Historical physics instruments - engineering education potentialities

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Abstract

In this workshop we will present some arguments to revisit historical instruments that have potentialities in the physics teaching of engineering education.

We will seek to inform and question the importance of different instruments, identify statutes historically assumed and analyze one or two cases where developments paved the way for issues such as the accuracy of measurements or the identification of properties of matter, topics of interest in the physics teaching context.

Keywords: Historical instruments; Physics teaching; Technology; Educational potentialities.

Summary

Old scientific instruments still enable a wide range of study for the historian of science, to the extent that in them converge knowledge and scientific / technical practices, revealing the context in which they have been designed and used, and on their protagonists.

Frequently they also allow a clearer demonstration of the concept(s) and/or property(ies) when compared with the modern black boxes.

They give evidence of the evolutionary path of experimental science in its own, and are important testimonies of the scientific culture in which we are immersed.

All these aspects are of great educative interest.

Introduction – Historical contextualization aspects

Modern science came up with a new paradigm: that it is possible to know and master nature through experimentation and through the use of instruments designed in purpose, combined with a possible mathematization of the observed phenomena.

The new scientific practice makes use of "objectives, specific languages and methods" that determine "attitudes, expectations and behaviors in the scientific community members themselves". For accomplishing this it makes use "of instruments that will allow a controlled experimental observation as one of the conditions for validation." However, before relying on the information given by these "artificial means", there was need to face them with skepticism until "the device could be accurately and thoroughly tested".(1)

Since the sixteenth-seventeenth centuries the use of scientific instruments formed the basis for legitimacy of research on natural phenomena, enabling the experimental repetition everywhere which led to the "acceptance of modern science as the cognitive device inherent to the culture of modernity."(2)

The status conferred to instruments differed over the centuries since the modern age. To philosophical instruments were assigned a greater importance compared to mathematical and navigation instruments, as those should illustrate the truths of nature. Their use was intended for the philosophers. The practitioners, cartographers, engineers, astronomers, navigators would resort to the other type in their practical tasks of measurement.

The emergence of the term 'scientific instrument' was studied by Deborah Warner, who dated the appearance of the English designation in the nineteenth century, motivated in part by commercial interests.(3, 4) Many of the objects that are now described as scientific instruments were produced and designated in the seventeen and eighteenth centuries, as 'mathematical', 'optical' and 'philosophical' instruments. To some extent these distinctions were related to instrumentalists' corporations, reflecting some specialized manufacturing practices from the standpoint of business and marketing. These designations also evolved over time.(2)

During the nineteenth and twentieth centuries, terms like 'science' and 'scientific instruments' were gradually and increasingly been used in contexts in which expressions like 'natural philosophy', 'experimental philosophy', and 'philosophical instruments' would have prevailed in earlier periods. The new terminology has been slowly adopted and replaced, while a set of objects described as scientific instruments also developed.

Maurice Daumas, historian of scientific instruments, was one of the first authors to emphasize the importance of natural philosophers and their artisans in developing a new culture where scientific instruments began operating.(5)

The nineteenth century witnessed, in a line clearly admiring and believing in progress, the importance of giving particular attention to science areas, in order to provide a new and solid education.

The attention to experimentation led to the acquisition of instruments whose function was to illustrate the phenomena or the start to the measurement techniques made possible by them. The reference to didactic/teaching instruments points out to those considered as “designed to show various physical effects and to assist the exposure of a scientific issue.”(6) It often indicates they needed to be robust, of appreciable size, and made of good materials. Recalling Ganguillem, and on the diffusion of new scientific concepts, he held the nineteenth century as the popularization of science century.(7)

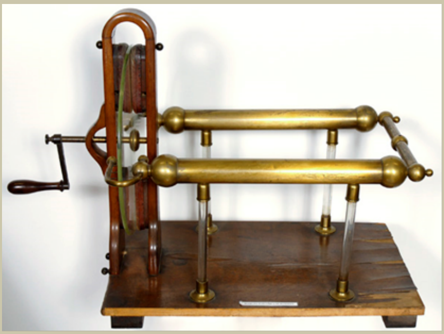
The action of a didactic instrument would not always be a proof for a scientific assertion just its illustration. But diversely, sometimes the important was to practice, to develop competencies of manipulation, measurement, and precision. The focus was using the instruments, put them showing some phenomena and still obtain, in some cases, the possible quantification to verify the subjacent physical law(s). It was then necessary to know the instrument through its description and learn on its manipulation in order to measure and obtain the values that would enable a deeper knowledge of the already established laws. Comparing some of the instruments existent in schools and some old instrument catalogues, one verifies the similitude between more recent instruments[1] (end of nineteenth/ beginning of twentieth century) and some of those used in the seventeenth-eighteenth centuries to illustrate phenomena/similar physical concepts, for instance the Ingenhouz apparatus to study thermal conductivity.[2] Other instruments illustrate or materialize recent discoveries or concepts, and do not possess a former correspondent and/or evolved to the discovery/ materialization of previously unimagined phenomena.

To meet them today is to revisit/ unveil their ‘lives’ from the objectives that led to their construction, to the producing processes, their inventors/ makers, to their circulation, finding them an educative meaning, old or new, when we look at them under the twenty-first century light or simply when we observe them, just leaving a sensitive approach, following a recent proposal by Arnold and Söderqvist.(8)

In a previous work dealing with scientific instruments, we tried a possible meaningful route connecting Oerstedt’s needle with the Schweigger’s multiplier, the Bourbouze galvanometer, the tangent galvanometer, Desprez’s galvanometer, the one by Weber and by Thompson until the demonstrative galvanometer, the amperimeter and the voltmeter.(10) At the time we also tried the 3D replication using modern communication technologies in order to a better access to those old instruments, completing it with some ‘history’ and ‘functioning’ information. At present we illustrate some other possibilities from the ephemeral production of a spark with a friction electric machine to the Volta pile and then to the necessity of conceiving and measure the current and some of the instrumental achievements (Case 1).

Case 1 – Electric current - From its production to its measurement

Producing 'electricity'…



Figs. 1 and 2 – Ramsden's electrical machine and Volta pile - http://baudafisica.web.ua.pt

but … there exists something else (Fig. 3)

Fig. 3. Oerstedt needle http://baudafisica.web.ua.pt

Studying how currents act on each other… with an Ampère's table (Fig. 4) and amplifying the magnetic field with a Schweigger's multiplier

Fig. 4 – Ampère's table – http://baudafisica.web.ua.pt

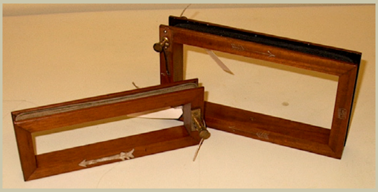


Fig. 5 – Schweigger's multiplier (11)

Fig. 6 – Nobili's galvanometer (11)

Detecting and measuring currents - Galvanometers developments

Two periods can be distinguished in the process of developing instruments able to detect and then measure the intensity of electric current. From 1820, we find out the so called "free 'magnet' instruments" that gave rise to the suspended magnet galvanometers. At first it was necessary to amplify the magnetic field created and that was possible with the Schweigger's multiplier to which followed some galvanoscopes as those proposed by Nobili (1826) and by Poggendorff (1826).

But difficulties arrived in quantifying the intensity of the electric current by deviation of the magnetic needle. Nobili's proposal included an astatic needles system so that the instrument is sensible just to the current magnetic field (Fig.6).

Poggendorf's proposal included an optical ballistic system in a mirror galvanometer to obtain a better measurement of the current intensity (Fig. 7).

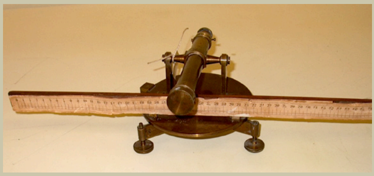


Fig. 7 - Optical ballistic system (11)

However there were difficulties in quantifying the intensity of the electric current by deviation of the magnetic needle, and some modifications were proposed as in the case of Pouillet's tangent (& sinus) galvanometer (1837), Weber's galvanometer (1842) or Thompson's (1851).

Thompson's galvanometer was improved with two smaller magnetic needles inside two coils; a torsion string; it possessed a quicker damping and an incurved magnetic bar to diminish the Earth's magnetic effect.

From 1851 on, some other perfection were introduced and some didactical instruments appeared as well of which Bourbouze's galvanometer was very common and also the projection galvanometer that was intended for projecting the detected current in the Nobili galvanometer to a larger audience.

Fig. 8 – Thompson's galvanometer (11)

Fig. 10 – Bourbouze's galvanometer (11)

Fig.11 - Projection galvanometer (7, 11)

Nevertheless, they met neither the electrical industry requirements, nor those of the developing research. From 1871 on a different propose emerged – the ‘free’ current instruments or suspended coil galvanometers to which succeeded later the capillary galvanometer and since 1881 the amperimeters and voltmeters.

Fig. 12 – Deprez D’Arsonval’s galvanometer – A suspended coil galvanometer (11)

Fig. 13 – Discharge tubes -http://baudafisica.web.ua.pt

The electrical discharges in rarefied ampoules gave rise to one of the most fascinating adventures in the history of physics and chemistry, while at the beginning nothing could be foreseen.

From discharges in the 'fulminant tube' and in the 'electric egg' ensued discharges in different and embellished forms of tubes with different gases at low pressures to which was possible to count on glassware craftsmen capable of producing such wrappers. For quite some time, the discharges were produced just for the visual effects. Geissler's (1814-1879) invention using glass tubes with two electrodes for low pressure gas discharges came to give new impetus to this type of experience.[3] The use of more efficient vacuum machines, made it possible to achieve better degrees of rarefaction inside the tubes / ampoules. Since then it was resorted to something more elaborate than the use of the electrostatic machine, using the so-called 'Magnetic motor' for producing the discharge.[4]

In a few decades we follow the discoveries of cathode rays, and the impressive proposals towards the structure of matter.(9) (Case 2)

Case 2 - Identifying properties of matter

From the 'electric egg' to the discharge ampoules or from spectacle to the interior of atom

Producing 'electricity'… for spectacular effects (fig. 13) … to J.J. Thomson's (1856–1940) cathode ray tube and the discovery of a negatively charged corpuscle not yet identified then as the electron (1897). We find easily such a tube in our secondary schools (Fig. 14).

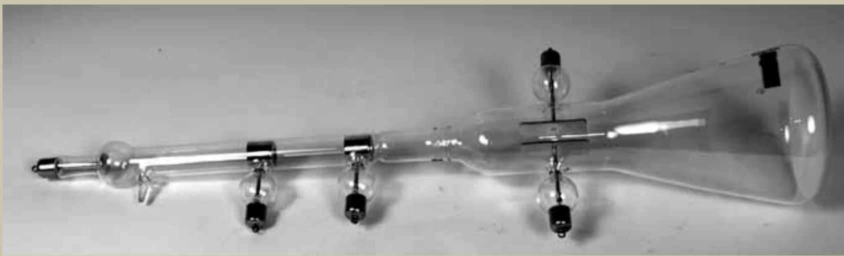


Fig. 14 – Cathode ray tube - http://baudafisica.web.ua.pt

At the same time, the development of electronic television systems was also connected with the development of the cathode ray tube. Karl Ferdinand Braun (1850-1918) in the same year proposed a cathode ray tube as a picture tube, although it was needed some decades until the commercial cathode ray tube for television was in the market place (in the 1930s) (Fig.15).

Fig. 15 – Brown's tube - http://baudafisica.web.ua.pt

When revisiting some of these old instruments, we find frequently the easiness to know what is happening inside instead of the black boxes that the modern instruments represent.

Concluding remarks

Historical physics instruments still have educational potentialities in the physics teaching

They were initially conceived to present the concepts in a more direct perception of what was going to happen

Engineering and teaching education may benefit from analyzing them in their potentialities to unveil the mysteries of the phenomena, elucidating on the experimental science trail assumed, or as icons of a given fundamental discovery

At the same time helps to educate students on the preservation of science material culture in which we are immersed in our daily life.

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Endnotes

1 - In the project 'Baú da Física e Química – Old Physics and Chemistry instruments of Portuguese secondary schools', we have studied several of those instruments still existente in many schools - <http://baudafisica.web.ua.pt>

2 - See different proposals for the Ingenhouz's apparatus at <http://baudafisica.web.ua.pt>

3 - See <http://baudafisica.web.ua.pt> – discharge tubes.

4 - See <http://baudafisica.web.ua.pt> – motor for discharge tubes.