CHAPTER VIII.

STATICAL ELECTRICITY.

I.—FUNDAMENTAL PRINCIPLES.

Definition of Electricity.

358. ELECTRICITY, as a science, is that branch of Physics which treats of the laws of attraction and repulsion exhibited by bodies under certain circumstances. Such phenomena are called *electrical phenomena*. The name electricity is derived from the Greek *elektron*, which means amber.

Discovery of Electrical Properties.

359. Six hundred years before the commencement of the Christian era, THALES, of Miletus, knew that when yellow amber was vigorously rubbed with wool, it acquired the property of attracting light bodies, such as small pieces of paper, barbs of quills, straws and the like. Comparing this action to suction, the ancients said that amber had a power of suction, and sucked light bodies towards it. In consequence of the rarity of amber, whose origin is even in our day unknown, they went so far as to say, that it was formed from the tears of an Indian bird, grieved at the death of King MELEAGER.

Six centuries later, PLINY, an eminent Roman naturalist, writes: "When the friction of the fingers imparts heat and life to yellow amber, it attracts straws, just as the magnet attracts iron." This

(358.) Define Electricity as a science. What are electrical phenomena? Whence the name? (359.) *Give an outline of the history of electrical discoveries.*

was all of the knowledge had on the subject until the end of the sixteenth century, when WILLIAM GILBERT, an Englishman, called anew the attention of scientific men to the properties of amber, and showed that a great number of other substances, such as glass, resin, silk, sulphur, and the like, acquired the power of attracting light bodies, on being rubbed with woolen cloth or cat's skin.

To repeat these experiments, rub a tube of glass or a stick of sealing-wax with a piece of woolen cloth, then present them to light bodies, as shreds of gold leaf, barbs of quills, or fragments of paper, and the latter will be seen to approach and adhere to the excited glass or sealing-wax. The manner of making these experiments is indicated in Fig. 248.

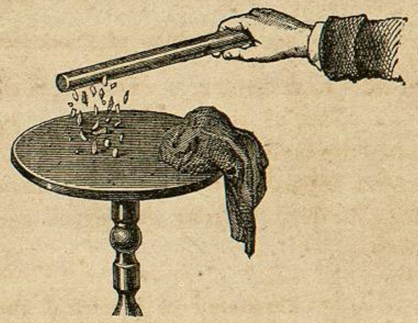

Fig. 248.

It will be seen hereafter, that resin and other substances named above, not only develop forces of attraction when rubbed, but also they become luminous, emit sparks, and display a number of other properties, all of which are known as electrical phenomena.

Since the beginning of the seventeenth century the process of discovery in electricity has been rapid, and a multitude of new facts have been developed, which have been so well studied as to form a very extensive branch of natural science.

Sources of Electricity.

360. The sources of electricity may be divided into three classes: *Mechanical*, *Physical*, and *Chemical*.

The mechanical sources are: *friction*, *pressure*, and *separation of the molecules of bodies*. When a piece of sugar is broken suddenly in a dark room, a feeble light is observable,

Explain GILBERT'S *experiments, and the manner of making them.* (360.) What are the principal sources of electricity? What are the mechanical sources?

which is due to the development of electricity at the moment of separating the molecules.

The physical sources are *variations of temperature*, and the like. Some minerals, particularly tourmaline and topaz, manifest electrical phenomena on being heated or cooled.

The chemical sources are *chemical compositions* and *decompositions of bodies*. Metals, like zinc, iron, and copper, when plunged into acids, are attacked by them, forming compounds known as salts. During these combinations considerable quantities of electricity are developed.

The most powerful of the causes of electricity are *friction* and *chemical action*. These will be studied in their order.

Electroscope.—Electrical Pendulum.

361. An ELECTROSCOPE is an apparatus for showing when a body is electrified.

The most simple electroscope is the ELECTRICAL PENDULUM, which consists of a small ball of elder pith, suspended by a fine silk thread, as shown in Fig. 249. The thread is fastened to the upper end of a stem of copper, which stem has a support of glass.

To ascertain whether a body is electrified or not, the pendulum is presented to it; if it is electrified, the pith ball will be attracted, otherwise not. When the quantity of electricity is too small to produce sensible attraction upon the pith ball, more delicate instruments are sometimes employed, called *electrometers*.

Two kinds of Electricity.

362. That there are two kinds of electricity, may be shown by the action of glass and resinous bodies, after being rubbed, upon pith balls.

What is the chief physical source? The chemical sources? *What is the most powerful cause of electricity?* (**361.**) What is an Electroscope? Describe the Electrical Pendulum. How used? (**362.**) How many kinds of electricity are there?

If a tube of glass be rubbed with a piece of cloth, and then presented to the electrical pendulum, the pith ball will at first be attracted, and after a short time it will be repelled, as shown in Fig. 250. The ball is then charged with the same kind of electricity as that in the glass.

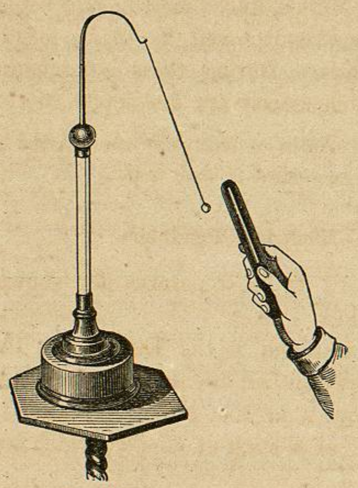

Fig. 249.

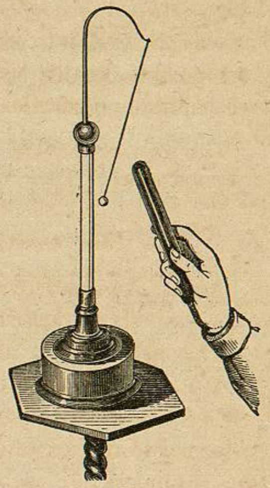

Fig. 250.

If now a piece of a resinous body, as sealing-wax, be rubbed with cloth and brought near the excited pith ball, the latter is immediately attracted to the former. In like manner, if the sealing-wax be first presented to the pendulum, it will be attracted and then repelled. If then the glass be brought near the pith ball, attraction will be observed. This shows that the action of electricity, as developed in glass and resin, is different, the one repelling when the other attracts. This fact was discovered by DUFAY, in 1734.

The electricity developed in rubbing glass with a piece

How is it shown that there are two kinds?

of silk, has been named *vitreous electricity*, that developed by rubbing resin or sealing-wax with the silk, has been named *resinous electricity.*

Hypothesis of two Electrical Fluids.

363. The discovery of DUFAY gave rise to the theory of two electrical fluids, which in unexcited bodies exist in a state of combination, forming what is called a *neutral fluid.* The earth is regarded as a great reservoir of this fluid, which has of itself no obvious properties; hence bodies which only contain it are said to be neutral. If by friction, chemical action, or other cause, the neutral fluid is decomposed, and the two fluids separated, electrical phenomena are at once developed.

These two fluids were at first named *the vitreous*, and *the resinous* fluids, but more recently they have been called *the positive*, and *the negative* fluids; the vitreous being called positive, and the resinous negative. These names were adopted by FRANKLIN the better to express their opposite characters. The positive fluid is often indicated by this sign, +, (*plus*), and the negative fluid by this sign, –, (*minus.*)

The hypothesis of two fluids was first made by SYMNER, and according to it the development of electricity consists in separating the two fluids. When glass is rubbed with silk, the positive fluid of the two goes to the glass, whilst the negative fluid goes to the silk. When sealing-wax is rubbed with silk, the reverse is the case, the negative fluid goes to the resinous body and the positive fluid to the silk.

It is to be observed that all of the phenomena can be equally well explained by the theory of a single fluid. This is the theory of FRANKLIN, and if we adhere to the hypothesis of two fluids, it is simply because it is more easily applied than that of one fluid.

What are they called? (**363.**) What is the neutral fluid? When are electrical phenomena produced? What other names are given to the two fluids? How are they indicated? *Explain in detail the two fluid hypothesis. Who is the author of the one fluid hypothesis?*

Laws of Electrical Attraction and Repulsion.

364. The following laws have been deduced from theory, and confirmed by experiment:

1. *Fluids of the same name repel each other; fluids of opposite names attract each other.*

2. *The intensities of the attractions and repulsions vary inversely as the square of the distances between them.*

Conductors.—Insulators.

365. CONDUCTORS, or *conducting substances*, are those which permit electricity to pass through them.

INSULATORS, or *non-conducting substances*, are those which do not permit electricity to pass through them.

GRAY observed that electrified bodies returned instantly to a neutral state when brought into contact with the earth, or when placed upon supports of metal, wood, stone, or any moist substance whatever. He also observed that they remained in an electrified condition for a long time when placed upon supports of glass, resin, sulphur, or when suspended by silken cords. From these facts, he concluded that metals, wood, stone, and the like, permitted the electricity to pass freely through them, whilst glass, resin, sulphur, and the like, opposed its passage. He also inferred that the latter class of bodies was not entirely incapable of conducting electricity, but that they were extremely poor conductors. When an electrified body is surrounded by non-conductors it is said to be *insulated*, and any non-conducting support of an electrified body is therefore called an *insulator*.

The best conductors of electricity are the metals; after these come plumbago, well calcined carbon, acid and saline

(**364.**) What is the first law of attraction and repulsion? The second law? (**365.**) What are Conductors? Insulators or non-conductors? *What observations were made by* GRAY? *When is a body insulated?* What are the best conductors? Next in order?

solutions, water either in a liquid or vaporous form, the human body or animal tissues, vegetable substances, and in general, all moist or humid substances.

The worst conductors, or best non-conductors, are resins, gums, india-rubber, silk, glass, precious stones, spirits of turpentine, oils, air, and gases when perfectly dry.

Methods of Electrifying Bodies.

366. Non-conducting bodies are only electrified by friction, but conductors may be electrified either by friction, by contact, or by induction.

In order to electrify a metal it must be insulated; that is, it must be surrounded by non-conducting bodies, and it must be rubbed by an insulated body.

This may be effected by mounting the metal upon a stand of glass and rubbing it with a non-conductor, such as a piece of silk. Were the metal not insulated, the electricity would flow off to the earth as fast as generated, and were the rubbing body not a non-conductor, the electricity would flow off through the hands and arms of the experimenter.

The method of electrifying by contact depends upon the property of conductibility. If a conductor is brought in contact with an electrified body, a portion of the electricity of the latter at once flows into the former body. If the two bodies are exactly alike, the electricity will be equally distributed over both. If they differ in size or in shape, the electricity will not be equally distributed over both.

The method of electrifying bodies by induction is similar to that of magnetizing bodies by induction, and will be treated of hereafter.

The worst conductors? (**366.**) How are non-conductors electrified? Can conductors be electrified by friction? *How?* How are bodies electrified by contact?

Accumulation of Electricity on the Surface of Bodies.

367. Experiment shows that when a body is electrified, the electricity all goes to the surface of the body, where it exists in a thin layer, tending continually to escape. It actually does escape as soon as it finds an outlet through a conducting body.

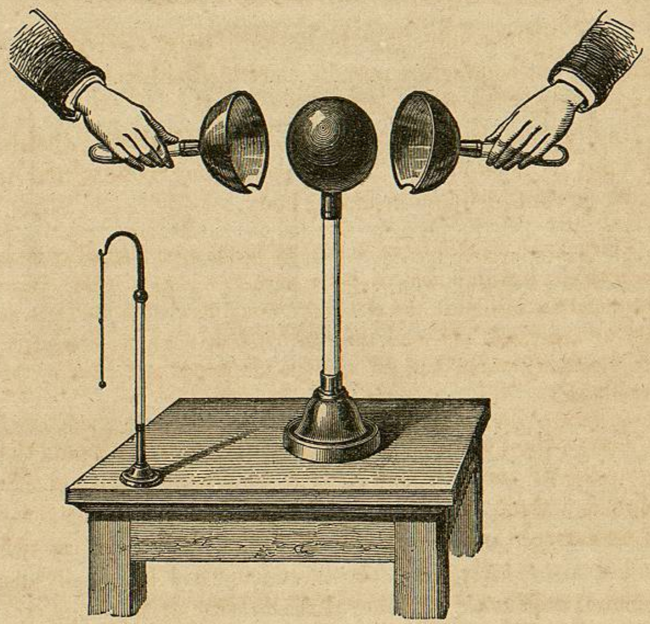

Fig. 251.

Of the various experiments intended to show this fact, we select one that was first performed by COULOMB. He mounted a copper sphere upon an insulating rod of glass, as shown in Fig. 251. He then provided two hollow hemispheres also of copper, which, when put together, exactly

---

(**367.**) Where is the electricity of a body found? Explain COULOMB'S experiment.

fitted the first sphere, and these he insulated by attaching them to glass handles. Having placed the hemispheres so as to cover the solid sphere, he brought the whole apparatus in contact with an electrified body till it was fully charged.

On removing the apparatus from the electrified body, he separated the two hemispheres abruptly, and applied to each in turn the electrical pendulum, when he found that both were electrified. On testing the solid sphere in like manner, he could discover no trace of electricity; in other words, it was perfectly neutral.

In taking away from the body its outer coating, he had removed every particle of its electricity, which proved that the electricity was entirely upon the surface.

Another fact which indicates the same conclusion is, that a hollow and a solid sphere of the same size and of the same material, will be charged with exactly the same quantity of electricity when made to communicate with the same electrical source.

When the electric fluid is accumulated upon the surface of a body, it tends to escape with a certain force, which is named the *tension.*

The tension augments with the quantity of electricity accumulated. So long as it does not pass a certain limit, it is held by the resistance of the air, but if the tension passes this limit, the electricity escapes with a crackling noise and a brilliant light called the *electric spark.* In moist air the tension is always feeble, because the electricity is slowly conveyed away by the moisture. In a vacuum, there is no resistance to the escape of electricity, and the tension is nothing. The electricity in this case flows off as fast as generated, with a feeble light

Influence of the Forms of Bodies.—Power of Points.

368. The distribution of electricity over the surfaces of bodies depends upon their form. If a body is spherical, the

What fact confirms Coulomb's *conclusion?* What is the tension? *What is the electric spark? Why is the tension feeble in moist air? In a vacuum?* (368.) What effect has the form of a body?

fluid is equally distributed, as may be shown by an instrument called a *proof-plane.*

The proof-plane consists of a disk of gilt paper attached to the end of a rod of gumlac, which insulates well. Taking the rod in the hand as shown in Fig. 252, it is applied successively at different points of the electrified surface, and after each contact it is presented to the electrical pendulum.

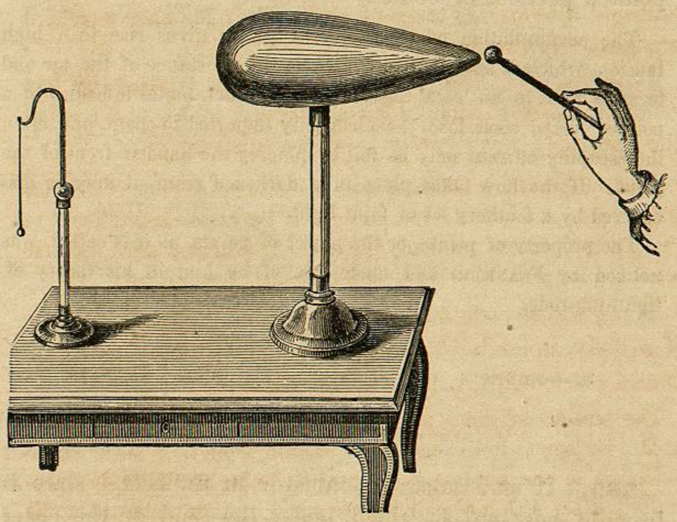

Fig. 252.

If the electrified body is a sphere, the same amount of attraction is for the pith ball shown, wherever the contact may be made; this shows that the proof-plane is equally charged at every point of the sphere, and consequently it is inferred that the distribution is uniform over the whole surface.

When the body is elongated and pointed, as in Fig. 252, different results are obtained. In this case the proof-plane

What is a proof-plane? How used?

is more highly charged at the sharp end of the body than at any other point, showing a larger amount of electricity at the point than elsewhere. In general, it may be shown that the greater the curvature of a surface at any part, that is, the nearer it approaches a point, the greater will be the accumulation of electricity there. This shows that electricity tends to accumulate at, or to flow towards the pointed portions of bodies.

The accumulation of electricity at points gives rise to a high tension, which is sufficient to overcome the resistance of the air and to give rise to an escaping current. In fact, metallic bodies of a pointed shape soon lose the electricity imparted to them, and often the escaping current may be felt by placing the hand in front of the point. If the flow takes place in a darkened room, it may be discovered by a feathery jet of faint light.

The property of points, or the power of points, as it is called, was noticed by FRANKLIN and made use of by him in his theory of lightning-rods.

II. — PRINCIPLE OF INDUCTION. — ELECTRICAL MACHINES.

Induction.

369. If an insulated conductor in a neutral state is brought near an electrified body, the fluid of the latter acting upon that of the former, decomposes it, repelling the fluid of the same name, and attracting that of a contrary name. This operation is called INDUCTION, and it may take place not only at considerable distances, but also through non-conducting bodies, such as air, glass, and the like.

The method of electrifying bodies by induction is shown in Fig. 253. On the right of the figure is the prime conductor of an electrical machine, which, as we shall see hereafter, is charged with the positive fluid. On the left is a

What effect has a pointed form? *Discuss the power of points.* (**369.**) What is Induction?

metallic cylinder with spherical ends, and supported by a rod of glass. Attached to its lower surface, at intervals, are pairs of pith ball pendulums, supported by threads of some conducting substance.

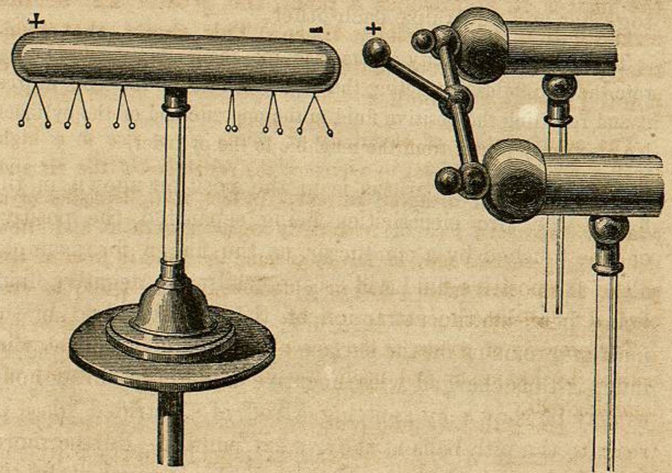

Fig. 253.

When the cylinder is brought slowly towards the electrical machine, we see the pith balls repel each other and diverge. This divergence is unequal at different points, being greatest near the extremities of the cylinder; towards the middle of the cylinder the pith balls remain in contact without repelling each other. We conclude from these facts that the fluids are driven towards the extremities of the cylinder, whilst the central portion remains in a neutral state.

If a stick of resin be rubbed with silk and brought near the pith balls towards the electrical machine, they will be repelled, showing that that end of the cylinder is negatively electrified. If it is brought near the pith balls at the remote

How is an insulated body affected by induction? Explain the phenomena in detail.

extremity of the cylinder, they are attracted, showing that that end of the cylinder is positively electrified. Finally, the electricities in the two ends are equal in quantity, as may be shown by removing the cylinder, when they flow together and neutralize each other.

The positive electricity of the machine, then, simply acts to separate the two fluids, attracting the negative fluid to the end nearest it and repelling the positive fluid to the opposite end of the cylinder. No electricity passes from the machine to the cylinder.

If, whilst the apparatus is in the position shown in the figure, the two electricities being separated, the positive end be touched by a conductor, as the finger, for example, all of the positive fluid will escape, whilst the negative fluid, being held by the attraction of the positive fluid in the machine, remains on the surface of the cylinder. The cylinder is thus charged with negative electricity throughout, as may be shown by applying a rod of electrified glass or resin to the pith balls at the two extremities. Furthermore, it is immaterial whereabouts the cylinder is touched by the conductor, for if touched at any point, the positive fluid escapes, and the cylinder is charged with the negative fluid.

Had the inducing body been charged negatively, the cylinder would in like manner have received a positive charge by induction.

The method of induction is of frequent application in experimental inquiries, and the principle set forth above serves to explain a great variety of electrical phenomena.

The Electrical Machine.

370. The Electrical Machine is a machine by means of which an unlimited amount of electricity may be generated by friction.

How does the positive electricity act? How is the negative fluid drawn off? Had the inducing body been negatively electrified, what would have happened? (**370.**) What is an Electrical Machine?

This machine was invented about two hundred years ago by Otto von Guericke, the distinguished inventor of the air-pump. The first machine was simply a ball of sulphur fixed upon a wooden axis. On turning the axis, and at the same time pressing one hand

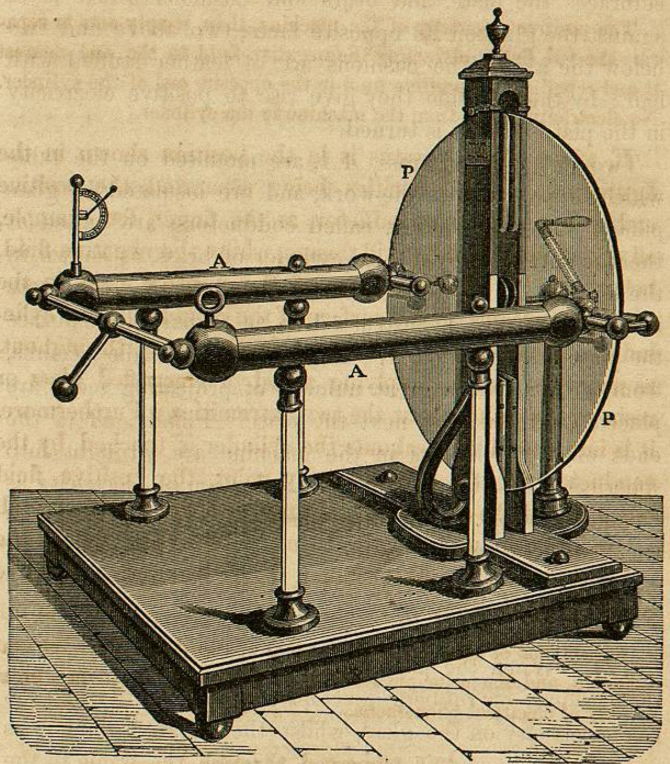

Fig. 254.

against the ball, a quantity of frictional electricity was developed. After various improvements the machine has taken the form shown in Fig. 254, which is the form that is now most generally employed in physical researches.

When invented and by whom?