cleons) that we began to understand why certain of the predictions of this model are approximately correct.

Nonetheless, the *naive* quark model was a phenomenological success of the first magnitude. Morpurgo has every right to be very proud of having played an important role in its development.

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Superconductors and the Meissner Effect

The legend on page 3 that describes the fascinating cover photo of your April 1987 issue appears to have a mistake in it. The experiment described there does *not* demonstrate the Meissner effect in $La_{1.85}Sr_{0.15}CuO_{4-y}$. It does, however, prove the infinite conductivity of the material.

The Meissner effect is the ejection of magnetic flux from a material when it is cooled from the "normal" state through the superconducting transition temperature. For it to be demonstrated, the sample must be in a magnetic field while in the "normal" phase, and then it must be cooled in the presence of this field.

In the experiment described by the legend the sample was, first of all, superconducting in "zero magnetic field"; second, the bar magnet was lowered toward the sample on the brass shovel; finally, the magnetic floated off the shovel and stayed off. The photograph purportedly depicts this final condition.

The approaching flux induces eddy currents in the conducting sample (Faraday's law) and these currents flow in such a direction as to oppose the approaching magnet by repelling it (Lenz's law). The repulsion persists, even after the magnet has come to rest in a floating position above the sample, for example, even after electromagnetic induction has ceased. This proves that the currents persist; that is, they encounter no resistance!

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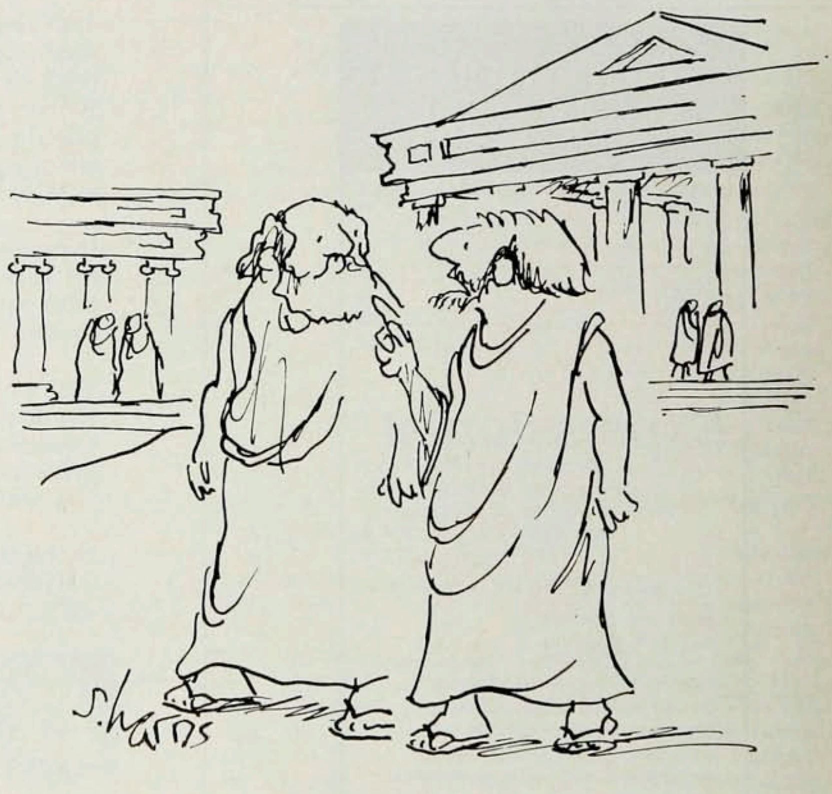
THE EXPERIMENTERS REPLY: The levitation of a permanent bar magnet above a dish of superconducting material is caused by the exclusion from the interior of the superconducting



"OF COURSE THE ELEMENTS ARE EARTH, WATER, FIRE AND AIR. BUT WHAT ABOUT CHROMIUM? SURELY YOU CAN'T IGNORE CHROMIUM."

material of the magnetic field produced by the bar magnet. The exclusion of the magnetic field can arise in two ways: one, by means of screening supercurrents induced on the surface of the superconducting material as the magnet is lowered toward the dish (Faraday's law); and two, by the expulsion of the magnetic field from the interior of the dish as it is cooled in a constant magnetic field through the superconducting critical temperature T_c. The distinction between these two effects is well known to us and other researchers in the field of superconductivity. As Alfred Leitner notes, the first effect relies on the infinite conductivity of a superconductor, while the second depends on the Meissner effect.

The cover picture of the April 1987 issue of PHYSICS TODAY was taken after the levitation had been produced by lowering the magnet on the brass shovel toward the superconducting dish until the magnet floated off the shovel, as the cover legend described. This procedure produces the highest levitation and is the most effective for demonstration purposes. Levitation also occurs when the dish is cooled through T_c with the magnet placed directly on top of the dish, or right above it on the stationary brass shovel. However, this method has several drawbacks: It is somewhat difficult to manage with the apparatus shown on the April cover, which relies on liquid helium to cool the superconducting $La_{1.85}Sr_{0.15}CuO_{4-y}$ powder (with a T_c of 40 K), and, because the magnetic field of the permanent magnet exceeds the lower critical field of the superconducting material, magnetic flux is trapped in the superconductor, so there is less levitation. Levitation of a permanent magnet above a disk of the superconducting compound $YBa_2Cu_3O_{7-y}$, with a T_c of 90 K, cooled with liquid nitrogen is discussed in several articles soon to be published.[1]

The legend to the April cover was abstracted, for brevity, from a letter we sent to PHYSICS TODAY describing the experiment. Unfortunately, the cover description was inconsistent, as Leitner points out.

Reference

1. E. A. Early, C. L. Seaman, K. N. Yang, M. B. Maple, submitted to Am. J. Phys. F. Hellman, E. M. Gyorgy, D. W. Johnson Jr, H. M. O'Bryan, R. C. Sherwood, to appear in J. Appl. Phys. **62** (15 December 1987).

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11/87

The Search for Superstrings

Because I disagree with it so completely, I have reread many times Paul Ginsparg and Sheldon Glashow's May 1986 (page 7) Reference Frame column, in which the authors assert that too much effort is being spent on superstring theory at the expense of experiment. They argue that "*a priori* arguments have deluded us from ancient Greece on" and that "Einstein's path, the search for unification now, is likely to remain fruitless."

For an opposing view, I cite Albert Einstein himself from his Hilbert Spencer Lecture of 1933, as quoted in Heinz Pagels's recent and excellent book *Perfect Symmetry* (Simon and Schuster, New York, 1985):

> It is my conviction that pure mathematical construction enables us to discover the concepts and the laws connecting them, which gives us the key to the understanding of Nature.... In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed.

Why was Einstein so enamored of this view? Pagels explains on the same page. The theory of general relativity was just such an *a priori* construct. Einstein again:

> If the basis of theoretical physics cannot be an inference from experience, but must be a free invention, have we any right to hope that we shall find the correct way? Still more—does this correct approach exist at all, save in our imaginations? To this I answer with complete assurance, that in my opinion there is the correct path. Moreover, that it is in our power to find it.

I agree wholeheartedly. The experiments that have verified general relativity would perhaps have been done even in the absence of the theory, perhaps not, most certainly not in a coherent way. It is a good bet that Nature has indeed not exhausted her bag of performable tricks. We can all hope that the superstring theorists are as successful as Einstein in helping her do so.

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3/87

Correction

October, page 139—In the photograph accompanying the story on the 1987 Franklin Institute awards, the names of Gerd Binnig and Heinrich Rohrer were reversed. ■