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Oersted's Experience Completes Two Hundred Years

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Abstract

In 1820 Oersted discovered that a long chain with wire altered the natural orientation of a magnetic needle placed nearby. He interpreted this experiment as being due to a direct interaction between electrical currents in the magnet and the wire. Thus, to substantiate his position, he undertook a series of experiments to establish an analogy between magnetic and electrodynamics phenomena. And in the same article in which he presented experiments confirming his predictions. It is usually said that Oersted accidentally arrived at the experimental result. However, as several researchers show us, their discovery was the result of a long journey. Not only from Oersted, but from all others that preceded it and contributed to the results obtained.

Key words: Electromagnetism, Oersted, Accidentally

SMALL OERSTED BIOGRAPHY

According to PABLO RAFAEL [(1)], Hans Christian Oersted, son of apothecary Søren Christian Oersted and Karen Hermansen, was born in Rudkobing, Denmark, on August 14, 1777. At age 17 Oersted was accepted at the University in Copenhagen where he graduated pharmacist and in 1799 completed his doctorate in philosophy. He worked in 1800 in a traditional pharmacy of Copenhagen and that same year became an adjunct pharmacist of the Faculty of Medicine. Between 1801 and 1803, he earned a scholarship for improvement in Germany, the Netherlands, and France, where he established great and important personal contacts with scientists and intellectuals. In 1804 he was hired to teach physics at the University of Denmark, and in 1806 he became extraordinary professor and in 1817 ordinary professor. In 1915 he was appointed lifetime secretary of the Copenhagen Academy of Sciences, shortly afterwards he was appointed by the king as knight of the Order of Danneborg. Founded in Denmark a Society for the Development of the Study of Science, in 1828 was appointed Councilor of the state. In 1829 he founded the Copenhagen Polytechnic School where he became the director of the institution. Oersted died in Copenhagen on March 9, 1851.

INTRODUCTION

One of the first studies that allowed a great advance in the study of magnetism was done by MARICOURT(2), who, based on experimentation, writes on August 8, 1269, a work called Letter on the Magneto by Pedro Peregrino de Maricourt addressed to Sygerus de Foucaucourt which came to be called the Magneto's Epistle. He carried out experiments on magnetism and wrote the first existing treatise on the properties of magnets. His work also stands out for the first detailed description of a compass, explaining how to identify its magnetic poles and how to identify the laws of attraction and magnetic repulsion. The eighteenth century produced a wealth of experimenters, including with regard to electricity and magnetism. In 1600 WILLIAM GILBERT, he published the book De Magnete(3) and is credited as one of the originators of the term "electricity". He is regarded by some as the father of electrical engineering or electricity and magnetism. GILBERT (3) managed to reproduce the effect observed in amber in a large amount of materials. The materials that, like amber, attracted light bodies after being rubbed were named by Gilbert as electrical and the other materials as non-electrical. Today we call the first insulating materials and the other materials of conductors of electric charge. STEPHEN GRAY[4] in 1729 carried out several interesting experiments in electricity, demonstrating important phenomena, such as the conduction of electricity and induction electrification, also came to the conclusion that there are conductive materials and non-conductive materials for electricity. CHARLES DUFAY[5] proposed in 1733 the existence of two types of electric charge, with charges of the same type repelling and charges of opposite types attracting each other. Thanks to Dufay's experiences, electrostatics were no longer seen only as an attraction phenomenon, but, along with magnetostatics, they exhibited both repulsion and attraction behaviors. On the other hand, several evidences [5] led some thinkers to believe in a relationship between magnetism and electricity. For example, it was observed that metallic parts were magnetized when a lightning bolt fell on them and when the lightning bolt fell near a compass, its orientation changed. This was strong evidence that generated the assumption of the connection between magnetism and electricity. Adding to all this, Priestley in 1767, John Robison in 1769 and Coulomb in 1785 announced the inverse square law for electrostatic force, and a similar law for magnetostatics was announced by Coulomb[5] in 1785. Several researchers tried in vain to find some empirical effect that related electrostatics and magnetism. Oersted[6] was among the researchers who believed that magnetic effects are produced by the same powers as electrical ones. To try to confirm his ideas, he carried out experiments in order to search for a relationship between a magnetized needle and "electrical conflict." This term used by Oersted came from his conception of the nature of the electric current. He imagined that there were two currents in a metallic wire connected to a battery, one positive and one negative, flowing in opposite directions. They would have to meet and separate several times along the wire. In view of this, Oersted[6] placed a metallic thread parallel to a magnetic needle that was oriented along the Earth's magnetic meridian. When passing a constant electric current in the thread, he noticed that the needle was deflected from its original direction. Such a discovery was described at the Royal Academy of Sciences in France on September 4, 1820 by then President Arago. In the face of widespread disbelief, he repeated Oersted's experience before the Academy on September 11. It is important to keep in mind the difficulties of carrying out the experiment, as well as its design, because, at that time, the type of materials for carrying out the experiment was very different from what we have today. Oersted's work was published for the first time, at the author's own expense, in 1820. It was a four-page leaflet with the following Latin(6) title: Experimenta circa effectum conflictus electrici in acum magneticam. It is usually said that Oersted arrived at the experimental result by accident. However, as Martins shows us, his discovery was the result of a long journey. Not only from Oersted, but from all the others that preceded it and contributed to the results obtained.

OERSTED'S DISCOVERY IN 1820: HAS IT HAPPENED?

Many textbooks establish the view that scientific discoveries are often the result of chance. Many teachers verbalize it in the classroom and, to exemplify many, mention that Oersted, by pure chance, discovered that an electric current was capable of deflecting a compass. According to KIPNIS(7) , ignoring the role of chance in science distorts the nature of the scientific process, and mentions that Oersted's discovery of electromagnetism was largely due to chance. The reproduction of the Oersted experiment in the classroom complements the story, allowing students to see for themselves the role of some accidental factors(7), such as the choice of materials and instruments. The message to students is that chance and logic go together in science. Teachers can address this issue through a number of in-depth historical case studies, such as Oersted's discovery of electromagnetism. At the time, Ludwig Wilhelm Gilbert was the editor of Annalen der Physik, where Oersted submitted his article. In his account of the acceptance of the text, Gilbert mentions that the Oersted experiment was a discovery of electromagnetism obtained accidentally. He himself admitted that he had difficulty understanding Oersted's Latin description (STAUFFER(8)). Further evidence of this is in a letter written by Christopher Hansteen, one of Oersted's assistants who were part of the audience that witnessed the experiment. The correspondence was sent to Michael Faraday in 1857, that is, thirty-seven years after the discovery and shortly after Oersted's death. In his message, Hansteen reports that the discovery of electromagnetism was accidental and that Oersted had no previous knowledge that could lead him to the discovery. On the other hand, MARTINS(8) defends the thesis that there was almost nothing accidental in this discovery by Oersted, on the contrary, from the beginning he sought to find the link between Electricity and Magnetism. For Magalhães the discovery of Oersted was not accidental, "as is unfortunately read in several textbooks, but the result of a careful and long plan to explore the unity of nature".

OERSTED's EXPERIMENT

Before the beginning of the 19th century, Electricity and Magnetism were considered separate sciences; however, there was evidence that lightning, which is electrical discharges, was able to magnetize pieces of iron. In his experience, Oersted initially placed the magnetic needle perpendicular to the conductive wire without noticing any noticeable movement. Then, using a powerful galvanic battery and placing the needle parallel to the wire, Oersted and the public were astonished to see the needle move quickly and position itself at a right angle to the lead wire. The report also states that after reversing the direction of the current, it was found that the compass needle was moving in the opposite direction. In fact, when the electric current is reversed, a magnetic field is produced in the opposite direction and, consequently, the displacement of the compass needle is reversed. The experimental apparatus consists of a simple electrical circuit with high electrical current. A compass is positioned close to the conductive wire and, when the circuit is switched on, the needle, which is usually oriented with the terrestrial magnetic field, undergoes an instant disorientation, returning to the original position when the circuit is switched off. At this moment, it is noticed that the electric current that passes through the wire can generate a magnetic field around it, making it capable of moving magnetic materials, such as the compass needle. To reproduce the Oersted experience, first of all, one must prepare the entire experimental apparatus. As shown in figure 1, glue the compass to a support and then, on the opposite side of the compass, insert the battery. Connect the ends of the conductive wire to the battery positive and negative poles. Bend the string so that it is close to the compass's glass surface to more effectively check your needle travel.

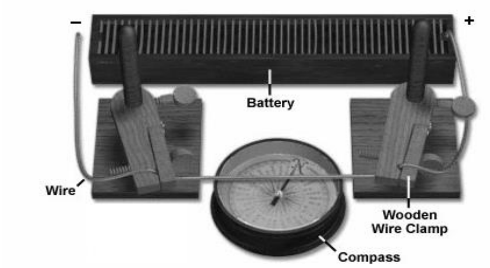

Figure 1 - Experimental apparatus of the Oersted experiment
Source : https://br.images.search.yahoo.com

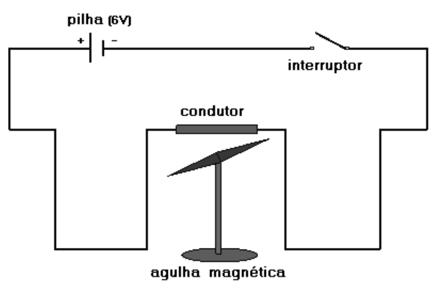

Figure 2 - Equivalent electrical circuit of the Oersted experiment
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INVERSE EFFECT

From the discovery of Oersted, several researchers tried to achieve the opposite result, that is, to obtain electric current from a magnetic field. That is, if we have an electric current and, associated with it, a magnetic field, then it must also be possible, with a magnetic field, to obtain electric current. This is exactly what FARADAY (9) showed, that is, that electric currents could be produced by moving magnets. Faraday's great achievement (9) was to obtain electric current in a conductive wire that was not connected to any source of energy, thanks to the movement of an electromagnet inside a coil. It was enough to stop the movement of the electromagnet and the current also stopped. Faraday(9) proved that the variation of a magnetic field is capable of provoking the appearance of an electric current in a conductive wire, even if it is not connected to any source of energy, such as a battery. When subjected to the presence of a variable magnetic field, the conducting wire starts to be traversed by an electric current also variable, called induced current. Faraday's law of electromagnetic induction is a basic law of electromagnetism that predicts how a variable magnetic field will interact with an electrical circuit to produce an induced electromotive force. This phenomenon is known as electromagnetic induction.

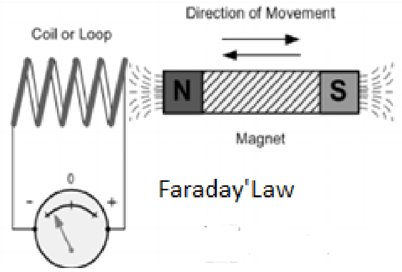

Figure 3- Faraday's Experimental Arrangement
Source: the author himself

The figure 3 shows a magnet and a coil that are connected to a galvanometer. When the magnet is at rest there is no deflection in the galvanometer, that is, the needle of the galvanometer is in the central or zero position. When the magnet is moved closer to or away from the coil, the galvanometer needle deviates in a given direction. It is noticed that the faster the change in the magnetic field, the greater the electromotive force or the voltage induced in the coil. Faraday's discovery of the law of magnetic induction makes it possible to build electric motors, generators and transformers that form the basis of modern technology. By understanding and using induction, we have an electrical power grid and many of the things we connect to it. According to FRIEDL [(11)] , electric motors operate as inverted electric generators, that is, instead of converting mechanical energy into electricity, they produce mechanical energy from electrical energy. In this case, instead of using the rotation of an axis to generate electricity, we cause an electric current to pass through an axis wound by several coils, causing it to rotate.

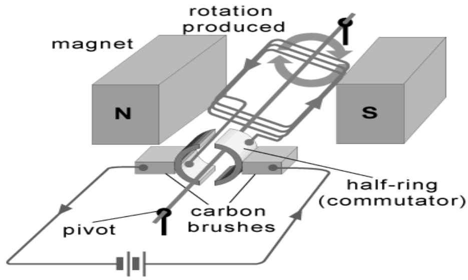

Figure 4- Illustration of a simple Faraday engine
Source: https://www.google.com/search?

In the case [11] of the simplest motor shown in figure 4 we have a coil that rotates between two permanent magnets. Initially, the magnetic poles of the coil are attracted to the opposite poles of the fixed magnets. As a result of this attraction, the coil rotates to bring these magnetic poles as close together as possible. However, when reaching this position, the direction of the current is reversed, which causes the poles that face each other to repel, continuing to drive the rotor. A motor cannot run if it is built exclusively with permanent magnets. In a more sophisticated engine we have as components the stator and the rotor. The Stator[10] is the part of an electric motor or generator that remains fixed to the frame and its function is to conduct the magnetic flow, in the motors to rotate and in the generators to transform the kinetic energy of the armature. The rotor, in turn, is a structure that rotates around its own axis, producing rotational movement and energy. The motor rotor needs torque to start its rotation. This torque is normally produced by magnetic forces developed between the magnetic poles of the rotor and those of the stator. Attracting or repelling forces, developed between stator and rotor, 'pull' or 'push' the mobile poles of the rotor, producing torques, which make the rotor rotate more and more quickly, until friction or loads connected to the shaft reduce the resulting torque to 'zero' value. After that point, the rotor starts to rotate with constant angular speed. Both the rotor and the motor stator must be 'magnetic', as it is these forces between poles that produce the torque necessary to make the rotor rotate. On the other hand, the simplest electrical generator is formed by a flat loop with sufficient freedom to move under the action of a uniform magnetic field. This loop turns around an axis perpendicular to the direction of the lines of force of the applied magnetic field. The variation in the value of the flow through the mobile loop induces an electromotive force. Thus, the electromotive force results from the relative movement that exists between the loop and the magnetic field. The current produced in this way is alternated. To obtain direct current, it is necessary to provide the generator with a device that rectifies the current, called the dynamo collector. By describing the principle of operation of generators, it is seen that they have two distinct circuits: the armature and the inductor. In the case of the elementary generator described, the armature would be the moving coil and the inductor the magnetic field (FRIEDL[(11)]).

FINAL CONSIDERATIONS

Oersted's experiment represented one of the most important and fundamental scientific discoveries: Electromagnetism. Despite this, the Danish scientist's work is often minimized. AL-KHALILI[(10)] points out that one of the main reasons for this is the version that the discovery was accidental. Using this experimental result, he further explained why such manifestation occurred only on appropriate materials. Despite this, his theory had few adherents; only its experimental results were quickly accepted by the scientific community. In a course on electromagnetism, whose central objective is reflection on science, the discussion of the experience of the magnetized needle is a point that deserves to be highlighted, as it was not random, due to chance. The historical contextualization of this work, unlike the mere presentation provided in textbooks, is an important point on which students can reflect on the role of experimentation throughout scientific development, and therefore provides a reflection on science.

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