Historien om elektromagnetismen

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Published in:
Nyt fra Teknologihistorie DTU

Publication date:
2018

Document Version
Også kaldet Forlagets PDF

News from
History of Technology DTU

2018:1

Photo: Tom Jersøe

The Story of Electromagnetism

English translation of newsletter *Historien om elektromagnetismen* no.1 September 2018

The Story of Electromagnetism

By Laila Zwisler, History of Technology DTU

In 1820, the Danish scientist Hans Christian Ørsted discovered something new during a lecture, when he allowed an electric current to pass through a platinum wire above a compass. The current caused the magnetic needle in the compass to twitch slightly. Ørsted had found a link between electricity and magnetism, which he called electromagnetism.

H.C. Ørsted is seen holding a wire above a compass needle in this plaque set up in Nørregade, Copenhagen, where Ørsted discovered electromagnetism. Photo: History of Technology DTU

With this discovery, Ørsted paved the way for a number of future inventions and a new field of research. But of course this prospect was unknown in Ørsted's day, where the discovery came as a shock to many prominent researchers, as it ran completely contrary to their theories. The principal character himself was probably not surprised. For a long time, Ørsted had been toying with the idea that an electric current could affect a magnet. He even wrote this directly in 1812 in the book *Ansicht Der Chemischen Naturgesetze:*

"At the same time, experiments should be conducted to try to determine whether in one of the conditions in which electricity is highly bound, one could produce an effect on the magnet, as a magnet. The matter will not be without its difficulties, because the electricity will act on the magnetic body as on the non-magnetic one; perhaps it might however be possible to obtain some information about this by comparing magnetic and non-magnetic needles."

The expectation of the existence of electromagnetism was also in accord with Ørsted's philosophy of life. Ørsted was inspired by the German Romantic school of natural philosophy. The Romanticists believed that there was a fundamental unity in nature, and that everything in the world was connected. The world was dynamic, and phenomena were to be understood as interactions between opposing forces that were constantly seeking to achieve balance through conflict. For Ørsted, phenomena such as electricity and magnetism were manifestations of this unity.

The Romanticist view stood in stark contrast to the mathematical description of nature which had been its forerunner in physics in the early 1800s, especially in France. The connection between electricity and magnetism was such a great surprise because the leading scientists believed that electricity and magnetism consisted of completely different types of particles – called Subtile Fluida – which could not possibly affect each other.

French scepticism

In Paris, the news of Ørsted's discovery of an electromagnetic effect was met with scepticism.

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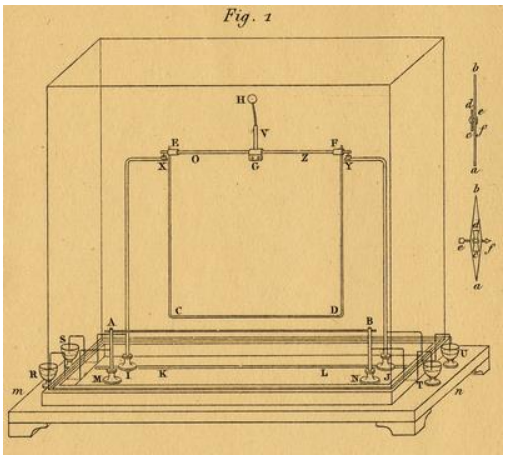
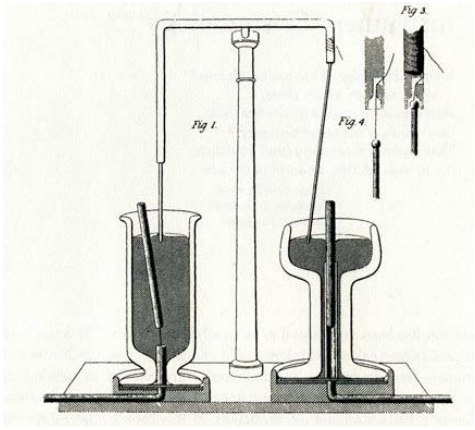


When a current is passed through the two conductors in this device, one of them will move. From: Ampères Recueil d'observations électro-dynamiques, 1822. Photo: History of Technology DTU

Was it simply Romanticist dreaming? The French Academy set up a group of researchers to repeat Ørsted's experiments, and a week later they demonstrated that it was true – a current-carrying wire could indeed affect a magnet.

A number of French scientists, including André-Marie Ampère, threw themselves into the work of investigating the new phenomenon. Ampère did not believe that Ørsted's experiments proved a link between electricity and magnetism. According to Ampère, the phenomenon dealt only with electricity, and he constructed a device in which two current-carrying wires attracted or repelled each other. Ampère believed that there were tiny electric currents in a magnet, and that these were what produced the observed effect, which thus had nothing to do with magnetism.

With his great efforts in the area Ampère laid the foundation for many later theories of electromagnetism, and he began the mathematical development of the field.



Faraday's apparatus, in which a current-carrying wire rotated about a magnet, and vice versa. From: Experimental Researches in Electricity, 1844. Photo: Wikicommons

Ørsted's discovery also attracted the interest of the British scientist Michael Faraday. In 1821, Faraday found that a magnet and a current-carrying wire could rotate about each other, and ten years later he discovered induction – that a magnet could create an electrical current in a wire if they were moving relative to each other. In the US, Henry Joseph discovered this effect at the same time as Faraday.

Ørsted himself contributed little to the scientific work on electromagnetism after 1820 – perhaps he had found what interested him. But the fame that accompanied the discovery brought Ørsted influence, and in his day, he was Denmark's leading scientist.

Ørsted and the effect he had demonstrated now began their separate journeys. Ørsted's next major discovery was in chemistry, where he discovered a method of isolating aluminium. This, however, did not arouse great interest in Ørsted's lifetime.

H.C. Ørsted's background

Hans Christian Ørsted was born in the town of Rudkøbing in 1777. His father was a pharmacist, and it was quite natural for the young Hans Christian to follow in his father's footsteps and work in the business. In 1797 he took his final university examination in Pharmacology, but Ørsted wanted more than that, and already in 1799 he submitted his doctoral paper in natural philosophy to the University of Copenhagen. In addition to running

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Løve Apoteket (The Lion Pharmacy) in Copenhagen, he worked in an unpaid capacity as an assistant professor at the Faculty of Medicine of the University of Copenhagen, and from 1801 onwards he undertook studies in chemistry and physics abroad.

Ørsted encountered the ideas of the Romantic movement in Copenhagen, inter alia through the lectures of the natural philosopher Heinrich Steffen. Ørsted succeeded in securing a position at the University of Copenhagen in 1806, when he became extraordinary professor of physics, and he became an ordinary professor of physics in 1817.

When Ørsted discovered electromagnetism, he held a good academic position and exercised considerable influence in Denmark. Leading international scientists, however, were sceptical of Ørsted's Romantic science.

Ørsted as a young man. Copperplate engraving by Gilles-Louis Chrétien, ca. 1800. Photo: History of Technology DTU

The all-embracing Ørsted and the theory of everything

On the basis of the narrow academic specialisations of our own day, we might wonder how a pharmacist and chemist could become a professor of physics. But Ørsted was very broadly oriented, and our discipline boundaries would seem meaningless to him. He saw himself as a 'investigator of nature' and perceived a connection between the laws of nature, morality, truth and aesthetics. "Science, art and morals provide insight into the true, the beautiful and the good, and thereby, each in their own way, lead to an understanding of God," wrote Ørsted in his book *The Spirit of Nature*. For Ørsted there was a deep rationality in nature, and insight into this rationality could be achieved by many means.

With his broad outlook, Ørsted became one of the leading cultural figures of the Danish Golden Age. Throughout his life, he fought to strengthen the natural sciences in Denmark, and he was one of the primary forces behind the establishment of the Polytechnic College (now the

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Technical University of Denmark – DTU).

Ørsted also contributed to the development of the Danish language. He believed that words of Nordic origin created a stronger and clearer impression on the human imagination and intuition, and was therefore behind the introduction of many new words into Danish such as *brint* (hydrogen), *ilt* (oxygen), *rumfang* (volume) and *ildsjæl* (activist). His circle of friends included leading Danish writers such as Adam Oehlenschläger and Hans Christian Andersen.

The Polytechnic College seen from Studiestræde. Ørsted's professorial residence became part of the college. Photo: History of Technology DTU

The idea of the spirit of nature led to a belief in the educational significance of the natural sciences, and to the establishment of *Selskabet for Naturlærens Udbredelse* (the Society for the Dissemination of Natural Science), through which Ørsted and others spread knowledge of physics and chemistry to the general population.

Ørsted also plunged into a lengthy debate with the pastor and writer N.F.S. Grundtvig. Grundtvig, a man of the people, was not enamoured with the elitist scholars of the time who sought to find God in nature. In Grundtvig's view, God was to be found in the Bible. Religion was highly central to the life of the Christian Ørsted, and he crossed swords with Grundtvig more than once.

But Ørsted's actions were not only compatible with the ideas of the Romanticists, who believed that knowledge was to be found through reason alone – in his scientific work, Ørsted was a diligent and thorough experimenter, who sought empirical confirmation of his hypotheses in the surrounding world. In this way, he united Romanticist ideals with the ideals of the Enlightenment.

Ørsted's philosophy of nature caused him to downplay the importance of mathematics in the natural sciences, and due to his considerable influence, this was to have a lasting effect on both scientific research and teaching in Denmark. Neither was Ørsted's successor as professor of physics, Carl Valentin Holten, mathematically oriented. As a result, Denmark stood outside the development of the new mathematical physics. Today, when science and mathematics are virtually synonymous, it is sometimes said that Ørsted was not particularly scientific, because he did not use mathematics.

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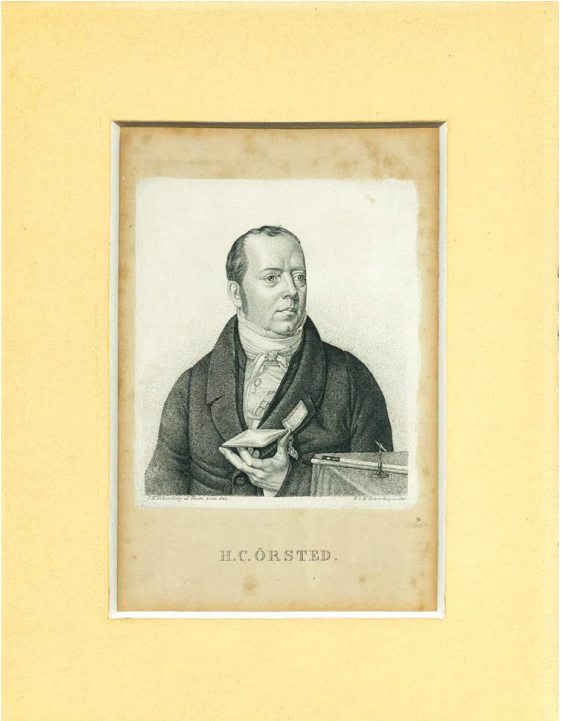

Ørsted, drawn by Eckersberg in 1822. A magnetic needle can be seen in the picture. Photo: History of Technology DTU

Was Ørsted first?

Was Ørsted the first scientist to observe an electromagnetic effect? The question of who was first is usually complex, and there are different interpretations of how electromagnetism was discovered, and by whom. Many accounts of the discovery mention the Italian Gian Romagnosi, who experimented with the effect of a voltaic pile on a compass in 1802, and published his findings in a local newspaper. But we cannot be sure that Romagnosi discovered electromagnetism, because the description of his experiments is unclear. It is not therefore possible to conclude whether the effect he observed was indeed an electromagnetic effect. Neither did Romagnosi describe his experiments to international scientific circles.

The true discoverer of electromagnetism? Gian Romagnosi by E. Moscatelli, after a work painted by Giuseppe Molteni. Photo: Wikicommons

Ørsted, on the other hand, was a professor of physics at the University of Copenhagen and part of the scientific community of his time. With his knowledge of the scientific theories of the day, Ørsted knew that he had seen something significant that contradicted the prevalent theories. Ørsted also knew that it was important to publish the discovery in scientific circles. He was familiar with scientific methods and performed thorough

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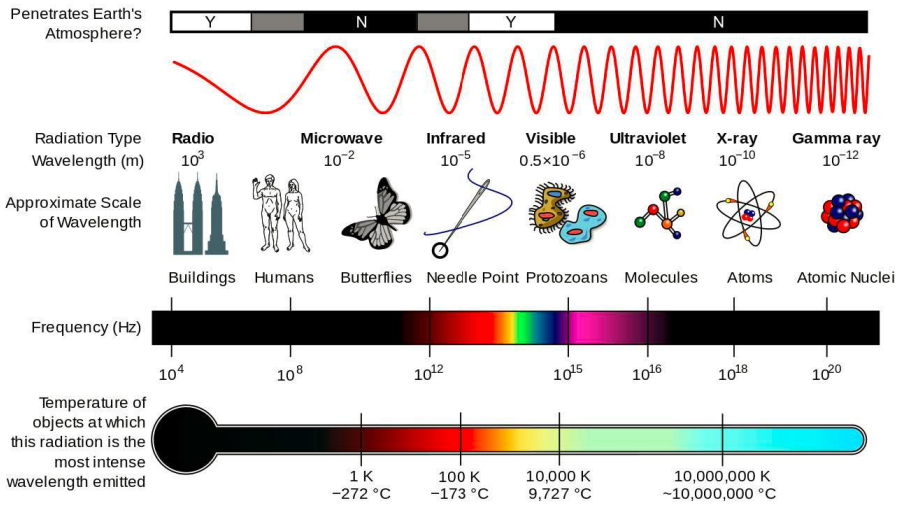
and systematic experiments that he described in detail, so that they could be verified by others. It is therefore quite clear that Ørsted observed an electromagnetic phenomenon and recognised its special characteristics. It is unclear, on the other hand, whether Ørsted knew about Romagnosi's work.

Electromagnetism and our view of the world

The discovery of electromagnetism came to change our understanding of the world. One of the scientists who further developed the theoretical understanding of electromagnetism was James Clerk Maxwell. In the mid-19th century he formulated a theory that united electricity, magnetism and light, and demonstrated theoretically that they were all manifestations of the same phenomenon.

Maxwell also showed that electromagnetic fields do not just have a local effect, but, in the form of electromagnetic radiation, can travel through space at the speed of light. In 1886, the physicist Heinrich Rudolf Hertz observed these waves, and in time it became the norm to view light as a form of electromagnetic radiation.

Light turned out to have several surprising aspects. Scientists found forms of light – ultraviolet and infrared – that human beings could not see with the naked eye. Eventually, it became clear that there was a whole spectrum of electromagnetic radiation of different wavelengths. This knowledge has been used, for example, to explore the Milky Way and to derive information about what we cannot see. NASA has inter alia described observing background radiation in the microwave area, which has been interpreted as residue from the Big Bang.



The electromagnetic spectrum. Photo: Inductive load, NASA - self-made, information by NASA https://commons.wikimedia.org/w/index.php?curid=2974242

With the advent of quantum physics around the beginning of the 20th century, light, and thereby electromagnetism, acquired an increasingly central role in physics. Today, electromagnetism is

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considered one of the four fundamental interactions that hold our world together. The best known of these interactions is gravity. Many physicists expect that the four fundamental interactions will one day be united into a single theory – three of them are already united, while gravity still resists. These efforts would probably have met with Ørsted's approval.

Electromagnetism and technology

Ørsted's discovery was quickly absorbed into the technological development of the time. A large number of technologies came to use electromagnetism; in the following are listed just a few examples of the use of electromagnetism in communication, electric motors and renewable energy.

In the field of communication, electromagnetism proved useful in telegraphy. Many people may associate telegraphy with Morse code, but point-to-point communication with visible signals, such as flags, is an old practice. When Ørsted discovered electromagnetism, several inventors had already attempted to use electricity in telegraphy, and they soon also tried to use electromagnetism for this purpose. The British inventors William Cooke and Charles Wheatstone developed the first commercial electromagnetic telegraphic system for the Great Western Railway in 1838, while in the USA, Samuel Morse developed his system at around the same time. The brief messages sent through the telegraph system were important for both political and business purposes. Both those in power and entrepreneurs invested in the system, and a broad network of telegraph cables was established.

With the great interest in communication, there were many suggestions on how to improve telegraphy. Could a telegram perhaps be transmitted through the air? Several inventors worked on the problem of wirelessly transferring sound – with electromagnetism as one of the co-players. There was fierce competition between the various technologies that emitted electromagnetic radio waves, such as the spark-gap transmitter of the Italian inventor Marconi and the arc transmitter of the Danish engineer Valdemar Poulsen. Anyone who had the right equipment could listen to wireless messages. This was a challenge for the military, who were not keen to share information with the enemy, but it came to benefit many in civilian life, who were happy to receive radio broadcasts in their living rooms with music and news from the outside world.

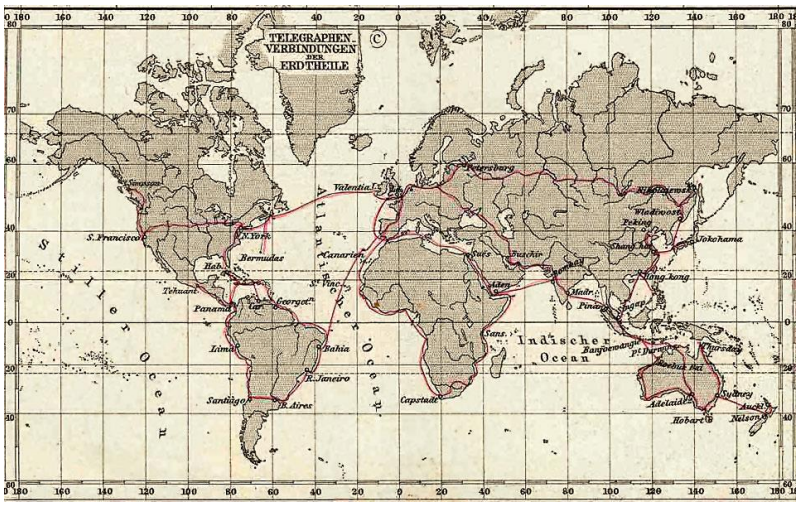
Cooke and Wheatstone used the electromagnetic effect to move needles in their telegraph device. This one has five needles, which together can point to any letter of the alphabet. Photo: Wikicommons

Inventors also worked on a talking telegraph, later called the electromagnetic telephone. Many people expected the telephone to be used for short messages between businesspeople, but to their surprise, women, for example, used it to maintain contact with their family and friends. Once again, a communication technology acquired an unexpected role in the private sphere.

Electromagnetism thereby became part of the standard arsenal of technologists who construct

Publisher: Teknologihistorie DTU, Kgs. Lyngby ISSN 2446-354X

mass communication devices. But it has also caused concern. Modern human beings live their lives surrounded by electromagnetic radiation, for example from mobile phones and other devices, and the possible health effects are still being debated.



The main telegraph lines in 1891, according to Stieler's Hand-Atlas. Almost the entire globe was connected up, and with the smaller cables a telegram could be transmitted a very long distance. Photo: Wikicommons

It is thanks to the electric motor that we can use vacuum cleaners. Photo: Wikicommons

Electromagnetism was not only useful in communication, but also in motors. Faraday's rotation principle from 1821, in which a current causes a magnet to move, can convert electricity into motion.

It could be said that Faraday created the first electric motor, although it did not have a practical aim. Both inventors and scientists worked to develop electric motors, but although many of them showed great inventiveness, it took a long time before such motors were widely disseminated.

Batteries were one of the limiting factors. They were large and expensive, and because of them, electric motors failed to become an advantageous competitor to other power sources. In 1837, for example, Thomas Davenport obtained a patent for a motor he had developed in collaboration with his wife Emily – but the couple's invention flopped commercially, and they went bankrupt.

Electric motors, however, gained ground after the 1880s, when electrical supply systems became widespread. The advantage of the electric motor was its flexibility. With an electric motor, you did not need to transfer movement with belts from a central power source such as a steam engine or water wheel. As electricity became established, the electric motor became a firm favourite, and electric motors found their way into, amongst other things, a number of household appliances. However, the electric motor did not win out in all fields. When automobiles arrived in the late 19th century, the inventors tried using steam, electric and internal combustion engines. The internal combustion

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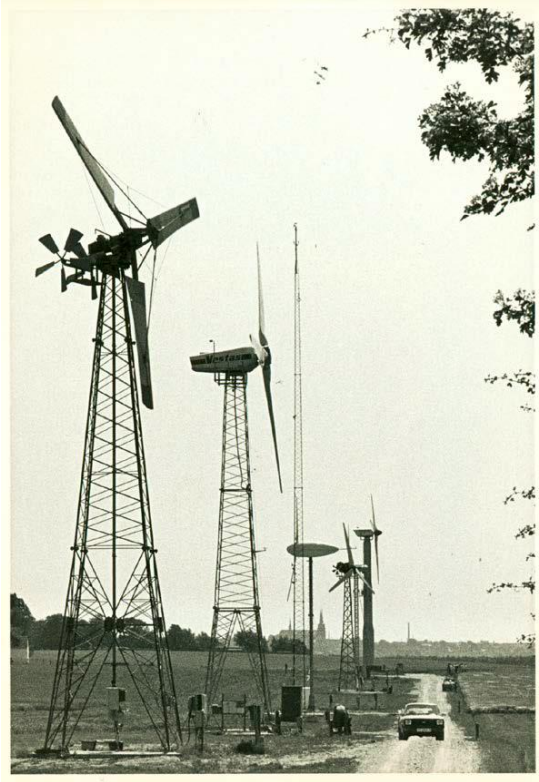
engine became the industry standard, while the electric motor was relegated to niches such as milk carts. Electric motors, electrical power plants and telephones all consume energy, and their widespread use has made our society deeply dependent on fossil fuels. Electromagnetism, however, can also be used to generate renewable energy through induction. If, for example, you can get wind or water to move a magnet relative to a coil, an electric current will arise in the coil.



Wind turbines in Risø, Denmark. Wind turbines use electromagnetic induction to generate electricity. Photo: History of Technology DTU

Electromagnetism has in general proved useful in many technologies – many more than are described here. It is now part of our standard technology arsenal, just like nails and gears, and scientists and inventors are constantly working to develop new applications. One example from DTU is a project designed to exploit the fact that water is itself electromagnetic. Water can easily be polarised, i.e. an electric field can be used to change the distribution of charge in the liquid. It is expected that using this principle, it will be possible to create artificial materials with completely new properties that are not otherwise found in naturally occurring materials.

If Ørsted had not discovered electromagnetism

What would our world look like if Ørsted had not discovered electromagnetism? It might seem that the way was paved for the discovery of electromagnetism after the invention of the battery, and many historians believe that if Ørsted had not conducted the experiment, someone else would have discovered electromagnetism within a relatively short period of time.

In recent times, we often see scientific discoveries being made by several people almost simultaneously, and you could argue that the discovery of electromagnetism would almost

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automatically follow the invention of the battery. But it might have been a long time coming, in which case the world might be in a different technological situation today, in which technologies other than those that use electromagnetism had won out. We might also have had a different scientific understanding of our world. A few observers have presented scenarios in which technological development would almost have ceased around 1820 if electromagnetism had not been discovered. However, we must not underestimate human inventiveness...

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Publisher: Teknologihistorie DTU, Kgs. Lyngby ISSN 2446-354X