MUSÉE
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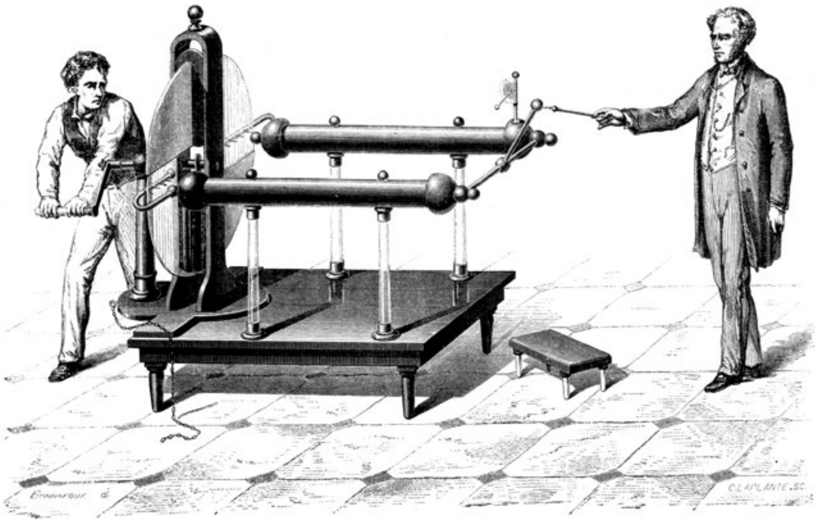
DES SCIENCES
GENÈVE

Booklets of the
Musée d'histoire des sciences
n° 2

Once upon a time, there was electricity



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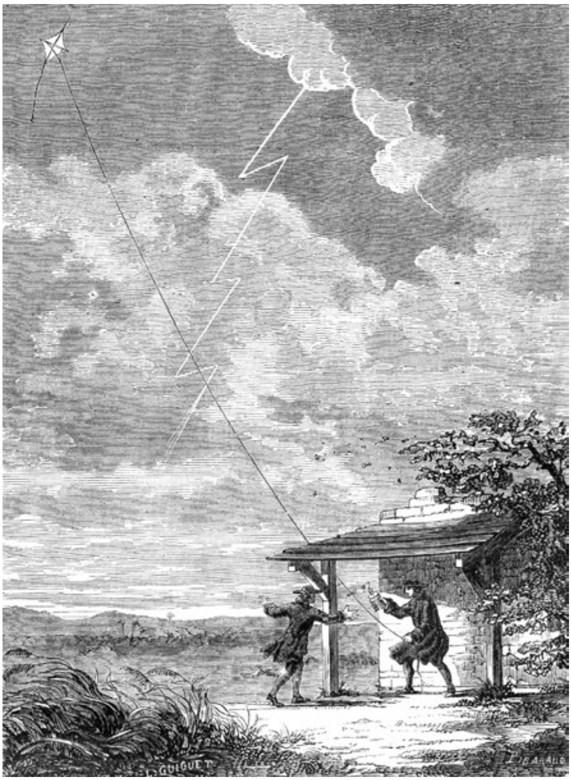
Cover : *Glass plate electrical machine*
Les phénomènes de la physique, Guillemin, Paris, 1869.
Library of the Musée d'histoire des sciences

A history of electricity told through instruments at the Musée d'histoire des sciences

The history of electricity begins in antiquity with the discovery of the attracting properties of amber under friction, and continues today across several contemporary themes such as electric engines, rechargeable batteries, solar panels and so on.

This booklet follows the main developments in the story of electricity through several outstanding objects either protected in the reserves at the museum or displayed in the showcases.



Franklin's experiment with an electric kite in 1752
Merveilles de la science, Figuier, Paris, 1867. Library of the Musée d'histoire des sciences

Produce, measure and store electric charge

A spark machine

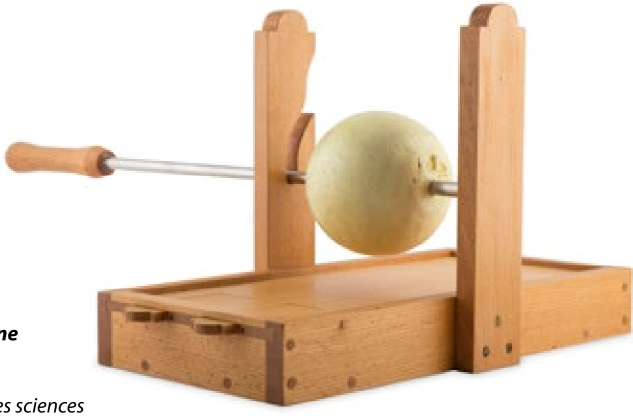
Greeks noticed that pieces of straw, feathers or other light objects were attracted to a piece of amber (*elektron* in Greek) which had been rubbed. In the 16th century the same phenomenon was observed with glass or resin. By the 17th century the first machines had been produced and, by the 18th century, they had been perfected. Discs were turned against a leather cushion by means of large handles. Through friction, the glass was charged. The charge was collected in brass containers and all that was required to produce a spark was to touch one with a metal point. By the 19th century, newly developed machines was able to generate several thousand volts and give powerful discharges.

Glass plate electrical machine
MHS 54
Wood, brass, glass, 18th century (?)

The electric earth

In the mid-17th century some scholars thought that electrification caused terrestrial attraction. To demonstrate this the German, Otto von Guericke, invented the first electrostatic machine in 1663. He rubbed a globe made of sulphur representing the earth and then rotated it at the end of a pole. He noticed that the globe attracted small feathers which followed its movement much as the moon follows the movement of the earth.

Otto Guericke 's electric machine
Merveilles de la science, Figuier, Paris, 1867.
Library of the Musée d'histoire des sciences



Copy of electrostatic machine
by Otto von Guerricke
MHS 2755
Collection, Musée d'histoire des sciences

A painfully charged flask

In the middle of the 18th century, attempts were being made to electrify water and at Leyden in Holland, a scientist was taking up the challenge. He touched an electrostatic machine with a rod placed in a bottle full of water. His attention was distracted and he failed to place the bottle on an insulated surface but held it in his hand. As he withdrew the rod with the other hand he felt a strong shock through his whole body. We are in 1746, the year which witnessed the birth of the first capacitor, the Leyden jar, which was able to store static electricity.

Separated and insulated by the glass, opposing charges accumulated on the one hand on the metal rod and, on the other, on the outside of the jar. If the person conducting the experiment touches the two sites at the same time, their body becomes the conduit for the discharge.

Human electric chain
Traité de physique, Ganot, Paris, 1866
Library of the Musée d'histoire des sciences

Leyden jar
MHS 1508
Pewter, brass, glass, 18th century

Electrified air

At the end of the 18th century, the Genevan scientist Horace-Bénédict de Saussure (1740-1799) became interested in everything to do with the atmosphere. In order to measure atmospheric electricity, he improved an existing electrometer (equipped with two balls of elder wood suspended from two threads) and fitted it with an aerial. This innovation was linked to Benjamin Franklin's (1706-1790) lightening conductor developed 15 years earlier, which de Saussure had installed on his house in Geneva. Before adopting the aerial for his electrometer, he had thought of using a long silver wire with a lead ball which he intended to throw as high as possible into the air in order to make the measurement.

Using an electrometer
Voyage dans les Alpes, Saussure, Neuchâtel, 1803
Library of the Musée d'histoire des sciences

Electrometer
MHS 1174
Brass, elder, glass, Paul, Genève, 18th century

A repeating capacitor

Having made its first appearance around 1800, the first electric battery caused a technological revolution. In a letter to the Royal Academy in London in April 1800, Alessandro Volta (1745-1827) presented an instrument "capable of producing the same effects as the Leyden jar but in which the charge re-establishes itself after each discharge". He described how the equipment was manufactured: alternating discs of copper and zinc, separated by absorbent material soaked in brine or acid. By joining the ends of two metal wires in contact with the first and last discs, the electrical charge produced circulated continuously: the first sustained electric current had been born.

Volta in front of his pile battery
Merveilles de la science, Figuier, Paris, 1867. Library of the Musée d'histoire des sciences

Voltaic Pile
MHS 373
Wood, cooper, zinc, glass, Volta, vers 1802

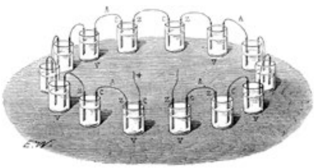
Decomposition of water by electricity

During 1800, the English scientists William Nicholson (1753-1815) and Anthony Carlisle (1768-1840), immersed two copper wires connected to a battery into mineralised water. They observed that the wire in contact with the silver disc of the battery produced a column of bubbles and that it changed colour. They collected the gas that was released in a tube and set it alight; it was hydrogen. They went on to conclude that the copper oxide which had formed was the result of the presence of oxygen. Thanks to the battery, they had achieved the first chemical decomposition of water.

Nicholson and Carlisle decomposing water using a Voltaic Pile
Merveilles de la science, Figuier, Paris, 1867. Library of the Musée d'histoire des sciences

Batteries of many kinds

Following Volta's first "column" battery, other types of battery were developed. Whatever form they took, they always had two poles which produced the charge (disc, metal or carbon rod), and one or several conducting materials (acid, chemical salt).



Crown battery
Volta could have designed this. Copper and zinc blades are inserted into jars of sulphuric acid.
Merveilles de la science, Figuier, Paris, 1867
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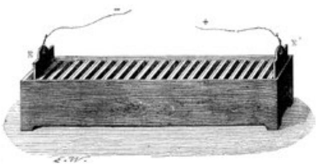

Galvanic trough
The troughs have walls of zinc and copper and are filled with acidified water.
Merveilles de la science, Figuier, Paris, 1867
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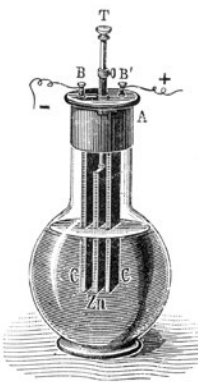

Bottle battery
The poles here are carbon sheets (carbon is a very good conductor) and a zinc blade.
Merveilles de la science, Figuier, Paris, 1867
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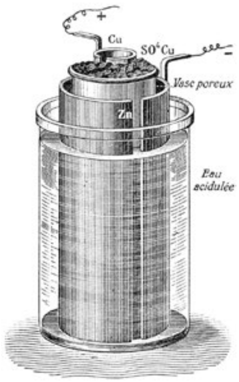

Daniell cell
An English scientist, Daniell, invented this battery which functions with copper sulphate and was one of the first to produce reliable and sustained current.
Merveilles de la science, Figuier, Paris, 1867
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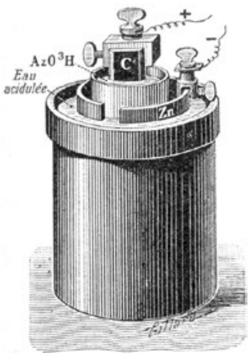
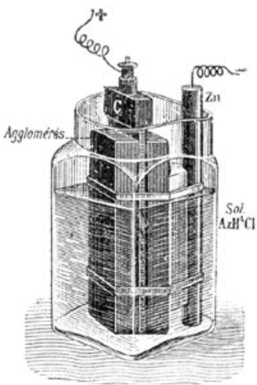


Bunsen cell
Following experiments by the German, Wilhelm Bunsen (1811-1899), this cell appeared in 1843. It is very efficient but dangerous because fumes from the nitric acid it contains are toxic.
Merveilles de la science, Figuier, Paris, 1867
Library of the Musée d'histoire des sciences



Leclanché cell
Developed in 1877 by the Frenchman Leclanché, this cell of zinc and carbon rods was used for the first electric doorbells.
Traité de physique, Ganot, Paris, 1884
Library of the Musée d'histoire des sciences

Electromagnetism: the birth of a new science

Electricity and magnetism

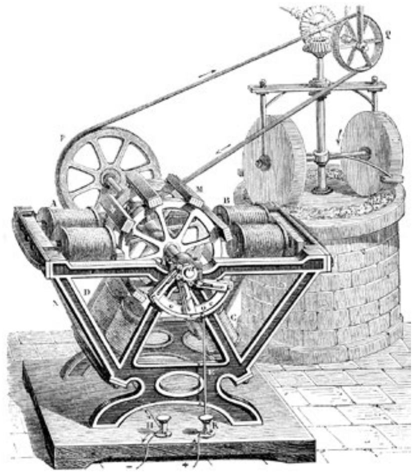
In 1820, the Danish scientist Hans Oersted (1777-1851) observed the deflection of a compass needle placed close to an electric current produced by a battery. Following up on Oersted's work, the Frenchman Ampère confirmed experimentally that a circuit carrying current attracts or repels another circuit according to the direction of the current. Immediately afterwards he also laid out the theoretical foundations of his discovery. If electricity produces magnetism, the reverse must also be true. In 1831 Michael Faraday (1791-1867), an Englishman, was able to produce electricity in a closed coil by moving a simple magnet. Henceforth, electricity and magnetism were brought together in a new science: electromagnetism.

Oersted discovers the magnetic effects of electrical current

Merveilles de la science, Figuier, Paris, 1867
Library of the Musée d'histoire des sciences

Electricity transformed into movement

Inspired by the work of Oersted and Ampère, Michael Faraday invented the first rudimentary electric motor in 1821. It consisted of a vertical conducting wire which turned around a magnet when supplied by electric current. However, electric motors were not an immediate success. Fed by batteries they offered little power and were largely used in demonstrations. It was not until 1870 with the appearance of more powerful dynamos and generators that they were finally used in industrial applications.



Froment's electric motor
Traité de physique, Ganot, Paris, 1884
Library of the Musée d'histoire des sciences

Model of an electric motor
MHS 69
Steel, copper, brass,
19th century

Movement transformed into electricity

In 1831, the ubiquitous Michael Faraday showed that it is possible to create electric current in a closed coil when a magnetic bar is introduced and then withdrawn. This marked the discovery of the principle of induction, the basis of the functioning of electricity generators, the first models of which were built in 1832. A coil of wire is turned by a handle in front of a magnet, or the inverse, a magnet is turned in front of a wire coil. In both cases, the aim is to cause variations in the magnetic field near the coil in order to produce electric current. From the second half of the 19th century, generators were gradually replaced by more powerful dynamos equipped with electro-magnets and often set in motion by steam engines.

Electric dynamo
MHS 207
Steel, wood, copper, iron, brass, Bréguet, Paris, 19th century

The magnetic effects of electricity

After the invention of the battery, scientists quickly realised the importance of measuring the mysterious flows they had discovered. Around 1820, they developed galvanometers based on the magnetic effects of electric current. A mobile magnetised needle was placed in the centre of a coil of wire through which the current to be measured was passed. As the current circulated it produced a magnetic field which displaced the needle from its equilibrium; the displacement is proportional to the intensity of the current. The first ampere-metres measuring the intensity of the charge in "amperes" did not appear until the end of the 19th century.

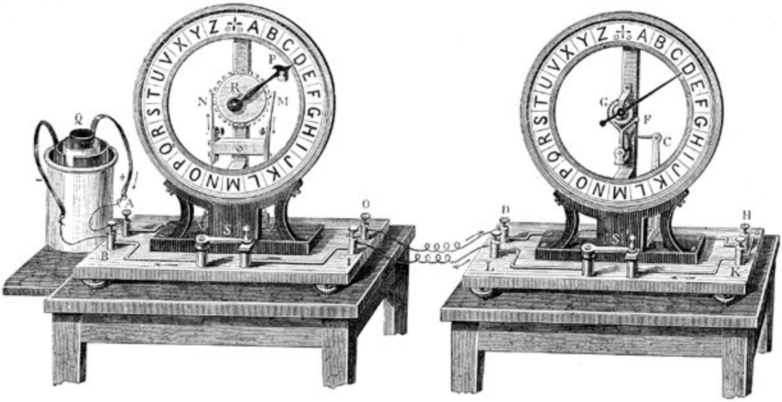
Galvanometer
MHS 229
Steel, copper, brass, glass,
19th century

Electric signals
for long distance communications

Sending signals

The telegraph is undoubtedly one of the first practical and industrial applications linked to the invention of the battery. The first dial telegraph equipped with 5 transmission wires was tested in England in 1837. In 1884, the American Samuel Morse (1791-1872) revolutionised the history of telegraphy by inventing a code which assigned a combination of dots and dashes to each letter of the alphabet. From that time on, a simple switch linked to a battery was enough to send electric signals. By the 19th century, the development of the telegraph had become closely linked to the development of railways. The first telegraphic messages usually signalled the arrival of a train or a technical problem.

Dial telegraph
MHS 221
Wood, copper, brass, 19th century



Dial telegraph
Traité de physique, Ganot, Paris, 1884
Library of the Musée d'histoire des sciences

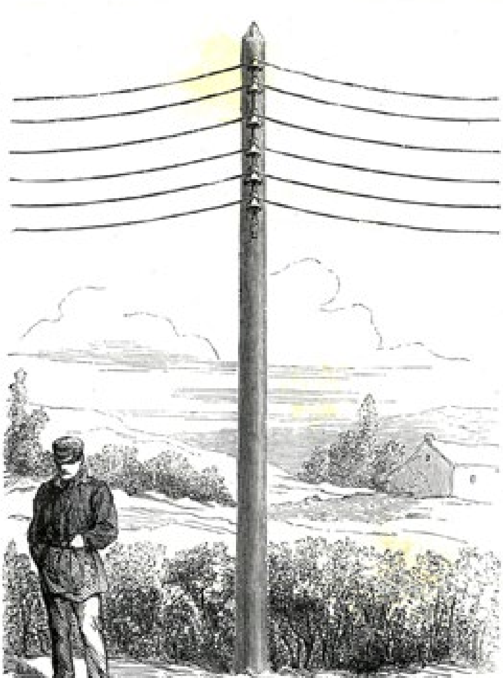
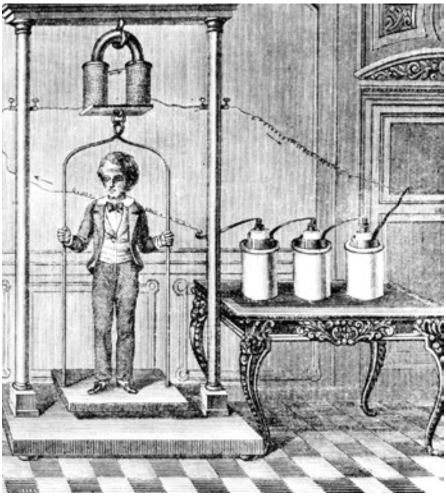


Fig. 83. — Poteau télégraphique.

Telegraph pole
Louis Figuier, Merveilles de la science, T.2, Paris, 1868
Library of the Musée d'histoire des sciences

The electromagnet, the heart of telegraphy

A coil of wire wound around an iron rod behaves like a magnet when an electric current passes through it. When the current is interrupted, the magnetic field disappears. This is the basic mechanism of electromagnets and is at the heart of numerous 19th century technological innovations including the telegraph. Morse telegraphic machines transform electric signals into combinations of dots and dashes. The alphabet versions also allow the synchronisation of the dial needle at the receptor with that of the emitter.



An electromagnet lifting an experimenter
Traité de physique, Ganot, Paris, 1884
Library of the Musée d'histoire des sciences

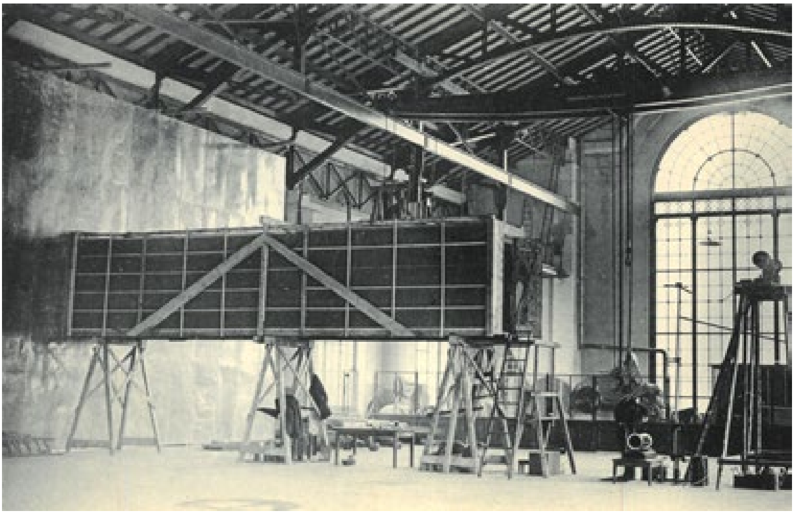
Electromagnet
MHS 2543
Wood, copper, cast iron, brass,
Max Kohl, Germany, 19th century

Invisible radio waves

In about 1880, the German physicist Heinrich Hertz (1857-1894) discovered radio waves experimentally. He found a specific type of magnetic wave the existence of which had been postulated twenty years earlier by the Scottish physicist James Clerck Maxwell (1831-1879).

The waves are produced by an oscillator consisting of an induction coil, the electric discharges of which produce sparks between two metal rods. Placed at a certain distance from the oscillator, a resonator (receptor) consisting of an iron ring broken by a small space in which different-sized sparks appear, detects the waves. The large sparks correspond to anti-nodes and nodes.

Hertz' experiments were repeated and refined in 1889 by two Geneva scientists, Edouard Sarasin (1843-1917) and Lucien de la Rive (1834-1924).



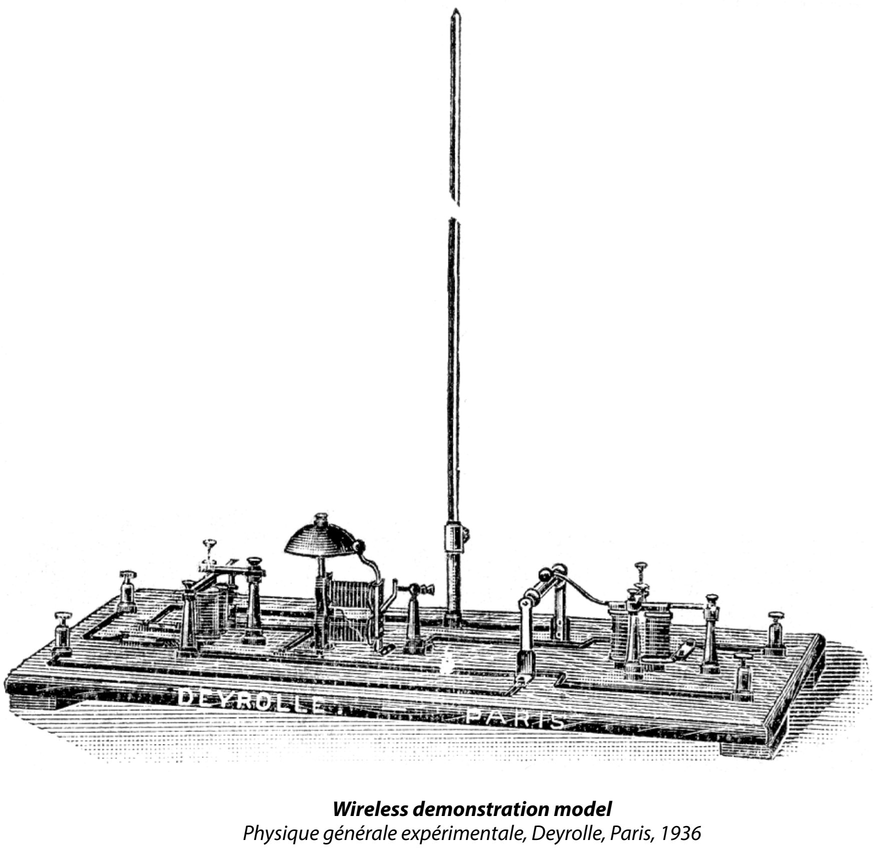
Replication of Hertz' experiments by Sarasin and de la Rive in the hydropower plant building (bâtiment des forces motrices) Geneva in 1889

On the left hand wall a large metallic mirror was installed to reflect the radio waves. In the centre is the observation gallery supported by trestles to which the resonators are attached. On the right, an induction coil can be seen attached to an oscillator (wave generator) on the wooden structure.

Physical and natural sciences archive, tome 28, 1893. Library of the Musée d'histoire des sciences

Wireless transmission

The invention of transmission without wires was the end result of a series of investigations by a number of scientists. Faraday began the trail with his discovery of induction, then Maxwell, his student, laid out the theoretical basis for electromagnetism incorporating both light and electricity. They were followed by Albert Hertz who experimentally proved the existence of electromagnetic waves and the French scientist Edouard Branly (1844-1940), who developed the first wave radio receiver which used iron filings. Finally, it was the Italian Guglielmo Marconi (1874-1937), who in 1895 managed to transmit Morse signals over a distance of over 2 km through the air and without a single earthbound telegraph wire.

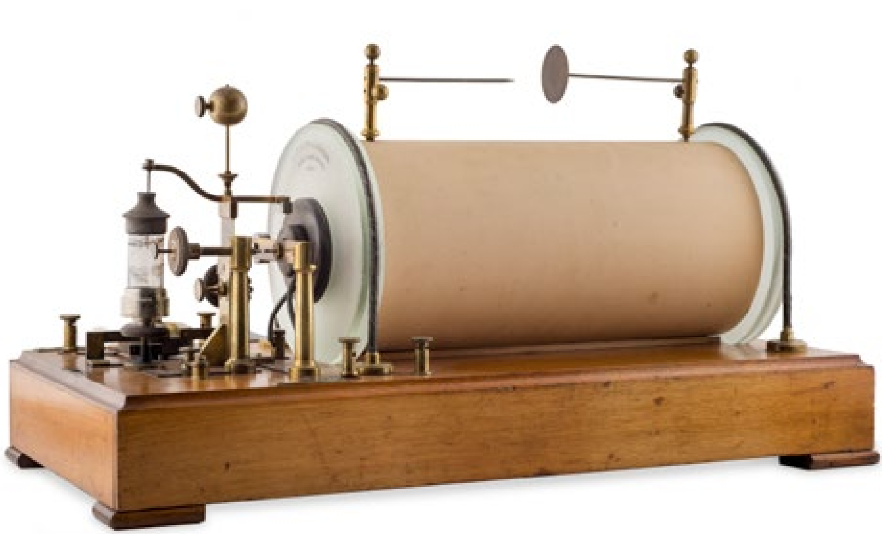


Wireless demonstration model
Physique générale expérimentale, Deyrolle, Paris, 1936

Induction coil

The induction coil appeared in the middle of the 19th century and played an important role in several scientific discoveries of the time: X rays, light discharges in rare gases, transmission of radio waves, etc.

The coil is an instrument which allows the production of high voltage electric discharges (several 10s of thousands of volts) from an initial low voltage source. It consists of an iron cylinder around which two sets of wires are coiled, the first (thick wire with few turns) and the second (finer wires and many turns). Continuous current introduced into the first coil is interrupted periodically by a switch. This produces high voltage current in the second coil.

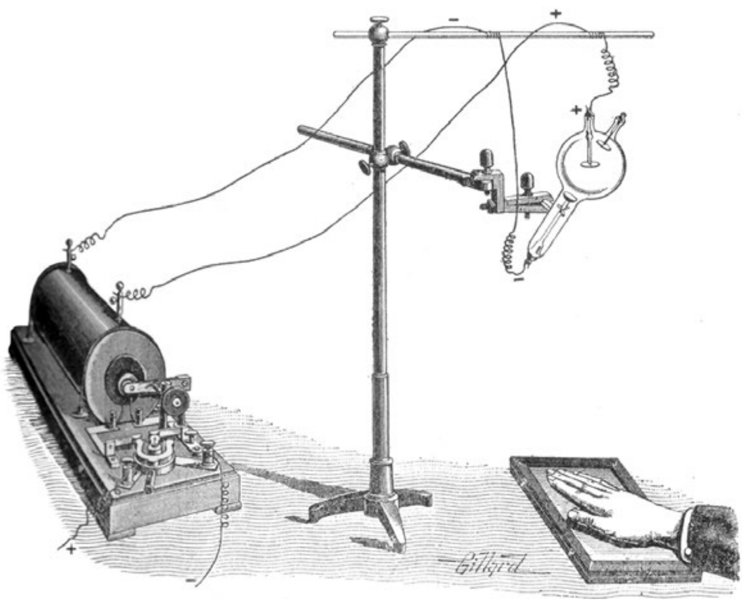


Induction coil
MHS 75
Wood, copper, rubber, 19th century

Luminous and therapeutic effects of electricity

From a spark to the X-ray

Since the 18th century, scientists had been using electric machines to study the effect of electrical discharges in tubes containing rare gases. They saw that the colours of the discharges varied with the type of gas. By increasing the extent of the vacuum in the tube, 19th century scientists observed that light was replaced by invisible rays which left a green residue where they were projected on the glass walls of the tube. In 1887, the English scientist Crookes demonstrated that these rays originated in the negative electrode, called the cathode, hence their name: cathode rays. In studying this, the German physicist Roentgen discovered, in 1895, a new type of ray able to pass through matter and leave an image on a photographic plate. He named these rays X-rays.



Radiography apparatus
A travers l'électricité, Dary, Paris, 1901. Library of the Musée d'histoire des sciences

Healing by electricity

Noting that electrical discharges give rise to palpitations and accelerate the pulse, some doctors (or perhaps quacks) quickly embraced the idea that the early electrostatic machines could be used for medical purposes, for example to encourage blood circulation or to heal scars.

In Geneva, the physicist Jean Jallabert (1712-1767) successfully restored the use of the paralysed forearm of a patient after electroshock treatment over three months. During the 19th century experiments were carried out which attempted to re-animate dead bodies by giving shocks produced by a strong battery.

The French doctor Guillaume Duchenne (1806-1875), sometimes considered the father of modern electrotherapy, used electricity (of low intensity) produced by a small portable induction machine to explore different muscle clusters in the human body. By applying electrodes locally to certain parts of the body, he managed to stimulate contractions in precisely identified muscles.

Electro-magnetic machine for electrotherapy
MHS 916
Wood, copper, iron, brass, Deleuil, Paris, vers 1865

Scientists and units of measurement

The scientists featured in this booklet have given their names to units of measurement which are still used today.

Ampère (A)
The intensity of electrical current or, in other words, the amount of electrical charge which flows through an electrical conductor per second.

Farad (F)
The electrical charge of a capacitor for a given potential.

Hertz (Hz)
Wave frequency; the number of cycles per second.

Maxwell (Mx)
A former measurement of magnetic flow. It is no longer in use today.

Oersted (Oe)
A former measurement unit for magnetic field intensity. No longer considered an official unit of measurement.

Volt (V)
Measurement of electromotive force (or difference in electrical potential). Voltage can be compared to the difference in height between two points of a water course.

Watt (W)
Although not referred to in this booklet, the Watt is a familiar unit for the measurement of electrical power. James Watt, an Englishman, was not involved in electricity research but in the development of steam engines.

Further reading

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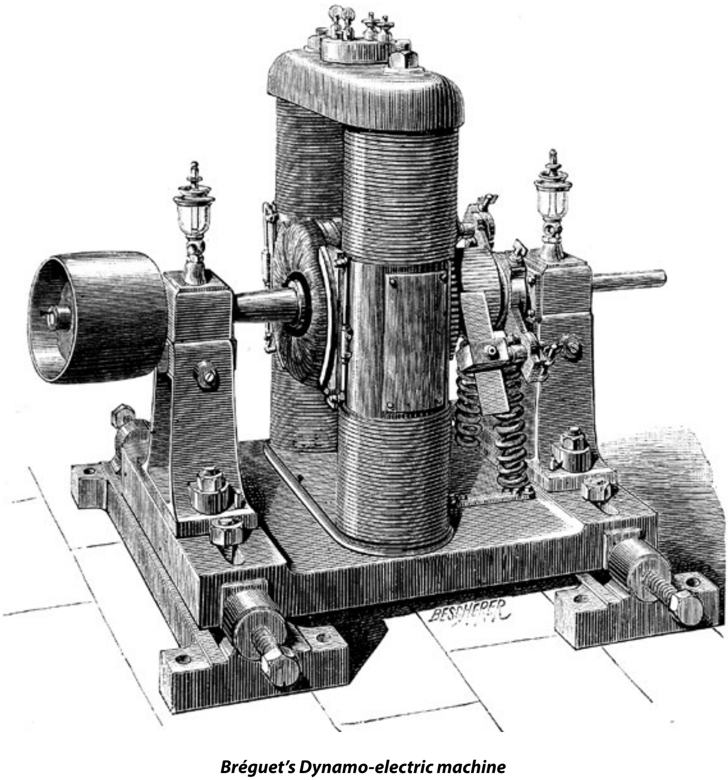
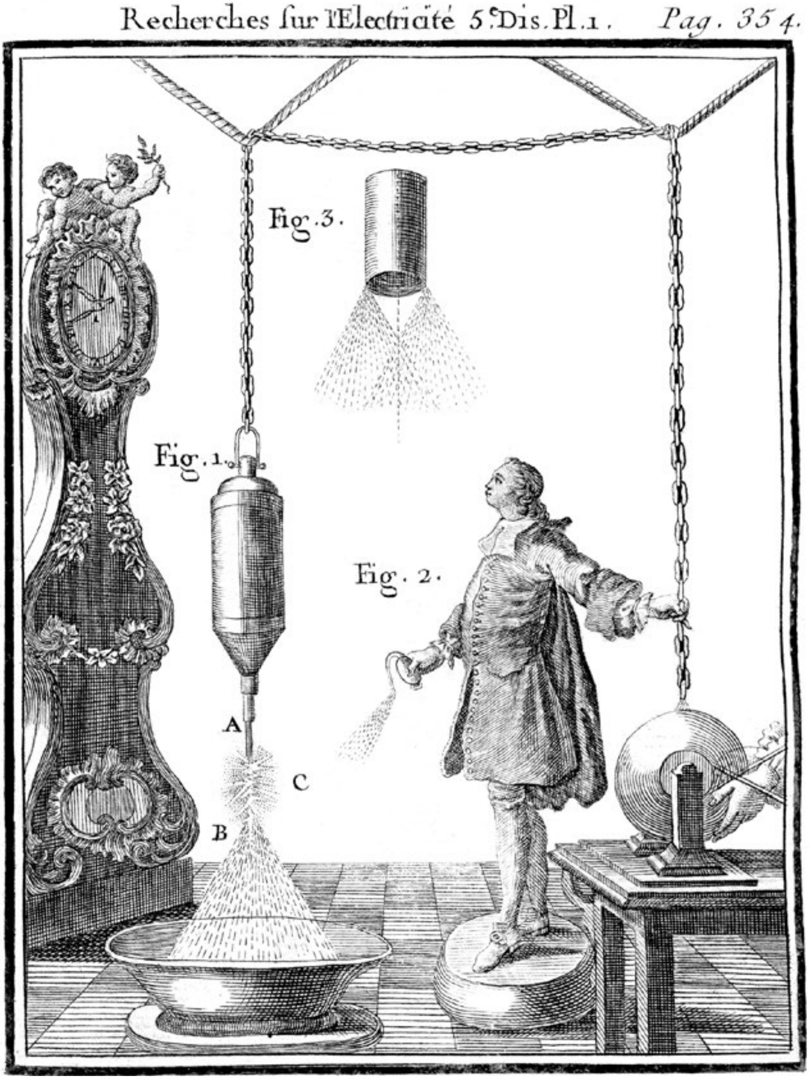


Bréguet's Dynamo-electric machine
Merveilles de la science, Figuier, Paris, 1887



Experiments on static electricity
Recherches sur les phénomènes électriques, Abbé Nollet, Paris, 1753
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3. Sun time
4. Seeing the infinitely small
5. Models of the universe
6. Observing the sky
7. The Pictet Cabinet
8. Jean-Daniel Colladon, Genevan scholar and industrialist
9. From foot to metre, from marc to kilo
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