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Paola y Bertucci

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Coulomb's torsions balance and the replication of historical experiments

As it is well known, in 1785 Charles Augustin de Coulomb published a memoir in which he described an experiment carried out with a torsion balance. The result of that experiment, according to the author, was that the electrical force between two charged bodies is proportional to the inverse square of their distance. In his paper, Coulomb described the apparatus and reported the result of three measurements as experimental proof of the law.

About two centuries later, in 1992, Peter Heering, at the Department of Physics of the University of Oldenburgh, in Germany, tried to replicate Coulomb's experiment. He built a torsion balance as similar as possible to that used by Coulomb and tried to follow the description of the experiment given in the celebrated 1785 memoir.

In replicating the experiment, however, several unexpected problems challenged Heering's attempt.

Apart from the obvious difficulty of making the balance identical to that of Coulomb (due to the unavailability of original materials), the experimental procedure itself appeared much more complex than could be inferred from Coulomb's report.

The main feature of the balance - its sensitiveness - turns out to be its weak point: as soon as the balls are charged by means of an external conductor, the handle starts moving because of the mechanical impulse communicated by the contact. Moreover, if the communicated charge is too strong the thread breaks very easily and external vibrations may cause the handle to move - thus perturbing the measurements. The body of the experimenter results to be another (unavoidable) source of electrostatic perturbation.

Heering's conclusion is that without an anachronistic Faraday's cage it is impossible to obtain results that fit the inverse square law.

Coulomb's assumption of the same law as an experimental result of just three measurements taken with the torsion balance appears therefore even more intriguing. Advantages and limits of historical replication are analysed in *Restaging Coulomb*, a volume edited by C. Blondel and M. Dorries, published at Florence in 1994. Questions on the relationship

between the difficulties encountered today and those faced by past experimenters are raised throughout the volume, although the replication of Coulomb's experiments results to be the starting point for further historical questions.

A common line of the several contributions to the book is that the replication of historical experiments gives insight on the "tacit knowledge" underlying them, a knowledge which cannot be inferred either from Coulomb's report or from that of any other experimenter of the late eighteenth-century.

By "restaging" Coulomb's experiment Heering turns to the analysis of the refutation of Coulomb's result by early nineteenth-century German physicists. The reactions of other European experimenters that objected Coulomb's results (such as Volta in Italy and Deluc in England) are the subject of other contributions to the book.

Controversial as it might well have been, Coulomb's balance became the symbol of the inverse square law for the electrostatic force. It was ever-present in nineteenth-century teaching laboratories and it was a commercial success. Instrument-makers included it in their catalogues throughout the century.

In the Museum of the History of Science, Oxford, there is a small torsion balance, made in 1845 by Watkins & Hills, instrument-makers in London. The balance was advertised by the makers as "an electrometer that measures very small quantities of electricity and yields accurate estimates of the attractive and repulsive force between charged bodies of given superficies".

With its 14 inches in height and 5 inches in diameter, however, its advertised accuracy appears quite "suspect", especially if one considers that the balance used by Coulomb in his famous experiment measured 12 inches in diameter and 36 inches in height.

Watkins & Hills, in the label that accompanies the advertisement of the balance in their catalogue of instruments, make a passing remark about "the requisite precautions" that are to be taken in measuring the electric force with the instrument, but what this exactly means is left to the skill and practical knowledge of the experimenter.

The adjective "accurate" became inextricably linked to Coulomb's balance. Besides Watkins & Hills, other instrument-makers in London exploited the rhetoric on accuracy associated to the torsion balance. Clarke as an example, described it in his catalogue (1850) as an "accurate instrument for measuring small quantities of electricity", while in Negretti & Zambra's 1878 catalogue we read:

"This instrument measures very minute quantities of electricity, and with careful manipulation, will give accurate values of the attractive and repulsive force of free electricity communicated to any body of known area".

The price of the balance made by Watkin & Hills was 2 pounds 2 schellings: it was one of the most expensive electrostatic devices, having the same price of a 6-inch plate electrical machine but costing less than half the price of a "model of a church with a lofty spire" which "falls to pieces when the electricity strikes the spire"!

In none of the catalogues of the London instrument-makers the size of the apparatus is mentioned, while in the same period new designs of the torsion balance were made. In nineteenth-century French textbooks on electricity Coulomb's words are quoted in the description of his experiment while in the English ones it is quite common to find a rough translation of Coulomb's original paper.

How often a torsion balance was actually used for a replication of Coulomb's experiment is difficult to determine. In nineteenth-century French textbooks on electricity, Coulomb's words are quoted in the description of his experiment and in the English ones it is quite common to find a rough translation of Coulomb's original paper.

Those who opposed Coulomb's results (the already mentioned Volta and Deluc) belonged to a different experimental tradition, not linked to what may be called the "torsion technique". Rather than the torsion balance itself, it seems that it was the technique of measuring forces by means of the angle of torsion of a thread that proved itself successful.

At the time of the publication of his memoir on the law for the electrostatic force, Coulomb had already gained his authority as a skilled experimenter thanks to his use of a torsion balance in magnetic measurements. The same technique was used throughout the nineteenth-century laboratories in other kinds of electrical apparatus (galvanometers and Thomson's quadrant electrometer are best-known examples). Its sensitiveness was exploited in electrical precision measurements as well as in the measurements of magnetic and gravitational forces.

The popularity of the balance as an ornament in the nineteenth-century was certainly due to Coulomb's established authority, but also to the promise of the future developments it evoked.

Paola Bertucci