Report from C9

Regular meetings of the commission occur every three years. The last was at the International Conference on Magnetism (ICM) in Kyoto, JAPAN in 2006 a IUPAP sponsored conference. Since then members of C9 meet when attending other conferences to discuss issues related to C9; these mini-meetings have been very useful.

A major part of the regular work of C9 is to select the site for ICM every three years (the next will be in Germany in 2009). The other half is to select the winners of the Magnetism Prize and the Young Scientist Prize which also occurs every three years. The deadline for nomination of these awards will close in November.

There is now a web site for C9 thanks to the efforts of C9 Commissioner Ching-Ray Chang of Taiwan; C9 thanks Professor Chang for his efforts.

Sincerely,
Dan Dahlberg
Chair C9 and IUPAP Vice-President

A Perspective on Magnetism in 2008

Historically the fundamental physics of magnetism, along with superconductivity, have been the model systems for the development of much of our understanding of quantum mechanics and statistical mechanics. This fact continues today as evidenced by the awarding of the 2008 Nobel Prize in Physics to Albert Fert and Peter Grunberg for the discovery of giant magnetoresistance in magnetic multilayers in 1988. In addition to magnetism’s central role in physics, magnetic technologies are ubiquitous and a significant element of today’s technologies which include information storage, motors, sensors, and dampers.

Prior to the development of quantum mechanics there was no fundamental understanding of the properties of magnetic materials as magnetism is intrinsically a quantum mechanical property of matter. For example, the concept of electron spin giving rise to the magnetic moment of the electron and its fermionic nature requiring the electrons in a metal to have an antisymmetric electronic wave function led to the development of the exchange energy needed to explain ferromagnetism and antiferromagnetism.

The study of magnetic materials has also been crucial in the development of an understanding of systems showing co-operative behaviour. Experiments on phase transitions led to scaling theories that are now applied to the early universe, the financial markets and the production of thin films, while work on disordered magnets has led to new models of the brain and artificial thinking machines.

Spectacular progress in the application of magnetic materials has followed from our ability to control the coercivity, anisotropy, magnetostriction, magneto-optics and magnetoresistance. Permanent magnets have been greatly improved as evidenced by the doubling of the stored energy product (the figure of merit for the best permanent magnets) every 12 years throughout the 20th century, making possible many new applications of magnetism. The significance of this progress is crucial today for the development of magnetic low-energy consumption devices (motors, generators, etc..).

Soft magnetic materials, used for example as transformer cores, have been improved so that the electromagnetic losses have been roughly halved every five years. Magnetic recording has also been enormously improved by controlling the grain size and anisotropy of the magnetic media, and by improvements in the designs and magnetic constituents of the read and write heads. As a consequence recording densities have been doubling every three years since the 1950s, and every year since 1990.

The study of magnetism in reduced dimensions, currently referred to as nanoscale research, flourished during the last decades of the 20th century and continues to do so. This was as much concerned with magnetic model systems for phase transitions in one, two or three dimensions as the realization of magnetic thin films and multilayer stacks. Original properties resulting from the reduced dimensions of the objects included surface anisotropy and oscillatory exchange. The discovery of giant magnetoresistance in 1988 was a development with spectacular consequences. Nowadays, much interest is focussed on understanding of the magnetic and transport properties of nanoscale objects: films, wires, fine particles and quantum dots. Some topics of current research are magnetization reversal by precession or under an electric current (spin-torque effect for which Dr. J. Slonczewski was awarded the Magnetism prize in 2006) and exchange-bias in small systems.

Other remarkable discoveries include the possibility to control the magnetic properties of matter under an electric field, in particular in the so-called multiferroic systems and in semiconductors for which Prof. H. Ohno and D. Awshalom were awarded the Magnetism prize in 2003. More recently it was demonstrated that the magnetisation may be reversed under the action of light (inverse Faraday effect).

In conjunction with the development of the understanding of many of the microscopic properties of many magnetic materials was the development of new experimental techniques which are now routinely used far beyond their origins in magnetics research. For example, SQUID magnetometry, largely developed in the seventies, can detect the magnetisation of a group of less than 1000 Fe atoms. In addition, the development of electron spin resonance (ESR) has been a powerful tool to study the dynamics of electrons. It is important to note that ESR led to nuclear magnetic resonance (NMR) which is the basis of the extremely powerful magnetic resonance imaging (MRI) technique used for medical and biological research. Other critical tools developed to investigate the magnetic state neutron scattering magnetic force microscopy, near-field magneto-optic microscopy and spin-resolved scanning tunnelling microscopy, and of X-ray Magnetic Circular dichroism and magnetic diffraction.

In summary, the past century has seen enormous developments in our understanding of magnetic materials. A combination of quantum mechanics and conventional condensed matter physics now provides an explanation for the properties of many magnetic materials. This understanding has underpinned the dramatic developments in the technology and facilitated the explosive growth in the use of magnetic materials, hard and soft, in electrotechnology, communications, data storage, and sensors technologies. Magnetism underpins many of our most advanced technologies, including magnetic resonance which are now of great importance in biology and medicine. The study of magnetism has also led to enormous advances in our understanding of co-operative phenomena and competing interactions which have directly influenced our understanding of other fields within and beyond physics.

In the future this progress will continue and probably lead to a new understanding of the physics of condensed matter with strong electron-electron interactions. New artificially grown or self-assembled magnetic nanostructures will lead to progress in spin electronics and magnetic media. The ability to tailor magnetic materials on characteristic magnetic length scales in the nanometer range opens a new chapter in the long history of one of the most attractive branches of Physics and in other scientific domains. In particular, functionalized magnetic nanoobjects have exciting new potential applications in medicine (contrast agent for NMR imaging, hyperthermia) and biology.