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signed to use Norman Ramsey's separated oscillating field method in a vertical atomic beam magnetic resonance apparatus. Gravity would slow and stop atoms that started upward with velocities at the low end of a thermal distribution, and the increased interaction time would yield a very narrow resonance. One Ramsey RF transition was to be on the ascending atoms, the second on the descending ones.

The successful work carried out by the Stanford-IBM group was in fact a variation on this experiment, as it relied instead on two RF pulses on these two sets of atoms while they were in the RF cavity. The realization of the Zacharias fountain in its original incarnation with two separated continuous-wave excitations, also with cooled atoms, was finally achieved two years later, in 1991, by researchers from the Laboratoire Primaire du Temps et Fréquences, Laboratoire Kastler-Brossel and Laboratoire Aimé Cotton in France and the National Institute of Standards and Technology in the US.²

References

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2. A. Clairon, C. Salomon, S. Guellati, W. D. Phillips, *Eur. Phys. Lett.* **16**, 165 (1991).

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Peer Instruction Can Work, Memorization Needs to Be Improved

I would like to follow up on Robert Jones's letter to the editor (September 1997, page 103) commenting on peer instruction, memorization and related issues.

His criticism of using peer tutoring as a means of achieving student understanding is accurate as far as it goes. Peer mistutoring is well documented in the educational literature. However, the literature overwhelming shows that lectures, demonstrations and cookbook labs cannot dispel misconceptions in an extremely large number of gifted students. It also

shows that many misconceptions are so resistant to change that doubling the number of lectures, demonstrations and problem solving activities usually has little positive effect. Demonstrations, in particular, can be counterproductive, especially when students claim to see something different from what the instructor sees. Misconceptions can blind them to actual outcomes. Of course, all teaching involves some degree of risk that students will pick up misconceptions. In some cases, unfortunately, misconceptions are reinforced by conventional instruction.

I disagree with Jones's reservations about Eric Mazur's *Peer Instruction: A User's Manual*. The book, one of the most significant texts on teaching physics, has some very specific instructions on how to use this technique. One of Mazur's points is that the technique works best when about 50% of the students initially get the correct answer to a question before discussion with their peers. It does not work well when a small percentage initially get the answer, and it is useless if a large percentage get the answer. Essentially, guided peer instruction works, while unguided peer instruction may not. The use of peer instruction has been well documented in the literature, and it works much better than other techniques in dispelling misconceptions.

Basically, Mazur has successfully adapted the idea of peer tutoring to the large lecture hall. By providing a comprehensive manual on how to use this method, he has given physics teachers a tool that could make a significant difference to physics education, in that it is likely to increase students' understanding of and enthusiasm for physics.

Jones's concern about students' lack of memorization skills is pointed and accurate, especially at the high school level. Students are well trained to memorize material for the next test, and then forget it immediately. Factors contributing to this sorry situation include use of short (two-week) units with little review in subsequent units, lack of cumulative final exams at the end of the school year and an overall decrease in emphasis on drill and practice in the lower grades. In addition, high school students tend to treat learning in an adult manner by simply looking up what they need to know and as they need to use it. Unfortunately, this attitude creates a low knowledge base that hampers students later on. Also, they are taught that formulas are merely information to be memorized rather than concepts to be mas-

tered. Clearly, this situation needs to be improved. One easily implemented change would be to require that physics teachers make it clear from the first day of class that their students need to both memorize certain facts and also acquire an understanding of the basic concepts that underlie those facts.

One final point: In my experience, hardly any physics instructors read the educational literature, and those who do, alas, tend to disbelieve the research results. I think that many have their own preconceived notions about education, and they find it difficult to change them. In this sense, they have much in common with physics students taking introductory courses.

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Breakthroughs Recalled on Transistor Precursors in Germany, France

There is not much one can add to the story of the brilliant performance of John Bardeen, William Shockley and Walter Brattain that led to the development of the transistor and the subsequent birth of the information age. As chronicled in the December 1997 issue of *PHYSICS TODAY* (see Ian Ross's article, page 34, and Michael Riordan and Lillian Hoddeson's article, page 42) and elsewhere,¹ their broad and sophisticated research was initiated in 1945 at Bell Laboratories under Mervin Kelly, and it culminated in the most spectacular breakthrough in the newly established area of solid-state physics.

It is also instructive, I think, to take a brief look at certain precursor efforts—namely, the European development of the crystal rectifier in connection with the development of radar during World War II. The story of the crystal rectifier reflects the fact that basic technical advances require a certain period of gestation and that breakthroughs occur when the technical effort is driven sufficiently by a particular need—in this case the demand for radar receivers in the ultrahigh-frequency range (centimeter wavelengths). In the later war years, German and Allied researchers engaged in an intense race to become the first to achieve higher-frequency operation of airborne radar sets. As Heraclitus said, "War is the father of all things."

I worked at Telefunken's research laboratories in Germany throughout