Faraday-Neuman-Lenz Law of Induction or Zantedeschi-Neuman-Lenz Law of Induction?

Stefano Selleri

DINFO – University of Florence
via di S. Marta 3, 50139, Florence, Italy
E-mail: stefano.selleri@unifi.it

A recent, extremely nice and entertaining book [1] (Figure 1a) cited Francesco Zantedeschi [Dolcè, Verona, Italy, August 18, 1797 – Padua, Italy, March 29, 1873] (Figure 1b) as a precursor of Michael Faraday [Southwark, London, UK, September 22 1791 – Hampton Court, Middlesex, UK, August 25, 1867] in discovering the law of magnetic induction in 1829, two years before Faraday himself. This is information that was reported elsewhere [2, 3], as well as on the Internet, most notably on Wikipedia [4]. However, other texts were more cautious [5, 6] or completely avoided citing Zantedeschi [7].

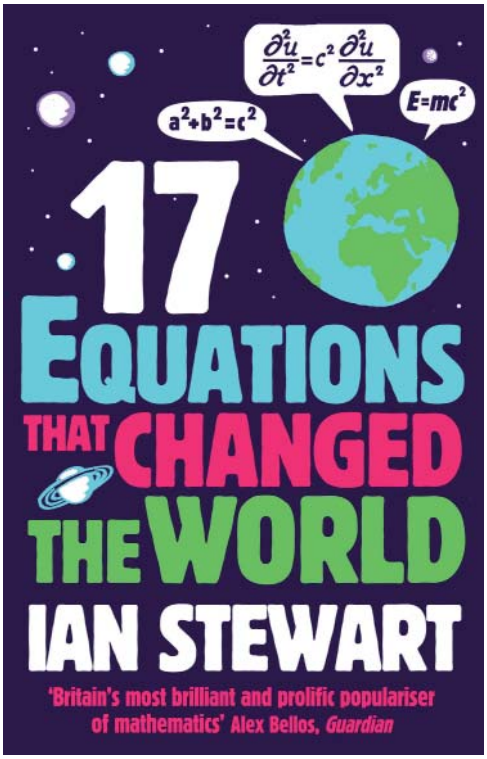

Figure 1a. The cover of the book by Ian Stewart.

Figure 1b. Fancesco Zantedeschi.

It interesting to understand what Zantedeschi really did, and why he is credited. Information was sought in the original papers, which are mostly in Italian and hence of difficult access to our international community.

In 1820, Hans Christian Ørsted [Rudkøbing, Benmark, August 14, 1777 – Copenhagen, Denmark, March 9, 1851] discovered that an electric current could deviate the magnetic needle of a compass. This was a landmark in the study of electricity and magnetism, since it proved a connection between the two. Once the magnetic effects of a current were established, the electric effects of a magnet were highly expected.

In 1929, an obscure Italian Abbot, Francesco Zantedeschi, published a short communication [8] on the chemical effects of magnets. As a *post scriptum*, he added the few lines reported in Figure 2, where he claimed to have obtained such electric effects. He then published a French version of the same communication [9].

PS. Aggiungo in forma di appendice all' esperienza 1.ª e 2.ª della 1.ª parte un altro fatto da me osservato più

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volte in questo mese, il quale non dovrà almeno riuscire discaro, perchè tende quale anello ad unire i diversi fatti elettro-magnetici colla loro sorgente. Ho preso una calamita fatta a ferro di cavallo del peso circa di una libbra francese, che potea sostenere un peso di circa 4 a 5 libbre, ed attorno a ciascun polo ho avvolto strettamente un filo sottilissimo di rame in modo che, collocata la calamita ad una distanza di 15 a 16 piedi parigini, potea sperimentare sulle estremità separate di detti fili. Ora preso un moltiplicatore a due calamite, ho ai capi del filo del medesimo (che è di rame circondato di seta) attaccate due piastrine di rame ben lucide, colle quali, mediante due verghe di legno per non alterare la temperatura, congiunsi i fili che abbiam detto essere in comunicazione coi poli della calamita, ho veduto che l'ago magnetico sviasi dalla naturale sua posizione declinando verso l'oriente il polo al disopra del quale entra l'azione magnetica del polo nord, e verso l'occidente, se questa entra al disotto di esso, non altrimenti di quello che avviene coll'elettrico ordinario. La declinazione era da 8° a 10°. Mi pare che questo fenomeno non si possa ascrivere alla facoltà elettromotrice, perchè il rame trovasi fra due forze eguali e contrarie. E dato anche, come ho esperimentato nei liquidi, che le correnti elettriche, qualunque sia la loro direzione, non sviinsi, come la luce e il calorico raggiante, non dovrebbe il moltiplicatore dare alcun segno, come è chiaro. Pare dunque che tale effetto debba ascriversi al magnetico, e però che il polo nord equivalga al polo zinco d'un apparato voltiano. Io spero che altri esperimentando con moltiplicatori più delicati, come col siderescopio di Lebaillif, potrà ottenere effetti maggiori che udirò quando che sia con piacere.

Pavia, 27 marzo 1829.

Figure 2a. The post scriptum in [8] where Zantedeschi wrote about his experiment on the electric effects of a magnet.

P.S. I add as an appendix to experiences n. 1 and 2 of part 1 another phenomenon I observed several times this month, which should not sound unlikely, because a, as a ring, it unite various electro-magnetic facts with its source. I took a horseshoe magnet, of about 1 French pound of weight, strong so as to lift a weight of about 4 or 5 pounds, and around each pole I tightly winded a very thin copper wire so that, with the magnet 15 to 16 French foot away, I could experiment with the open ended of these wires. Now, taken a two needle galvanometer, I connected to the its wires (which are in copper wrapped in silk) two shiny copper plates, which I moved with wooden sticks, not to alter their temperature, and connected them with the wires which we said winded around the magnet. I saw the galvanometer needle move from its rest position, going east the point of the needle above which the action of the north pole of the magnet enters, going west if the action enters from below, analogously as for ordinary electricity. The deviation was from 8° to 10°. I believe that this phenomenon cannot be due to electromotive force, since the copper is placed between two opposite, equal, forces. Furthermore, as I noticed in liquids, electrical currents, notwithstanding their direction, do not deviate, as it happens for light and caloric rays, the galvanometer should give no sign, as it is clear. It hence looks like that such a phenomenon is to be ascribed to magnetism, such that north pole is equivalent to the zinc pole of a voltaic pile. I hope that further experiments, with more sensible galvanometers, as Lebaillif galvanometer, could show larger effects, of which I will hear news with delight.
Pavia, March 27, 1829

Figure 2b. A translation by the author of the post scriptum in Figure 2a.

Zantedeschi wound coils of copper wire around the poles of a magnet. He then connected these wires with a galvanometer (a two-needle multiplier, as Nobili's astatic galvanometer with a multiplication coil was called at that time), and affirmed seeing a deviation in the magnetic needle (Figure 3). From both texts [8, 9] we can understand that the magnet had tight windings of copper, and that the wires forming the coils extended far from the magnet, so that their free ends were 15 to 16 French feet (about 5 m) from the magnet itself. It was quite unlikely that such an experiment would have led to the described effect. We know now that the electric effect is bound to a *variation* of the magnetic-induction flux in a coil. Zantedeschi's tightly wound coils were not a possible source of such a variation, and the transient nature of the phenomenon was not described at all by Zantedeschi. It is anyway important to stress that something was longed for and awaited. We therefore can think that Zantedeschi might have genuinely believed to have seen an effect. Indeed, Michael Faraday himself had already made some early experiments [10], which failed due to the low sensitivity of his galvanometer.

In 1931, Faraday set up a more-refined experiment. He understood that the magnetic field generated by a coil of currents does indeed induce a current in a close but electrically disconnected coil, *but only at the transients*, that is, when the current in the primary coil passes from zero to a steady-state value and – still extremely important – an opposite current is generated when the primary coil excitation ends. The details of the communication of this discovery are interesting. Other researchers, among whom was Leopoldo Nobili, duplicated these experiments very early, and much excitation ran in the Italian journals on priority. In particular, Giuseppe Gazzeri [Florence, Italy, November 9, 1771 – Florence, Italy, June 22, 1847], in the pages of the *Antologia Fiorentina* [11], explicitly cited Zantedeschi's 1829 work [8] in a note, saying:

> Concerning preliminary studies, we warn the reader that prof. Zantedeschi published in March 1829 (*Biblioteca Italiana* vol. 53, p. 393) a result by him obtained winding a coil around the poles of a magnet, connecting the wires to a galvanometer. His result was the deviation of the needle by 8°-10°. Apparently, it seems the discovery by Faraday, but it cannot be, because in his set-up the currents discovered by Faraday cannot exist [11, p. 174 footnote].

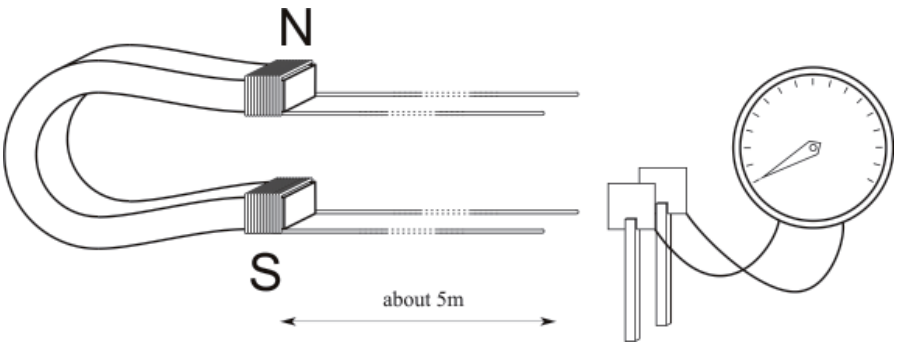

Figure 3. Zantedeschi's experiment, according to his description in [8].

Of course, this enraged Zantedeschi, who bitterly replied on the same *Antologia* pages [11], stating that,

> What is the difference between the Englishman [Faraday] experiments and mine? I coiled the wire on the magnet, while he moved the coils toward the magnet. On anything else and on the fundamental fact [emphasis by Zantedeschi] I see no differences [11, p. 232].

He then claims that the *post scriptum* was too short to explain every detail of his experiment, that he placed and removed an iron bar to the magnet as Nobili did [13, p. 233], and that the effect was transient. Zantedeschi continued claiming for a long time [14] with even more strong words against Faraday:

> When it is said that I connected the coils to a galvanometer "in the usual way" it is unjust. Who, before me, imagined to connect a galvanometer to a coil? Faraday two years later did, and did not mention me. I formally invite Mr. Faraday to break his silence and disrobe himself of the vest of an usurper which he wore up to now on this topic. I wrote letters to him, which never got reply [14, p. 11].

Indeed, Faraday in the end, cites Zantedeschi positively! Zantedeschi, among the other things, experimented with flames, observing a deviation in the flame when a magnet was present. He explained the phenomenon by a diamagnetic effect of hot gasses, and published his observations in an Italian gazette [15]. Faraday had previously affirmed that gasses had no magnetic properties at all. Once Faraday knew about Zantedeschi's results, he experimented again and found that indeed they had magnetic properties [16]. Faraday fully acknowledged Zantedeschi, and added a partial English translation of [15] to his paper.

Yet it is somewhat ironical that, again, Zantedeschi was not the discoverer of the phenomenon he was studying. Another Italian priest, Michele Alberto Bancalari [Chiavari, Genoa, February 20, 1805 – Genoa, August 10, 1864] made the first observation on flame deviations and reported it to the Italian Scientific Assembly in Venice in 1847. No written record by Bancalari stands, only verbal accounts of the sessions [17], which Zantedeschi attended. Yet both Zantedeschi and Faraday correctly cite him.

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