It should be clear from this brief outline that the alternating sequence brings to the program a dynamic and versatile balance between basic and applied science. We should mention that one does not have to be an hi-fi expert to teach such a course—for anyone trained as a physicist who takes the time for a little outside reading, the transition is easy to make. The implicit reward for the effort will be the assurance that physics remains in the mainstream of student education. The explicit reward will be overwhelming enrollments!

While providing a stage for the exposition of physics principles, the physics of hi-fi possesses relevancy and excitement that students can carry with them many years after leaving the classroom. Whenever they turn on a radio, play a record or tape, or simply hum a tune, we are hopeful they will remember the experience of physics—its utility and beauty.

A more detailed version of this report as well as the lab manual are available directly from the authors. The lab manual costs $5.00.

KENNETH W. JOHNSON
WILLARD W. WALKER
RALPH HARPER
ARTHUR ADAMS
Southern Illinois University at Carbondale

Repression in Argentina

Since the military coup of 24 March, the Argentine scientific and academic establishment, which had already been hard hit by a big purge of the universities under the regime of Isabel Peron, has been decimated to an unprecedented degree by another purge. According to information published in several issues of the Buenos Aires daily *La Opinión* of March, April and May, and from other sources, in the first two months after the coup more than 2000 lost their jobs at the universities and no fewer than 700 at different research institutes, among them the National Science and Technology Research Council, the Physics and Technology Institute at San Miguel, the Atomic Energy Committee, the National Institute of Industrial Technology, the National Institute of Agricultural and Cattle Breeding Technology and other places. According to an estimate by members of the Associacion Fisica Argentina, one fourth of the members of this organization have lost their jobs. Also grade-school and high-school teachers have been fired, as have several hundreds of physicians, psychologists and social workers at hospitals and mental-health institutions.

These dismissals have been carried out under two laws passed by the Junta, the so-called "security" law and the *ley de prescindibilidad* (not needed personnel law). The second law allows any public employee to be fired, with the proviso that he or she cannot be given any job in the public sector for the next five years. The leading positions at the universities, like those of rectors, deans of schools and even directors of courses of study (such as psychology and so on) have been taken over by military officers. They have also taken over the leading positions at all research institutes mentioned.

New repressive regulations have been passed at the universities that cover everything from dressing habits to "immoral" and "potentially subversive" actions carried out by teachers and students even outside their institutions. Some university libraries have been depurated of "subversive" literature and the books of Marx and Freud (called "ideological criminals" by an Air Force officer who is now Secretary General of the Universidad Nacional de Cordoba) publicly burned. Several intellectuals have disappeared and may have been killed by the repressive forces, others have been arrested, some have been tortured and some have had their houses plundered. Among those arrested since March or April and not accused of any specific crime nor being tried are the physicists Antonio Misetich and Máximo Victoria and the sociologist Emilio de Ipola. The constitutional right according to which people arrested under an *état de siege* but not being tried could choose to leave the country has been suspended by the Junta.

We are seriously worried by this situation, which can only cause further damage to the development of scientific and cultural activities in Argentina. We call on our colleagues to demand that our imprisoned fellow scientists be freed and that those dismissed should be given back their jobs, as a first step towards the reestablishment of a climate favorable to the development of science and culture.

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Nuclear waste disposal

In his letter to the editor (January, page 9), Bernard Cohen presents what he calls a numerical estimate of the health hazards of buried nuclear waste. His conclusion is that the upper limit is 1.1 cancer deaths from the waste produced in generating 400 gigawattyears of electrical energy, and he illustrates this in his figures 1 and 2. If one reads the text carefully, however, one finds the following condition that must be met in order to expect such a low number: The waste would have to be incorporated into the

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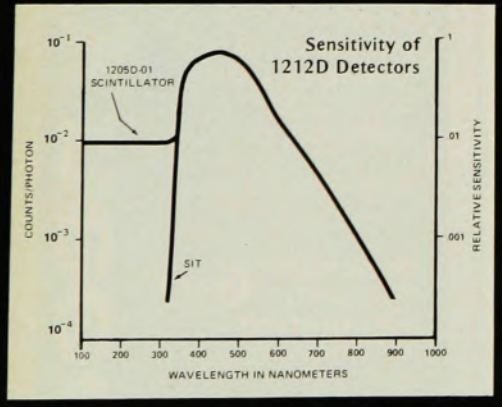
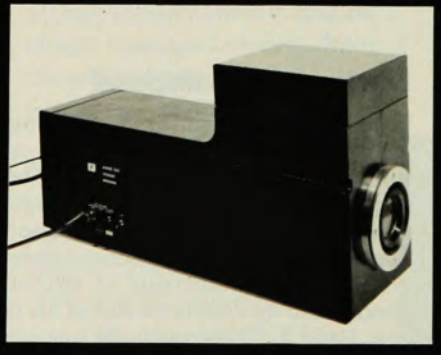


*SIT is the acronym for Silicon Intensified Target tubes used to build the Model 1212D Detectors, whose spectral response is shown above.



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rock in the same way as are the naturally occurring radioactive elements like radium. Only then may one equate the relative release rate for the nuclear waste with that for the natural radium, which is very small indeed. (We use the term "relative release rate" for the expression $(dn/dt)/N$ used by Cohen, where dn/dt is the rate of cancer deaths caused, and N is the activity contained in the top 600 meters of the Earth's crust, expressed in numbers of lethal cancer doses.)

Obviously, the real burial will be entirely different: Our nuclear waste will be buried in high concentrations, in a form that is chemically and physically quite different from its surroundings, and the burial site itself can hardly be viewed as an undisturbed segment of the Earth's crust. Does this make a difference, as far as the transport of the waste back to the biosphere is concerned? Cohen assumes that it does not, but makes no effort to prove this assumption, which is crucial for his numerical estimate.

We mention only a few questions: How does the barrier to escape provided by the man-made seal of the burial site compare with that provided by an undisturbed geologic formation? Do chemical or physical reactions like radiation damage, present a risk for the containment of the waste? Does the encapsulation of the waste in a glassy matrix offer any long-term barrier against leaching in the same way that rock does for radium? Can the radioactive heat fracture the rock overlying the burial site through thermal expansion, thus opening easy routes for transporting the waste back into the biosphere? These examples should suffice to show how questionable Cohen's assumption is. (More questions can be found in the recent review by W. C. McClain and A. L. Bloch from the Oak Ridge National Laboratory, "Disposal of Radioactive Waste in Bedded Salt Formations," Nucl. Tech. **24**, 398 (1974).) We see no reason why the two relative release rates should be at all comparable or even be equal; in fact it appears likely that the rate could be far higher for the nuclear waste than for the natural radium in the ground. Consequently, the cautious reader should view Cohen's number of deaths as a guess rather than as a "numerical estimate" or even an "upper limit."

In any scientific discussion, one must take great care not to confuse a qualitative argument with a numerical estimate. In discussing a subject of such vital importance as nuclear waste management, this distinction is important.

ROBERT O. POHL
Cornell University

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While I am not in a position to judge the scientific merit of Cohen's letter concerning long-term dangers of nuclear waste storage, I am chagrined to notice that Cohen, like most proponents of nuclear power, has neglected the problem not of accidental dispersal of nuclear wastes but of intentional dispersal. It is not a question of technology, but rather one of policing. For the first 100 years or so, even a tiny amount of this waste, if deposited in a city's water supply, would not only result in the death of all the inhabitants of the city, but would so contaminate the pipes of the city that they would all have to be replaced before being safe again. It is to concerns of this sort that more thought must be given.

J. DOUGLAS MCDONALD
University of Illinois at Urbana-Champaign
Urbana, Illinois

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While we agree with Cohen's thesis that potential public-health hazards associated with the deep geologic disposal of high-level radioactive wastes are often grossly overstated, there are several important considerations that his letter does not address.

▸ Cohen implies that radioactive materials will not move in any appreciable concentrations into zones where they may come into contact with Man. This conclusion is based on a combination of factors, such as slow rates of leaching, the slow movement of water in deep geologic formations, and interactions of the radionuclides with the rock or soil material in the receiving formation. However, high-level radioactive wastes will be thermally hot for several decades following fuel reprocessing. It is not certain how thermal stresses will affect rates of leaching and influence the movement of waste. At first, water will probably move out of the zone surrounding the emplaced radioactive waste at a higher rate than normal. If this occurs prior to leaching, the probability of movement of radionuclides should be reduced for several decades. As the formation cools, water will reenter the zone surrounding the waste and provide a potential for leaching and transport of radionuclides from the waste. The range of the influence of these factors must be addressed in applying Cohen's arguments.

▸ The speeds of water movement in deep aquifers referred to by Cohen are *average* speeds. One must take into account the distribution of rates of water movement in considering the transport of small fractions of the radionuclide inventory. In any porous medium, some water moves at a much faster rate than the average. This phenomenon is more noticeable in aquitards, where most of the water movement occurs along bedding planes, joints and fractures rather than through the bulk of the material. Zones of rapid water movement also tend to have a low degree of contact between the moving

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solution and the immobile rock or soil material; hence retardation of radionuclides resulting from ion exchanges, filtration and other interactions is reduced.

▸ In principle, the understanding and technology needed to contain radioactive wastes completely now exist, given sufficient effort and expense. In this sense, Cohen's detailed arguments are directed at a straw man—routine, normal disposal of high-level wastes can be carried out safely. Probably the most likely potential source of public exposure is, however, an inadvertent release during the handling, shipping and emplacement of radioactive wastes. While Cohen has addressed the problem of long-term containment after emplacement, which is perhaps perceived as foremost by the public, he has omitted the important consideration of inadvertent releases prior to emplacement. In addition, there is, in geologic time, a certain small, but finite risk that Nature will drastically alter a storage site by means of an earthquake or other catastrophic event.

▸ The operation of nuclear power reactors and the storage of radioactive wastes over thousands or even millions of years must be put in the perspective of the amount of energy available from various sources. Fossil fuel is running out in a matter of a few centuries. There is enough fission fuel to carry Mankind several centuries, using breeder-reactor concepts. Over the very long future, solar and fusion sources offer the only known solutions to sufficiently plentiful energy. Thus, we need to manage radioactive wastes that are generated over a period of several hundred years, rather than millennia, as often implied. During this time, not only will solar and/or fusion energy (or some other, as yet undiscovered, source of energy) be developed, but technology will advance to an unknown degree. As Cohen speculates, perhaps there will be cures for many kinds of cancer; most certainly, also, the ability to deal with radioactive wastes will improve.

▸ Cohen's discussion of the "cleansing effect" of nuclear power (associated with the depletion of uranium in the Earth's crust due to consumption by a nuclear power economy) is misleading. Even with the development and utilization of breeder reactors, it is unlikely that there will be a significant reduction of radon emanation due to depletion of uranium from surface geologic formations. Most of the current uranium stock has come from far below the Earth's surface and has not contributed significantly to radon levels in the atmosphere. In fact, tailings from which 95–99% of the uranium has been removed will emanate radon at a greater rate than most surface formations that comprised the overburden at the mine sites, because the radium-226 (halflife = 1600 years) and thorium-230 (halflife = 76 000 years) are not currently extracted during milling operations and remain in the mill tailings.

There are potential public-health problems, including those that might arise from nuclear waste storage, that must be—and are being—carefully studied in connection with nuclear power. There are also known public-health hazards associated with mining, transporting and combustion of large amounts of fossil fuels, as well as the handling of fossil wastes. These are hazards of another kind in being dependent, as a nation, on sources of energy that we do not control. Cohen admonishes us in the twentieth century not to be remembered as the generation that consumed all of the high-grade ores and literally burned up the Earth's hydrocarbons, which took millions of years to form. It seems to us that the most practical—and indeed desirable—alternative is to utilize fission energy over the next several decades while long-term solutions to Man's energy problems can be planned and developed. During this time, policy decisions that affect health and safety should be guided by comparisons of the impacts on society of all available options.

D. G. JACOBS
J. E. TURNER
Oak Ridge National Laboratory
Oak Ridge, Tennessee

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I read Bernard Cohen's letter on the hazards of radioactive wastes with great interest and admiration, but with deep uneasiness.

Physicists have yet to share our widespread and bitter experience as physicians of using a drug or procedure, to find out some time later that the extensive and favorable scientific studies had their blind spots, and we had done our patients real harm. Irradiation of the thymus in infancy leading to adult thyroid cancers, estradiol salvage of threatened pregnancies followed by vaginal cancers in the children years later, oral hypoglycemic agents for diabetics leading to increased cardiovascular complications, and so on—how can I convey to you how this feels for the physician? I fear you may find out the hard way. The use of the atomic bomb may have been primarily a political–military decision, but the problem of nuclear wastes is in your hands. For your own sake, do not be too glib with your reassurances.

Two blind spots in Cohen's letter: First, the health hazard was calculated on the basis of "dosage to various body organs if ingested by adults." There are in fact lots of children and pregnant women in our society, and there always will be barring a mass death-wish. Shouldn't their increased susceptibility to radiation be the standard for safety? Maybe this

problem is tackled in the complete article.

Secondly, the graphs and numbers are fascinating and to me, a non-physicist, quite reassuring in their own way—but a little beside the point. They assume that some major problems are already solved, that the wastes will all get to be buried 600 meters deep without incident. It would be nice to see first a successful fuel reprocessing plant in operation. Like fusion power, it's an easy goal to state but seems annoyingly difficult to achieve in the real world. Would reaching it twenty years behind schedule affect Cohen's predictions?

The hazards described were for the US from one year's operation of nuclear plants. The thought of having to achieve this level of technology world-wide for years with very little room for error is disturbing. In fact, one worries about whether it is possible to multiply the numbers of reactors here by ten without any decrease in quality of personnel. I have seen enough sloppy handling of radiation in hospitals to worry about what will happen if nuclear reactors become commonplace. If problems do occur in reality, an adequate theory of what should have happened will be cold comfort. How does one include human error in a calculation? Cohen says "there is every intention to handle the radioactive wastes from reactors with great respect." I hope that these good intentions do not pave the proverbial road for Mankind.

HELEN T. O'KEEFFE, MD
Walnut Creek, California

THE AUTHOR REPLIES: The principal questions raised by Robert Pohl are whether the buried waste behaves like average rock in its susceptibility to leaching, and whether the burial operations disturb the geology and hydrology in a way that increases the probability of contact with ground water. The first question has been studied for many years by a Battelle-Northwest Laboratory group [see, for example, J. A. Mendel, W. A. Ross, F. P. Roberts, R. P. Trucotte and J. H. Westsek, Jr, "Thermal and Irradiation Effects on Borosilicate Waste," BNWL-SA-5534 (1976)]. They find that the glass into which the waste is incorporated is about as leachable as granite and ten times *less* leachable than shale. If it should spend an appreciable time at temperatures above 700°C, which is not normally expected, the glass may be devitrified, which increases its leachability by up to an order of magnitude. Since glass is already a disordered system, radiation damage is not expected to have important effects, and this is confirmed by experiment; in one test with Cm^{244} (an alpha emitter) incorporated, the glass was subjected to the equivalent of 2000 years of irradiation by waste with no significant effect on its leach rate or mechanical

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strength. The answer to the first question thus seems to be that the waste will be no more leachable than the radium in average rock with which it is compared in my paper. Work is continuing, including efforts to improve the properties of the glass (W. A. Ross, private communication).

The second question has been studied mostly with regard to burial in salt; in fact one of the principal advantages of salt is that it flows plastically and seals cracks, so the waste ends up sealed inside a gigantic crystal. This still leaves the problem of the vertical shaft through which the waste is brought in. This has a minuscule area in comparison with the area of the repository, and it is widely believed that if reasonable care is taken, this shaft can be satisfactorily plugged with concrete and cement. There is some work in progress on the possibility of using fused rock to simulate the original geological situation better (Owen Gormley, ERDA, private communication). Burial in rock other than salt would require considerable research, but it appears reasonable to expect that filling with concrete or some other material would handle the situation. After all, the original rock was formed by simple sedimentation followed by the pressure of the overlying rock, so why shouldn't Man-introduced fill behave as well? As a general principle I do not understand why Man with all his science and technology should be assumed to be inept in comparison with the random and undirected processes of Nature.

On other points raised: The concentration of radioactivity in the waste is irrelevant; only the probability of escape enters the calculation when the linearity hypothesis is used for radiation effects. The effects of heating on the overlying rock have been extensively studied by the Oak Ridge group; they conclude that these effects are not serious but this will be studied experimentally in the first repository. If it is found to be a serious problem, the waste can be retrieved and reburied—the heat generation rate decreases by a factor of ten per century.

I am disappointed in Pohl's giving no credit for the conservatism in my two basic assumptions. Surely random burial, which includes burial directly in aquifers, in highly fractured rock, in tectonically unstable regions, and so on is far inferior to the use of all the knowledge available from geological and hydrological studies in choosing an optimum site. And with regard to my other assumption, surely the vast majority of erosion, including that by rivers, wind, freeze–thaw cycles, and so on occurs at the surface; so nearly all the radium in our environment comes from near the surface. The amount released from hundreds of meters below must be quite small by comparison, but I took it to be equal to the total. In fact in quoting my result as "1.1 cancer deaths," Pohl does not even give credit for added security during the first hundred years when there is additional protection from the five separate and independent time delays I discuss in some detail. In addition to these, there would be careful surveillance during this period, and this is certain to provide protection even if all else fails.

Above and beyond these matters, there is the demonstration in my paper that on any long time scale, the uranium consumed is much more dangerous than the waste it produces. This is simple physics. A uranium nucleus is destined to decay with emission of eight alpha particles, whereas when it undergoes fission it is split into two nuclei, which are beta-gamma emitters, 90% of which have decayed away before the material leaves the reactor; beta-gamma emitters are two orders of magnitude *less* dangerous for ingestion than alpha emitters. From this is surely clear that on any long time scale, nuclear power cleanses the Earth of radioactivity.

In response to Douglas McDonald my letter dealt with the problem of the waste after burial; malevolent intrusion at this stage would be extremely expensive (millions of dollars), time consuming (weeks of work), and dangerous to the perpetrators, and hence would be essentially unthinkable.

McDonald is correct in stating that the waste is exceedingly dangerous before burial, as is emphasized in my paper. However, he somewhat overstates the case. From my figure 1, after 100 years of decay, one year's waste from all nuclear power *could* kill 3×10^9, but since only about $1/300$ of a city's water supply is ingested, it would take $1/10$ of it, or about 250 tons after solidification (hardly a tiny amount) to kill a million people (with 65% efficiency). Moreover, it could not be handled without thousands of tons of shielding (one percent of this waste would give a lethal gamma-ray dose in 15 minutes at a distance of 10 meters without shielding). It would have to be in soluble form at normal pH (no minor trick), and this radioactivity would have to go undiscovered for many days while a reservoir full of water is consumed. If this is a worry, radioactivity monitoring systems could protect against it at a cost compensated by increasing the cost of electricity by one part in 10^5. As a chemist, McDonald may want to compare this with what can be done with a few thousand tons of poisonous chemicals (or biological agents) readily available in soluble form at low cost with no simple detection systems possible.

Basically Jacobs and Turner go into the problem more deeply than was intended by my letter, which was written to give physicists an over-all physical understanding of the problem. For example, it

was implicitly assumed that the waste can be brought to the burial area and emplaced, that the burial cavity can be backfilled, and that the shaft leading to it can be sealed. These are technological problems that must be solved; I did not mean to imply otherwise. I also hope the readers appreciate that I was calculating for the average situation, not for the worst imaginable. By concentrating on the latter, any technology can be made to appear highly dangerous; perhaps the worst example of this in production of electricity is a collapse of a hydroelectric dam which could kill a quarter of a million people.

My information is that transmission through cracks is relatively minor at great depth where pressure and crushed rock at interfaces give a rather good seal.

It is not obvious to me that fission is for centuries rather than for millenia. With breeder reactors, one can use very low-grade uranium ore without appreciably increasing the cost of electricity.

On the cleansing effect of burning uranium, my calculation is actually highly conservative. I assume that mined uranium comes from all depths between 0 and 600 meters with equal probability, but actually most of it comes from the top 30 meters. Of course most of it was covered by a thick overburden as Jacobs and Turner say, but this is taken into account in my calculation. If all of the uranium came from the surface, the number of lives saved from burning it would be orders of magnitude higher. The mill-tailings comparison is made in my paper, and if these tailings are not properly handled they could delay the time before there is a net cleansing by up to 100 000 years; but my letter discussed the cleansing effect on a million-year time scale.

There is nothing glib about our national effort on the waste-disposal question. There are large research programs at Oak Ridge National Laboratory, Battelle Northwest Laboratory, and Sandia Corp. (Albuquerque), and many smaller programs.

On the first "blind spot," the BEIR Report indicates that effects of radiation on children are less than on adults for cancers other than leukemia, which account for 80% of the fatalities. This is clearly indicated by survivors of the atomic-bomb attacks on Japan: among 5000 children of ages 0 to 9, there were an excess of 4 cancers between 1960 and 1970, whereas among roughly equal numbers of ages 20–34 and 35–49 there were excesses of 21 and 35 respectively. There is evidence that the fetus is an order of magnitude more radiation sensitive, but we spend only 1% of our lives *in utero*, so this is only a 10% correction.

On the second "blind spot" it is difficult for me to see what great obstacles lie in the path of waste burial, unless they are political. The technology is essentially all

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available. Surely this is not comparable with the problems of fusion power, for which scientific feasibility, let alone technical feasibility and economic feasibility, is yet to be demonstrated.

I don't understand why people expect perfection from everything nuclear, or consider it necessary. We kill 10 000 people per year with air pollution, 1000 per year from coal-mine accidents and disease, 500 per year with asphyxiation by natural gas, 300 per year from fires started by leaking oil and gas, and 1200 per year by electrocution, all in the name of providing energy. We have never killed anyone with nuclear energy, and one of the points of my paper is that the potential hazards of nuclear waste are smaller than those from many other man-made substances. As in everything else, mistakes are always possible, but what is the justification for the special concern about nuclear waste?

BERNARD L. COHEN
University of Pittsburgh
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Support for Russian Jews

I recently had the opportunity to speak with my Congressional Representative on an issue of concern to the American Institute of Physics: the plight of Russian Jews who wish to emigrate. I was told that, with rare exceptions, this is an issue of primary concern only to those Congressmen with large Jewish constituencies.

In other Congressional Districts, my Congressman suggests that constituents of all backgrounds, who believe in freedom of emigration for these Russian Jews, notify their Congressmen in no uncertain terms.

E. SACHER
Binghamton, New York

Rapid publication?

As a librarian I applaud the good sense behind the stand taken by N. P. Mermin and K. B. Wilson in the March issue (page 11). D. Caplin, D. Sherrington and R. Jacobs's defense was predictable, but two questions arise from their letter.

Firstly, they seem to imply that American referees consider European papers on grounds other than scientific. They also seem to imply that editors and referees of some European journals of national physical societies do the same. Is there really national bias in the refereeing and editing of journals? And are we to surmise from the nationality of Caplin, Sherrington and Jacobs that the bias has been against British papers?

Secondly, on the question of rapid publication, I did a quick survey of several letters journals and letters sections in journals. Using all the papers from the latest issue in each case, I found the following figures for the average number of days from the date of receipt of the paper by the journal and the journal's arrival in our library:

Communications on Physics	81.6
Lettere al Nuovo Cimento	99.0
Physics Letters A	100.6
Journal of Physics C (Letters section)	104.1
Nature	111.1
Physics Letters B	124.3
Applied Physics Letters	144.0
Journal of the Optical Society of America (Letters section)	150.6
Physical Review Letters	155.2
Journal of Chemical Physics (Letters section)	165.5

From the slim evidence given here it would appear that *Communications on Physics* is at present leading the "rapid-production" race. But just what are the benefits to science of beating *Journal of Physics C* by 20 days, *Physics Letters B* by a further 20 days, and so on? If we agree that priority of discovery is safeguarded by the date-of-receipt device, then what indeed are the virtues of rapid publication?

Incidentally the low placing of the American journals on the above list is partly explained by the fact that our library is obliged to take out surface-mail instead of the more expensive air-freight subscriptions. That we have to make such economies indicates the climate in which we will consider a subscription to this new rapid-publication journal next year.

IAN MALLEY
University of Bristol
Bristol, UK

More on astrology

I am pleased to see that PHYSICS TODAY has reviewed the reprint booklet, *Objections to Astrology*, and I wish to thank Robert March for his kind comments (March, page 54). However, I would like to take issue with his statement that there is nothing in the book that astrology's "true believers" have not "heard (and dismissed) before."

There is much in the book that astrologers have not seen before: 1) The statement by 192 scientists disavowing astrology is the first such public position ever taken by the scientific community against the ancient "art." 2) Both Bok and Allport stress the psychological dangers of astrology as a form of escapism from reality. 3) All too rarely have astrologers seen their "art" described as a system of magic, and thus totally invalid in terms of modern science. 4) Finally, by associating the origins of astrology with