Electric Charge

Gilbert, who originated the earth-magnet idea, also studied the attractive forces produced by rubbing amber. He pivoted a light metal arrow so delicately that it would turn under the application of a tiny force. He could, in that way, detect very weak attractive forces and proceeded to find substances other than amber, which, on rubbing, would produce such forces. Beginning in 1570, he found that a number of gems such as diamond, sapphire, amethyst, opal, and even ordinary rock crystal produced such attractive forces when rubbed. He called these substances "electrics." A substance showing such an attractive force was said to be electrified or to have gained an electric charge.

A number of substances, on the other hand, including the metals in particular, could not be electrified and hence were "non- electrics."

Eventually, electricity came to be considered a fluid. When a substance like amber was electrified, it was considered to have gained electric fluid which then remained there stationary. Such a charge was called static electricity, from a Latin word meaning "to be stationary." and the study of the properties of electricity under such conditions is called electrostatics.

Before electric forces could be studied easily, the fluid had to be concentrated in sizable quantities in greater quantity than could be squeezed into small bits of precious and semiprecious materials. Some "electric" that was cheap and available in sizable quantities had to be found.

In the 1660's, the German physicist Otto von Guericke (1602-1686) found such a material in sulfur. He prepared a sphere of sulfur, larger than a man's head, arranged so that it could be turned by a crank. A hand placed on it as it turned gradually electrified it to a hitherto unprecedented extent. Guericke had constructed the first electrical friction machine.

Using it, Guericke discovered several similarities between electrostatic forces and magnetic forces. He found, for instance, that there was electrostatic repulsion as well as electrostatic attraction, just as there is both repulsion and attraction in the case of magnets. Again, a substance brought near the electrified sulfur itself exhibited temporary electrification, just as a piece of iron held near a magnet becomes itself temporarily magnetized. Thus there is electrostatic induction as well as magnetic induction.

In 1729, an English electrician, Stephen Gray (1696-1736), electrified long glass tubes and found that corks placed into the ends of the tubes, as well as ivory balls stuck into the corks by long sticks, became electrified when the glass itself was rubbed. The electric fluid, which came into being at the point of rubbing, must obviously spread throughout the substance, through the cork and the stick into the ivory, for instance. This was the first clear indication that electricity need not be entirely static but might move.

While the electric fluid, once it was formed within an "electric" by rubbing, might spread outward into every part of the substance, it would not pass bodily through it, entering at one point, for instance, and leaving at another. It was otherwise in the case of "non-electrics." where such bodily passage did take place, indeed, the flow of electric fluid took place extremely readily through substances like metals; so readily that a charged electric lost its charge altogether--was discharged--if it were brought into contact with metal that was in turn in contact with the ground. The fluid passed from the electric, via the metal, into the capacious body of the earth, when it spread out so thinly that it could no longer be detected.

That seemed to explain why metals could not be electrified by rubbing. The electric fluid, as quickly as it was formed, passed through the metal into almost anything else the metal touched. Gray placed metals on blocks of resin (which did not allow a ready passage to the electric fluid). Under such circumstances, pieces of metal if carefully rubbed, were indeed electrified, for the fluid termed in the metal, unable to pass readily through the resin, was trapped so to speak, in the metal. In short, as it eventually turned out, electric forces were universally present in matter, just as magnetic forces were.

As a result of Gray's work, matter came to be divided into two classes. One class, of which the metals--particularly gold, silver, and copper and aluminum--were the best examples, allowed the passage of the electric fluid with great readiness. These are electrical conductors. The other group, such as amber, glass, sulfur, and rubber--just those materials that are easily electrified by rubbing--presents enormous resistance to the flow of electric fluid. These are electrical insulators (from a Latin word for "island," because such a substance can be used to wall off electrified objects, preventing the fluid from leaving and therefore making the objects an island of electricity, so to speak.)

Ideas concerning electrostatic attraction and repulsion were sharpened in 1733 by the French chemist Charles Francois Du Fay (1698-1739). He electrified small pieces of cork by touching them with an already electrified glass rod, so some of the electric fluid passed from the glass into the cork. Although the glass rod had attracted the cork while the latter was uncharged, rod and cork repelled each other once the cork was charged. Moreover, the two bits of cork, once both were charged from the glass, repelled each other.

The same thing happened if two pieces of cork were electrified by being touched with an already electrified rod of resin. However, a glass-electrified piece of cork attracted a resen-electrified piece of cork.

It seemed to Du Fay, then, that there were two types of electric fluid, and he called these "vitreous electricity" (from a Latin word for "glass") and "resinous electricity." Here, too, as in the case of the north and south poles of magnets, likes repelled and unlike attracted.

This theory was opposed by Benjamin Franklin. In the 1740's, he conducted experiments that showed quite clearly that a charge of "vitreous electricity" could neutralize a charge of "resinous electricity," leaving no charge at all behind. The two types of electricity were therefore not merely different; they were opposites.

To explain this, Franklin suggested that then was only one electrical fluid, and all bodies possessed it in some normal amount. When this fluid was present in its normal amount, the body was uncharged and showed no electrical effects. In some cases, as a result of rubbing, pan of the electrical fluid was removed from the material being rubbed; in other cases  it was added to the material. Where the body ended with an excess of the fluid, Franklin suggested, it might be considered positively charged, and where it ended with a deficit, it would be negatively charged. A positively- charged body would attract a negatively-charged body as the electric fluid strove (so to speak) to even out its distribution, and on contact, the electric fluid would flow from its place of excess to the place of deficiency. Both bodies would end with a normal concentration of the fluid, and both bodies would therefore be discharged.

On the other hand, two positively-charged bodies would repel each other, for the excess fluid in one body would have no tendency to add to the equal excess in the other--rather the reverse. Similarly, two negatively-charged bodies would repel each other.

Electrostatic induction was also easily explained in these terms. If a positively-charged object was brought near an un- charged body, the excess of fluid in the first would repel the fluid in the second and drive it toward the farthest portion of the uncharged body, leaving the nearest portion of that body negatively charged and the farthest portion positively charged. (The uncharged body would still remain uncharged, on the whole, for the negative charge on one portion would just balance the positive charge of the other.)

There would now be an attraction between the positively-charged body and the negatively-charged portion of the uncharged body. There would also be repulsion between the positively- charged body and the positively-charged portion of the uncharged body. However, since the positively-charged portion of the un-charged body is farther from the positively-charged body than the negatively-charged portion is, the force of repulsion is weaker than the force of attraction, and there is a net attractive force.

The same thing happens if a negatively-charged body approaches an uncharged body. Here the electrical fluid in the un- charged body is drawn toward the negatively-charged body. The uncharged body has a positively-charged portion near the negatively-charged body (resulting in a strong attraction) and a negatively-charged portion farther from the negatively-charged body (resulting in a weaker repulsion). Again there is a net attractive force. In this way, it can be explained why electrically charged bodies of either variety attract uncharged bodies with equal facility.

Franklin visualized a positive charge and negative charge as being analogous to the magnetic north and south poles, as far as attraction and repulsion was concerned. There is an important difference, however. The magnetism of the earth offered a standard method of differentiating between the magnetic poles, depending upon whether a particular pole pointed north or south. No such easy way of differentiating a positive charge from a negative charge existed.

A positive charge, according to Franklin, resulted from an excess of electric fluid, but since there is no absolute difference in behavior between "vitreous electricity" and "resinous electricity," how could one tell which electric charge represents a fluid excess and which a fluid deficit? The two forms differ only with reference to each other.

Franklin was forced to guess, realizing full well that his chances of being right were only one in two-an even chance. He decided that glass, when rubbed, gained electric fluid and was positively charged; on the other hand, when resin was rubbed it lost electric fluid and was negatively charged. Once this was decided upon, all electric charges could be determined to be positive or negative, depending on whether they were or repelled by a charge that was already determined to be positive or negative.

Ever since Franklin's day, electricians have considered the flow of electric fluid to be from the point of greatest positive concentration to the point of greatest negative concentration, the process being pictured as analogous to water flowing downhill. The tendency is always to even out the unevenness of charge distribution, lowering regions of excess and raising regions of deficit.

Franklin's point of view implies that electric charge can neither be created nor destroyed. If a positive charge is produced by the influx of electric fluid, that fluid must have come from somewhere else, and a deficit must exist at the point from which it came. The deficit produced at its point of origin must exactly equal the excess produced at its point of final rest. Thus, if glass is rubbed with silk and if glass gains a positive charge, the silk gains an equal negative charge. The net electric charge in glass- plus-silk was zero before rubbing and zero after.

This view has been well substantiated since the days of Franklin, and we can speak of the low of conservation of electric charge. We can say that net electric charge can neither be created nor destroyed; the total net electric charge of the universe is constant. We must remember that we are speaking of net electric charge. The neutralization of a quantity of positive electric charge by an equal quantity of negative electric charge is not the destruction of electric charge. The     sum of + x and - x is 0, and in such neutralization it is not the net charge that has changed, only the distribution of charge. The same is true if an uncharged system is changed into one in which one part of the system contains a positive charge and another part an equal negative charge. This situation is exactly analogous to that involved in the law of conservation of momentum.