On 21 July 1820 the Danish physicist and chemist Hans Christian Oersted (1777–1851) announced in a four-page Latin pamphlet his discovery of the effect of an electric current on a magnetic needle suspended in the earth’s magnetic field. He sent his publication to a large number of prominent men of science and scientific societies. It was headed Experimenta circa effectum conflictus electrici in acum magneticam. Before long it was translated into Danish, Dutch, English, French, German and Italian. The English version appeared in the October issue of the Annals of Philosophy as ‘Experiments on the Effect of a Current of Electricity on the Magnetic Needle’.

In the spring of 1820 Oersted found out that a pivoted magnetic needle placed parallel to a wire carrying an electric current made a great oscillation. The needle deflected one way for one direction of the current and the opposite way for the other direction. Oersted made use of a large battery of low internal resistance, which he had constructed together with his friend, the lawyer Lauritz Esmarch (1765–1842). The apparatus consisted of twenty copper troughs, twelve inches long and equally high and two and a half inches broad (fig. 18). The trough formed the positive pole of the cell. In each cell a zinc plate was fastened to a hoop which protruded from the copper trough of the adjoining cell. The troughs were filled with water containing 1/60th of its weight of sulphuric acid and an equal weight of nitric acid:

Let the straight part of this wire [carrying the current] be placed horizontally above the magnetic needle, properly suspended, and parallel to it. If necessary, the uniting wire is bent so as to assume a proper position for the experiment. Things being in this state, the needle will be moved, and the end of it next the negative side of the battery will go westward.

If the wire was held under the magnetic needle, it moved in the opposite direction. The deflection of the magnetic needle depended on the distance between the needle and the wire and on the ‘power of the battery’. In Oersted’s experiments the declination of the needle made an angle of about 45°.

It came as a surprise that the direction of the force was perpendicular to a plane through the wire and the needle. This observation was more remarkable than the fact that an electric current acted on a magnetic needle. For a long time scientists had assumed some connection between electricity and magnet-
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Oersted's discovery, however, seemed to contradict Newton's law that forces of gravitational attraction act along the line connecting the two gravitational bodies. Charles Coulomb's law of the interaction of electrically charged bodies and of magnetized bodies, respectively, implied that the attractive and repulsive forces between magnetic bodies as well as between electrified bodies also lay along the connecting lines. Oersted, however, had found that the force between a current and the pole of an adjacent magnet was not along the line connecting the two, but perpendicular to that line.

At first sight Oersted's explanation of his discovery seems somewhat strange. Already in the title of the Latin pamphlet he spoke of a 'conflictus electricus', an electric conflict, and not of an electric current. The Italian, the German and the Danish translations also used this expression. The English translation, however, spoke about 'a Current of Electricity', and the Dutch about 'de werking van het galvanismus op de magneetnaald' (the action of galvanism on the magnetic needle). But in the texts of these translations we also meet the term 'electric conflict':

The opposite ends of the galvanic battery were joined by a metallic wire, which, for shortness sake, we shall call the uniting conductor, or the uniting wire. To the effect which takes place in this conductor and in the surrounding space, we shall give the name of the conflict of electricity.\(^1\)

The expression 'electric current' was already used before Oersted's time. In the Dictionnaire raisonné de physique (1781) of Mathurin Jacques Bisson (1723-1806) we find the entry 'courant électrique'. The reason for Oersted's use of the concept of an electric conflict is to be found in his philosophical background.

Oersted's apparatus, now in the Danmarks Tekniske Museum, Elsinore.

OERSTED'S EARLY LIFE

Oersted, son of a pharmacist at Rudkøbing on the Danish island of Langeland, was born in 1777. At the age of eleven he began to assist in his father's apothecary shop. He developed an increasing interest in chemistry and physics. In 1794 Oersted started his studies in natural sciences at the University of Copenhagen. Here he also followed courses on Kant and the critical philosophy, given by the Kantian philosopher Børne Rissbrigh (1722-1809). In 1797 Oersted passed his examination in pharmacy. Two years later he wrote a paper on Kant's Metaphysische Anfangsgründe der Naturwissenschaft (Metaphysical Foundations of Natural Science) (1786) for a new Danish journal which was started for the purpose of promoting Kant's philosophy. Oersted treated the same subject more elaborately in his thesis for the doctorate from the same year. The Dissertatio de forma metaphysicae elementaris naturae externae (1799) was a critical account of the content of
Kant's ideas on natural philosophy, in particular on such questions as: what is the a priori basis of science, what are the necessary presuppositions of all experience and what laws of matter and its motion may be deduced a priori? Kant considered the concept of matter as 'the moveable insofar as it fills a space'. He immediately added that matter does not fill a space 'by its mere existence, but by a special moving force'. Matter fills its space by the antagonism between two forces: attracting and repulsing. Both forces determine the dynamical nature of matter. Kant used these concepts for the explanation of chemical and physical processes: solution, separation, friction and elasticity. In his dynamical theory he restricted himself to a general foundation on which matter is built up, namely the two basic forces. That there are two basic forces is essential: by mere attraction, matter would 'coalesce in a mathematical point and the space would be empty and hence without any matter.' With only repulsive forces matter 'would be held within no limits of extension, i.e. would disperse itself to infinity, and no assignable quantity of matter would be found in any assignable space.' According to Kant the physical divisibility of a substance which fills a space continues as far as the mathematical divisibility of that space. Therefore he rejected an atomistic structure of matter: 'Matter is divisible to infinity, and indeed into parts each of which is again matter.'

Oersted became an ardent exponent of Kant's new critical philosophy, which was to be of fundamental importance to his scientific development. He was less affected by the speculative elaboration of the Kantian philosophy by Schelling and his adherents. Kant saw the world as an equilibrium between the opposing forces of attraction and repulsion, while Schelling believed in a conflict in which these forces constantly strove to overcome each other, an attractive force constantly battling with a repulsive force producing a basic polarity in matter and, ultimately, in the whole universe.

In his thesis Oersted showed his reserve against the rising Naturphilosophie. He was critical of the way Schelling used empirical theses in his books Ideen zu einer Philosophie der Natur (Ideas of a Philosophy of Nature: 1797) and Von der Weltseele (On the World Soul: 1798):

These two books no doubt deserve attention for the beautiful and great ideas we find in them, but on account of the not very rigorous method by which the author intermingles empirical propositions without sufficiently distinguishing them from a priori propositions these books are robbed of much of their value, especially as the empirical propositions adduced are often utterly false.

Oersted's study of Kant's critical philosophy gave him an excellent background for his later scientific work. It led him to the realization that for a law of nature which is absolutely valid an a priori foundation is necessary. But it also made him an opponent of the atomic theory for the greater part of his life.

After his studies at Copenhagen University Oersted became manager of the Lion Apothecary in Copenhagen. In 1801 he was appointed an assistant professor, without pay. He began experimental studies with the Galvanic pile, which was described by Alessandro Volta in 1800. With this new source of electric current a continuous flow of electric fluid could be produced.

From the summer of 1801 until the end of 1803 Oersted made an educational trip (Wanderjahr) through Germany, France and the Netherlands. In September 1801 he met the German Romantic physicist Johann Wilhelm Ritter (1776–1810) in Oberweimar. Ritter was first and foremost an experimental physicist, but was also strongly influenced by the thoughts of the Romantic movement. Time and again his publications illustrate excellent experimental methods based upon fanciful speculations. His interest was mainly focused on the nature of galvanism. For three weeks Oersted worked together with Ritter on the subject of galvanism.

The latter's belief in a connection between electricity and magnetism had taken a firm hold of Oersted's mind during his stay with Ritter. It was this Romantic belief in and search for unity and polarity in nature that became the guiding principle in Oersted's scientific researches. Oersted and Ritter met for the second time in Jena (August to September 1802). The two meetings led to an animated and interesting correspondence lasting until Ritter's untimely death in 1810.

In a letter to Oersted of 22 May 1803, Ritter prophesied a remarkable discovery in 1819 or 1820. He meant that the years of maximum inclination of the ecliptic (1745, 1764, 1782, 1801) coincided with outstanding discoveries in the field of electricity ('it means in the first four months of the year, and so forth'):

1745 Invention of the Leiden jar by Kleist (1745)
1764 Invention of the electrophorous by Wilcke (1764)
1782 Invention of the condenser by Volta (1783)
1801 Invention of the Voltaic pile (1800).

Ritter went on: 'You will not have to reckon with a new epoch or its start any earlier than the year 1819 or 1820. This we might well witness.' And then lo and behold Oersted discovered in 1820 the effect of the electric current upon the magnet!

Ritter was not the only one to influence Oersted. During a six-months' stay in Berlin, he not only studied chemistry and physics, but also attended lectures by Fichte and the brothers Schlegel; he got acquainted with Franz von Baader and studied intensively, but not uncritically, the writings of Schelling. He found a complement to these philosophical pursuits during a stay in Paris (1802), where he met French savants and was impressed by their highly developed use of careful experiments in the study of nature. In Germany he was confronted with scientists who—often through mere speculation—were
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In the same year he published an article in which he stated that the electric conflict in a wire is caused by the contrary effect of the two kinds of electricity which are accumulated in the poles of the galvanic battery. The propagation of electricity in a wire is a continuous disturbance and restoration of an equilibrium and therefore not to be considered as a continuous current.

OERSTED'S DISCOVERY OF ELECTROMAGNETISM

During a stay in Berlin (May 1812 – Summer 1813) Oersted wrote a book entitled Ansicht der chemischen Naturgesetze durch die neuen Entdeckungen gewonnen (Consideration of the Physical Laws of Chemistry Deduced from the New Discoveries) (1812), in which he stated that only chemical affinities, but also heat and light are produced by the same two powers, which probably might be only two different forms of one primordial power. He stated also, that the magnetic effects were produced by the same powers, but he was well aware, that nothing in the whole work was less satisfactory, than the reasons he alleged for this. His researches upon this subject, were still fruitless, until the year 1820.

An important reason for these claims was the action of the column of Volta and the chemical action of an electric current. A description of the background to the discovery of electromagnetism was given by Oersted in an article on thermo-electricity, which he wrote for David Brewster's Edinburgh Encyclopaedia in 1827:

In the winter of 1819–20, he delivered a course of lectures upon electricity, galvanism, and magnetism, before an audience that had been previously acquainted with the principles of natural philosophy. In composing the lecture, in which he was to treat of the analogy between magnetism and electricity, he conjectured, that if it were possible to produce any magnetic effect by electricity, this could not be in the direction of the current, since this had been so often tried in vain, but that it must be produced by a lateral action. This was strictly connected with his other ideas; for he did not consider the transmission of electricity through a conductor as a uniform stream, but as a succession of interruptions and re-establishments of equilibrium, in such a manner, that the electrical powers in the current were not in quiet equilibrium, but in a state of continual conflict. As the luminous and heating effect of the electrical current goes out in all directions from a conductor, which transmits a great quantity of electricity, so he thought it possible that the magnetic effect could likewise irradiate. The observations... of magnetic effects produced by lightning, in steel-needles not immediately struck, confirmed him in his opinion. He was nevertheless far from expecting a great magnetic effect of the galvanic pile; and he still supposed that a power, sufficient to make the conducting wire glowing, might be required.

The electric conflict in the conductor between the opposite electivities produces many effects: chemical effects in the conductor in the direction of the current, and heat and light effects which radiate in all directions from the
conductor. Might it therefore not be possible that the magnetic effect is a special action of the same forces that are found in heat and light? In his *Ansicht der chemischen Naturgesetze* Oersted remarked that one must try to show the action of magnetism on electricity. 'One feels that magnetic forces are as general as electric forces. An attempt should be made to see if electricity, in its most latent stage, has any action on the magnet as such.'\(^9\)

It was not until 1820 that Oersted succeeded in proving the connection between electricity and magnetism with a very simple experiment. In April 1820, during an evening lecture on electricity, galvanism and magnetism, he found that the current in a wire caused a magnetic needle, placed at a distance from it, to move. The effect, however, was very feeble. At the beginning of July 1820 the experiments were resumed using a stronger galvanic apparatus. The effects were still feeble and irregular because Oersted employed very thin wires, supposing that the magnetic effect would not take place when heat and light were not produced by the galvanic current. Soon he found that wires of a greater diameter give a much stronger effect. The experiments were done in the presence of a number of witnesses: Lauritz Esmarch, the mathematician Peter Wleugel (1766–1835), the physicist Adam Hauch (1755–1838), the biologist Johannes Reinhardt (1776–1845), the physician and biologist Ludwig Jacobson (1783–1843) and the chemist William Zeise (1789–1847). Soon after he published a preliminary report of his results. This report caused a sensation, but the verdict of the French chemist Pierre Louis Dulong (1785–1838) was significant. On 2 October 1820 Dulong wrote to the Swedish chemist Jöns Jacob Berzelius (1779–1848): 'At first the news is received very coolly here. One believes that it is again a German dream.'\(^20\) The German physicist Ludwig Wilhelm Gilbert (1769–1824), editor of the *Annalen der Physik*, who published attacks on *Naturphilosophie*, as well as appending critical notes to articles with a speculative tendency, declared Oersted's discovery to be a mere accident (1820). His colleague Christian Heinrich Pfaff (1773–1852) also held the same opinion (1824). Of course Kantian and Schellingian scientists and philosophers were very enthusiastic. On 2 August 1820 the Kantian mineralogist Christian Samuel Weiss (1780–1856) wrote to Oersted that his discovery was a confirmation of Kantian dynamics.

Despite Oersted's fundamental experiments, his explanation was clearly speculative. The electric conflict exerts only an influence 'on the magnetic particles of matter'. All non-magnetic bodies appear permeable by the electrical conflict, while magnetic bodies (or rather their magnetic particles) resist the passage of this conflict. 'Hence they can moved by the impetus of the contending powers.'\(^9\) Oersted himself realized that 'the electric conflict is not confined to the conductor, but dispersed pretty widely in the circumjacent space' and must be assumed to traverse circles whose planes are at right angles to the conductor:

From the preceding facts we may likewise collect that this conflict performs circles; for without this condition, it seems impossible that the one part of the unifying wire, when placed below the magnetic pole, should drive it to the east, and when placed above it towards the west; for it is the nature of a circle that the motions in opposite parts should have an opposite direction.

The centre of force does not act attractively or repulsively on the magnetic poles, but it drives the poles in a circle around it. Oersted was well aware that this whirling was a new action of force and that it was not analogous to the central forces (forces acting in straight lines between points) of attraction and repulsion that underlie the phenomena of gravitation, electricity and magnetism. His notion of circular magnetic lines of force, which cut a current-carrying wire in planes perpendicular to the conductor, seems very modern, but has nothing to do with the later concepts of field theory.

Immediately after the foregoing, Oersted suggested that the ideas of a circular movement in the medium surrounding the electric conflict would be of significance for the theory of the nature of light:

I shall merely add to the above that I have demonstrated in a book published five years ago that heat and light consist of the conflict of the electricities. From the observations now stated, we may conclude that a circular motion likewise occurs in these effects. This I think will contribute very much to illustrate the phenomena to which the appellation of polarization of light has been given.

Oersted's Latin pamphlet was a preliminary communication. It was rather too brief to be perfectly intelligible. In the July issue of the *Journal für Chemie*
electricity, but solely on its forces. In the circle of the German Romantics, he was held in great respect. But was a direct consequence of his metaphysical belief in the unity of all natural forces. He took a liking to vaguely formulated hypotheses, but the critical philosophy of Kant, but he was also influenced by the speculative Naturphilosophie. He took a liking to vaguely formulated hypotheses, but differed sharply from Schelling in his acceptance of the fundamental importance of careful observation. His attitude towards Naturphilosophie changed in the course of his life, but the idea of unity and polarity in nature remained prominent. Until the end of his life, Oersted believed in a philosophy of the unity of all forces of nature:

The laws of nature in the material world, are laws of reason, revelations of a rational will; but when we thus consider all material nature, as the constant work of eternal reason, our contemplation cannot remain at this point, but leads us by thought to view the laws of the universal nature. In other words, soul and nature are one, seen from two different sides: thus we cease to wonder at their harmony."

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4 Ibid., p. 275.
5 Ibid., p. 274.
7 Ibid., p. 41.
8 Ibid., p. 60.
9 Ibid., p. 57.
10 Ibid., p. 49.
19 Ibid., p. 148.
23 Ibid., p. 375.

FURTHER READING


Secondary sources on Oersted:
O. I. Franken, H. C. Oersted. A Man of the Two Cultures (Birkcrod, 1981)

NOTES