diagnoses novarum plantarum in medium proponere, ut prioritas vindicetur nominibus quæ his novis tribuantur, et quæ in volumine Actorum Societatis Regiæ publice emittentur.

Nunc igitur in medium profero aliquas diagnoses novorum generum et specierum. In hac parte prima plantas novas Dicotyledonearum Polypetalasarum solum descripsi; in partibus subse-