should induce precessional magnetization reversal of a ferromagnetic device element.

Spin-transfer torques may allow magnets to be manipulated in ways that are impossible with traditional magnetic fields. Potential applications in high-density magnetic-memory devices, for instance, computer random access memory, are particularly exciting. As memory elements are scaled to sizes well below 1 μm, it is proving very difficult to control the orientation of the magnetic bits with the use of magnetic fields. On such small scales, very large current densities (approaching destructive levels) are needed to generate magnetic fields strong enough to produce magnetic switching. Furthermore, these fields decay slowly with distance, making it difficult to switch one magnetic element without disturbing its neighbors. Spin transfer has neither of these drawbacks. The spin-transfer effect can produce stronger torques per unit current than current-induced magnetic fields in devices much smaller than a micrometer, and spin-transfer torques extend only over atomic length scales. The additional ability of the spin-transfer effect to generate and control oscillations in magnetic materials in the tens of gigahertz range also opens possibilities for applications in high-speed logic and communications.

**References**

1. W. Weber, S. Riesen, H. C. Siegmann, *Science* **291**, 1015 (2001).
2. L. Berger, *Phys. Rev. B* **54**, 9353 (1996).
3. J. C. Slonczewski, *J. Magn. Magn. Mater.* **159**, L1 (1996).
4. M. Tsoi *et al.*, *Phys. Rev. Lett.* **80**, 4281 (1998); see also *Phys. Rev. Lett.* **81**, 493 (E) (1998).
5. J. Z. Sun, *J. Magn. Magn. Mater.* **202**, 157 (1999).
6. E. B. Myers *et al.*, *Science* **285**, 867 (1999).
7. J. A. Katine *et al.*, *Phys. Rev. Lett.* **84**, 3149 (2000).
8. M. Tsoi *et al.*, *Nature* **406**, 46 (2000).
9. J.-E. Wegrowe *et al.*, *Europhys. Lett.* **45**, 626 (1999).

RETROSPECTIVE IN SCIENCE

# Louis Néel (1904–2000)

**Bernard Barbara and Claudine Lacroix**

Louis Néel, perhaps the last pioneer of classical magnetism, died on 17 November 2000 in Brive in southwestern France, where he had rejoined his daughter Marguerite a year before.

Louis Néel was born in Lyon on 22 November 1904. He studied at the Ecole Normale Supérieure in Paris before moving to Pierre Weiss' laboratory at Strasbourg University, where he began his studies of magnetism. Enlisted in 1939 to help improve the French naval defense, he invented an effective method for protecting ships against magnetic mines. Thousands of soldiers were saved from dying in magnetic mine explosions in the Channel. After the Armistice of 1940, Néel joined the University of Grenoble. In 1946, he received funds from the Centre National de la Recherche Scientifique (CNRS) to establish the Laboratoire d'Electrostatique et de Physique du Métal, the first CNRS laboratory outside Paris. Néel became its director. The laboratory expanded rapidly and in 1970 was divided into separate laboratories for the study of electrostatics, very low temperatures, thin films, crystallography, and magnetism. After Néel's retirement in 1976, the Magnetism Laboratory was renamed "Laboratoire Louis Néel." Ph. Nozières moved from Paris to replace him at the university. Having feared brain drain to the capital at the beginning of his career, Néel had succeeded in reversing the tendency.

Néel created and led numerous laboratories in Grenoble and contributed to the decision to install the Nuclear Research Center of Grenoble (CENG), the Institut Laue-Langevin (the European neutron scattering facility), and the European Radiation Synchrotron Facilities (ESRF) in Grenoble. Néel was also a member of the Board of Directors of the CNRS from 1949 to 1969, a scientific adviser to the French Navy since 1952, and the French representative at the Scientific Committee of NATO from

CREDIT: AIP EMILIO SEGRE VISUAL ARCHIVES

1956 to 1957 and 1960 to 1980. He received an impressive collection of French and foreign distinctions and honors.

After his arrival in Grenoble in 1940, Néel started to work with a few students on new research directions such as the magnetism of thin films and the random aspects of magnetic hysteresis. In 1947, he generalized his theory of antiferromagnetism, building on earlier work in Strasbourg. His theory of ferrimagnetism allowed the properties of ferrites and garnets to be understood. The applications of these systems, for example, in lasers, filters, and power attenuators, still have a large impact on our society. In 1970, Néel was awarded the Nobel Prize in physics for these discoveries. The research directions initiated by Néel and his collaborators are still active. For example, the magnetism of thin films and fine particles is now intensely studied under the name of nanomagnetism, and the random aspects of hysteresis have led to the physics of disordered systems.

An important aspect of Néel's style was his broadmindedness. Besides physics, Néel contributed to the development of other disciplines such as applied mathematics and computer science. He also fostered strong relationships with industry that continue today. With his communicative passion for research, he inspired his former students, and their students, with an eagerness that is not ready to fade.

At the height of his career, Néel greatly impressed young researchers, so great was his prestige and so elegant his manner. But beyond the severe appearance and through occasional remarks, one could catch a glimpse of the enthusiastic, nonconformist, progressive man. During one of the weekly seminars for young physicists that he organized at the Laboratory of Magnetism, he blurted out "If I were you, I could not go to sleep before managing to explain this phenomenon." To a boisterous colleague, he said "you remind me of myself when I was young." But Néel did not easily commiserate with his researchers when it came to working conditions. In the "heroic" 1950s, he refused to buy a stove for one of the labs although the room temperature was only 14°C, arguing that it was good for the health. He readily agreed to buy the stove when he realized that the measurements were not accurate at this temperature.

In his memoirs (*1*), Louis Néel said that research and human or family relationships cannot be put on an equal footing and that he would have been as satisfied with his lot living as a country lawyer with his wife (*2*). Nevertheless, physics and magnetism played an essential role in his life until the last moment. The day before his death, Néel was preparing a TV programme for the Academy of Science; at 95, he still had lucid views on most important questions.

**References and Notes**

1. L. Néel, *Un siècle de Physique* (Edit. Odile Jacob, Paris, 1991).
2. In 1931, Louis Néel married Hélène Hourticq. They had three children, Marie-Françoise, Marguerite, and Pierre.

The authors are at the Laboratoire de Magnetisme Louis Néel, CNRS, 38042 Grenoble Cedex 09, France. E-mail: barbara@labs.polycnrs-gre.fr