letters

physical world to children in a hands-on equipment environment. To attempt the education course with uncomfortable elementary-school teachers would be counterproductive.

With the support of the National Science Foundation,[3] the physics department and the school of education of City College, in cooperation with Districts 6 and 10 of the New York City school system, bring a yearly total of 75 teachers (25 in each of three groups) to the college for two comfortable-physics workshops: one with the physics department and the other with the school of education.

What is "comfortable physics"? If Philip Morrison (MIT) were to enroll 25 in-service elementary-school teachers in a one-semester workshop covering classical physics with lecture, demonstrations and laboratory, that would be a comfortable-physics course, and it wouldn't make much difference what text he decided to use. At City College we try to provide a reasonable facsimile of these conditions, and others can too.

During the first year of our NSF grant, 70 elementary-school teachers from New York's Districts 6 and 10 survived the rigors of the program and were awarded certificates of Master Teacher of Physical Science. The program has been expanded this year to include New York's Districts 3, 4 and 5, and we are well on the way to creating a cadre of New York elementary-school teachers comfortable in the world of physics.

There are thousands and thousands of teachers who will require a staff-development program in comfortable physics to be at home in the physical world. College physicists cooperating with the schools of education of their colleges and nearby school districts can contribute much to improvement of this situation on a national level. I would offer the following advice to other colleges and communities:

▶ Chairman of physics departments: Find the one professor on your faculty who has the charisma and motivation, and talk him into teaching a comfortable-physics course for prospective and in-service elementary-school teachers.

▶ Physics professors with charisma: Volunteer to teach a comfortable-physics course. You will derive great satisfaction as apprehensive teachers gradually become comfortable in the world of physics.

▶ Parents and PTA members: See that the elementary schools in your district have a staff-development program that will produce teachers comfortable in physical science.

▶ The rest of us: Hope or pray that the people mentioned above are doing their thing, because otherwise we are all in trouble.

References

1. L. B. Resnick, Science **220**, 477 (1983).
2. The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, CPCE-NSF-03, NSF (1983).
3. Supported by NSF contract DPE 8470160.

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Bohr in the 1980s

After reading the very well-written and informative Niels Bohr centennial issue (October 1985), I wonder if a young Bohr can do well today.

Government-supported big science has favored self-confident "can do" scientists, the equivalent of "full speed ahead and damn the torpedoes" naval commanders. While these spirits may be necessary for the construction of super colliders, disadvantages do come with advantages, according to Bohr's complementarity principle. Directly or indirectly, this approach does discourage Bohr's method, to "believe in one idea one hundred percent one day and work on it with all the force of [one's] being," while on another day, to "adopt with equal single-mindedness the directly opposite view."

At the turn of the century it was generally recognized that classical physics was inadequate for atoms. There were many clues from diverse fields—not only in physics but also in chemistry—such as the electron charge–mass ratio, blackbody radiation, hydrogen spectral series, photoelectric effect, kinetic theory of gases, specific heat and equipartition of energy, periodic table, chemical valence and electrochemical reactions. Even with many clues, the transition between classical and quantum physics was difficult, and Bohr contributed greatly to the careful mapping of the few firm footholds while avoiding the numerous traps. The situation, however, is different today. Tremendous efforts have been devoted to searches for such entities as fractionally charged particles and magnetic monopoles, but the results are inconclusive. Before Bohr, the vacuum was filled with ether; it is now filled with virtual photons. The scientific community *does* need a young Bohr to work on "particle physics without quarks" or "GUTs without proton decay"!

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