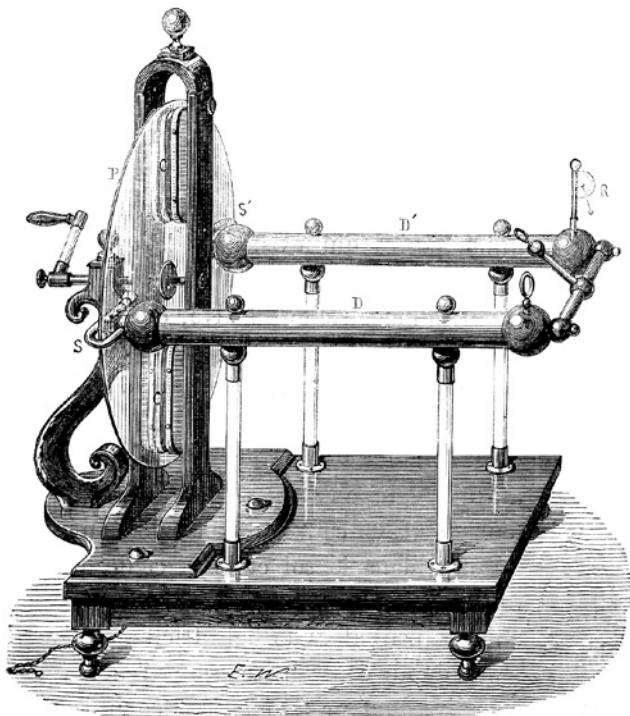
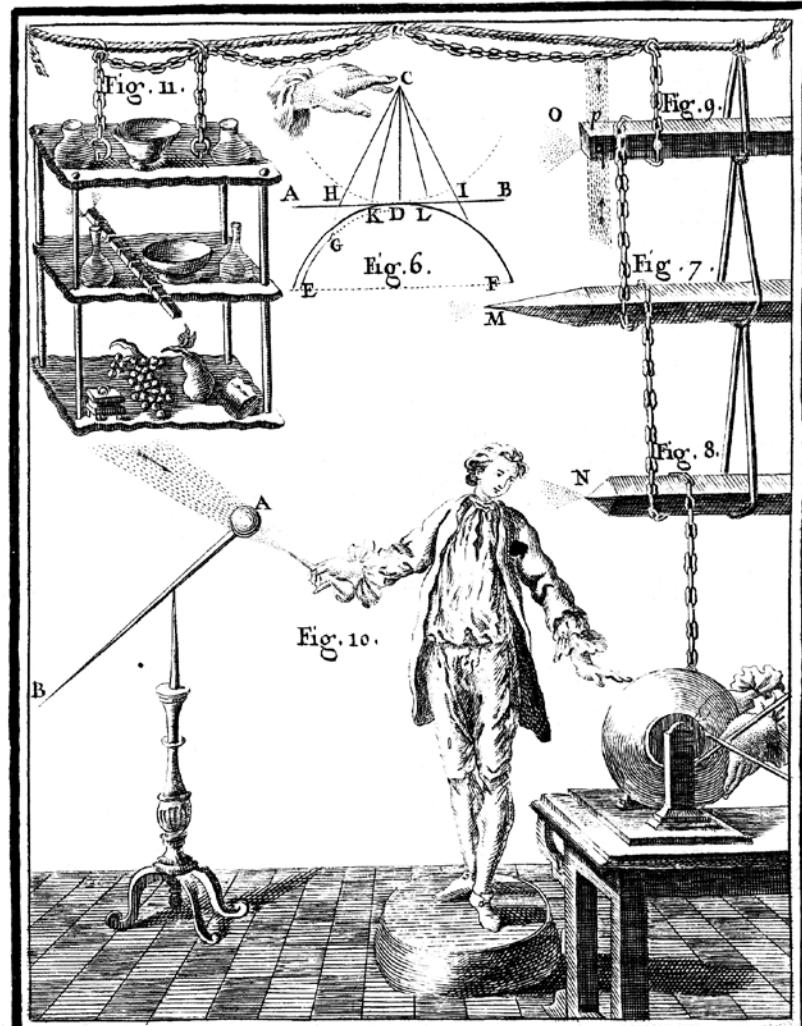


Through the looking glass: once upon a time, there was electricity

The story of electricity told through the
collection of instruments of the
Musée d'histoire des sciences of Geneva





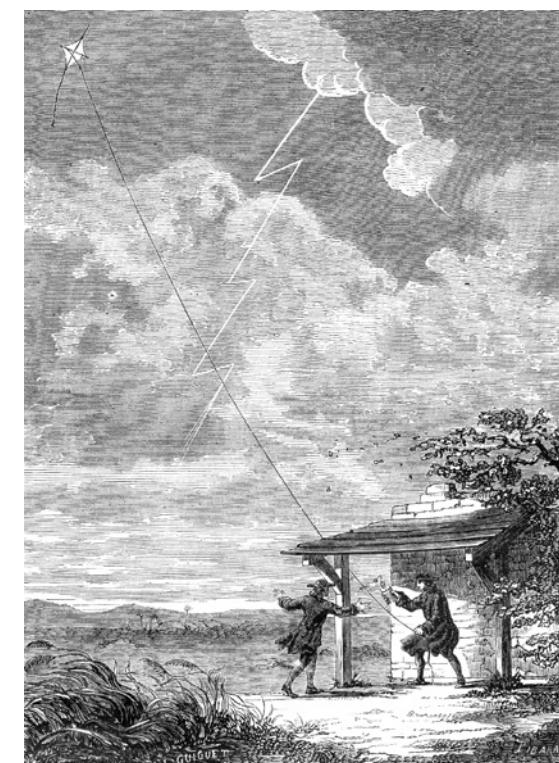
Experiments on static electricity

Recherches sur les phénomènes électriques, Abbé Nollet, Paris, 1753,
Library of the Musée d'histoire des sciences

Cover: Plate electrical machine
Merveilles de la science, Figuier, Paris, 1867, Library of the Musée d'histoire des sciences

Through the looking glass: once upon a time, there was electricity

This booklet is designed to accompany visitors to the two rooms of the permanent exhibition on electricity. For those who wish to learn more, texts in the cabinets give further details on the objects displayed.



Franklin's experiment with an electric kite in 1752

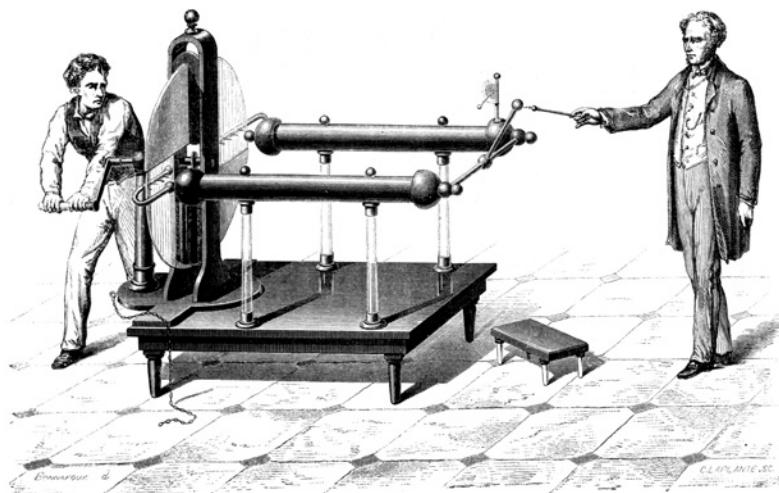
Merveilles de la science, Figuier, Paris, 1867, Library of the Musée d'histoire des sciences

Produce, measure and store electric charge

- cabinets: friction machines, influence machines, measuring 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 charges were powerful enough to start newly developed machines able to supply several thousand volts.

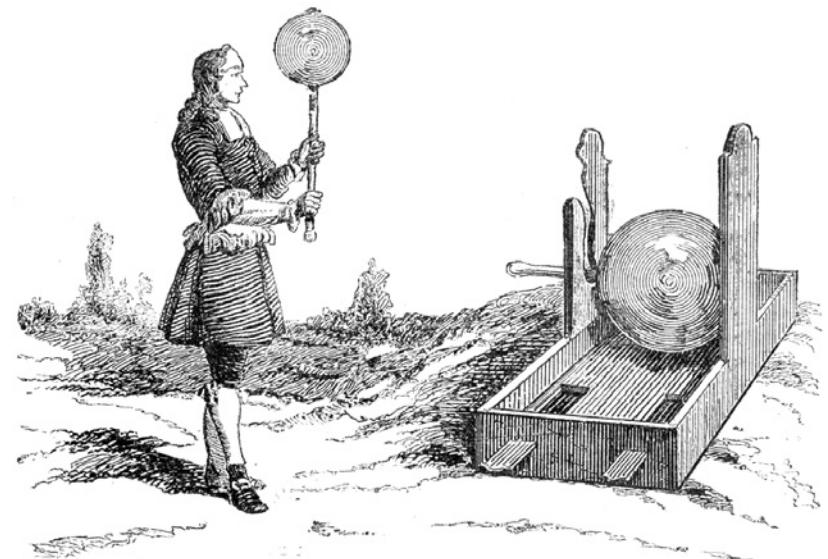


Glass plate electrical machine

Les phénomènes de la physique, Guillemin, Paris, 1869, Library of the Musée d'histoire des sciences

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.



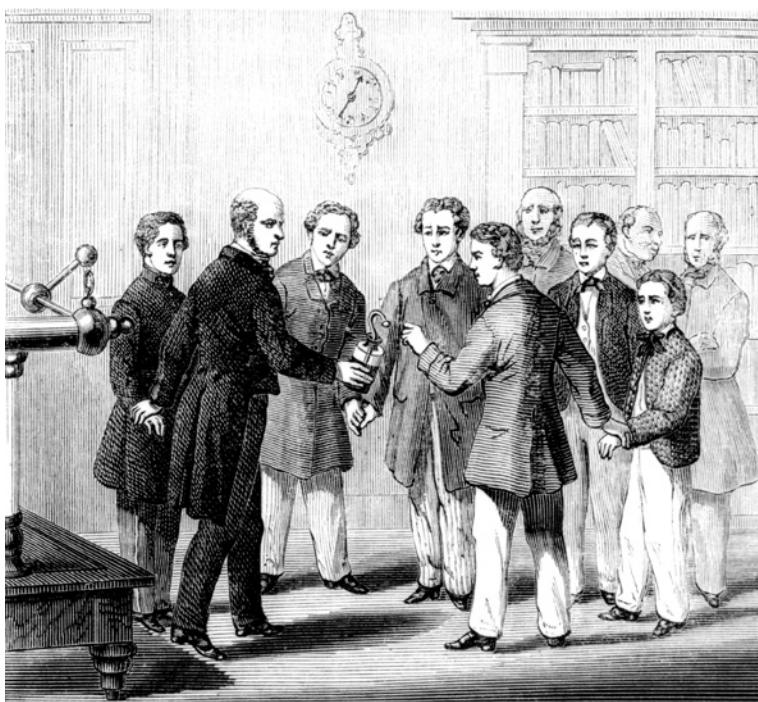
Otto Guericke's electric machine

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

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, her own body becomes the conduit for the discharge.



Human electric chain

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

Electrified air

At the end of the 18th century, the Geneva scientist Horace-Bénédict de Saussure 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 lightning 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

Electricity tamed

- cabinets : the first electric battery, the nested battery, decomposition of water by electricity

A repeating capacitor

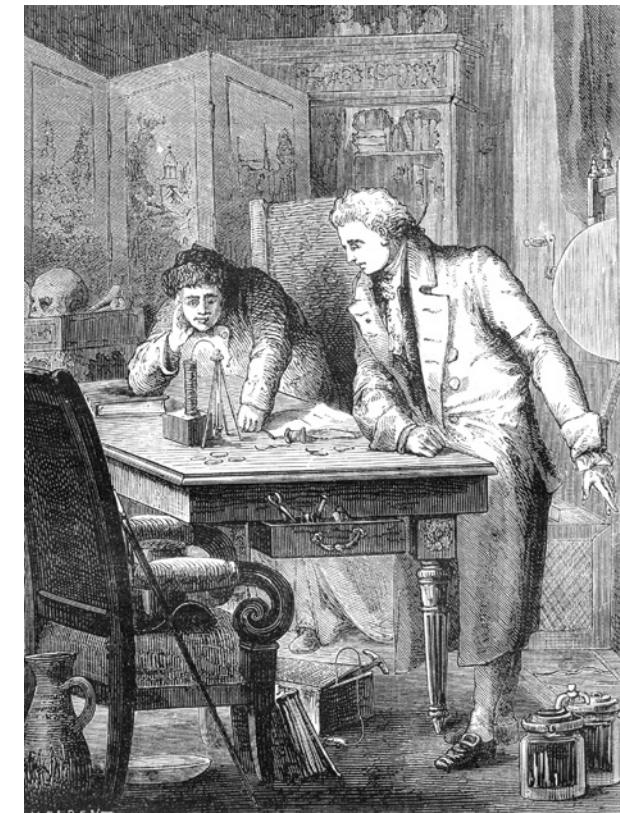
Having made its first appearance around 1800, the first electric battery caused a technological revolution. In a letter to the Royal Academy in London in April 1800, Alessandro Volta presented an instrument "capable of producing the same effects as the Leyden jar but in which the charge re-establishes itself after each explosion". 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

Decomposition of water by electricity

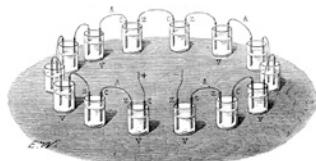
During 1800, the English scientists Nicholson and Carlisle, immersed two copper wires connected to a battery into mineralised water. They observed that the wire in contact with the silver disc of the battery produced a column of bubbles and that it changed colour. They collected the gas that was released 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

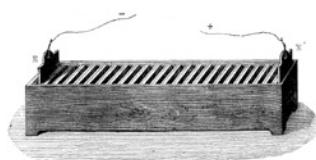
Following Volta's first "column" battery, other types of battery were developed. Whatever form they took, they always had two poles which produced the charge (disc, metal or carbon rod), and one or several conducting materials (acid, chemical salt).



Crown battery

Volta could have designed this. Copper and zinc blades are inserted into jars of sulphuric acid.

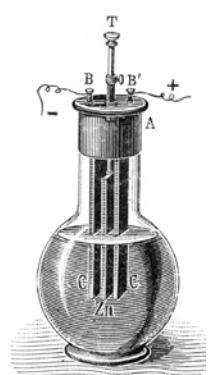
Merveilles de la science, Figuier, Paris, 1867, Library of the Musée d'histoire des sciences



Galvanic trough

The troughs have walls of zinc and copper and are filled with acidified water.

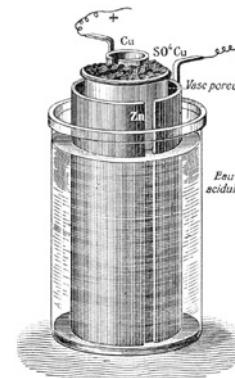
Merveilles de la science, Figuier, Paris, 1867, Library of the Musée d'histoire des sciences



Bottle battery

The poles here are carbon sheets (carbon is a very good conductor) and a zinc blade.

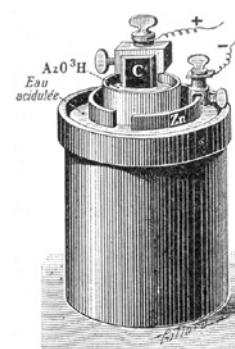
Merveilles de la science, Figuier, Paris, 1867, Library of the Musée d'histoire des sciences



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.

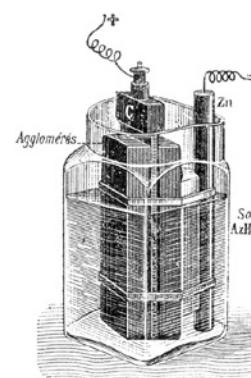
Merveilles de la science, Figuier, Paris, 1867, Library of the Musée d'histoire des sciences



Bunsen cell

Following experiments by the German, Bunsen, 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

- cabinets: the magnetic effects of electrical current, electromagnetic machines, measuring electric current

Electricity and magnetism

In 1820, the Danish scientist Oersted 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 Faraday, 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.

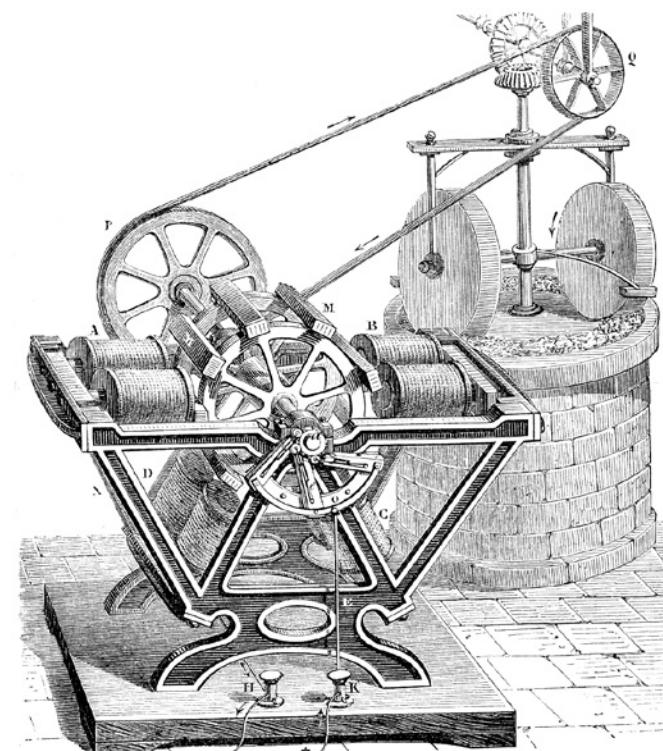


Oersted discovers the magnetic effects of electrical current

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.

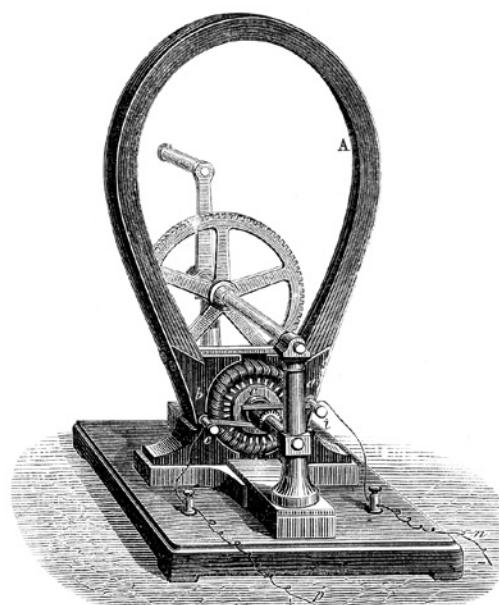


Froment's electric motor

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

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.

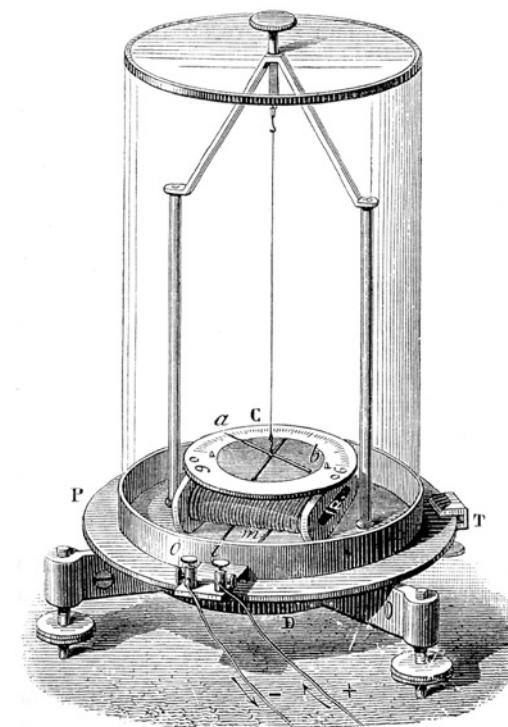


Gramme's Magneto-electric machine

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

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

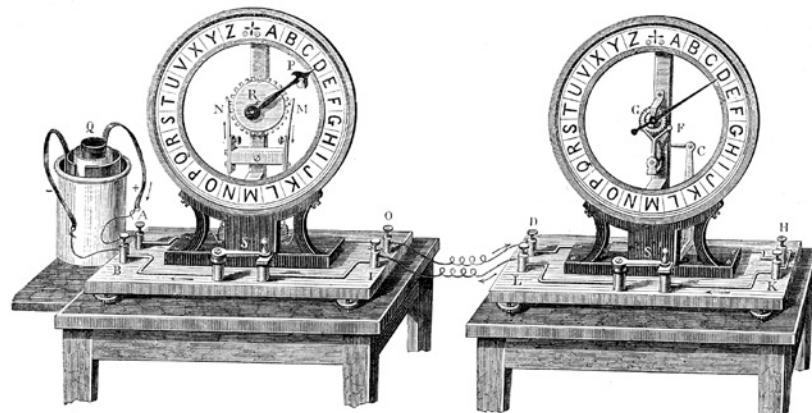
Traité de physique, Ganot, Paris 1884, Library of the Musée d'histoire des sciences

Electric signals for long distance communications

- cabinets : the telegraph and wireless transmission

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 1834, the American, Morse, 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.

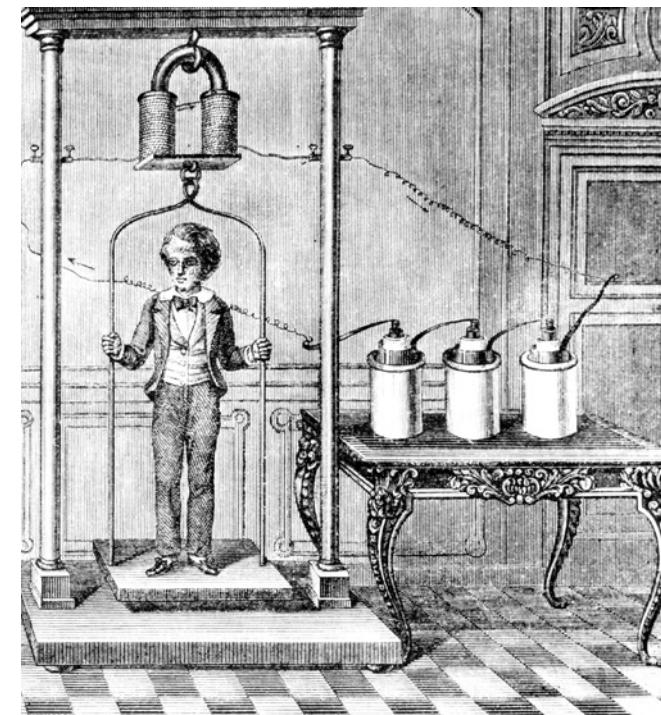


Dial telegraph

Traité de physique, Ganot, Paris, 1884, 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.

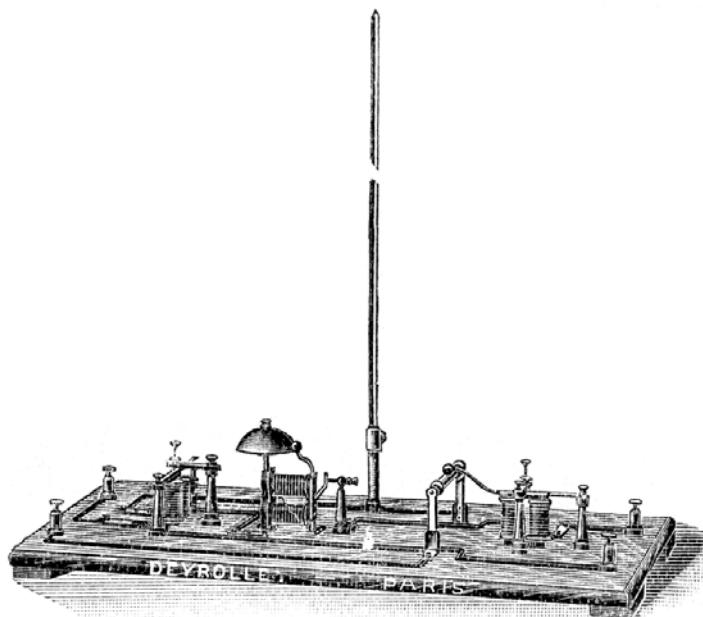


An electromagnet lifting an experimenter

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

Wireless transmission

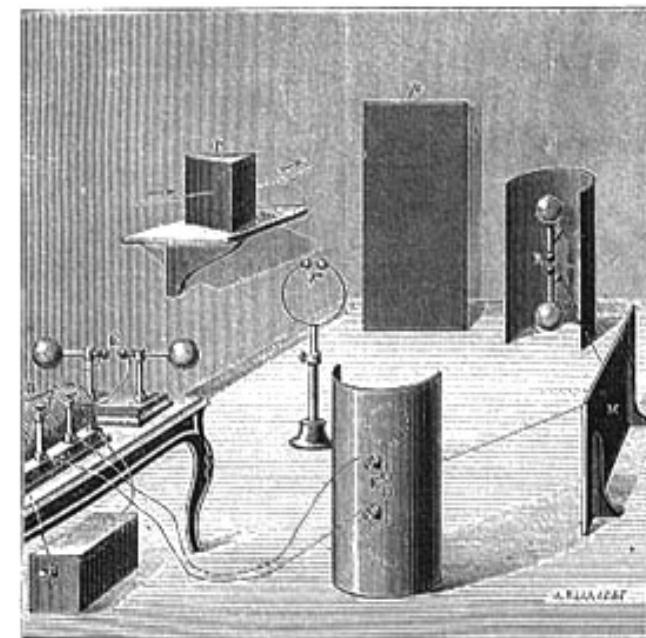
The invention of transmission without wires was the end result of a series of investigations by a number of scientists. Faraday began the trail with his discovery of induction, then Maxwell, his student, laid out the theoretical basis for electromagnetism incorporating both light and electricity. They were followed by Albert Hertz who experimentally proved the existence of electromagnetic waves and the French scientist, Branly, who developed the first wave radio receiver which used iron filings. Finally, it was the Italian, Marconi, 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*

Invisible waves

Using Maxwell's mathematical equations, in 1880 Hertz proved the existence of a specific type of electromagnetic wave: hertzian or radio waves. Using an induction coil generating a high voltage, he produced sparks between two electrodes. By placing a receiver, a copper ring with a small break in it, a short distance away he observed the appearance of sparks in the break. Hertz also described how the waves could be concentrated, deviated or reflected as with light rays.



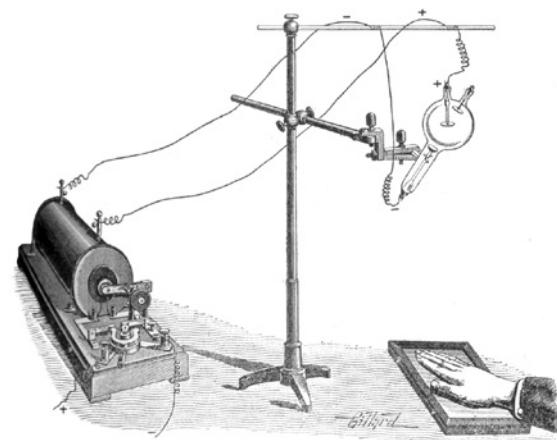
*A Hertz experiment
Tirée du site www.Alternativaverde.it*

Luminous effects of electricity

- cabinets: the luminous effects of electricity, induction coils, Guye's electron cannon

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 christened these rays - X-rays.

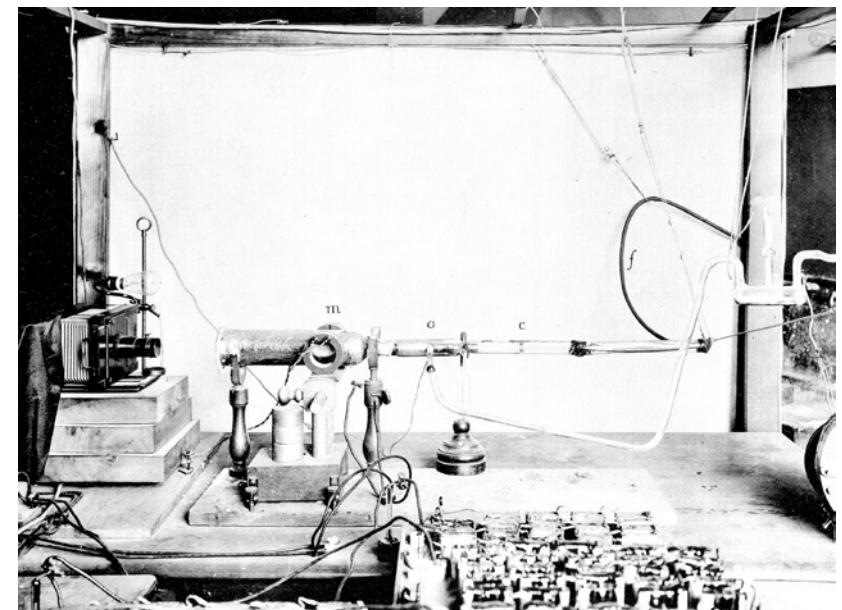


Radiography apparatus

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

Guye's Electron cannon

In 1897, ten years after their discovery, cathode rays were found to be composed of negatively charged particles, or electrons. It was through using an electron cannon, or cathode tube fed by a high voltage generator, that the Geneva physicist Guye experimentally verified Einstein's famous law $E=mc^2$ which states that, under certain conditions, mass (electrons) varies as a function of their speed.

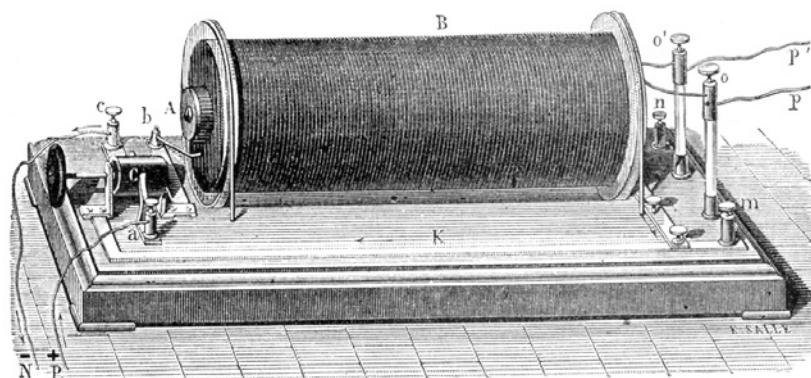


Guye's electron cannon

Mémoires de la société de la SPHN, Genève, 1921, Library of the Musée d'histoire des sciences

Induction coils

If there is one instrument which contributed above all others to the discovery of X-rays, it is without doubt the induction coil invented around 1850. It produces high voltage discharges of between several thousand and several tens of thousand volts usually from a battery ignition. The coil became a commercial success. At the beginning of the 20th century, all the radiographic installations for medical and dental surgeries were equipped with an induction coil.



Rhumkorff coil

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

Healing by electricity

In addition to the production of X-rays, induction coils were also used in another medical field, electrotherapy. From 1850, doctors gave patients shocks through electrodes linked to a coil to treat certain nervous complaints or paralyses. Coils were also used by the Frenchman Duchenne de Boulogne, one of the pioneers of electrotherapy, for his notorious physiological experiments on the face muscles of mentally retarded patients. By placing electrodes at certain points on the face of his patients he produced contractions which were similar to various mental states (ecstasy, joy, hatred, etc.).



Expression of ecstasy and of hate following the application of electrical current to facial muscle groups

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



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)

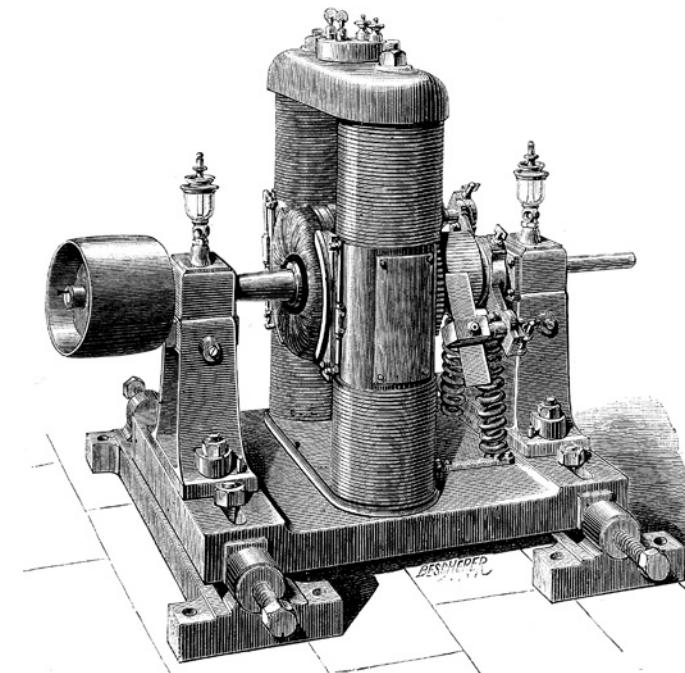
Measurement of electromotive force (or difference in electrical potential). Voltage can be compared to the difference in height between two points of a water course.

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.

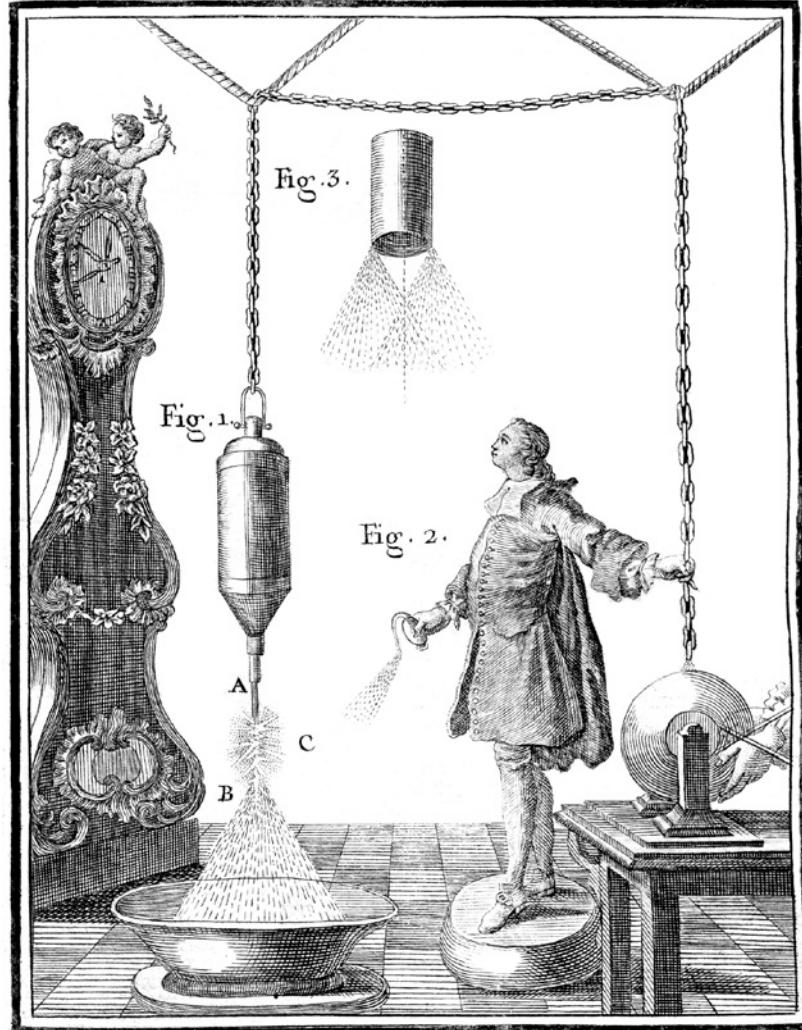
Further reading

- Histoire de l'électricité, Christine Blondel, Explora Pocket sciences, Paris, 1994
- Du tam-tam au satellite, Patrice Carré, Explora Pocket sciences, Paris, 1991
- La fée électricité, Alain Beltran, Découvertes Gallimard, Paris, 1991
- Les merveilles de la science, Louis Figuier, Paris, 1867
- Traité de physique, Ganot, Paris, 1884
- A travers l'électricité, Georges Dary, Paris, 1901



Bréguet's Dynamo-electric machine

Merveilles de la science, Figuier, Paris, 1867



Experiments on static electricity

*Recherches sur les phénomènes électriques, Abbé Nollet, Paris, 1753,
Library of the Musée d'histoire des sciences*

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- Révolution(s) – A brief history of celestial measurement told through some of the astronomical instruments in the Musée d'histoire des sciences of Geneva. September 2011
- The skies of Mont Blanc - Following the traces of Horace-Bénédict de Saussure (1740-1799) pioneer of Alpine meteorology. September 2011
- Sun time: Description and use of the main types of sundial exhibited at the Musée d'histoire des sciences of Geneva. September 2011
- Seeing the infinitely small : Instruments at the Musée d'histoire des sciences of Geneva trace the history of microscopy. September 2011
- Observing the sky: A brief introduction to astronomy and presentation of instruments from the first Geneva Observatory. September 2011
- The Pictet Cabinet: The art of teaching science through experiment. September 2011
- From foot to metre, from marc to kilo: The history of weights and measures illustrated by objects in the collections of the Musée d'histoire des sciences of Geneva. September 2011

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