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Foreword by the Associate Editor

In this issue, we host – for the second time – a paper on the Italian-American physicist, Enrico Fermi. The first paper (*IEEE Antennas and Propagation Magazine*, **53**, 3, June 2011, pp. 226-230) was focused on a commemoration of Guglielmo Marconi by Enrico Fermi. The present paper spans a period of the life of Fermi that is not so well known, which he spent at the University of Florence as an Assistant Professor. He also taught at the School of Engineering, to which the three authors of this paper belong. This period is relevant for electronic engineers. In those Florentine years, Enrico Fermi developed and published the Fermi-Dirac statistics. These are fundamental in semiconductor physics, and therefore in modern electronics.

The authors of the paper, beside myself, are probably quite well known to our readers, having authored quite a few contributions to this corner in the past.

Enrico Fermi in Florence

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A Brief Biography (from 1921 to 1926)

Enrico Fermi [Rome, Italy, September 29, 1901 – Chicago, Illinois, USA, November 28, 1954] got his degree in Physics in 1921 at the Scuola Normale Superiore in Pisa, Italy. Among his fellow students, Fermi had Nello Carrara [Florence, Italy, February 19, 1900 – Florence, Italy, June 5, 1993], who introduced the term *microwaves* in scientific literature and with whom the readers of this *Magazine* have a long-term acquaintance [1, 2] (Figure 1). Another personality known to our readers is Gian Antonio Maggi [Milan, Italy, February 19, 1856 – Milan, Italy, July 12, 1937], who was among Fermi's teachers, and to whom was dedicated a former Historical Corner [3].

Just after graduation, Fermi spent a semester at the University of Göttingen, Germany, studying under Max Born, where he met also Werner Heisenberg. He was then in Leiden, The Netherlands, with Paul Ehrenfest, meeting also Hendrik Lorentz and Albert Einstein.

Before becoming the prominent scientist we know, Enrico Fermi came back to Italy, and spent a couple of years in Florence (Figure 2). This is seldom remembered and scarcely documented, yet it is relevant for the electronic community. The only records of this period are in Emilio Segre's book (one of Fermi's students, and himself a Nobel Laureate in Physics in 1959) [5], and in the book by Enrico Fermi's wife, Laura Fermi [6].

Figure 1. A historical photograph taken in the Apuane Alps in 1920: (l-r) Enrico Fermi, Nello Carrara, and Franco Rasetti [Pozzuolo Umbro (Italy), August 10, 1901 – Waremme (Belgium), December 5, 2001] physicist, botanist, and paleontologist. Another rare photograph of young Enrico Fermi with Nello Carrara was published in this *Magazine*'s Historical Corner in [4].

Fermi joined the Arcetri Institute of Physics of the University of Florence. This was directed at that time by Antonio Garbasso [Vercelli, Italy, April 16, 1871 – Florence, Italy, March 14, 1933] (Figure 3), renowned physicist, who studied with H. Hertz in Bonn and H. von Helmholtz in Berlin. He was also an active politician, being Major of Florence from 1920 to 1928, and Senator of the Kingdom of Italy since 1926. Garbasso was indeed more in politics than in science when he called Fermi to Arcetri [7].

In his few years in Florence, Enrico Fermi undertook both educational and research activities, these latter having a huge but somewhat underestimated impact on electronics. These achievements will be briefly detailed in the following.

In 1926, Fermi then applied for a professorship at the "Sapienza" University of Rome. This was one of the first three Chairs for theoretical physics in Italy. It was created at the urging of Professor Orso Mario Corbino [Augusta, Italy, April 30, 1876 – Rome, Italy, January 23, 1937] (Figure 4), Chair of Experimental Physics, Director of the Institute of Physics, and member of Benito Mussolini's cabinet. Corbino then helped Fermi in recruiting his new team, among others: Edoardo Amaldi, Bruno Pontecorvo, Ettore Majorana, Emilio Segrè, and Franco Rasetti. These were soon known as the "Via Panisperna boys," after the street where the Institute of Physics was located (Figure 5).

Educational Activities in Florence

Enrico Fermi taught Mechanics (*Meccanica Razionale*), at the School of Engineering and at the Faculty of Sciences, and Mathematical Physics, at the Faculty of Sciences, as reported in several documents of the University of Florence. The course of mechanics lessons were picked up by two of Fermi's students. Their handwritten notes of the course *Meccanica Razionale* were printed [9]. A rare copy of this book is conserved at Temple University (Philadelphia, Pennsylvania, USA) (Figure 6).

Even more interesting for the reader are the lectures on Electrodynamics Fermi gave in the same period, within the Mathematical Physics, the notes of which were gathered as a manuscript, available in three copies. The first copy, of reduced length, kept in Pisa, was probably not written by Fermi himself, as the many citations to other of Fermi's works suggests [7]. It is probably the latest of the three versions. A second copy, much

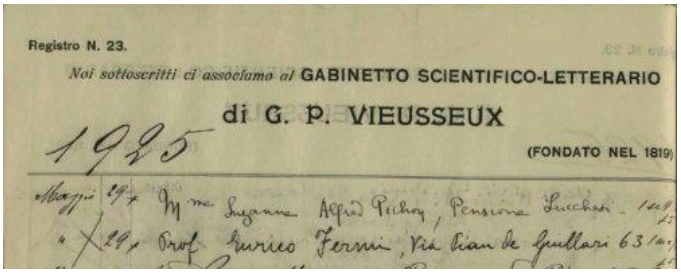


Figure 2a. Enrico Fermi's signature in the Member's book of the *Gabinetto Scientifico-Letterario G. P. Vieusseux,* a very important cultural association in Florence, founded at the beginning of the XIX century. Next to the signature there is Fermi's home address in Florence, reading "Via Pian de Giullari 63/a." The address is very close to the house of Galileo Galilei at Arcetri.

Figure 2b. The house of Galileo Galilei at Arcetri, which now belongs to the University of Florence.

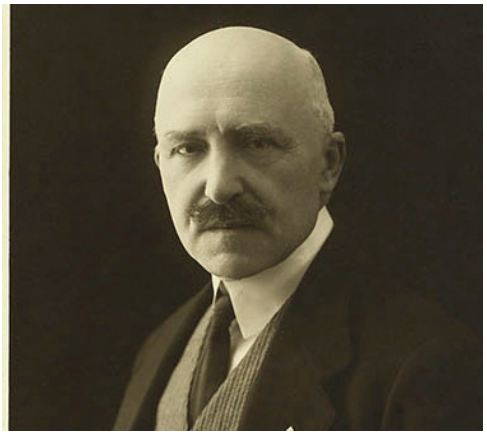
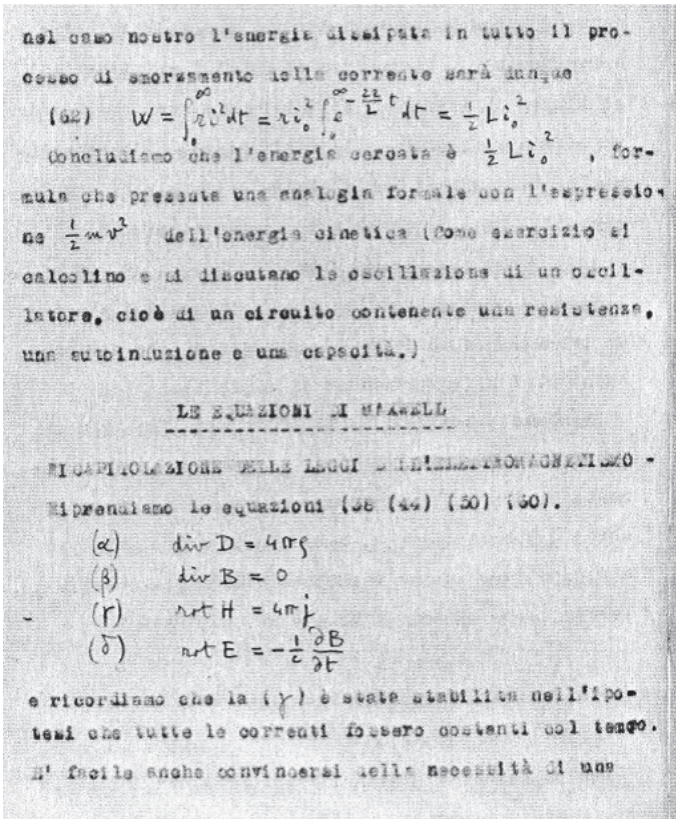


Figure 3. Antonio Garbasso, Director of the Arcetri Institute of Physics, about 1925.

Figure 4. Orso Mario Corbino, Chair of Experimental Physics at the "Sapienza" University of Rome, when Enrico Fermi won the Chair of Theoretical Physics.

Figure 5. The Institute of Physics on Via Panisperna, Rome.

Figure 6. The front cover of the lesson notes of the Mechanics (*Meccanica Razionale*) course of Enrico Fermi, at the School of Engineering of the University of Florence, taken by the students B. Bonanni and P. Pasca [9] [courtesy of Temple University (Philadelphia, Pennsylvania, USA)].


nel caso nostro l'energia dissipata in tutto il processo di smorzamento della corrente sarà dunque

(62) $W = \int_0^\infty r i^2 dt = r i_0^2 \int_0^\infty e^{-\frac{2t}{L}t} dt = \frac{1}{2} L i_0^2$

Concludiamo che l'energia cercata è $\frac{1}{2} L i_0^2$, formula che presenta una analogia formale con l'espressione $\frac{1}{2} m v^2$ dell'energia cinetica (Come esercizio si calcolino e si discutano le oscillazioni di un oscillatore, cioè di un circuito contenente una resistenza, una autoinduzione e una capacità.)

LE EQUAZIONI DI MAXWELL

RICAPITOLAZIONE DELLE LEGGI ELETTROMAGNETICHE -

Riprendiamo le equazioni (58) (44) (50) (60).

(α) $\operatorname{div} D = 4\pi\varrho$

(β) $\operatorname{div} B = 0$

(γ) $\operatorname{rot} H = 4\pi j$

(δ) $\operatorname{rot} E = -\frac{1}{c}\frac{\partial B}{\partial t}$

e ricordiamo che la (γ) è stata stabilita nell'ipotesi che tutte le correnti fossero costanti col tempo. E' facile anche convincersi della necessità di una

Figure 7. The first page of the Maxwell's equations chapter from Fermi's typescript (page 50) [8]. According to W. Joffrain [7, 8] this is the original copy of the notes, possibly with Fermi's handwriting.

Figure 8a. John Bardeen [Madison, Wisconsin, USA, May 23, 1908 – Boston, Massachusetts, USA, January 30, 1991), who shared the 1956 Nobel Prize for Physics for his work on the transistor.

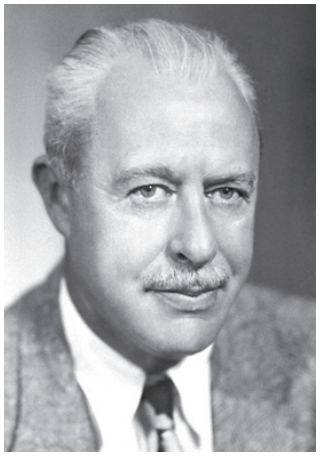
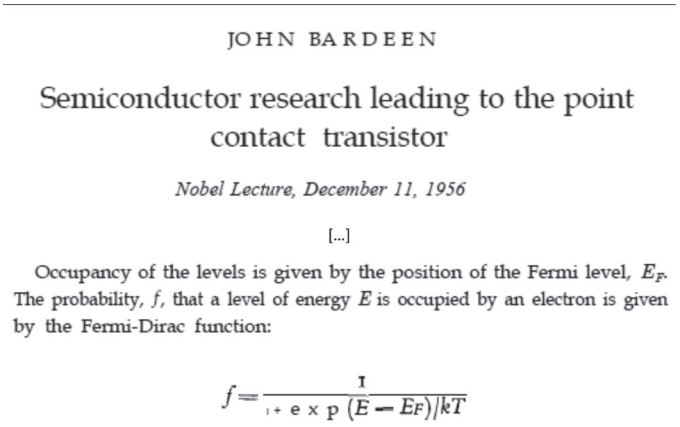


Figure 8b. Walter H. Brattain [Amoy, China, February 10, 1902 – Seattle, Washington, USA, October 13, 1987], who shared the 1956 Nobel Prize for Physics for his work on the transistor.

Figure 8c. William B. Shockley [London, United Kingdom, February 13, 1910 – Stanford, California, USA, August 12, 1989], who shared the 1956 Nobel Prize for Physics for his work on the transistor.



JOHN BARDEEN

Semiconductor research leading to the point contact transistor

Nobel Lecture, December 11, 1956

[...]

Occupancy of the levels is given by the position of the Fermi level, E_F. The probability, f, that a level of energy E is occupied by an electron is given by the Fermi-Dirac function:

$$f = \frac{1}{1 + \exp (E - E_F)/kT}$$

Figure 9. Taken from the first page of the Nobel Lecture by John Bardeen (1956). Bardeen is the only one to have ever won two Nobel Prizes in Physics: this in 1956 (for the transistor), the second in 1972 (for superconductivity).

longer and kept in Rome, has been credited to Fermi's student, A. Morelli, of Rome. It covers the lectures given by Fermi in Rome in 1926, which strictly follows those given in Florence in 1924 and 1925. The original notes are probably those kept at the University of Chicago (Illinois, USA), donated by Fermi's widow Laura Fermi in 1955. They have been dated to 1925 (Figure 7) [7].

It is important to mention that the Electrodynamics notes were republished after a critical investigation into the three manuscripts in 2006, and are now available (in Italian) [8].

The Mechanics (*Meccanica Razionale*) lecture notes, in the version kept at the Temple University Library, are now being processed by the Firenze University Press. An edition is foreseen for next year.

Research Activities in Florence

During his period in Florence, early in 1926 Fermi worked and published one his major scientific contributions [10, 11]: the calculus of the statistical distribution of the atoms' energy in a gas. This was a fundamental question at that time. The classical mechanics applied to atoms gave results for the specific heat that were not in agreement with measurements. The statistical distribution of Fermi solved the question, as did Paul Dirac in October of the same year, publishing the same results [12]. Fermi wrote a letter to Dirac to claim his priority, and the English scientist kindly recognized it [13].

The Fermi-Dirac distribution, as it will be known, refers to a gas, but has more general validity. The first to apply it to semiconductors was Alan Wilson, in 1931 [14]. Finally, the Nobel Prize in Physics of 1956 was awarded jointly to William B. Shockley, John Bardeen, and Walter H. Brattain "for their researches on semiconductors and their discovery of the

transistor effect" (Figure 8). Significantly, the first formula that Bardeen (Figure 9) showed at the Nobel Lecture was the Fermi-Dirac distribution [15, 16].

Acknowledgments

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