

**EU Project HIPST**  
**Case Study 1 developed by Fondazione Scienza e Tecnica, Italy**

**1. Title**

The Discovery of Dynamic Electricity and the Transformation of Distance Communications

**2. Author and Institution[1]**

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**3. Abstract**

The case study described in this document[2] concerns an educational and communication project conducted at the Fondazione Scienza e Tecnica of Florence, centred on the early practical applications of the discoveries of electrodynamics and electromagnetism.

The project is aimed at upper high school students and teachers. For the contents confronted, it is tied to a specific section of the instruments collection of the Fondazione's Physics Laboratory. It was elaborated and realised by an interdisciplinary work group in an initial prototype version (2007/08 s.y.), and repeated – with improvements following an evaluation process – during the following year (2008/09 s.y.) in the HIPST context.

The project is formed by a seminar section aimed at teachers, and an interactive lesson of a narrative-experimental nature aimed at students. The project's main purpose is to reconstruct a well-developed picture that contextualises the bases of electrodynamics and its early technical applications in the historical-social dimension, stimulating comprehension of several practical applications in physical phenomena tied to everyday life.

From the historical viewpoint, the project concerns a time span that extends from the late eighteenth century to the 1860s.

From the curricular viewpoint, it is tied to high school programmes, especially the final year of study or, in experimental disciplines, earlier.

The project is tied to the electromagnetism section of physics programmes, and proposes to integrate and enlarge on the historical-social aspects which for reasons of time, formulation of ministry programmes, and training of physics teachers (normally of a strictly scientific nature) are generally not proposed.

From the pedagogical viewpoint, like all project activities, the interactive lesson is held at the Fondazione Scienza e Tecnica headquarters, and is quite different from “top-down” lessons or lectures. It is conducted by a facilitator, has an

interactive structure combining “narration” and “experimentation”, and proposes to involve young people by getting them to become “protagonists” of the workshop instead of being passive listeners. The intention is to stimulate curiosity and invite them into an active and cooperative participation also by conducting group experiments.

From the viewpoint of broadening the learning scenario, the fact of working in an extra-scholastic and particular setting like that of the headquarters of an historical instruments collection, assumes particular significance. For here, it is easier to perceive the “material” dimension of science, its development and applications in the course of time, and the fact that science does not have a linear and univocal development. It instead has a complex history consisting not only of a theoretical side but also a practical dimension that develops through trials, errors and corrections that are often necessary before reaching consolidated and universally accepted results. Also for these reasons, the interactive lesson is planned to be enriched by presenting students historical scientific instruments that are a concrete testimony of this complexity.

The part of the project more strictly aimed at teachers is conducted with seminars aimed at offering cultural and extra-curricular instruments that can be reused with students at school, reworking the indications offered by the workshop activity conducted at the Fondazione.

The instructional packet concludes with a final evaluation in a meeting with teachers in order to verify possible advantages received to enhance their teaching activity and the project’s impact on students.

#### **4. Case study description**

The “Discovery of Dynamic Electricity and the Transformation of Distance Communications” project takes on concrete form in a set of educational and communications activities aimed at high school students and teachers, tied to part of the “electricity and magnetism” section of the Fondazione Scienza e Tecnica’s physics laboratory collection.

In elaborating the entire project, composed of a seminar for teachers and an interactive lesson for students, the main interests include that of bringing out several interrelations existing between the “history of science” and the “social history” of man.

In constructing the instructional packet, it was decided to start from a “key point” for the Physics Laboratory collection, which is also tied to two fundamental subjects handled in high school physics courses, that is electromagnetism and electrodynamics, not in the general sense but instead examining the beginning of their applicative “history”, which started with the invention of the battery, and later developed in the experiments of Oersted and Ampere (electrical currents-magnets actions), which made it possible to

imagine very concrete uses for the properties of “electricity in motion”. These include the invention of the telegraph, which provoked a “revolution” in the field of communications, and substantially contributed to modifying man’s social history.

As for the interactive lesson for students, this begins with an introduction aimed at explaining “why” it is being conducted at the Physics Laboratory collection, and providing a brief synthesis of its history starting from the formation of the Istituto Tecnico Toscano in 1850. Then, starting from a problem from everyday life, proposed by a facilitator, we “go” back through time to explore several of the principal points of electrodynamics: from the invention of the battery (1800, Volta) to the discovery of currents-magnets action, to the first practical applications (galvanoscope – galvanometer – electromagnet), to then move on to the invention of the telegraph, which provided a fundamental stimulus to the development of railways (tied to the problem of establishing standard time), up to submarine telegraphy, which promoted an extraordinary development of communications (including communications across oceans and with colonies).

From the pedagogical viewpoint, the lesson for students with a duration of two hours and conducted by a facilitator, is based on a narrative-experimental approach: as part of a narration aimed at presenting students the historical backdrop against which certain scientific discoveries occurred, their technical applications developed, and their consequent repercussions on society, the students will have “experimental” moments to try their hand at conducting experiments suggested by the workshop’s theme, based on suggested indications, and employing “poor materials”.

More specifically, during the narration which is accompanied by slide projections, the students will have four “experimental” moments in which they are asked to solve several practical problems. They are thus invited to “teach themselves” and to create simple technical instruments to solve concrete problems, and not to be simple passive users of technology. During and on conclusion of the workshop, several of the collection’s original scientific instruments will be shown.

## **5. Historical and philosophical background, including the nature of science**

From the historical viewpoint, both the interactive lesson for students and the seminars for teachers, though following totally different modalities of realisation, concern a span of time that goes from the late eighteenth century to the 1860s. In particular, we will pause on Galvani’s studies on frogs and Volta’s invention of the battery (1800), which represents the first concrete possibility to avail of a dynamic “electricity”. The history of electrodynamics and its early practical applications is introduced: electrochemistry (starting from the contribution of Carlisle and Nicholson who in 1800 break down water to its constituent elements, hydrogen and oxygen); the applications of electrotherapy (for the more or less presumed treatment of the most disparate illnesses:

motorial disturbances, paralysis, ulcers, deafness, madness, ...), galvanoplasty and electroplating, techniques which develop as of the 1830s and which, making it possible to reproduce metal objects in series (tableware, cutlery, candelabra, decorative objects in general ...) or to plate them with precious metals, bringing about a veritable social transformation. Objects that had indeed been the exclusive privilege of the aristocracy for centuries, become easily available also to the middle class.

We then move on to the experiment of Oersted (1820) who for the first time gave proof of the tie between electricity and magnetism, which had often been hypothesised but never demonstrated. Reference is made to the theoretical contributions of great importance (Ampere, Biot-Savart, Arago, Faraday ...) that followed that experiment, and we introduce the practical application that proved of revolutionary importance for the repercussions it had in diverse sectors: the electric telegraph. This invention indeed produced an epoch-making transformation in long distance communications. The fastest telecommunications system implemented till then had been the optical telegraph invented by the Chappe brothers in France. Though ingenious, the system's concrete possibilities of transmission and speed had several drawbacks. It was, however, with the needle telegraph patented by Cooke and Wheatstone (1837), the construction of the first telegraph lines, the successive evolution of the communication code introduced by Morse and Vail with their devices, and the construction of the first telegraph line based on this new system (1838) that the history of communications was totally overturned with repercussions on the economy and trade, transport, the military and political ambits, the press, communications in everyday life between private citizens, and so on. Among the various changes connected to the telegraph's development, we cite the introduction of standard time and the development of railway traffic.

Submarine telegraphy, the great economic-technological challenge of nineteenth-century man, later constituted yet another factor of change which would lead to the greatest expansion of telegraphic communications via cable as of the mid 1860s.

In this rapidly changing scenario, we feel it timely to single out several aspects concerning the nature of science, particularly those concerning the transformations that took place, during the first half of the nineteenth century, in the manner of practising science and in the relationships between science, technology and society.

The focal point lies in the gradual specialisation of the sciences, which emerges in the nineteenth century, the most evident consequence of which was that of drawing scientific research away from society. The "public" in the nineteenth century began to have access to the results of scientific research only through mediated forms of a popular nature, expositions (like the first universal

exposition, the one organised in London in 1851, that was also a celebrative expression of the conquests of science and technology), and through museums.

Gradually, the natural sciences become accessible only to limited groups of people, because they presuppose a very advanced technical-scientific education. The new characterisation of universities in the nineteenth century progressively isolate the figure of the scholar or the amateur, typical of scientific culture of the previous century, instead promoting the “professionalisation” of the scientist’s figure.

The relations between science and politics transform: Napoleon was the first ruler to intuit the political and strategic utility of the sciences. He viewed the scientist as a technocrat who applies the scientific method – particularly that of the exact sciences – to the administration of the State, thereby guaranteeing efficiency and prosperity.

In an overall celebrative picture of science, fuelled by the positivist philosophy that triumphed in the nineteenth century, scientists stripped scholars and philosophers of cultural supremacy in the span of a few decades. Even Comte, founder of Positivism, believed that scientific thought could promote a complete transformation of society.

The relationships between science and technology were further transformed in the nineteenth century. Allied with industrial power, they were celebrated in the great universal expositions. The value of a scientific discovery tends to be increasingly more measured on the basis of its large-scale applicability to the production of innovative technological solutions, and on that of economic profit.

Another change concerns the figure of the inventor who already around 1840 was no longer a scientist, as was generally the case before. A new figure emerges, that of the technician, sometimes self-taught, who starts his own business to develop and economically profit from his inventions. Cooke and Morse are examples, followed by other technician-businessmen like Siemens, Edison, Eastman, and Marconi, who all shared the lack of an academic scientific training. Endowed with great inventiveness and business spirit, they explored new horizons of technology which they often developed with applications and apparatuses that were not the products of a well-defined scientific and theoretical picture, but instead preceded it. Also innovative was their search for a possible commercial use of their inventions, even in the financial sphere. They did not necessarily seek academic acknowledgement, and instead tended to combine their activity of inventors and technologists with that of businessmen.

## **6. Target group, curricular relevance and educational benefits**

The “Discovery of Dynamic Electricity and the Transformation of Distance Communications” project is principally aimed at high school students in their

final year of study, and exceptionally to experimental classes that tackle physics topics concerning electricity and magnetism earlier.

The scientific concept most pursued in the instructional packet concerns the bases of electrochemistry (starting from the construction of the battery), the currents-magnets interactions and the technological applications of these properties in telecommunications. Several ideas are offered to get students to reflect on the correspondences between telegraphy and contemporary telecommunications (the Internet and digital communications): for example, the use of codes to compress transmission signals, cryptography, etc.

The project's evaluation phase has evidenced that students' interest is particularly stimulated by the interdisciplinary outlook that this activity is based on, the possibility to conduct experiments (bear in mind that in many schools, laboratory activity is extremely limited and, at times, inexistent) and to have a "direct contact" with historical objects (such as nineteenth-century batteries, objects produced using the techniques of galvanoplasty or electroplating, nineteenth-century telegraphs, pieces of underwater cable for telegraphic communications), and the possibility to work in groups to conduct joint activities.

## **7. Activities, methods and media for learning**

The principal activity offered students is the interactive lesson itself, which proposes an account of an historical nature, supported by the use of a power point presentation, and provides for experimentation. Divided into groups, the students build the pile and verify its operation, repeat Oersted's experiment on the current-magnets interaction, simulate optical telegraphy communications, build a model of the Morse telegraph, and experiment "telecommunications" by using it. The lesson does not enter into the merit of mathematical-theoretical issues, which are instead handled in school.

At the end of the workshop, the students receive a profile summarising the historical developments that serve as guideline for the workshop. The Fondazione staff who have worked on the project will remain at the disposal of teachers and students for further assistance until the end of the school year. This has proven particularly useful for students who have chosen to prepare a short written dissertation on one of the aspects confronted during the workshop, as part of their school-leaving exams.

Two seminars are devoted to teachers: the first anticipates and enlarges on the historical-social aspects at the basis of the interactive lesson for the students. The second instead provides for an introduction and visit to the Physics Laboratory, to the "Electricity and Magnetism" section in particular, an introduction to "reading (interpreting) objects", and conducting an experiment in electroplating, which can be repeated in school, as an example of a practical application of electricity supplied by the pile. The exercise of "reading objects"

seeks to stimulate the capability to draw information from objects which is not necessarily found in text books, but that can be gathered especially by careful direct examination (for example: shapes, materials, technical details, etc.).

## **8. Obstacles to teaching and learning**

As for obstacles to teaching and learning, it should be emphasised that as this instructional packet is an informal educational activity for the students, the proposer should have the personal capability to lead a group more as a facilitator than as a teacher delivering a stand-up lesson. In addition to the necessary basic scientific knowledge, the group leader should also possess knowledge of an interdisciplinary nature, especially historical, which enables him/her to appropriately deliver the lecture. The bibliographical references under point 11 offer a good point of departure for further study in this direction.

As for the students, though the activity is dedicated to young people of classes handling electromagnetism in the course of the school year, we have concluded that the activity can be easily followed independently of possessing scientific knowledge on the specific subjects. As for the historical viewpoint, the lack of knowledge about certain connections between scientific development and historical-social development does not pose an obstacle to learning but instead stimulates the curiosity.

More generally speaking, we hereinafter report the main results of the meeting held to evaluate the project's educational effectiveness, as they emerged from a quality study conducted at the teachers' year-end meeting.

During this meeting, the value of the project was underlined for its characteristic of contextualising the physics discoveries or the technological innovations in the framework of the temporal development in which they were realised. The workshop's capacity to arouse the students' explicit interest has been pointed out and, in various cases, there has been a greater request from the students who have participated in this project to be assigned short dissertations in physics to prepare for their school-leaving examinations. It has been pointed out that quite often, students' impact with physics in school has been quite negative, perceived as a disappointment for "something" that one supposes should describe reality, and instead remains in a very theoretical and abstract ambit, often hard to understand, and generally detached from everyday experience. Faced with an observation like this, it should come as no surprise that an activity like the one described in this case study has a considerable impact on the students, because it proposes a different and more interdisciplinary approach to the subject, one mindful of interesting connections between different fields, and more connected to the practical-experimental dimension. In the opinion of many teachers, before presenting students a definition or a formula, it is important to propose a different approach to the concepts of physics, one more connected with the historical and human development to problems. Also in this sense, the workshop

developed at the Fondazione constitutes a different outlook in support of didactic practise in schools.

Another important aspect observed by various teachers is that of stimulating cooperation between young people, even in cases of difficult classes from the viewpoint of relations between students. Indeed, precisely for the way it is conceived, the workshop enables students to work together solving practical problems, to use their “heads and hands”, and to do team work in quite a different manner from what usually happens everyday at school. Particular attention is devoted to the “material” dimension, so often neglected in Italian schools where the cultural supremacy of humanistic subjects is accompanied by the supremacy of the theoretical approach even in disciplines like physics where the practical and experimental dimension have a fundamental role.

From the viewpoint of the topics dealt with, the students show no particular learning difficulties. Teachers, though, underline that students tend to have more short-term memory and that also for this reason, proposing the laboratory activity with interactive lessons differentiated by themes more frequently and to the same students would make the lessons much more incisive.

## **9. Pedagogical skills**

As already pointed out in the preceding paragraphs, the instructional packet for students is presented as an educational activity of an informal nature, conducted in a setting other than that of a school (in the case in point, in the setting of a collection of historical scientific instruments). The facilitator heading the activity must have character traits that incline him/her to conduct a group through a lecture, as well as to stimulate the development of practical experimentation. The pedagogical ability required is therefore that of keeping attention alive, coordinating a group, getting the young people to feel free to express their ideas, proposals and questions without feeling they are being judged, and getting them to work in an open space ready to meet their needs. Moreover, the facilitator must possess the capability to get the young people to work together.

In the sections where the students become protagonists and conduct their own experiments, they must have a series of materials (it has been decided to use poor materials) such as disks of zinc, copper and cotton, wooden supports, bowls to prepare the solution of salt and water, in order to built the pile; magnets, electrical wires and compasses to repeat Oersted’s experiment; cards and a codification table to simulate the optical telegraph; telegraph key, light bulb, electrical wire and battery to simulate a transmission/receiving system with Morse code.

On completion of the workshop, the students receive an historical supplement, enclosed as an appendix to this case study.



## 10. Research evidence

The research conducted to implement the project was oriented towards interweaving the points of interest of the school activity with those of the activity of valorising historical collections, so as to obtain results useful for all of the subjects involved. This research activity was developed in meetings which involved the staff of the Fondazione Scienza e Tecnica, the teachers involved in the project, and experts in science communication.

As for the main observations made by the teachers on how the participation in the project presented in this case study reflected on the normal teaching at school, please refer to paragraph 8.

## 11. Further user professional development

Di seguito alcuni suggerimenti bibliografici per ulteriori approfondimenti:

- [1] AA.VV., *La Télégraphie Chappe*, FNARH, 1993
- [2] W. Beck, *I telegrafi Chappe sulla costa adriatica*, in *Archivio per la storia postale, comunicazioni e società*. Anno III, n. 7-9, gennaio – dicembre 2001
- [3] Joseph Ben-David, *Scienza e società. Uno studio comparato del ruolo dello scienziato*, Il Mulino, 1975
- [4] Marco Beretta, *Storia materiale della scienza – Dal libro ai laboratori*, Bruno Mondadori, 2002
- [5] Paolo Brenni, *La nascita di un Laboratorio moderno. Il Gabinetto di Fisica dell'Istituto tecnico toscano*, in Franco Gravina (a cura di), *Le meraviglie dell'ingegno*, Ponte alle Grazie, 1990
- [6] Paolo Brenni, *Introduzione in Gli strumenti di Fisica dell'Istituto Tecnico Toscano/Elettricità e Magnetismo*, Fondazione Scienza e Tecnica, Le Lettere, 2000
- [7] Paolo Brenni, *Dal Crystal Palace al Palais de l'Optique: la scienza alle esposizioni universali: 1851-1900* in Alexander C. T. Geppert, Massimo Baioni (a cura di), *Memoria e Ricerca Esposizioni in Europa fra Otto e Novecento. Spazi, organizzazione, rappresentazioni* n. 17/2004, Franco Angeli
- [8] Urbano Cavina, Carlo Matteucci, *padre della telegrafia italiana*, *Archivio per la storia postale*, n. 16-18, gennaio-dicembre 2004
- [9] Urbano Cavina, *L'arma segreta di Napoleone: la " telegrafia" di Chappe*, *Archivio per la storia postale*, N. 19-21, gennaio-dicembre 2005
- [10] Gildo Cesco-Frare, *Punto e linea – Il mio rapporto con il telegrafo*, in *Archivio per la storia postale*, n. 13 maggio 2003
- [11] Louis Figuier, *Les grandes inventions modernes dans les sciences, l'industrie et les arts*, Hachette, 1876
- [12] Gabriele Falciasacca – Andrea Vico, *Dal tam tam al telefonino*, Editoriale Scienza, 1997
- [13] Simone Fari, *La tecnologia che corre sul filo. Il cambiamento tecnologico nei primi trent'anni dell'esperienza telegrafica italiana fra successi e difficoltà* in Andrea Giuntini (a cura di) *Sul filo della comunicazione – La telegrafia*

nell'Ottocento fra economica, politica e tecnologia, Quaderni di storia postale, n. 28, ottobre 2004

[14] Simone Fari, Le vie del telegrafo. Linee telegrafiche e ferrovie italiane nel corso dell'Ottocento, Archivio per la storia postale, n. 22-23, gennaio-agosto 2006

[15] Louis Figuier, Les grandes inventions modernes dans les sciences, l'industrie et les arts, Hachette, Paris, 1976

[16] Patrice Flichy, Storia della comunicazione moderna, Baskerville, Bologna, 1994 – versione originale: Patrice Flichy, Une Histoire de la communication moderne. Espace public e vie privée, La Decouverte, Paris, 1991

[17] Franco Foresta Martin, Dall'ambra alla radio, Editoriale Scienza, Trieste, 2002

[18] Anna Giatti e Stefania Lotti (a cura di), Le stanze della scienza. Le collezioni dell'Istituto Tecnico Toscano a Firenze – Fondazione Scienza e Tecnica, Artigraf, 2006

[19] Guido Gori, L'Accademia delle Belle Arti e l'Istituto Tecnico Toscano 1809-1859, in Anna Giatti e Mara Miniati (a cura di), L'acustica e i suoi strumenti, La collezione dell'Istituto Tecnico Toscano, Giunti, 2001

[20] Andrea Giuntini, Il potere dei cavi. Le telecomunicazioni sottomarine nel Mediterraneo in Andrea Giuntini (a cura di) Sul filo della comunicazione – La telegrafia nell'Ottocento fra economica, politica e tecnologia, Quaderni di storia postale, n. 28, ottobre 2004

[21] Amédée Guillemin, Les applications de la physique aux sciences, a l'industrie et aux arts, Hachette, 1874

[22] Luca Novelli, Volta e l'anima dei robot, Editoriale Scienza, 2002

[23] Marco Piccolino, Marco Bresadola, Rane, torpedini e scintille – Galvani, Volta e l'elettricità animale, Bollati Boringhieri, Torino, 2003

[24] Margareth Rowbottom – Charles Susskind, Electricity and Medicine, History of their Interaction, San Francisco Press, San Francisco, 1984

[25] Tom Standage, The Victorian Internet, Walker and Company, New York, 2007

[26] Donatella Ventimiglia, James Trollope, Serao, Scanabissi: Il fascino del telegrafo, Archivio per la storia postale, n. 12 dicembre 2002

[27] Alessandro Volta, On the Electricity excited by the mere Contact of conducting Substances of different kinds, Università degli Studi di Pavia, Hoepli, 1999

## **12. Written resources**

Enclosed is a copy of the original materials produced for the “Discovery of Dynamic Electricity and the Transformation of Distance Communications” project:

- Power Point slide presentation to support the narrative part of the instructional packet
- Supplement integrating the instructional packet
- Laboratory photographs supplement

[1] The following teachers have participated in the project: Barbara Bellaccini, Rossano Bigiarini, Ivan Casaglia, Cristina Dianzani, Michelangelo Fabbrini, Luca Frediani, Francesco Parigi, and Maria Angela Vitali from the Liceo Scientifico Castelnovo of Florence; Paola Falsini from the Liceo Scientifico Agnoletti of Sesto Fiorentino, Alessandra Renzi from the Istituto Statale di Istruzione Superiore Tecnica e Scientifica Russell Newton.

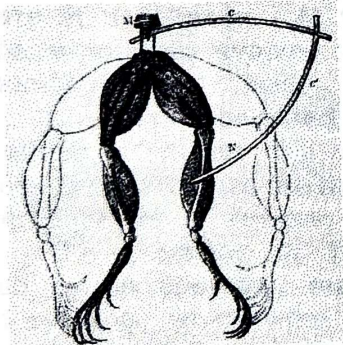
[2] The description of this case study has been elaborated using the general structure “Case Study Exchange Format” proposed within HIPST.

## THE DISCOVERY OF DYNAMIC ELECTRICITY AND THE TRANSFORMATION OF LONG DISTANCE COMMUNICATIONS

Classroom supplement, 2008/09

During the eighteenth century, the history of electricity coincided with the history of static electricity, that is to say the electricity concerned in the phenomena of electrically charged bodies in the absence of electrical currents. It was only towards the end of the century that the scenario expanded, thanks to the discovery of dynamic electricity.

In 1791, professor of anatomy at the University of Bologna, Luigi Galvani published the result of eleven years of experiments and studies, in which he announced that he had identified a new form of electricity. One night in 1780, on a wooden panel that served as the support for the electrostatic machine in his laboratory, Galvani placed the lower limbs of a dissected frog with the nerves exposed. He observed that by placing the tip of his scalpel near the nerves, at the same time producing a spark with his electrostatic machine, the animal's muscles contracted violently.

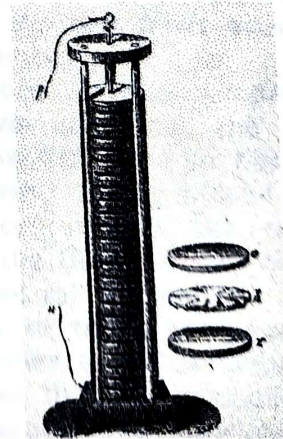


Experiment of the frog leg that contracts when touched by an arc made up of two metals.

In 1786, however, while studying the influence of atmospheric electricity on muscular contractions, Galvani passed a copper hook through the spinal cord of a frog that had been prepared as stated above, and hanged it from the iron banister of the terrace of his home. For the whole day, nothing happened. In the evening, however, irritated by the failure of this experiment, he briskly rubbed the copper hook against the iron banister to improve the contact between the two metals, and saw the limbs contract, which occurred every time the copper hook touched the iron banister. Galvani thought this effect

was due to the frog's own electricity, which he identified as animal electricity.

Galvani's results sparked great interest among physicists, physicians, physiologists and surgeons, who all wanted to repeat his experiments. Alessandro Volta, professor of physics at the University of Pavia, was also interested and shared the enthusiasm for Galvani's discoveries. However, he soon hypothesised that the cause of the contractions of the frog's body was the contact between the two metals that flanked the animal's body, rather than the existence of a presumed animal electricity. In conducting experiments to substantiate his hypothesis and refute Galvani's theory, he built the voltaic pile, notifying the Royal Society of his invention in a letter dated March 20<sup>th</sup> 1800, in which he announced: "This device which will doubtlessly amaze you is only the result of piling up a number of good conductors of various types, arranged in a certain manner, 30, 40, 60 or more pieces of copper, or better still of silver. To each of these I combine a piece of tin or, better still, of zinc, and an equal number of layers of water or of another humour that is a better conductor than simple water, such as brine, lye, etc., or of cardboard, leather, etc. soaked in these humours. In this manner, I continue coupling a plate of silver with one of zinc, and always in the same order, according as I have begun, and interpose between each of those couples a moistened disk: such is the makeup of my new instrument which imitates [...] the effects of the Leyden jar or of electric batteries, and provokes the very same commotions as these".



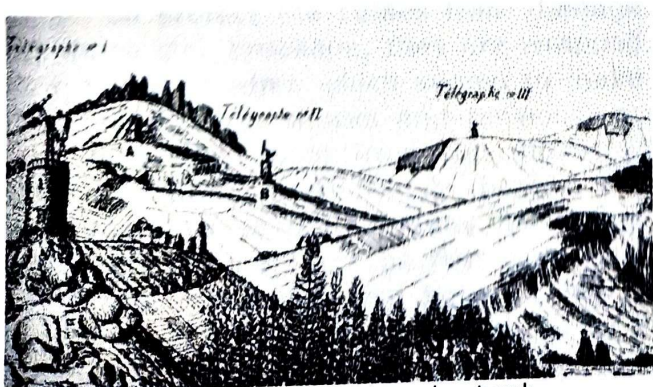
Volta's pile

Thanks to the electric pile, for the first time it became possible to produce a constant electric current. However, except for

applications that immediately led to the birth of electrochemistry (for example, Humphry Davy isolating potassium and sodium through electrolysis), and other uses in electrotherapy, the pile remained a laboratory object without any practical use for about twenty years. Things changed in 1820 when the Danish physicist Hans Christian Oersted discovered that a wire with an electric current placed near a magnetic needle caused the needle to deflect.

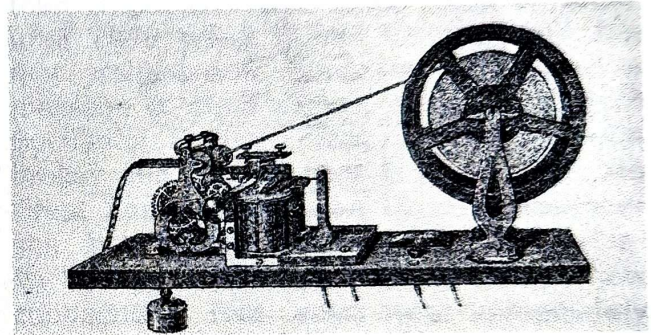
This discovery, which was the concrete proof of the long supposed connection between electricity and magnetism, provoked a very rapid chain reaction in terms of new theoretical acquisitions and practical applications by the scientists of the epoch (Ampère, Biot and Savart, Arago, Faraday ...). The phenomenon observed by Oersted sparked the invention of the first instruments for measuring currents – the galvanometer – and the first electromagnets. At the same time, employing a mathematical structure, Ampère formulated a theory of electromagnetism.

In the course of the 1830s, several inventors thought that some of the properties of magnetic phenomena could be applied in order to send signals and communicate at a distance. At the time, the most technologically evolved system of "telecommunications" was optical telegraphy, a system invented by the Chappe brothers in France: tall poles with three mobile arms attached to them were installed on a series of towers and high buildings. The positions of the arms manoeuvred by an operator, represented letters and symbols, which were observed from one tower to another by an observer using a telescope. Chappe's system (and other similar ones) had several disadvantages, however, such as conditions of poor visibility which made it unusable.



Stations of an optical telegraph network

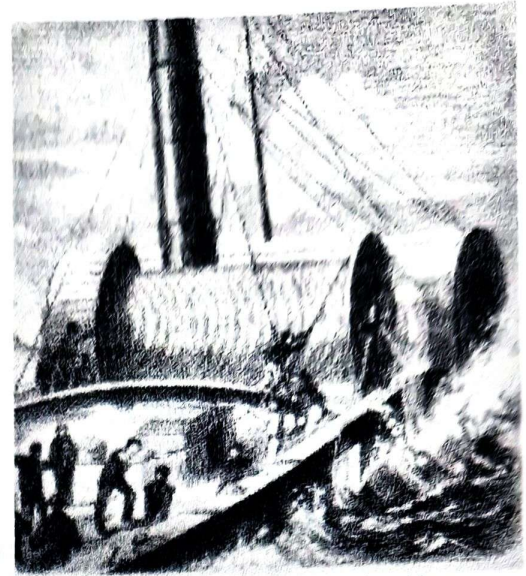
The availability of a generator of continuous current – the pile – and the effect of a magnetic needle deflecting due to the passage of electricity, soon led to the idea of the electrical telegraph. In 1837, William Fothergill Cooke and Charles Wheatstone patented the needle telegraph, and in 1842 the first system was activated with a line measuring 21 km along the Paddington-West Drayton train line. In the United States, Samuel Morse invented another type of telegraph: by employing the properties of the electromagnet, which controlled by an electrical current can activate an inked stylus (or a dry bit), and formulating a suitable code (the Morse code), he invented the system that would override all the other available technologies for the long-distance transmission of signals. The first Morse telegraph line was inaugurated in 1844, and connected Washington and Baltimore.



Morse telegraph

In the course of a few years, telegraphs and telegraphic lines multiplied, causing considerable changes in society for their economic, military, and political repercussions, as well as in the diffusion of information in newspapers (the introduction of the electrical telegraph corresponded to the birth of the first news agencies) and, more generally, in everyday communications between people. It is interesting to note that the telegraphic network expanded hand in hand with the railway system. In the second half of the nineteenth century, all the countries of Europe and the United States began to set up a complex railway system. Thanks to the capacity of trains to transport much larger quantities of goods faster and over long distances than was possible on roads, the train became the principle means to transport freight. The combined development of the telegraph and the railway led to a more efficient distribution of resources on both the national and

international levels, and this determined the development of the economy. The telegraph was the first telecommunications instrument that made it possible to simultaneously conduct trading operations and financial transactions at a distance. There was thus a rise in trading products which, once sold via the telegraph, had to be rapidly delivered, and that is where the railway system came into the picture. Moreover, when installed along the railway lines, the telegraph lines were built and repaired more easily. In turn, the railways, too, received advantages from the telegraph as far as trains leaving and arriving on time, and also for the possibility to communicate unforeseen events or problems on the railway lines.



Laying submarine telegraph cables

However, an enormous step in the evolution of telegraphic communications came with submarine telegraphy, which represented the most formidable undertaking in terms of invested capital, financial risk, technological challenge, and involvement of public opinion. Planning and laying the cables was a long and difficult affair. It indeed proved a very delicate task to transport and, by means of special machinery, lay the cables on the ocean floor, following adequate sounding, without breaking them. It required the use of very large ships as well as the collaboration of expert technicians, especially physicists, geologists and engineers. Furthermore, the transmission of electrical impulses, properly translated into signals, by means of a cable submerged in deep waters represented a technical and scientific challenge that greatly differed from that of land telegraphy. The copper cable transporting the signal has to be wrapped in a special waterproof material that completely isolates it: gutta-perch, a plastic material of vegetable origin from southeast Asia, has the ideal characteristics for this use.

To protect the cables from damage or, worse still, breakage, they are wrapped in a bundle of wires which served to make them resistant to shocks and tensions, as well as protect them from sea molluscs, ships' anchors, and fishing boats, the involuntary cause of the many failures in submarine telegraphy. The first successful submarine connection was between Dover and Calais in 1851, using a 30 Km cable, 3 cm in diameter, and with a total weight of 180,000 kg.

The greatest ambition, however, was to connect the two shores of the Atlantic. The undertaking proved much more difficult than expected, and failed several times until 1858 when Queen Victoria sent the first transoceanic telegram, containing a message of good wishes, to U.S. president Buchanan. The cable, however, soon broke, and it was only in 1866 that the Great Eastern, then the largest passenger ship in existence, transformed into a cable-laying ship, succeeded in establishing a new connection. Two cables were immediately opened to commercial traffic and, with a transmission capacity of 5-6 words per minute, connected Hearts Content in Newfoundland with Valentia Island in Ireland, both territories belonging to Great Britain, the undisputed leader in telegraphic communications.

In time, electrical telegraphy employed quicker and more sophisticated apparatuses and connected cities. Cables crossed the continents and reached the most distant colonies. News, war bulletins, diplomatic dispatches, stock exchange quotations, calls to fire brigades, and personal messages by now all travelled over telegraphic lines. The world became increasingly "smaller", and the "Victorian Internet", as the telegraph has been recently defined, not only shortened distances but also profoundly changed society.

## The Fondazione Scienza e Tecnica Physics Laboratory

The Fondazione Scienza e Tecnica was founded in 1987 with the purpose of promoting and diffusing scientific and technological culture, starting from the recovery and valorisation of the historical-scientific heritage of the Istituto Tecnico Toscano, which was founded in 1850 by order of grand duke Leopold II, and held its first classes in 1857. It was founded with the intention of training technicians capable of boosting and managing the then nascent industry of Tuscany. Under mathematician Filippo Corridi, its first and very competent director, the Istituto was therefore conceived to share many characteristics with the other technical schools of Europe, which had served as models. The disciplines contemplated by the original programmes went from mechanical technology to mining engineering, from chemistry to agricultural science ... and teaching focused on their practical and applicative aspects. In particular, "technological physics and the special technology of the physical arts", as applied physics was then called, occupied a very important place in the Istituto's programmes. For innumerable reasons, such as the changes deriving from the unification of Italy, the creation of the Istituto di Studi Superiori, and the numerous teaching reforms, the Istituto Tecnico Toscano soon lost many of the characteristics desired by its founders. As of the 1850s and until the early twentieth century, however, the scientific laboratories and, in particular, the physics laboratory, were enriched with extremely important collections, be it for instrument quantity and quality. The acquisitions were guided by several of the Laboratory directors, who were among the most distinguished physicists of the time, men like Gilberto Govi (1826-1888), Antonio Roiti (1842-1921), and Adolfo Bartoli (1851-1896). Today's collection of almost 3000 pieces is the largest in Italy and one of the most complete collections in Europe of instruments used to study and teach physics in the second half of the nineteenth century. It represents the best that instrument makers of the epoch had to offer. Moreover, for its homogeneity and systematic formation (it is indeed not an "artificial" collection like those created "a

posteriori" and found in many museums), it documents the progress of the instruments employed in physics, and the evolution of instrument design over more than half a century.

While the collection was created with essentially didactic purposes, many of its apparatuses are sophisticated laboratory instruments more than aids to science teaching. The collection instruments can be divided into the following categories: didactic, research, professional, machine models and parts, and "physique amusante" apparatuses.

The Physics Laboratory collection as it was at the turn of the century has come to us practically intact: we can indeed state that almost all of the pieces then in the collection have survived.

In addition to the physics collection, the Istituto Tecnico Toscano also formed other collections: mineralogy, palaeontology, zoology, botany, commodities, chemistry, topographical instruments ... These collections represent a historical-scientific heritage of a European breadth and, at the same time, perhaps the only surviving image of what science teaching was from the mid nineteenth century to the first decades of the twentieth century.



The Physics Laboratory in a photo of 1899



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