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]

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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 mastered. 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 the war. We did research on ultra-high-frequency rectifiers, aiming at the development of an effective crystal mixer as a duodiode or three-electrode crystal, based on the advances that had been made in crystal rectifiers over the past two decades. Early on, the director of research, Horst Rothe, gave us the task of comparing electronic noise measurements for vacuum mixer diodes and crystal rectifiers. We also studied the compensation of the oscillator noise through the use of duodiodes in push/pull microwave mixers and the improvement of the signal/noise ratio through the use of crystal mixers with crystals such as silicon, silicon carbide, lead sulfide and germanium. And we sought ways to equalize the current/voltage characteristics of crystal duodiodes for oscillator noise compensation. In fact, I made three-electrode crystals, trying to locate both top whiskers so that the current/voltage characteristics were identical. But the crystal material was so inhomogeneous that most tests failed to result in noise compensation. In 1942, though, we published our results on noise measurements in crystal rectifiers.[2] The following year, I applied for a patent on crystal diodes with electrolytic contacts,[3] and later I sought one on crystal duodiodes for centimeter-wavelength mixers.[4]

Eventually, better crystal material became available. Karl Seiler of Breslau University evaporated silicon on graphite substrates and Heinrich Welker of the Institute of Physical Chemistry in Munich used the Bridgman technique to make germanium crystals.

After the war, I accepted an offer—as did Welker—to relocate to Paris to establish a semiconductor diode plant for Westinghouse Electric Corp under contract from France's Ministry of Post, Telegraph, and Telephone. As Welker started the buildup of a Bridgman-type crystal furnace and produced pencil-like germanium rods that were cut for use in diodes, I installed the production line for making and testing the actual devices. In those tests, I renewed my work with two whiskers with the aim of exploring the barrier layer. I noticed that in some cases I got injection and amplification when the crystal had been cut from a larger ingot, and also when certain grain boundaries were present. So I asked Welker to increase the size of his graphite boats to grow larger ingots.

Working in war-ravaged Europe, we were hampered by the problem of obtaining high-purity germanium, and no real effort was made to monocrystallize. In the US, on the other hand, companies were able to reach a high degree of purification, Gordon K. Teal at Bell Labs was starting to grow Czochralski-type monocrystals and minority carrier lifetimes had improved to the point where (under advice from Bardeen) Brattain's surface state tests had led to minority carrier injection.

Finally, early in 1948, I was able to get amplification more regularly—that is, injection into a reverse-biased point contact. Our results were duly presented to the French government, published and patented.[5] The "transistron," as the French called it, was also shown to the press and we were dubbed "les pères du transistron."[6] However, our achievement did not lead to enhanced financial support for the Paris laboratory, and so both Welker and I took up other activities. He went to Siemens to start his well-known work on III–V compounds. I started the Intermetall Corp in West Germany to produce diodes and transistors, and installed a lab for III–V compounds.

I left in 1953, when Intermetall was bought by the Clevite Transistor Corp, which—to bring this account full circle—later purchased the Shockley Semiconductor Lab from Beckman Instruments. I then emigrated to the US to continue my research project on the electrical effects of crystal defects that I had started as a young man in Düsseldorf.

References

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3. Swiss Patent No. 243 490 (16 November 1943).
4. French Patent No. 22 307 (23 May 1947).
5. French Patent No. 1 010 427 (13 August 1948); US Patent No. 2 673 948 (11 August 1949).
6. For a complete survey of all related patent applications and research efforts from 1925 until the final breakthrough in 1948, see B. G. Bosch, "The Multifaceted History of the Transistor" (1994) (available from the author at the University of Bochum in Germany).

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ConCERNed Scientist Says Work on Two-Beam Accelerators Goes On

I found Bertram Schwarzschild's story entitled "Stanford Wants to Build a TeV Linear Collider with Japan" (PHYSICS TODAY, November 1997, page 21) to be very well written and quite accurate with regard to the work being done both at the Stanford Linear Accelerator Center (SLAC) and Japan's High Energy Accelerator Research Organization (KEK). However, he gives the impression that the work on two-beam accelerators at CERN has stopped. On the contrary, the two-beam approach combined with high-frequency acceleration (30 GHz) is still being actively pursued at CERN. This frequency permits a high acceleration gradient and may be the ideal choice for a multi-TeV electron–positron linear collider.

I have been working on the Next Linear Collider research effort for the past ten years or so, and I have led an outstanding group of physicists and engineers to build the Next Linear Collider Test Accelerator at SLAC. The NLCTA brings together the NLC technology and accelerator physics development in a complete system test.

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Name Put Forward of Another Physicist Who Writes Sci-Fi Novels

It was pleasant to read Elisabeth M. Brown's letter (PHYSICS TODAY, October 1997, page 142) recognizing scientists who have written accurate, entertaining science fiction. However, I found one notable omission: Robert L. Forward, whose scientific work is as speculative and well-grounded as his fiction.

As a physicist, Forward has studied the design of interstellar probes, the possibility of using antimatter and laser-propelled lightsails for spacecraft propulsion and the use of space tethers for orbital maneuvers. In his novels *Dragon's Egg* and *Starquake*, he envisions life on the surface of a neutron star, based on nuclear rather than chemical reactions and proceeding vastly more rapidly than our own; in *Rocheworld* and its sequels, he explores a pair of co-orbiting planets so close together that they are distorted from spherical shape.

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