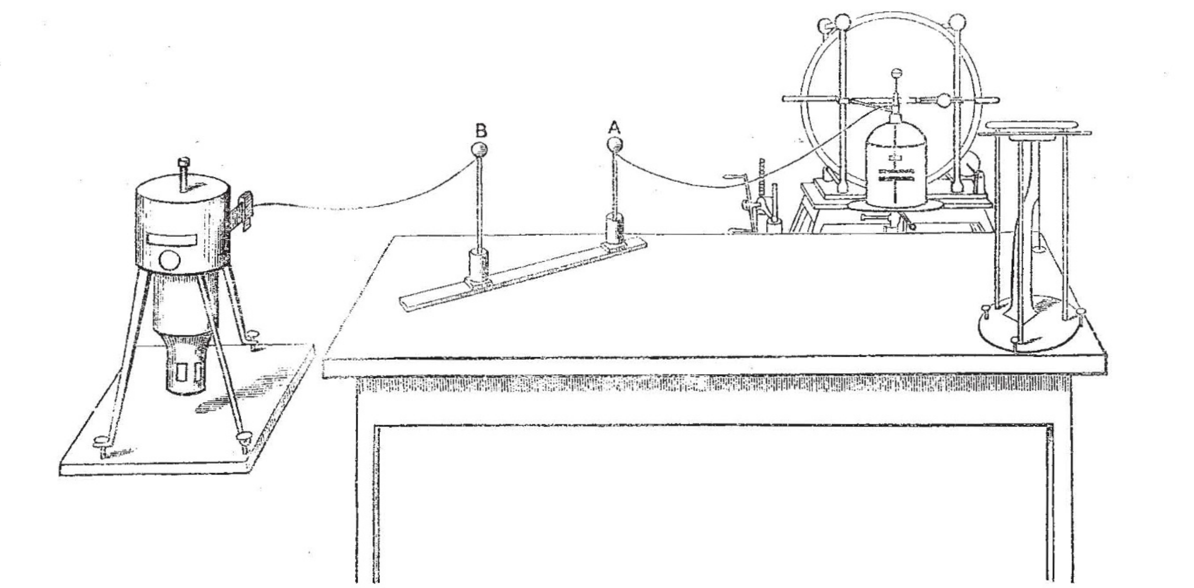
"It is obvious," he continues, "that the description given of the phenomenon is incomplete, for ductility, elasticity, variation of the resonance-plate, &c., co-operate to produce a more complicated phenomenon. I have tried a great many materials for undertones, and found that they fall, in this respect, into three groups. In the middle stand those materials which furnish undertones, that is, the great majority of all substances in general. On the one side are those substances which, as soon as the vibrations are pretty strong, give no resonance-tones, but merely an indeterminate noise; to this group belong rolled plate metal and most kinds of glass. On the other side are those substances which, however strong the vibrations, always give the tone of the tuning-fork. I have found only one example of this, viz., the wood of mountain fir, in thin polished plates. It was natural to try the belly of a violin, which is mostly made of fir-wood, for undertones, and in this way form an idea as to the elasticity of the wood, on which the excellence of the instrument greatly depends. From the German violins I have examined, I have always obtained undertones; from the few authentic Italian violins accessible to me I obtained, on the other hand, always the original tone. But I acknowledge that more abundant material is necessary for a decision of this question."

THE DISRUPTIVE DISCHARGE OF ELECTRICITY[1]

By means of the following method we have been able to investigate the laws of the disruptive discharge of electricity of high potential—a subject of investigation which is the complement of that in which Drs. Warren de la Rue and Müller have been simultaneously engaged. In making these experiments I have had the able co-operation in succession of Messrs. Salvesen, Connor, Stewart, Simpson, and Playfair.

The method essentially consists in connecting the prime conductor of the Holtz machine, not with the electrometer directly, but with an insulated spherical ball placed at some distance from an equal spherical ball, the latter being connected with the electrometer. The woodcut represents, *in situ*, the apparatus which was used in the case of the gases. The receiver of the air-pump, which has a rod capable of moving air-tight, was attached to one of the conductors of the Holtz machine in such a manner that the conductor and the rod formed one conducting system. Projecting from the plate of the air-pump was a short metal rod, which formed one conductor with the metallic parts of the air-pump, and, by means of a wire, with the uninsulated conductor of the Holtz machine. Electrodes of various forms were made to screw on to the ends of the rods. Of the two insulated brass balls one, A, was fixed; the other, B, could be moved along the connecting board. The wire joining A to the collar of the receiver is insulated with gutta-percha. The electrometer in connection with B is one of Sir W. Thomson's divided ring reflecting electrometers.

When the potential of A is raised by driving the machine, the potential of B is also raised, and this goes on until a discharge takes place between the electrodes inside the receiver. Hence the maximum deflection of the spot of light from zero is an indication of the difference of potential of the two surfaces between which the spark passed immediately before the discharge. By breaking the contact between the conductors of the Holtz machine before beginning to turn the wheel, and, by turning slowly and uniformly, we were able to make the image of the



wire move up continuously, and to be at rest at the instant of discharge. After the discharge took place the image fell back to zero, or a point near zero. We always noted the position taken up by the image when the conductor of the machine was completely discharged.

The force resisting the deflection of the mirror is the action of two external magnets upon several small magnets fixed to the back of the mirror.[2]

One great merit of our method is the rapidity with which observations can be made. Three readings were in general taken for each entry. The mean of these is very probably free from any error due to accidental variations in the passage of the spark. An extensive series of observations have been printed in full in the *Transactions* of the Royal Society of Edinburgh. The following are the more important results:—

A spark was taken through air between plates at a constant distance, and the distance between the balls A and B varied. Let V denote the induced potential, and r the distance between the centres of A and B; then the experimental curve obtained satisfies the equation—

$$V = 6081 r^{-1} - 42\cdot26$$

for values of r greater than 24 centimetres; but for less values of r the function requires to be corrected by being multiplied by—

$$\cdot524 + \cdot02 r.$$

Sparks were taken through air at the atmospheric pressure between parallel metal disks of 4 inches diameter for distances up to 1·2 centimetres. The function for V, the difference of potential in terms of s, the length of the spark is—

$$V = 66\cdot94 \sqrt{\{ s^2 + \cdot205 s \}},$$

[1] Abstract by the author of thesis for D.Sc. and other papers printed in the recently issued part of the *Transactions* of the Royal Society of Edinburgh. By Alexander Macfarlane, M.A., D.Sc.

[2] Our results were reduced to absolute measure by means of the absolute electrometer represented on the table.

the equation of a hyperbola whose semi-transverse axis is ·1025 centimetres, and semi-conjugate axis 6·8623 C.G.S. units. From the above equation we infer that—

$$R = 66·94 \sqrt{\left\{1 + ·205 \frac{1}{s}\right\}}$$

where R denotes the electrostatic force; from which it is evident that as s becomes smaller R becomes greater. A similar curve was obtained when hydrogen was substituted for air.

When the disks were heated before taking the sparks, the curve obtained satisfies the equation—

$$V = 87·04s - 19·56s^2,$$

a parabola, from which we deduce—

$$R = 87·04 - 19·56s.$$

It was found that when the capacity of the charged conductor was changed, the difference of potential required to produce a spark remained constant.

When the discharge was continued so as to keep the spot of light at a fixed deflection, the reading was always less than for the corresponding single discharge, but the curves were similar.

Readings were taken of the difference of potential required to produce a ·5 centimetre spark through air at different pressures from the atmospheric to 20 mm. They give—

$$V = ·0458 \sqrt{\{p^2 + 203p\}}$$

where p denotes the pressure in millimetres of mercury.

The electric strengths of several gases were determined by comparing the differences of potential required to pass a ·5 centimetre spark through the gas at the atmospheric pressure.

Dielectric.	Electric Strength.		
	Macfarlane.	De la Rue and Müller.	Faraday.
Air	1	1	1
Carbonic Acid ...	·95	1·06	·91
Oxygen	·93	1	·71
Hydrogen	·63	·54	·53
Coal Gas	·93	—	·71

"Electric strength" is the term used by Prof. Clerk-Maxwell to denote the physical constant in question. I have added, for the sake of comparison, values deduced from the results of De la Rue and Müller and of Faraday, but the ratios given do not strictly give the relative electric strength, but the ratio of the lengths of spark when the difference of potential is kept constant.

The difference of potential required to produce a spark between two spherical balls is approximately proportional to the square root of the length of the spark. This we have verified up to 15 cm.

On proceeding to investigate the discharge through insulating liquids, we first took up oil of turpentine. The liquid was placed in a glass jar of 7 inches diameter and 5 inches height. A screw passing through the bottom of the jar served to fix the lower electrode, and also to afford conducting connection with the earth. We observed four modes of discharge: by means of threads of solid particles, by motion of the liquid, by a disruptive discharge, and by motion of gas bubbles. When a chain was formed the index of the electrometer behaved as if a current were passing. The discharge, when sufficiently great, broke the thread and turned into a spark. The liquid was more easily set in motion when its surface was not much higher than the upper plate. The bubbles of gas appeared to be formed by the passing of the spark. They were always attracted to the negative electrode. When the electrification was neutralised they of course adhered to the under surface of the upper disk; when the disk was electrified negatively they still adhered; when positively they were repelled so as to remain suspended in the liquid or to adhere to the lower electrode, according to the greater or less distance between the electrodes. At a diminished pressure the bubbles produced at the upper surface were observed to effect the discharge by carrying the electricity with them to the negative electrode. The fact that it is possible to cause a shower of electrified bubbles to descend and produce a flash and sound on impinging on the lower surface appears to throw some light upon the nature of lightning balls.

Similar phenomena were observed in paraffin oil, excepting that the gas bubbles produced were generally attracted to the positive surface.

We observed the differences of potential required to pass a spark through paraffin oil and oil of turpentine between plates for distances up to ·5 cm. It was impossible to observe for greater distances, as our insulated wire allowed the charge to escape. For paraffin oil,

$$V = 750\,s - 15;$$

therefore, $R = 750.$

The above has not been reduced to absolute measure. Thus R is constant in the case of the liquids, but variable in the case of the gases.

Electric Strength of Liquid Dielectrics

Air	1
Paraffin Oil (kind used for burning)	4
Oil of Turpentine	3·7

Sparks were taken between two platinum wires placed at right angles to one another. When one of the wires was heated by a voltaic current the electrometer deflection was diminished by about one-fourth of its amount.

We have also investigated the effect upon the electric spark of heating the air round the disks, the pressure being kept constant. The deflections of the electrometer for a constant spark for temperatures from 20° C. to 280° C. indicate a curve which slopes down gradually as the temperature is increased, while the deflections during cooling give a curve which is somewhat lower at the lower temperatures.

These experiments were made in Prof. Tait's laboratory, to whom we are indebted, not only for the use of apparatus, but also for ever ready advice.

SCIENTIFIC SERIALS

Annalen der Physik und Chemie, No. 10.—The loss of electricity by an insulated charged body in rarefied gas in an envelope that has conductive connection with the earth is here stated by Herr Narr to be due to two processes distinct in time and intensity, the first, one of outflow, rapid and intense, the other, one of dispersion, slow and weak. The intensity of the former increases with decreasing density of each of the gases used (CO_2 air and H), and also on substituting one gas for the other in the order just given, the density remaining constant. These differences between the gases decrease with the density, and in vacuum fal within the limits of errors of observation. In discussing these results, Herr Narr is led to regard the condensed layer of gas on the conducting system as an insulator, not as a conductor.—Dr. Holz finds that the specific magnetism of magnetic ironstone is the greatest of all magnetic substances hitherto examined. Its maximum permanent magnetism is nearly as great, and partly greater than that of steel as hard as glass. Its permanent magnetism is sooner removed in demagnetisation with the same external forces than that of steel, &c.—Dr. Strouhal enunciates the laws of a mode of sound-production not much studied hitherto, that, viz., of rapid swinging of a rod, a blade, or the like, in air, or the passage of air-currents over strong wires or sharp edges, &c.—Herr Braun contributes a long and interesting paper on the development of electricity as equivalent of chemical processes.—Herr Koch demonstrates the applicability of the method of determining coefficients of elasticity from the bending of short bars supported at the two ends, the sinking in the middle being measured by means of Newton's interference-bands, and he suggests a more thorough investigation of the elasticity of crystals, by the improved means he describes.—Some remarks on the atomic weight of antimony, with reference to Cooke's recent research, are communicated by Herr Schneider.

American Journal of Science and Arts, November.—In the opening paper Prof. Dana considers the value of some distinctive characters generally accepted in defining certain kinds of rocks, as, "older and younger," foliated or not, and porphyritic structure; showing them to be often trivial and inapplicable.—With regard to the relative agency of glaciers and sub-glacial streams in the erosion of valleys, Prof. Miles considers that the streams are of primary importance in working in advance of the ice in deepening and enlarging these valleys, and that the glaciers abrade, modify, and reduce the prominent portions left by the streams, and give them the well-known glaciated sur-