The importance of Ampère's work

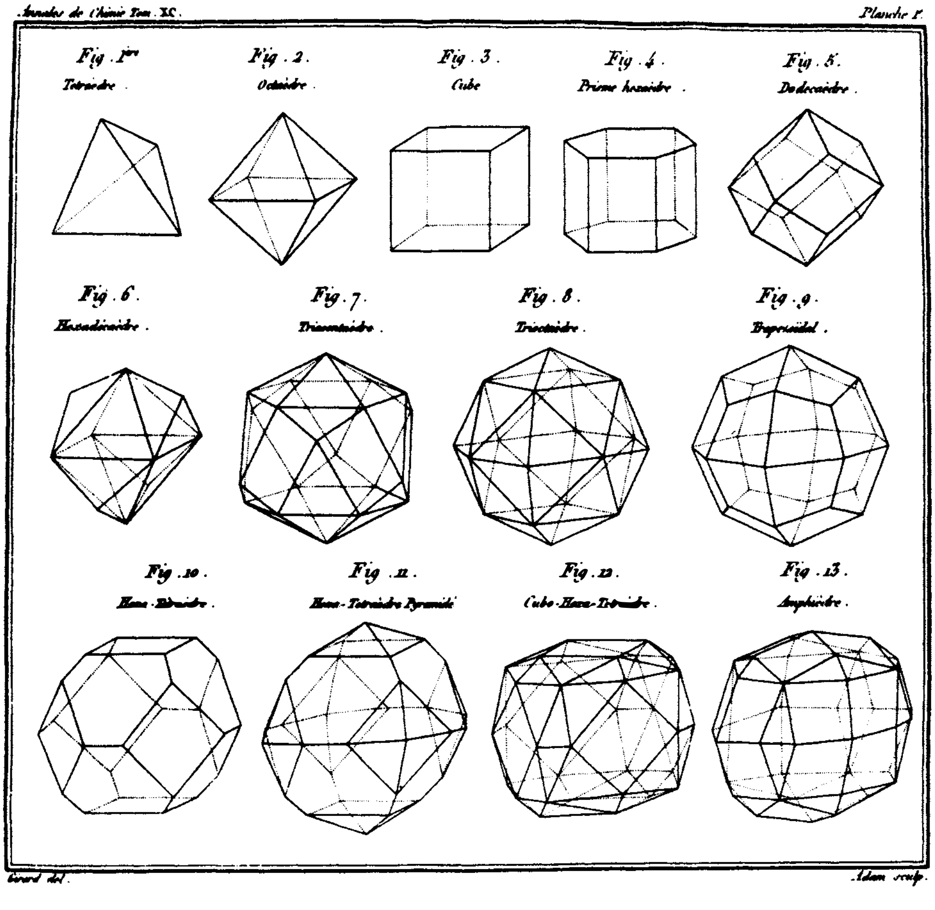
by Laurence Hecht

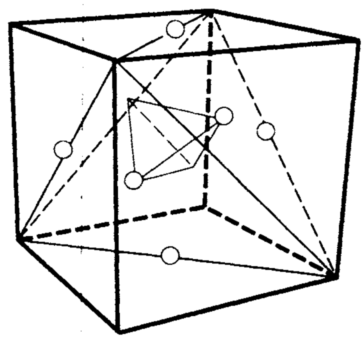
André-Marie Ampère (1776-1836) was professor of physics at the central School at Bourg, taught mathematics at the Ecole Polytechnique in Paris, and was elected a member of the Academy of Sciences in 1814, at a time when France was the center of world scientific activity.

Though best known for his electrical researches begun in 1820, Ampère's scientific work was wide-ranging and always profound in its philosophical appreciation. As a youth he studied natural history and botany, learned Greek, Latin, and Italian, studied French literature, wrote poetry, and attempted to develop a universal language. He had a special interest in mathematics: He taught himself advanced algebra and the calculus by reading Euler's works, and mastered the most advanced mathematical physics work of the day, Lagrange's celestial mechanics, while still in adolescence. But at the age of 18 he suffered a terrible blow when his father, a provincial official in a village outside Lyons, was led to the guillotine.

Early in his scientific career, Ampère had rejected the materialism and atheism of the *Ideologues,* the Enlightenment philosophy fashionable among French intellectuals of the day. After a close study of Immanuel Kant, he rejected that philosophy, too, for its underestimation of the powers of mind. Ampère thus returned to one of the inspirations of his early youth, the philosophical writings of Gottfried Wilhelm Leibniz, and ended his life in a close study of Leibniz's doctrine of the pre-established harmony.

Before conducting his groundbreaking researches in electrodynamics, which he began at the age of 44, he had done important work in theoretical chemistry. Ampère was one of the first to embrace the revolutionary 1811 hypothesis of the Italian physicist Amadeo Avogadro, that equal volumes of gases at the same temperature and pressure contain the same number of molecules. In a groundbreaking paper in 1814, Ampère applied Avogadro's hypothesis to the phenomena observed by the chemist Gay-Lussac: that the volumes of gases which combine in a chemical reaction are in the ratios of small integers. He concluded that Gay-Lussac's observations could only be accounted for by assuming, with Avogadro, that equal volumes of the gases contain the same number





Ampère's geometrical model (left) depicted the most fundamental molecules as made of points arranged as the vertices of the regular or nearly regular polygons (top row). Reactions between these molecules could only occur if they resulted in solids with a degree of regularity and symmetry, as shown in the bottom 2 rows. The diagram above, from the Moon-Hecht model of the atomic nucleus, shows the probable location of the 8 neutrons and 8 protons of the oxygen-16 nucleus. There is a neutron on all 6 faces of the cube and on 2 of the 4 vertices of the inner tetrahedron (alpha particle). Eight protons cover the 8 vertices of the cube.

of molecules. This proof of the existence of molecules, led Ampère to conceive a scheme of molecular interaction based on the Platonic and derived solids of hexagonal symmetries.

The nature of electricity and magnetism

Ampère's electrical research began in 1820. This led quickly to his invention of the galvanometer and soon to his working out of the laws of interaction of electrical currents. Crucial to Ampère's deductions was his hypothesis that within what appeared to be the continuous flow of electrical current were actually discrete entities, current elements, which he considered irreducible carriers of the electric energy.

This led him to hypothesize that the phenomenon known as magnetism was in fact inseparable from electricity. Hans Oersted's 1820 demonstration of the association of magnetism—previously only known in connection with magnetized bodies such as iron (permanent magnets)—with electric currents moving in wires, had led to the upsurge in researches into the phenomenon of which Ampère was a part. But Ampère was the first to advance the modern hypothesis that electricity was responsible for the magnetic action in all cases. He supposed that in the case of permanent magnets, the magnetism is caused by tiny electric currents moving in circles, which he referred to as the *magnetic molecule*.

The experiments which Ampère carried out to test his hypothesis and to determine the laws of interaction of current-carrying wires, still valid today, were a model of simplicity. They involved the arrangement of wires, either straight, circular, or wound into spirals known as helices, in various geometric configurations one to another. His deductions were immediately and repeatedly attacked. In 1821 an anonymous pamphlet recounting the history of electromagnetism appeared in England and was translated immediately into French. The work, which erroneously challenged Ampère's hypothesis that permanent magnetism is the result of electrical currents, turned out to be written by Michael Faraday, then in the employ of Sir Humphrey Davy, a powerful figure in the British science establishment.

Today, when unexplained phenomena such as cold fusion, the unusual clusterings of molecules into buckyballs and met-cars, high-temperature superconductivity, and sonoluminescence, beseech the inquiring mind to examine the fundamentals of our knowledge of atomic and nuclear processes, more than ever the method of scientific hypothesis exemplified by André-Marie Ampère is needed. It was the aim of Prof. Robert Moon to open up this inquiring spirit in young minds and to provide sound paths for its development by carefully steering them through the classical experiments by which the fundamental laws of electrical interaction were first deduced. To the truth-seeking mind, which attempts to know not by citation or textbook authority, but by the method of rigorous hypothesis and experiment, the questions examined by Ampère are as fresh today as the day he first explored them, and with respect to many of the fundamentals, still unanswered.

The Ampère crucial experiments

Dr. Moon's plan was to have the students rediscover Ampère's original results, but also to construct more advanced diagnostics for the experiments than those that were available to Ampère when he first did his research in the 1820s.

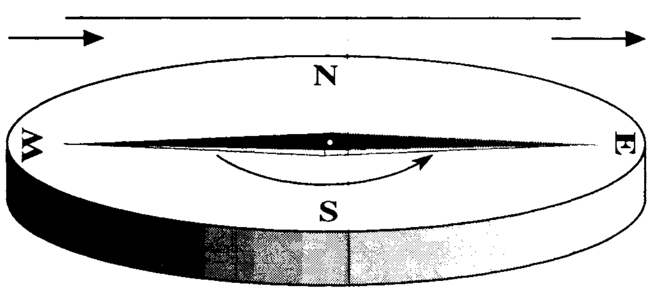
In particular, Dr. Moon had the students construct the elements of a "torsion" balance, originally designed by Tom O'Donnell, the leading machinist and engineer of the University of Chicago, whose creations were key to the success of the Manhattan Project of World War II. This torsion balance provided the means of making very minute measurements of the mechanical interaction between "current elements." Moon's idea was that after the students had "rediscovered" the Ampère results, they could move on to examine more advanced questions, which Ampère's more limited facilities would not allow—such as how Ampère-Gauss-Riemann electrodynamics could allow for the possibility of force-free "cold nuclear fusion."

The apparatus made by the children included carefully constructed magnetic coils, the so-called Ampère solenoids, which provide the means of canceling out the effects of the Earth's magnetic field.

Experiments 1-4 are very simple, and take about one class period to do. The first establishes that a compass needle is deflected by an electric current, telling you that a magnetic field has been created. The next experiments explore what the magnetic field is like. Experiments 6-9 are the most complex, and the construction of the apparatus for them requires

FIGURE 1

Deflection of compass needle by a current



Connect a thick wire to the battery, place the compass on a table near the wire, and observe what happens to the compass needle when you run current through the wire.