Tucholsky Wagner Zola Scott Sydow Fonatne Schlegel Freud
Turgenev Wallace
Twain Walther von der Vogelweide Fouqué Friedrich II. von Preußen
Weber Freiligrath
Kant Ernst Frey
Fechner Fichte Weiße Rose von Fallersleben Richthofen Frommel
Hölderlin
Fehrs Engels Fielding Eichendorff Tacitus Dumas
Faber Flaubert
Eliasberg Ebner Eschenbach
Feuerbach Maximilian I. von Habsburg Fock Zweig
Ewald Eliot Vergil
Goethe London
Elisabeth von Österreich
Mendelssohn Balzac Shakespeare Ganghofer
Lichtenberg Rathenau Dostojewski
Trackl Stevenson Doyle Gjellerup
Tolstoi Hambruch
Mommsen Thoma Lenz Hanrieder Droste-Hülshoff
von Arnim
Dach Verne Hägele Hauff Humboldt
Reuter
Karrillon Rousseau Hagen Hauptmann Gautier
Garschin
Defoe Baudelaire
Damaschke Hebbel
Descartes
Hegel Kussmaul Herder
Wolfram von Eschenbach Schopenhauer
Dickens
Darwin Rilke George
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Bebel
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Storm Casanova Tersteegen Grillparzer Georgy
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Brentano
Lafontaine
Strachwitz Claudius Schiller Kralik Iffland Sokrates
Schilling
Katharina II. von Rußland Bellamy
Gerstäcker Raabe Gibbon Tschechow
Löns Hesse Hoffmann Gogol Wilde Vulpius
Gleim
Luther Heym Hofmannsthal Morgenstern
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John Munro

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THE STORY OF ELECTRICITY

BY

JOHN MUNRO

AUTHOR OF ELECTRICITY AND ITS USES, PIONEERS OF ELECTRICITY, HEROES OF THE TELEGRAPH, ETC., AND JOINT AUTHOR OF MUNRO AND JAMIESON'S POCKET-BOOK OF ELECTRICAL RULES AND TABLES

PREFACE.

A work on electricity needs little recommendation to stimulate the interest of the general reader. Electricity in its manifold applications is so large a factor in the comfort and convenience of our daily life, so essential to the industrial organization which embraces every dweller in a civilized land, so important in the development and extension of civilization itself, that a knowledge of its principles and the means through which they are directed to the service of mankind should be a part of the mental equipment of everyone who pretends to education in its truest sense. Let anyone stop to consider how he individually would be affected if all electrical service were suddenly to cease, and he cannot fail to appreciate the claims of electricity to attentive study.

The purpose of this little book is to present the essential facts of electrical science in a popular and interesting way, as befits the scheme of the series to which it belongs. Electrical phenomena have been observed since the first man viewed one of the most spectacular and magnificent of them all in the thunderstorm, but the services of electricity which we enjoy are the product solely of scientific achievement in the nineteenth century. It is to these services that the main part of the following discussion is devoted. The introductory chapters deal with various sources of electrical energy, in friction, chemical action, heat and magnetism. The rest of the book describes the applications of electricity in electroplating, communication by telegraph, telephone, and wireless telegraphy, the production of light and heat, the transmission of power, transportation over rails and in vehicles, and the multitude of other uses.

July, 1915.

PUBLISHERS' NOTE.

For our edition of this work the terminology has been altered to conform with American usage, some new matter has been added, and a few of the cuts have been changed and some new ones introduced, in order to adapt the book fully to the practical requirements of American readers.

CONTENTS.

THE STORY OF ELECTRICITY.

CHAPTER I.

THE ELECTRICITY OF FRICTION.

A schoolboy who rubs a stick of sealing-wax on the sleeve of his jacket, then holds it over dusty shreds or bits of straw to see them fly up and cling to the wax, repeats without knowing it the fundamental experiment of electricity. In rubbing the wax on his coat he has electrified it, and the dry dust or bits of wool are attracted to it by reason of a mysterious process which is called "induction."

Electricity, like fire, was probably discovered by some primeval savage. According to Humboldt, the Indians of the Orinoco sometimes amuse themselves by rubbing certain beans to make them attract wisps of the wild cotton, and the custom is doubtless very old. Certainly the ancient Greeks knew that a piece of amber had when rubbed the property of attracting light bodies. Thales of Miletus, wisest of the Seven Sages, and father of Greek philosophy, explained this curious effect by the presence of a "soul" in the amber, whatever he meant by that. Thales flourished 600 years before the Christian era, while Croesus reigned in Lydia, and Cyrus the Great, in Persia, when the renowned Solon gave his laws to Athens, and Necos, King of Egypt, made war on Josiah, King of Judah, and after defeating him at Megiddo, dedicated the corslet he had worn during the battle to Apollo Didymaeus in the temple of Branchidas, near Miletus.

Amber, the fossil resin of a pine tree, was found in Sicily, the shores of the Baltic, and other parts of Europe. It was a precious stone then as now, and an article of trade with the Phoenicians, those early merchants of the Mediterranean. The attractive power might enhance the value of the gem in the eyes of the superstitious ancients, but they do not seem to have investigated it, and beyond the speculation of Thales, they have told us nothing more about it.

Towards the end of the sixteenth century Dr. Gilbert of Colchester, physician to Queen Elizabeth, made this property the subject of experiment, and showed that, far from being peculiar to amber, it was possessed by sulphur, wax, glass, and many other bodies which he called electrics, from the Greek word elektron, signifying amber. This great discovery was the starting-point of the modern science of electricity. That feeble and mysterious force which had been the wonder of the simple and the amusement of the vain could not be slighted any longer as a curious freak of nature, but assuredly none dreamt that a day was dawning in which it would transform the world.

Otto von Guericke, burgomaster of Magdeburg, was the first to invent a machine for exciting the electric power in larger quantities by simply turning a ball of sulphur between the bare hands. Improved by Sir Isaac Newton and others, who employed glass rubbed with silk, it created sparks several inches long. The ordinary frictional machine as now made is illustrated in figure i, where P is a disc of plate glass mounted on a spindle and turned by hand. Rubbers of silk R, smeared with an amalgam of mercury and tin, to increase their efficiency, press the rim of the plate between them as it revolves, and a brass conductor C, insulated on glass posts, is fitted with points like the teeth of a comb, which, as the electrified surface of the plate passes by, collect the electricity and charge the conductor with positive electricity. Machines of this sort have been made with plates 7 feet in diameter, and yielding sparks nearly 2 feet long.

The properties of the "electric fire," as it was now called, were chiefly investigated by Dufay. To refine on the primitive experiment let us replace the shreds by a pithball hung from a support by a silk thread, as in figure 2. If we rub the glass rod vigorously with a silk handkerchief and hold it near, the ball will fly toward the rod. Similarly we may rub a stick of sealing wax, a bar of sulphur, indeed, a great variety of substances, and by this easy test we shall find them electrified. Glass rubbed with glass will not show any sign of electrification, nor will wax rubbed on wax; but when the rubber is of a different material to the thing rubbed, we shall find, on using proper precautions, that electricity is developed. In fact, the property which was once thought peculiar to amber is found to belong to all bodies. ANY SUBSTANCE, WHEN RUBBED WITH A DIFFERENT SUBSTANCE, BECOMES ELECTRIFIED.

The electricity thus produced is termed frictional electricity. Of course there are some materials, such as amber, glass, and wax, which display the effect much better than others, and hence its original discovery.

In dry frosty weather the friction of a tortoise-shell comb will electrify the hair and make it cling to the teeth. Sometimes persons emit sparks in pulling off their flannels or silk stockings. The fur of a cat, or even of a garment, stroked in the dark with a warm dry hand will be seen to glow, and perhaps heard to crackle. During winter a person can electrify himself by shuffling in his slippers over the carpet, and light the gas with a spark from his finger. Glass and sealing-wax are, however, the most convenient means for investigating the electricity of friction.

A glass rod when rubbed with a silk handkerchief becomes, as we have seen, highly electric, and will attract a pithball (fig. 2). Moreover, if we substitute the handkerchief for the rod it will also attract the ball (fig. 3). Clearly, then, the handkerchief which rubbed the rod as well as the rod itself is electrified. At first we might suppose that the handkerchief had merely rubbed off some of the electricity from the rod, but a little investigation will soon show that is not the case. If we allow the pithball to touch the glass rod it will steal some of the electricity on the rod, and we shall now find the ball REPELLED by the rod, as illustrated in figure 4. Then, if we withdraw the rod and bring forward the handkerchief, we shall find the ball ATTRACTED by it. Evidently, therefore, the electricity of the handkerchief is of a different kind from that of the rod.

Again, if we allow the ball to touch the handkerchief and rub off some of its electricity, the ball will be REPELLED by the handkerchief and ATTRACTED by the rod. Thus we arrive at the conclusion that whereas the glass rod is charged with one kind of electricity, the handkerchief which rubbed it is charged with another kind, and, judging by their contrary effects on the charged ball or indicator, they are of opposite kinds. To distinguish the two sorts, one is called POSITIVE and the other NEGATIVE electricity.

Further experiments with other substances will show that sometimes the rod is negative while the rubber is positive. Thus, if we rub the glass rod with cat's fur instead of silk, we shall find the glass negative and the fur positive. Again, if we rub a stick of sealing-wax with the silk handkerchief, we shall find the wax negative and the silk positive. But in every case one is the opposite of the other, and moreover, an equal quantity of both sorts of electricity is developed, one kind on the rod and the other on the rubber. Hence we conclude that EQUAL AND OPPOSITE QUANTITIES OF ELECTRICITY ARE SIMULTANEOUSLY DEVELOPED BY FRICTION.

If any two of the following materials be rubbed together, that higher in the list becomes positively and the other negatively electrified:—

POSITIVE (+).

Cats' fur.
Polished glass.
Wool.
Cork, at ordinary temperature.
Coarse brown paper.
Cork, heated.
White silk.
Black silk.
Shellac.
Rough glass.

NEGATIVE (-).

The list shows that quality, as well as kind, of material affects the production of electricity. Thus polished glass when rubbed with silk is positive, whereas rough glass is negative. Cork at ordinary temperature is positive when rubbed with hot cork. Black silk is negative to white silk, and it has been observed that the best radiator and absorber of light and heat is the most negative. Black cloth, for instance, is a better radiator than white, hence in the Arctic regions, where the body is much warmer than the surrounding air, many wild animals get a white coat in winter, and in the tropics, where the sunshine is hotter than the body, the European dons a white suit.

The experiments of figures 1, 2, and 3 have also shown us that when the pithball is charged with the positive electricity of the glass rod it is REPELLED by the like charge upon the rod, and ATTRACTED by the negative or unlike charge on the handkerchief. Again, when it is charged with the negative electricity of the handkerchief it is REPELLED by the like charge on the handkerchief and ATTRACTED by the positive or unlike charge on the rod. Therefore it is usual to say that LIKE ELECTRICITIES REPEL AND UNLIKE ELECTRICITIES ATTRACT EACH OTHER.

We have said that all bodies yield electricity under the friction of dissimilar bodies; but this cannot be proved for every body by simply holding it in one hand and rubbing it with the excitor, as may be done in the case of glass. For instance, if we take a brass rod in the hand and apply the rubber vigorously, it will fail to attract the pithball, for there is no trace of electricity upon it. This is because the metal differs from the glass in another electrical property, and they must therefore be differently treated. Brass, in fact, is a conductor of electricity and glass is not. In other words, electricity is conducted or led away by brass, so that, as soon as it is generated by the friction, it flows through the hand and body of the experimenter, which are also conductors, and is lost in the ground. Glass on the other hand, is an INSULATOR, and the electricity remains on the surface of it. If, however, we attach a glass handle to the rod and hold it by that whilst rubbing it, the electricity cannot then escape to the earth, and the brass rod will attract the pith-ball.

All bodies are conductors of electricity in some degree, but they vary so enormously in this respect that it has been found convenient to divide them into two extreme classes—conductors and insulators. These run into each other through an intermediate group, which are neither good conductors nor good insulators. The following are the chief examples of these classes:—

CONDUCTORS.—All the metals, carbon.

INTERMEDIATE (bad conductors and bad insulators).—Water, aqueous solutions, moist bodies; wood, cotton, hemp, and paper in any but a dry atmosphere; liquid acids, rarefied gases.

INSULATORS.—Paraffin (solid or liquid), ozokerit, turpentine, silk, resin, sealing-wax or shellac, india-rubber, gutta-percha, ebonite, ivory, dry wood, dry glass or porcelain, mica, ice, air at ordinary pressures.

It is remarkable that the best conductors of electricity, that is to say, the substances which offer least resistance to its passage, for instance the metals, are also the best conductors of heat, and that insulators made red hot become conductors. Air is an excellent insulator, and hence we are able to perform our experiments on frictional electricity in it. We can also run bare telegraph wires through it, by taking care to insulate them with glass or porcelain from the wooden poles which support them above the ground. Water, on the other hand, is a partial conductor, and a great enemy to the storage or conveyance of electricity, from its habit of soaking into porous metals, or depositing in a film of dew on the cold surfaces of insulators such as glass, porcelain, or ebonite. The remedy is to exclude it, or keep the insulators warm and dry, or coat them with shellac varnish, wax, or paraffin. Submarine telegraph wires running under the sea are usually insulated from the surrounding water by india-rubber or gutta-percha.

The distinction between conductors and non-conductors or insulators was first observed by Stephen Gray, a pensioner of the Charter-house. Gray actually transmitted a charge of electricity along a pack-thread insulated with silk, to a distance of several hundred yards, and thus took an important step in the direction of the electric telegraph.

It has since been found that FRICTIONAL ELECTRICITY APPEARS ONLY
ON THE EXTERNAL SURFACE OF CONDUCTORS.

This is well shown by a device of Faraday resembling a small butterfly net insulated by a glass handle (fig. 5). If the net be charged it is found that the electrification is only outside, and if it be suddenly drawn outside in, as shown by the dotted line, the electrification is still found outside, proving that the charge has shifted from the inner to the outer surface. In the same way if a hollow conductor is charged with electricity, none is discoverable in the interior. Moreover, its distribution on the exterior is influenced by the shape of the outer surface. On a sphere or ball it is evenly distributed all round, but it accumulates on sharp edges or corners, and most of all on points, from which it is easily discharged.

A neutral body can, as we have seen (fig. 4), be charged by CONTACT with an electrified body: but it can also be charged by INDUCTION, or the influence of the electrified body at a distance.

Thus if we electrify a glass rod positively (+) and bring it near a neutral or unelectrified brass ball, insulated on a glass support, as in figure 6, we shall find the side of the ball next the rod no longer neutral but negatively electrified (-), and the side away from the rod positively electrified (+).

If we take away the rod again the ball will return to its neutral or non-electric state, showing that the charge was temporarily induced by the presence of the electrified rod. Again, if, as in figure 7, we have two insulated balls touching each other, and bring the rod up, that nearest the rod will become negative and that farthest from it positive. It appears from these facts that electricity has the power of disturbing or decomposing the neutral state of a neighbouring conductor, and attracting the unlike while it repels the like induced charge. Hence, too, it is that the electrified amber or sealing-wax is able to attract a light straw or pithball. The effect supplies a simple way of developing a large amount of electricity from a small initial charge. For if in figure 6 the positive side of the ball be connected for a moment to earth by a conductor, its positive charge will escape, leaving the negative on the ball, and as there is no longer an equal positive charge to recombine with it when the exciting rod is withdrawn, it remains as a negative charge on the ball. Similarly, if we separate the two balls in figure 7, we gain two equal charges—

one positive, the other negative. These processes have only to be repeated by a machine in order to develop very strong charges from a feeble source.

Faraday saw that the intervening air played a part in this action at a distance, and proved conclusively that the value of the induction depended on the nature of the medium between the induced and the inducing charge. He showed, for example, that the induction through an intervening cake of sulphur is greater than through an equal thickness of air. This property of the medium is termed its INDUCTIVE CAPACITY.

The Electrophorus, or carrier of electricity, is a simple device for developing and conveying a charge on the principle of induction. It consists, as shown in figure 8, of a metal plate B having an insulating handle of glass H, and a flat cake of resin or ebonite R. If the resin is laid on a table and briskly rubbed with cat's fur it becomes negatively electrified. The brass plate is then lifted by the handle and laid upon the cake. It touches the electrified surface at a few points, takes a minute charge from these by contact. The rest of it, however, is insulated from the resin by the air. In the main, therefore, the negative charge of the resin is free to induce an opposite or positive charge on the lower surface and a negative charge on the upper surface of the plate. By touching this upper surface with the finger, as shown in figure 8, the negative charge will escape through the body to the ground or "earth," as it is technically called, and the positive charge will remain on the plate. We can withdraw it by lifting the plate, and prove its existence by drawing a spark from it with the knuckle. The process can be repeated as long as the negative charge continues on the resin.

These tiny sparks from the electrophorus, or the bigger discharges of an electrical machine, can be stored in a simple apparatus called a Leyden jar, which was discovered by accident. One day Cuneus, a pupil of Muschenbroeck, professor in the University of Leyden, was trying to charge some water in a glass bottle by connecting it with a chain to the sparkling knob of an electrical machine. Holding the bottle in one hand, he undid the chain with the other, and received a violent shock which cast the bottle on the floor. Muschenbroeck, eager to verify the phenomenon, repeated the experiment, with a still more lively and convincing result. His. nerves were shaken for two days, and he afterwards protested that he would not suffer another shock for the whole kingdom of France.

The Leyden jar is illustrated in figure 9, and consists in general of a glass bottle partly coated inside and out with tinfoil F, and having a brass knob K connecting with its internal coat. When the charged plate or conductor of the electrophorus touches the knob the inner foil takes a positive charge, which induces a negative charge in the outer foil through the glass. The corresponding positive charge induced at the same time escapes through the hand to the ground or "earth." The inner coating is now positively and the outer coating negatively electrified, and these two opposite charges bind or hold each other by mutual attraction. The bottle will therefore continue charged for a long time; in short, until it is purposely discharged or the two electricities combine by leakage over the surface of the glass.

To discharge the jar we need only connect the two foils by a conductor, and thus allow the separated charges to combine. This should be done by joining the OUTER to the INNER coat with a stout wire, or, better still, the discharging tongs T, as shown in the figure. Otherwise, if the tongs are first applied to the inner coat, the operator will receive the charge through his arms and chest in the manner of Cuneus and Muschenbroeck.

Leyden jars can be connected together in "batteries," so as to give very powerful effects. One method is to join the inner coat of one to the outer coat of the next. This is known as connecting in "series," and gives a very long spark. Another method is to join the inner coat of one to the inner coat of the next, and similarly all the outer coats together. This is called connecting "in parallel," or quantity, and gives a big, but not a long spark.

Of late years the principle of induction, which is the secret of the Leyden jar and electrophorus, has been applied in constructing "influence" machines for generating electricity. Perhaps the most effective of these is the Wimshurst, which we illustrate in figure 10, where PP are two circular glass plates which rotate in opposite directions on turning the handle. On the outer rim of each is cemented a row of radial slips of metal at equal intervals. The slips at opposite ends of a diameter are connected together twice during each revolution of the plates by wire brushes S, and collecting combs TT serve to charge the positive and negative conductors CC, which yield very powerful sparks at the knobs K above. The given theory of this machine may be open to question, but there can be no doubt of its wonderful performance. A small one produces a violent spark 8 or 10 inches long after a few turns of the handle.

The electricity of friction is so unmanageable that it has not been applied in practice to any great extent. In 1753 Mr. Charles Morrison, of Greenock, published the first plan of an electric telegraph in the Scots Magazine, and proposed to charge an insulated wire at the near end so as to make it attract printed letters of the alphabet at the far end. Sir Francis Ronalds also invented a telegraph actuated by this kind of electricity, but neither of these came into use. Morrison, an obscure genius, was before his age, and Ronalds was politely informed by the Government of his day that "telegraphs of any kind were wholly unnecessary." Little instruments for lighting gas by means of the spark are, however, made, and the noxious fumes of chemical and lead works are condensed and laid by the discharge from the Wimshurst machine. The electricity shed in the air causes the dust and smoke to adhere by induction and settle in flakes upon the sides of the flues. Perhaps the old remark that "smuts" or "blacks" falling to the ground on a sultry day are a sign of thunder is traceable to a similar action.

The most important practical result of the early experiments with frictional electricity was Benjamin Franklin's great discovery of the identity of lightning and the electric spark. One day in June, 1792, he went to the common at Philadelphia and flew a kite beneath a thundercloud, taking care to insulate his body from the cord. After a shower had wetted the string and made it a conductor, he was able to draw sparks from it with a key and to charge a Leyden jar. The man who had "robbed Jupiter of his thunderbolts" became celebrated throughout the world, and lightning rods or conductors for the protection of life and property were soon brought out. These, in their simplest form, are tapes or stranded wires of iron or copper attached to the walls of the building. The lower end of the conductor is soldered to a copper plate buried in the moist subsoil, or, if the ground is rather dry, in a pit containing coke. Sometimes it is mere-