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Volta 100 years later or the state of art of Volta's battery in physics textbooks at the end of the 19th century

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ABSTRACT. This paper provides some differences found in didactic textbooks with regard to batteries at the end of the 19th century up to the present. In several situations the everyday use of batteries eclipses the nature of electricity in motion. This occurs because of the superficial scientific treatment in "didactic" physics textbooks, which show a lack of the powerful motivation they used to have in the last decade of the 19th century when the machine revolution was based upon electrical current, and the machines were the precursors of the new century's modernization.

Key words: Volta's battery, the history of science, physics teaching.

RESUMO. Volta 100 anos depois ou o estado d'arte da pilha de Volta nos livros didáticos do final do século XIX. Este trabalho procura mostrar a diferença de tratamento sobre a pilha ou bateria em livros didáticos de física no final do século XIX. O uso cotidiano de pilhas na vida moderna eclipsa a questão da eletricidade em movimento. Isto decorre de um tratamento superficial nos atuais livros "didáticos" de física, dissociado da forte motivação que existia na última década do século XIX, quando estava em curso uma revolução das máquinas movidas à corrente elétrica, precursoras da modernidade de um novo século.

Palavras-chave: pilha de Volta, história da ciência, ensino de física.

A brief history of Volta's achievements

Alessandro Volta started to do active researches on electricity applying after 1770. In 1775 he invented the electrophorus by charging a machine at a distance the phenomenon of applying influence (Figure 1 - Ganot, 1887), already observed by Gray in 1730 and studied by Du Fay in 1773. This invention took place in Como. He moved to the University of Pavia in 1779 and two years later he started to study the conclusions of Galvani about animal's electricity in the classical experiments of the frog's legs (Figure 2 - Ganot, 1887). Besides the movement (contraction) of the legs, he discovered that other effects could be observed, such as the luminosity of the frog's eyes when the edge of a metal rod touched its mouth and another different metal rod that touched the eyes of the animal. The same effect could be perceived when two different coins (gold and silver) were placed against the tongue. A bitter taste was produced when two coins were linked by a metal wire.

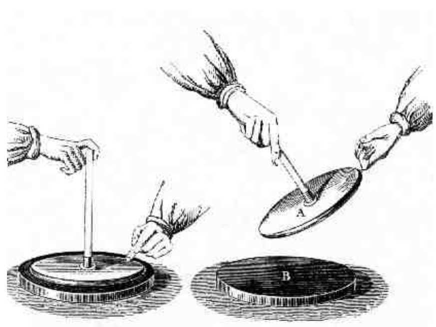


Figure 1. Electrophorus

These experiments led Volta to way an opposite to the one adopted by Galvani. According to Volta, the effects produced were not due to a mysterious property of the animal's nerve, but to the contact with two bodies made of different metals.

The frog's legs were not the cause of electrical effects and the wire did not have the simple function of a discharging element (as the superior part of a Leyden jar). If there was such a thing as a mysterious animal electricity, the legs would also contract when touched by one metal. However, this fact never occurred. Volta conducted experiments by using the edges of a metal rod at different temperatures. Contractions were violent. The phenomenon of thermoelectricity was not sufficiently explored by Volta. When the edges of a metal rod were at the same temperature, no contraction was observed.

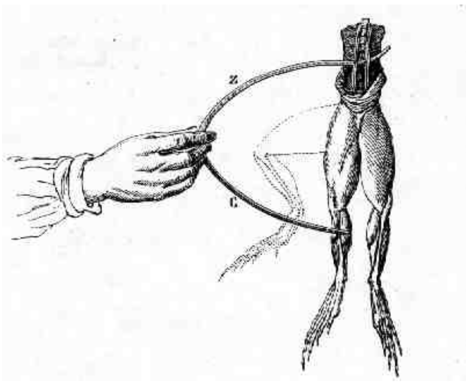


Figure 2. Classical experiment of the frog's legs

If there weren't any animal electricity, it would be necessary to explain how an electrical current was formed. Volta imagined (and constructed) an apparatus to allow the conduction of the electrical fluid. He imagined that when dry (first class) and wet conductors (second class) were linked by a wire, they would awaken the electrical fluid and impressed upon it a kind of impetus. This is the original idea that stood at the back of the construction of Volta's battery.

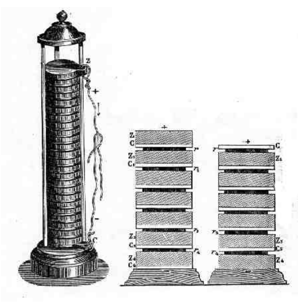


Figure 3. Volta's battery

His new apparatus consisted of a column of zinc and silver and flannels soaked with brine (Figure 3 - Ganot, 1887). The arrangement was repeated till several stages were obtained. Another invention related to batteries was the "garland of glasses". It consisted of containers filled with a kind of vinegar or acid diluted with water, a chain linked together by means of several metallic rods, whose edges ended in small plates of different metals (zinc and copper plates, for example). The zinc and the copper plates were immersed in two different glasses forming a couple of zinc and copper plates inside each. Similarly to a battery, terminals were of different metals.

Electrical discharges obtained by Volta were of low intensity if compared to those obtained by the Leyden jar. However, discharges originated in the battery had a long duration and thus opened the possibility of using electricity in motion to revolutionize the new century.

Physics textbooks at the end of 19th century: the treatment given to batteries

It is very interesting and curious to open a physics textbook published at the end of the 19th century. The treatment given in a century of changes in all the fields of science and society may be analyzed. We can observe a great concern with technical teaching without forgetting the original ideas that were landmarks in the history of science.

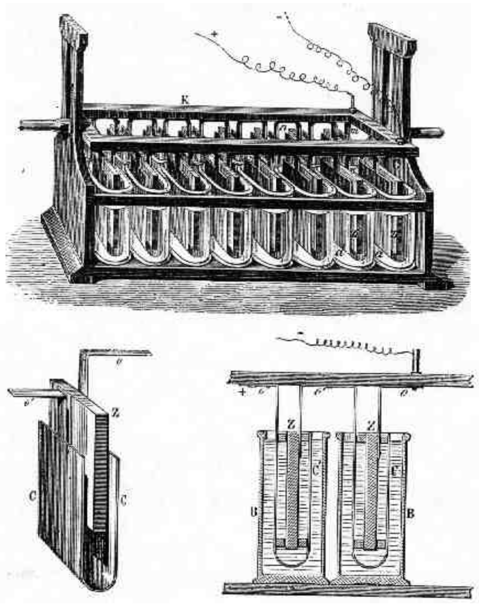
When we open, for example, *Traitè Elementaire de Physique* (Ganot, 1887), published in 1887, Volta's works are mentioned after a long explanation of the fundamentals of static electricity. In this section good and bad conductors of electricity, Coulomb's law, electrical force and electrical field are analyzed. Electroscopes and electrical pendulums are used to describe an extensive series of electrical phenomena.

In the chapter on electrical machines (Ramsden, Bertsch, Carré, Holtz), Volta's electrophorus is shown, characterized as the simplest example of electrical machine based upon the phenomenon of influence.

A long discussion about the condensation of electricity is made, basically using the principles derived from Volta's electrophorus (Figure 1) and Leyden jar. The chapters are full of high quality drawings, very much like modern photographs. Only after this long explanation a new chapter entitled "Electricity in the dynamic state" starts with an introduction to the fundamentals of Volta's battery (Figure 3).

Contradictions between Volta and Galvani are described in this chapter. After this historical section, the modifications of Volta's battery (Figures 4 - Ganot, 1887), or rather, Cruikshank's and Wollaston's and dry batteries like Zamboni's (Figure 5 - Ganot, 1887) are also presented.

This chapter is then partly interrupted to introduce the notions of electrical conductivity represented by Pouillet's and Ohm's law. Descriptions of the modifications in Volta's battery using copper in sulfuric acid ($SO_4Cu + H = Cu + SO_3HO$), Bunsen battery (Figures 6 - Ganot, 1904), Leclanché's battery, Platé battery and many others.



Figures 4. Cruikshank's and Wollaston's batteries

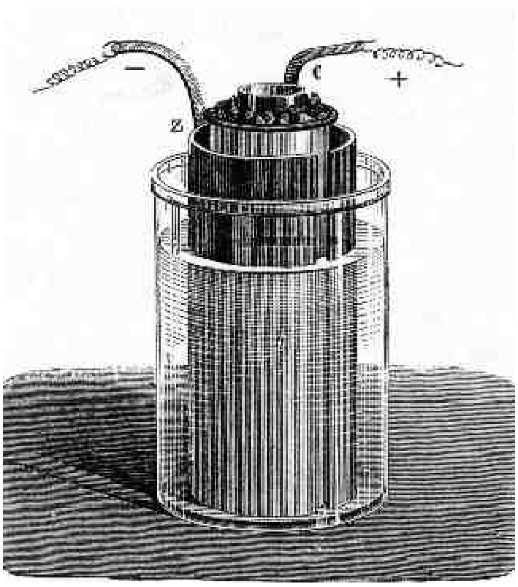
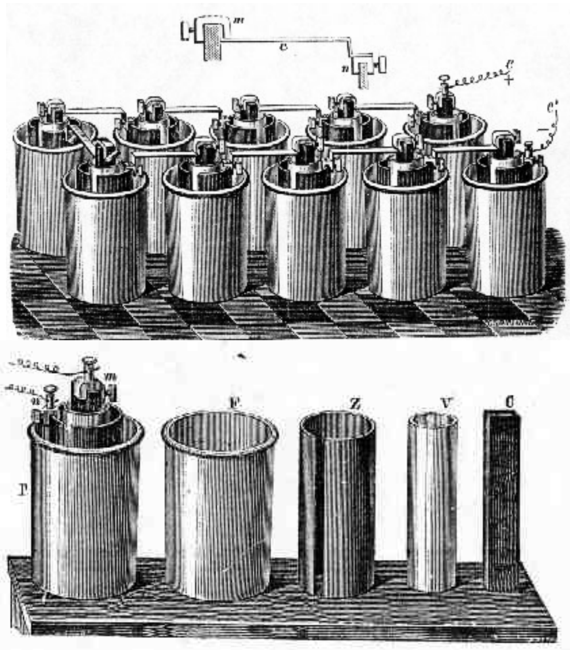


Figure 5. Zamboni's battery

The phenomena of electrolysis and electrochemistry in general, the displacement of currents, the effects of currents in the neighborhood of wires, solenoids, and others are extensively analyzed. Thermoelectricity and, more deeply, electrodynamic induction (Figure 7 - Ganot, 1904) are discussed. The final part ends with practical applications of voltaic induction: Ruhmkorff's bobbin, Foucault's quicksilver switch and such machines as Clarke's and Gramme's. The telegraph and the telephone are discussed at the end of the *traite*.



Figures 6. Bunsen battery

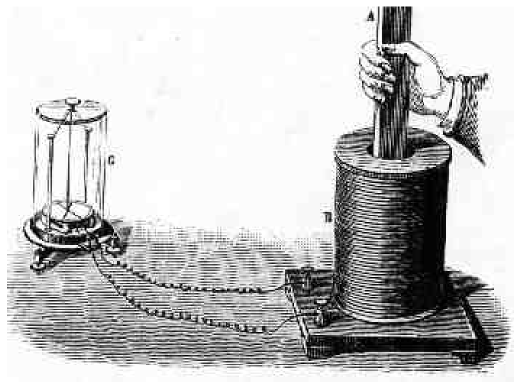


Figure 7. Electrodynamic induction

Petit Cours de Physique (Ganot, 1904), published seven years later, follows the same scheme of *Traitè,* although albeit with a very important difference. Electrostatics is studied in a chapter following that on Electrodynamics. Cathode and X-rays are discussed at the end of the chapter on electrostatics, and thus notions of modern physics are introduced. The *Petit* is more condensed than the *Traitè*.

In *Nozioni di Fisica* (Amaduzzi, 1930), published almost thirty years after the last book described above, explanations are more condensed than those in *Petit Cours*, and even more than the ones in *Traitè*. Electrostatics and electrodynamics are placed together giving attention to the telegraph and wireless telephone.

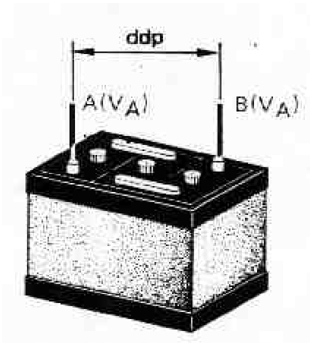


Figure 8. Battery or black box?

Today's physics textbooks and the forgotten past: the black boxes of science

At present, physics elementary textbooks don't transmit the reader a proper idea of the history of science. The achievements of Galvani, Volta and others were forgotten and batteries are first mentioned after long discussions on electrostatics, electrical force, electrical field, electrical work and potential, Coulomb's law etc. It is only after that notions on electrical current are introduced. In modern books illustrations are frequently very poor and extremely distant from those of their ancestors of a hundred years ago. In a popular textbook (Ramalho *et al.*, 1977), used in some high schools in Brazil, an illustration of the battery as a black box (a car's battery - Figure 8, Ramalho *et al.,* 1977) may be seen. The things that exist inside the box are inadequate and inaccessible to the students' desire to construct knowledge. Such bad teaching is responsible for the presentation of technological products (television sets, computers, microwave ovens) considered as a set of incomprehensible physical processes disconnected from basic notions of Physics.

Volta´s battery is known to have been assimilated as a product consecrated by our technological culture. However, the past and mainly the nature of scientific discoveries have been forgotten and this amounts to condemning the future to Plato's cave in which shadows are not distinguished from the light. Our cave is a strange black box and, paradoxically, we find ourselves outside it. A perverse science teaching puts shadows systematically where first there was light and knowledge as a construction.

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