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

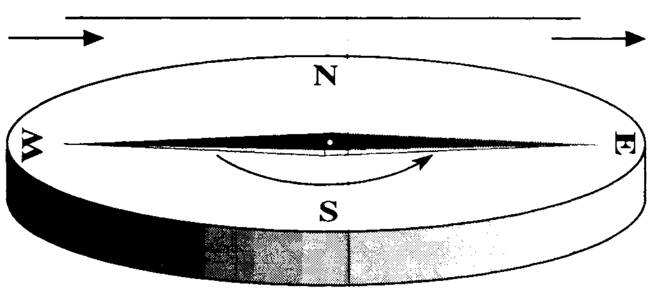
Dr. Moon's plan was to have the students rediscover Ampère's original results, but also to construct more advanced diagnostics for the experiments than those that were available to Ampère when he first did his research in the 1820s.

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.

FIGURE 2

Two parallel wires attract when current flows in the same direction

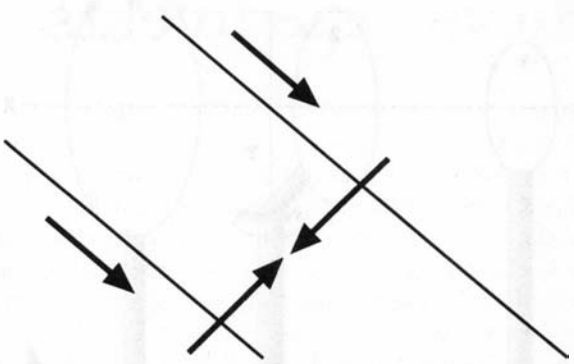
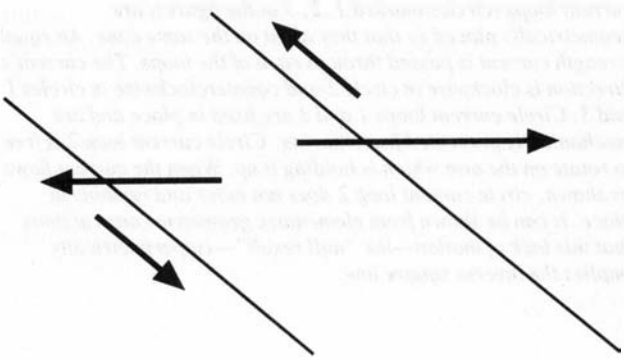


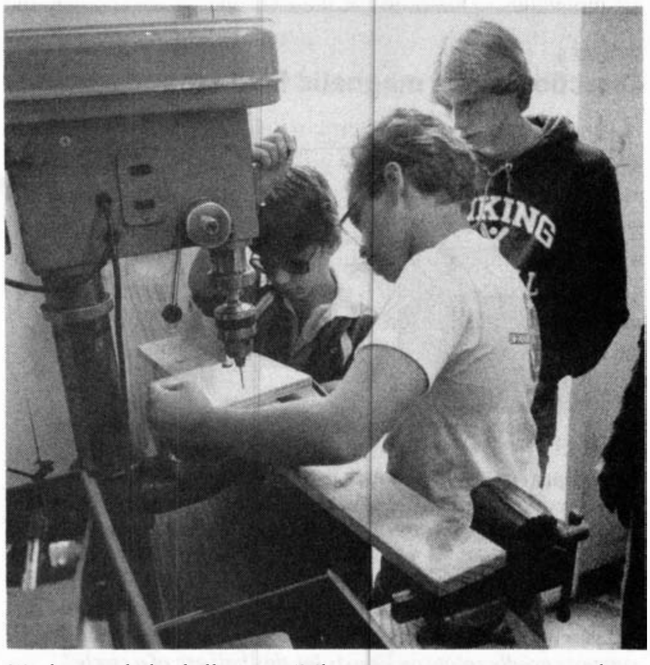
FIGURE 3

Two parallel wires repel when current flows in the opposite direction



several weeks.*

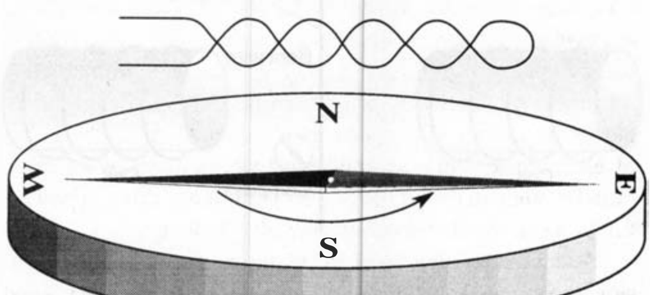
The last four experiments, if successful, produce no observable results: They are "null" experiments. If something *does* happen, then the hypotheses upon which the experimental design was based must be reexamined and new hypotheses formed and new experiments designed. Of these, only the experiment shown in **Figure 6** was done by the students. The others in the series were intended by Moon for future work.



Working with the drill press. "What was important to us was that the student came to realize, 'Yeah, I can do things.' "

FIGURE 4

Current flowing in a twisted wire has no effect on a compass needle

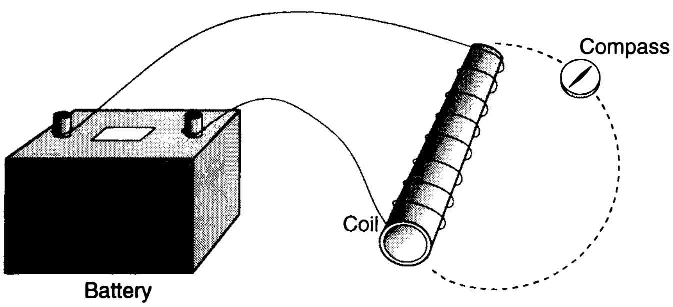


The inverse square law

Benjamin Franklin had carried out null experiments which led to the demonstration of the inverse square law for the interaction among "statically" charged bodies, as Joseph Priestly, Franklin's collaborator, went on to show in detail. Franklin had suspended an electrically charged ball with a nonconducting thread within a closed metal can. The can's surface was also electrically charged. But no matter where the ball was suspended within the closed can, the charged surface of the can had no effect upon the ball. (If the ball is

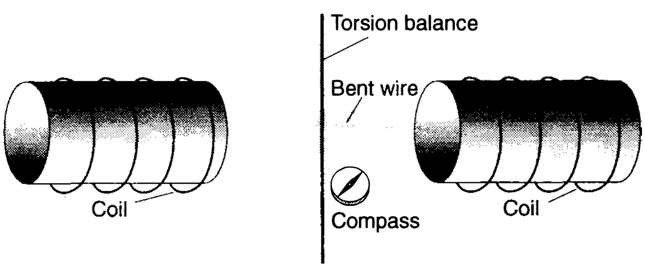
* We present here our best approximation of what Dr. Moon did in his 1984-86 classes, reconstructed from the memories of some who participated (particularly Moon's assistant, Robert McLaughlin), with expert help from others who knew Moon well, but were not there (Charles B. Stevens and Laurence Hecht). The editor wishes to thanks all three for their help, while noting that this description of the experiments is not a step-by-step "how-to" manual, and may not be complete or fully accurate.

FIGURE 5
Direction of the magnetic field around a coil



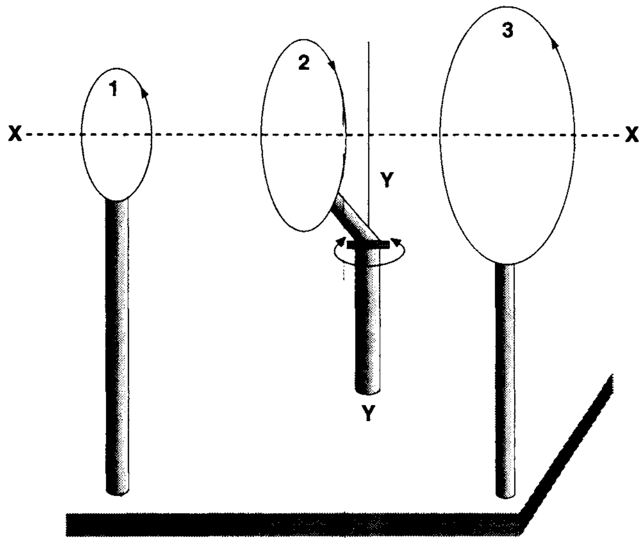
In the simplest experiment with the Ampère solenoid (No. 14 gauge insulated or enameled wire wound around a piece of PVC tubing), the two free ends of the wire are attached to the terminals of a storage battery. A magnetic compass can be used to detect the direction of the magnetic field at any point around the coil. Lay the coil on a table top as shown, and move the compass in a semi-circular arc around it (dotted line). How many times does the compass needle rotate on its axis for this half arc of a circle?

FIGURE 6
Measurement of the force between two currents



The amount of deflection of the wire will be the same for the same current, no matter what the shape of the wire between the two coils.

FIGURE 7
The three-circle experiment



This is a simplified diagram of Ampère's experimental design, which is intended to isoperimetrically demonstrate the inverse square law for the interaction between current elements. The three current loops (circles marked 1, 2, 3 in the figure), are geometrically placed so that they all fit on the same cone. An equal strength current is passed through each of the loops. The current's direction is clockwise in circle 2 and counterclockwise in circles 1 and 3. Circle current loops 1 and 3 are fixed in place and are mechanically prevented from moving. Circle current loop 2 is free to rotate on the arm which is holding it up. When the current flows as shown, circle current loop 2 does not move and remains in place. It can be shown from elementary geometric constructions that this lack of motion—the "null result"—isoperimetrically implies the inverse square law.

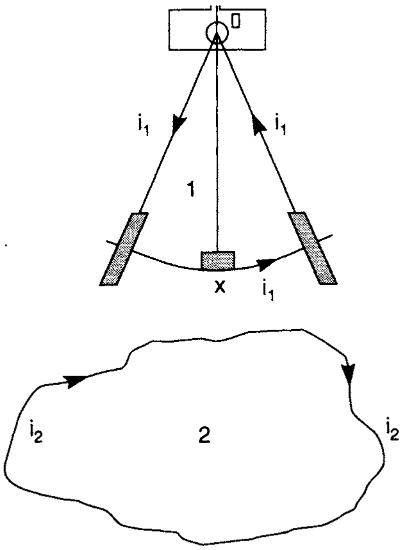
taken outside the can, the ball will either be repelled by the can, or it will be pulled toward it, depending on whether the ball and can are charged with like or unlike charges.)

The inverse square law says, roughly, that if the distance between charged bodies is decreased by one-half, then the force exerted between them increases by a factor of four. In the case of the ball suspended in the closed can, all of the interactions cancel each other out. Geometrically, in terms of what is called the isoperimetric principle, it can be shown that these different pulls only balance if the interaction is of the inverse square form.

Nicolaus of Cusa in the mid-fifteenth century suggested that the same isoperimetric principles could be applied to demonstrating the inverse square law for the interaction between magnets—"magnetic poles," that is. In fact, the form of Cusa's experimental design is closely related to that of Ampère. Cusa's experimental design also implies an inverse square law for gravity; this was developed by Johannes Kepler, a century and a half later, following Cusa's specifications, and applied to Kepler's gravitational model for how the Moon generates tides on the Earth by its gravitational interaction.

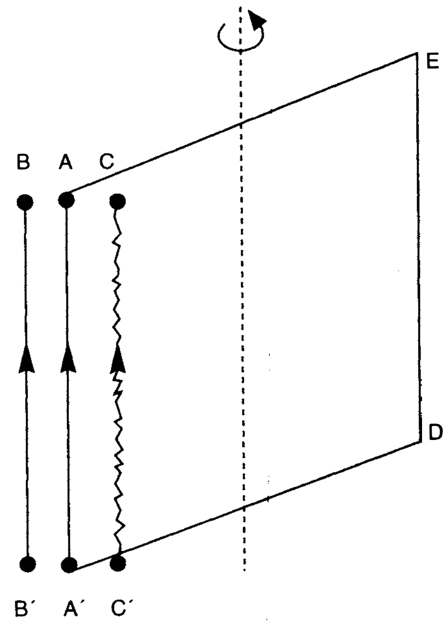
The combined result of experiments 6-9 can be summarily represented as demonstrating that the interaction between current elements must fundamentally involve a "multiply-connected," self-similar conic spiral form of geometry. (For more information on Ampère's experiments, see Peter Gra-

FIGURE 8
The wire-arc experiment



Here there are two electric circuits marked 1 and 2. The second one is made with a bendable wire that can be easily configured into a wide variety of closed, simply connected curves. The 1 circuit is configured so that it is mechanically free to rotate or otherwise move in any direction which is perpendicular to the direction of the flow of the electric current in the circular arc portion of the circuit. (Direction of the current flow in the circular arc portion of circuit 1 is shown with an arrow.) No matter what simply connected shape circuit 2 is bent into, or where it is placed with respect to circuit 1, the circular arc portion of circuit 1 does not experience any mechanical force in a direction tangent to the direction of flow of electrical current in it—that is, no force directed along a tangent to the circular arc.

FIGURE 9
The bent-wire experiment



This experiment (illustrated here in simplifed form) is designed to demonstrate that a straight segment of an electrical circuit can be replaced with a bent and deformed segment, and no difference in the observed effects will be seen. AA′DE is a rectangular current loop in a vertical plane, suspended so that it is free to rotate around its vertical center line.

neau, *Ampère-Neumann Electrodynamics of Metals,* Hadronic Press, 1985.)

To put the matter most simply, what is usually presented in modern textbooks on electrodynamics as Ampère's law for the interaction between current elements, is a fraud. The law in the textbooks is based on that inspired by the Marquis Pierre-Simon de Laplace (1749-1827), the Biot-Savart law, which was directly developed in opposition to the work of Ampère. This fraud replaces Ampère's results with a simply-connected, linear Cartesian field model. As implied in Wilhelm Weber's 1872 paper on electrodynamics, and in the 1915 paper of Dr. Moon's teacher at the University of Chicago, Dr. William Draper Harkins, the Laplace-inspired re for Ampère's actual result excludes the possibility of nuclear fusion in a form which is coherent with electrodynamics. It also, according to Harkins's 1915 formulation for hydrogen nuclear fusion reactions, excludes the possibility of "force-free" cold nuclear fusion.

Materials required

One 6′×2′ wooden work table is needed for every eight children (two set-ups per table, with at most four children at each one). Work space should have as little magnetic metal as possible.

Needed for each experimental set-up:
a motorcycle or auto battery
2 pieces 8-inch PVC pipe
8 terminals
1 mirror
1 piece conducting thread
assorted wood dipped in wax
magnetic compass
copper wire—10 gauge, 14 gauge, 22 gauge