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The Nature of an Electric Current

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THE NATURE OF AN ELECTRIC CURRENT

Electricity at rest upon the surface of a non-conductor or upon the surface of a completely insulated conductor is commonly called a static charge of electricity. As has been explained by the writer in a previous article in the Science Bulletin, a static charge is negative when it consists of an aggregate of electrons and positive when it consists of an aggregate of unneutralized protons. It was also pointed out in the same article that a static charge possesses a static field of force whose lines, in the case of a charge upon a spherical surface, Fig. 1, extend radially from the surface into space.

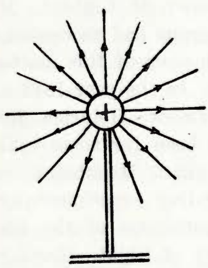

Fig. 1.

Before discussing the phenomena of current electricity in general, it might be instructive to see just how electricity in motion, which we call a current, differs from electricity at rest, which we call a static charge. Let us assume in one explanation of this difference, the smallest current imaginable; that caused by a single electron in motion through a good metallic conductor. Let us assume for the sake of clearness that an electron possesses either a sperical or circular disc shape. We know already that it consists only of negative electricity. Furthermore, we understand that when it is at rest it possesses a static field whose lines of force extend into space perpendicularly from its surface, as shown in connection with the charge in Fig. 1.

Now what change takes place in this electron when it moves and thus becomes a current of electricity? To answer this question let us study carefully Fig. 2.

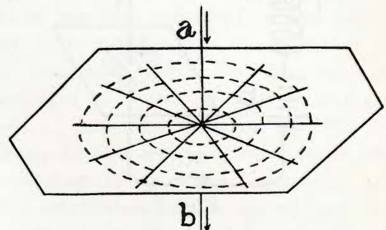

Fig. 2.

In Fig. 2 we will assume that an electron moves swiftly from a to b along a wire that passes perpendicularly through the center of a piece of cardboard. As it moves the electron retains its static field with its lines radial to the wire, as is indicated on the surface of the cardboard where the wire passes through it. Besides this radial static field the electron by some mysterious process develops also, by virtue of its motion, a second field of force called a magnetic field. The lines of force of this field are circular, as shown by the dotted circles drawn around the wire on the surface of the cardboard. We should also note from Fig. 2 that the motion of the electron, which we will call the electrical displacement, is at right angles to both the static lines of force and the magnetic lines of force. Furthermore the circular lines of magnetic force are perpendicular to the radial static lines of force. We can say then, finally, that in a free current of electricity its electric line of displacement, its magnetic lines of force and its static lines of force are mutually perpendicular.

The magnetic field of an electric current is easily shown to a class by means of a simple apparatus arranged as in Fig. 3.

By attaching two dry cells to the perpendicular wire passing through the cardboard a current of 20 to 30 amperes can be sent through it for a moment by operating the key. Before closing the

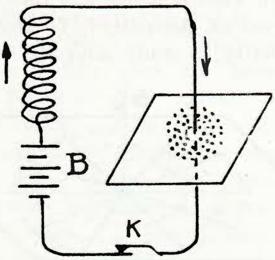

Fig. 3.

circuit fine iron filings should be sprinkled over the surface of the cardboard. Then when the circuit is closed a gentle tapping of the cardboard will cause the filings to arrange themselves in perfect circles around the wire. The cardboard should be resting upon a firm support during the experiment. Another way of showing the magnetic field of a current passing through a non-insulated copper wire connected to a dry cell is to dip a portion of it into a pile of fine iron filings, then close the circuit and raise the wire. A large cluster of filings, Fig. 4, will be found clinging to it. These filings immediately fall off when the cir-

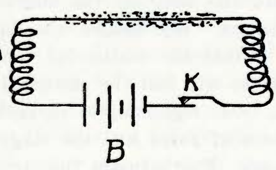

Fig. 4.

cuit is opened. Both of these experiiments will create much interest when performed in the classroom.

The static field of an electric current cannot readily be shown unless one has a Tesla coil. Wires attached to such a coil when in operation in a darkened room show bright luminous discharges reaching out radially from the wires. Ordinary electric currents, where the voltage does not rise above a few thousand volts, have only weak static fields that cannot be sensed by the eye in a darkened room. However, it is interesting to know that when alternating currents of electricity are stepped up to 10,000 volts or more there is always a loss of electrical energy through silent discharge that takes place along the radial static lines of force. For this reason it would not be economical in the distribution of electrical energy by means of conducting wires to step the voltage up too high.

As stated above, an electrical current is characterized by its possession of three concurrent phenomena: its electrical displacement; its static field, and its magnetic field. In 1873 J. Clerk Maxwell, a prominent British physicist, expressed these three phenomena in terms of six mathematical equations. With these equations as a basis, he wrote a mathematical treatise on Electricity and Magnetism in which he propounded the ''Electro-magnetic Theory of Light''. Maxwell died before anyone had succeeded in verifying the conclusions of this mathematical dissertation. In the year 1888 a young German professor, Heinrich Rudolf Hertz, who had been for some years a student of the great Helmholtz, succeeded in demonstrating experimentally the fundamental postulates of the Electro-magnetic Theory of Light. Hertz published his work in a treatise called Hertzian Waves. Hertz's experimental work led directly to wireless telegraphy, which was brought to commercial importance by Marconi. The works of Maxwell and Hertz have been a veritable mine of discovery to succeeding pure and applied scientists. Today we have not only wireless telegraphy but also radio, the movietone, and some television, all of which are the direct fruits of Maxwell's great mathematical dissertation. The ''Electro-magnetic Theory of Light,'' by J. Clerk Maxwell was probably the greatest single mental achievement of the nineteenth century. At the present time the scientific world is confronted with another great mathematical thesis by Einstein called the ''Theory of Relativity''. It is expected that this also may lead to great achievements in science. Who can tell?

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