Elementary Particles," dissertation, U. of Calif. at Santa Cruz (1987).

8. D. Beau, S. Horachi, C. R. Acad. Sci. Ser. A **281**, 183 (1975).

THOMAS R. LOVE
*Daemen College*
11/87 *Amherst, New York*

SCHWARZ REPLIES: I should have said "*compact* simple Lie groups."

JOHN H. SCHWARZ
*California Institute of Technology*
5/88 *Pasadena, California*

GLASHOW REPLIES: I have no idea how to build a meaningful gauge theory based upon a noncompact real form of SU(5). Neither does Thomas Love.

SHELDON LEE GLASHOW
*Harvard University*
5/88 *Cambridge, Massachusetts*

## Nature's Indecision on Gravity's Nature

In relation to the article by John H. Schwarz (November 1987, page 33) I would like to raise the following question: Is gravity classical or quantum? Nature should provide the answer. At ordinary energies the gravitational interaction between elementary particles is negligible with respect to the other known interactions. At energies comparable to the Planck energy gravitation might have dominated. According to the standard model for a radiation-dominated universe, the age $t$ of the universe is related to its energy density $\rho$ by

$$t = \frac{1}{2}\sqrt{\frac{3c^2}{8\pi G\rho}}$$

and the distance to the horizon is $2ct$. According to the Planck distribution, radiation at temperature $T$ has an energy density

$$\rho = \frac{\pi^2}{30}\frac{(kT)^4}{(\hbar c)^3}\left(N_b + \frac{7}{8}N_f\right)$$

and a particle number density

$$n \simeq 0.218\left(\frac{kT}{\hbar c}\right)^3\left(N_b + \frac{3}{4}N_f\right)$$

wnere $N_b$ and $N_f$ are the number of boson and fermion degrees of freedom (including spin), respectively. Combining these equations, we find the number of particles within the horizon when the universe had temperature $T$:

$$N \simeq 0.11\left(\frac{T_p}{T}\right)^3 \frac{N_b + {}^3\!/\!_4 N_f}{(N_b + {}^7\!/\!_8 N_f)^{3/2}}$$

where $T_p$ is the Planck temperature. Note that $N$ is less than 1 when $T = T_p$. Thus at the Planck temperature, where quantum effects of gravity may have been important, particles did not yet have time to interact.

Is gravity classical or quantum? Perhaps Nature never answered this question.

BRUCE HOENEISEN
*Universidad de Guanajuato*
12/87 *Leon, Mexico*

## The Long and Short of Relaxation Times

Though I read with great interest Martin Karplus's article "Molecular Dynamics Simulations of Proteins" (October 1987, page 68), I feel compelled to point out a completely misleading and incorrect sentence concerning nuclear magnetic relaxation times of proteins in solution. First, $T_1$ is the "longitudinal," or spin–lattice, relaxation time and not the "transverse," or spin–spin, relaxation time as claimed in the article. A more important point, however, is that Karplus claims the observable nmr relaxation times "are on the nanosecond to picosecond time scale," which is why the technique "has played an essential role in the analysis of the internal motions of proteins." In fact proton relaxation times in protein solutions are on the millisecond time scale, whether the protons are solvent protons or nonexchanging protons firmly anchored deep in the protein's interior. The transverse relaxation time of protons of proteins in the crystalline state is significantly shorter than in solution but still on the order of microseconds and never on the nano- or picosecond time scale.

There is no doubt that detailed nmr studies of all the nmr-visible nuclei in protein solutions have been and will continue to be of unique and invaluable utility in studying both dynamic and structural aspects of these important systems. It is with sadness, however, that I mention that the relaxation times, though sensitive to the internal motions of proteins, are in the 1- to 2000-msec range for most protons in biological systems, which leaves nmr imaging the tortoise in the race against traditional CAT scanning techniques.

ROBERT V. MULKERN
*Harvard Medical School*
10/87 *Boston, Massachusetts*

KARPLUS REPLIES: Robert V. Mulkern is correct in pointing out that $T_1$ is the longitudinal relaxation time and that the relaxation *times* are on the millisecond or longer time scale in most cases. The original manuscript for my article stated, "Nuclear magnetic resonance is an experimental tech-

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nique that has played an essential role in the analysis of the internal motions of proteins because most of the relaxation *processes* are on the nanosecond to picosecond time scale." (I have added the italics for the purposes of this reply.)

At a later stage, the offending phrase "for example, the transverse relaxation time $T_1$" was introduced after "processes." I am grateful to Mulkern for catching this error.

MARTIN KARPLUS
*Harvard University*
3/88 *Cambridge, Massachusetts*

# Do the Best Physicists Spot the Best Talent?

Although I agree with Philip Anderson's view (September 1987, page 7) that the postdoc application process is too unwieldy, I think he fails to make a crucial point. Deciding which members of the current crop of PhDs are most likely to do original research in the future requires an understanding of people far more than of science. This is because (among other things) a new PhD has typically produced little or nothing independently, and an objective assessment of his or her scientific ability is essentially impossible. At the same time, we all know scientists, even superb ones, whose judgments about people are consistently less than astute. Thus I am very uncomfortable with Anderson's suggestion that the selection process be made even more informal (and hence error-prone) by limiting letters of recommendation to a single one from the applicant's thesis adviser. A better solution might be to identify one or two people in each department whose "track record" of predicting students' future performance is good. A letter of recommendation from one of these people could be worth a lot more than a letter from the applicant's adviser, no matter how accomplished a scientist that person is.

DAVID MERRITT
*Canadian Institute for Theoretical Astrophysics*
9/87 *Toronto, Canada*

# Committees to Aid Oppressed Scientists

I was pleased to see two letters on refusenik news in the October 1987 issue (page 152). I just want to remind the PHYSICS TODAY readership that the APS has in place two programs that give physicists an opportunity to assist oppressed physicists, including refusenik scientists. One is the Small Committee program of the Committee on the International Freedom of Scientists, which currently consists of 78 committees that have each adopted an oppressed scientist. Small-committee members write to and lobby for their adopted scientist, providing a valuable link between him or her and the Western scientific community. Former refuseniks have repeatedly emphasized the importance of these letters, both for needed moral support and for their practical effect on Soviet officials. Anyone wishing to join a small committee should write to me.

The second program is the matching membership program for scientists from third world or dollar-poor countries. The APS will contribute one half of a physicist's membership fee if an APS member donates the other half. For refusenik scientists, membership in the APS provides another valuable connection to and source of information about the Western scientific community. Anyone wishing to contribute to the matching membership program should send his or her contribution to the APS Membership Department at 335 East 45th Street, New York, NY 10017. I would hope that those of us who are blessed with freedom, financial security and the opportunity to do science are willing to share a very small fraction of our time, wealth and knowledge with those so very less fortunate than ourselves.

BERNARD FELDMAN
11/87 *University of Missouri, St. Louis*

# Questions for Introductory Physics

The project to study introductory physics courses discussed in the May 1987 PHYSICS TODAY (page 87) by Donald F. Holcomb, Robert Resnick and John S. Ridgen is highly welcome—and insufficient. What is needed is consideration of all physics courses (not only those for majors), and more than their content, their rationale. We must be concerned not only about future physicists but also about students who take physics because they want to learn it, and even—especially—about those who do not want to learn it but are required to take it anyway, and perhaps still more about the ones who do not want to take it and do not, but then go on as citizens to make decisions, including ones critical to physics, for which an understanding of it is essential.

More than for physics our concern must be for education. Before we consider the syllabus, before we consider whether to include atomic physics, before we think about what goes into the course, we must think about what comes out, what should come out. What should a well-educated person know and understand about physics, not just before the final, but many years after leaving school? How can that understanding be achieved? What's the purpose of the whole course anyway?

Based on the present courses and books these questions seem never to have been considered, and it shows. If the public feels that science is beyond it, frightening, impossible, incomprehensible, an esoteric subject of interest only to weird characters like us, it is not surprising. Too often that is what we teach.

Why should nonmajors take physics? What should they learn? More important than Newton's laws, atomic physics or electromagnetism is an understanding of nature, of how the universe works, how physicists work. More important is the ability of a person to understand and cope with his world, his own life, his own body.

Isn't it to achieve this understanding that we teach the laws? Isn't this understanding a main reason for education? Can a study of physics aid in achieving it? Does it now? Would our students believe this understanding is valuable? Do they believe now that this is what they are learning?

I regard physics as one of the liberal arts, and believe that my responsibility is not merely to teach Newton's laws but to educate my students. This often differs both from their view of why they are taking physics (it is required) and from the view of the physics community on why these courses are offered (to provide jobs for PhDs who are needed to do their mentors' research while in graduate school but who themselves are not able to get research positions).

The question then is not so much what topics should be in the course or how much emphasis to give to the laboratory, but how we can educate our students. Is knowledge and understanding of physics necessary for a modern educated person? Do we believe so? Do we teach as if we believe so? Why do we have so much difficulty convincing everyone? How can we teach how important this knowledge and understanding are?

One aspect of education is learning skills: the ability to read, write, comprehend; to think logically and rationally; to obtain, process and absorb knowledge; to do things in a careful, organized way; to understand what we are doing; to understand our environment and deal with it. Does