roles of quasars and on the behavior of black holes at singularities were my concentration from 1971–1975. My ideas did not receive acceptance readily in this area, and I can say (in all humility) that I was a decade ahead of then-published material in journals. I now concentrate on quantum field theory and extensions on several complex variables, keeping up with developments thanks to my membership in APS and AMS. I am not unique—there are thousands like me throughout the US and the world who are "scientists by night."

However, we do lack one very crucial ingredient for truly serious results—interaction with fellow scientists. How well would Einstein have done without his "Akademie" meeting every Tuesday evening to discuss Mach, Poincaré, Lorentz, Maxwell and so on? Would he have published in 1905 without the help of his former classmate and lifelong friend Marcel Grossman? I think not.

I propose a national organization, affiliated with APS, called the Society of Non-Affiliated Physicists (SNAP) and will gladly help to develop this needed organization.

If interested, please write to:

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6/83

Credit for coauthor

A news story in May (page 17) mentioned my work on density inhomogeneities in the new inflationary universe, but it failed to mention my coauthor, So-Young Pi. While she was not present at the Nuffield Conference, she did collaborate in these calculations.

ALAN H. GUTH
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6/83

Non-proliferation treaty

In June, Harold Lewis writes (page 98): "he [Rau] states that 'an essential component' of the [non-proliferation] treaty is a commitment on the part of the nuclear powers to stop production. My copy of the treaty contains no such item."

In the preamble to this treaty, the states concluding the treaty declare "their intention to achieve at the earliest possible date the cessation of the nuclear arms race and to undertake effective measures in the direction of nuclear disarmament." Two other clauses have a similar tone.

In the main text of the treaty, one of eleven clauses reads: "Each of the Parties to the Treaty undertakes to persue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."

J. A. EADES
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7/83

Uranium tailings hazard

It is unfortunate that I have only now read the article in the December 1982 issue by Robert Pohl, but comment still seems required. I will limit myself primarily to his section on uranium mill tailings (page 41), although some of the considerations are directly transferable to other parts of his presentation.

The layman starts with the preconception that without human intervention the environment is free of radiation and of radioactive materials. In fact, uranium is fairly evenly distributed in soil and rock at some 5–8 parts per million (less in Illinois black loam, more in the mountain rock near Pohl's Ithaca), and thorium is on average about four times as abundant. Pohl's presentation not only fails to address this fundamental fact, but in his discussion of the mill tailings he seems to carry along the popular fallacy that only after mining and processing does the radioactive content come into being.

The activity in the tailings existed in the ore, which in turn was located in the ground. Most current mining is in open-pit operations, which means it comes from relatively shallow subsurface locations. Ore currently being exploited is frequently considerably leaner even than Pohl's 0.1%, by as much as a factor of ten and more. We are thus talking about material that starts at factors of tens, not hundreds, and certainly not thousands, above universal background. But local background, in the plateau regions which are the site of current mining and milling operations, runs definitely above the average, so the difference from a random surface location in the area is even less.

Further, the ores are leached with sulfuric acid, to precipitate barium and other alkaline earth sulfates, and thus co-precipitating the radium isotopes. In this form the radium is effectively nonemanating, as anyone who has dealt with it in the laboratory can testify. This is in contrast to the naturally occurring state. The uranium in these ores was deposited from

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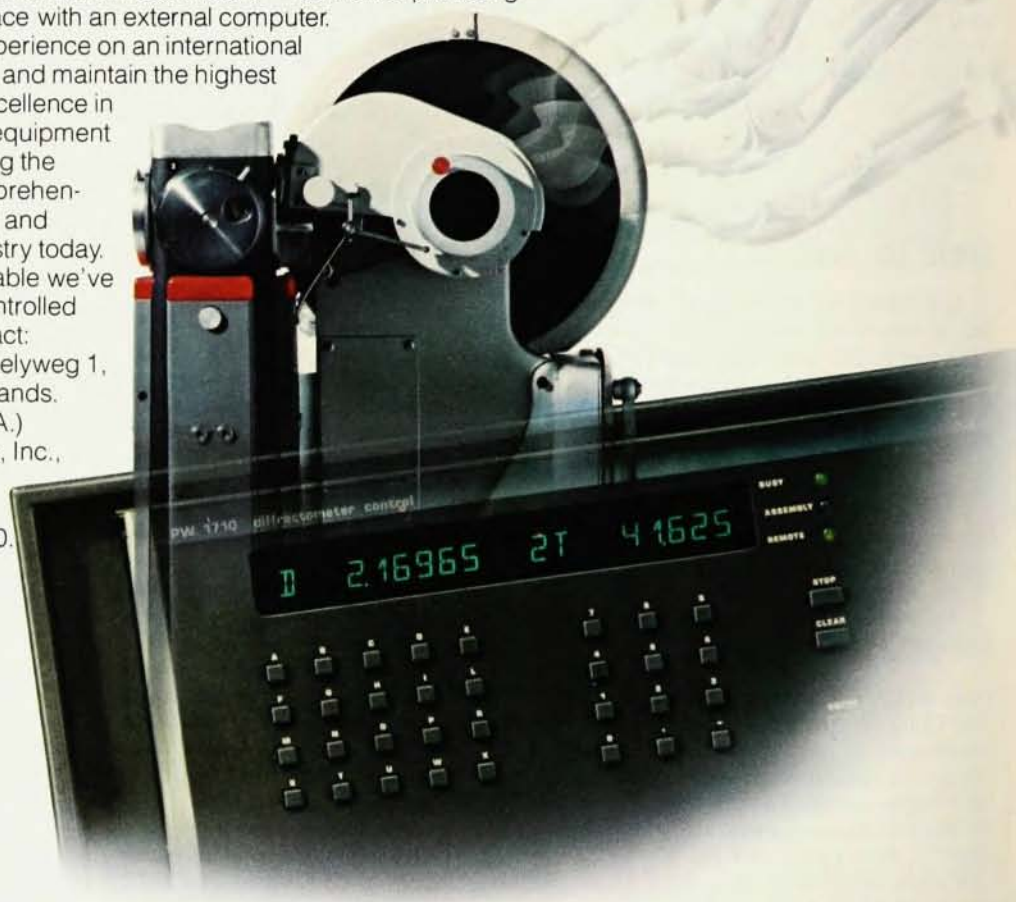

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aqueous solution, in subterranean flow, by reducing materials, generally organic compounds. The decay chain thus proceeds in a crystallographically "loose" environment, which the decay recoils disrupt further, so that one expects the medium to be a relatively good emanator, compared to the situation after mining. Air sampling gives radon readings indistinguishable from local background very quickly as one moves off the tailings pile. By the site boundary the readings are well at background. It seems significant that, according to Pohl's own figures, even sitting on a tailings pile full-time (168 hours per week) leads to a gamma-ray exposure only twice that of the acceptable occupational exposure, which is based on a 40-hour week. "If a building were constructed on a tailings pile . . . " Pohl worries—without explaining why one would pick that unstable and unattractive substrate instead of the firm surrounding prairie—that one would, in ten years of steady living there, perhaps double the change of dying from lung cancer. A choice to smoke cigarettes would multiply that probability by an even larger factor, even in a less ridiculous habitat.

Has Pohl measured the radon and decay product levels in his stone-and-concrete office building on the Cornell campus, far removed from Western mines and mills? Unless he is an energy spendthrift, wasting heat in winter and air-conditioning in summer, by having both heat and cold blow out through open windows, he may have more in common with his Western house-dweller and uranium miners than he realizes. And the coal-fired power plant he mentions is probably spewing forth radioactivity in its smoke and fumes comparable to the emanations of the tailings pile. He underestimates the depth of burial for the District of Columbia, since ores processed are becoming so much leaner. The pile would be even more impressive if he simply included all material with a uranium content of, say, 20 ppm and above—after all, the hazard is there before processing as well.

Yes, radiation is dangerous. Yes, one must take account of it and its sources to minimize its harmful aspects. But it behooves professional scientists to approach these activities in a logical and professional, not polemical, fashion. The general public receives sufficient misinformation and disinformation from sources with axes to grind; it should be able to rely on cool and objective orientation from professional scientific sources. The article under discussion, under the cachet of a professor of physics at a reputable university, seems to me to fail the test badly.

LEONARD I. KATZIN

6/83 *Port Hueneme, California*

THE AUTHOR REPLIES: Leonard Katzin asserts that the estimates of the toxicity of uranium mill tailings quoted in my article are too high, and that their health impact is not too different from that caused by the natural background radon. His estimates, however, are based on unsubstantiated guesses.

The average grade of the ore to be mined between now and the year 2000 is 0.1%, according to an estimate by the Nuclear Regulatory Commission[1] (in 1980 the average grade mined[2] was 0.12%.) From the resulting unprotected dry mill tailings piles containing an average of 280 pCi Ra^{226}/g, the radon flux[1] would be 280 pCi Rn^{222}/m^2sec. Average radium-226 background soil concentrations[1] in the Western uranium-milling areas is 1 pCi Ra^{226}/g, leading to 280 times smaller radon fluxes than from the mill tailings, and not to merely factors of ten smaller fluxes, as Katzin asserts.

Katzin also claims that the excess radon concentration quickly diminishes away from the pile, stating "By the site boundary the readings are well at background." According to a recently published report by the Environmental Protection Agency,[3] radon decay products from unprotected uranium mill tailings will cause individual lifetime risks of fatal (lung) cancer of 0.84% at a distance of 1000 meters from the center of the pile; at 2000 meters, this risk is[3] 0.26%. The chance of lung cancer death from all causes is 2.9% for the entire population.[4] A local increase of this figure by approximately 30% or 10%, respectively, seems hardly negligible. Unless one assumes the site boundary to be miles away from the edge of the pile, Katzin's claim is clearly untenable.[5]

I am convinced that a non-radioactive waste dump that would threaten to increase the incidence of lung cancer from the national average by 30% for people living 1,000 meters away from the dump would be considered a very serious threat to the public health. The rules for the disposal of uranium mill tailings recently proposed by EPA[6] demonstrate that this agency also recognizes the threat posed by these wastes. I am equally convinced that the worst enemies of the nuclear industry are the very people who are trying to belittle its problems.

References

1. *Final Generic Environmental Impact Statement on Uranium Milling*, NUREG-0706, US Nuclear Regulatory Commission, September 1980.
2. *Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics,*

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DOE/NE-0017-1, US Department of Energy, October 1982, page 261.

3. *Draft Environmental Impact Statement for Standards for the Control of By-product Materials from Uranium Ore Processing* (40 CFR 192), EPA 520/1-82-022, US Environmental Protection Agency, March 1983.
4. *Environmental Impact Final Statement for Remedial Action Standards for Inactive Uranium Processing Sites*, EPA 520/4-82-013-1, US Environmental Protection Agency, October 1982.
5. The estimated risks of lung cancer from naturally occurring radon decay products found in homes that are not near mill tailings or any other specifically identified radon source is 4×10^{-6} to 4×10^{-3} (see reference 3, page 6). The issue of health risks posed by elevated indoor radon concentrations resulting from a variety of causes other than mill tailings has been discussed previously in these Letters (PHYSICS TODAY, May, page 102); see also reference 4. Reference to these problems, of course, does not reduce the risks posed by improperly discarded mill tailings.
6. Standards for Uranium and Thorium Mill Tailings at Licensed Commercial Processing Sites, Part VI, 40 CFR 192, U.S. EPA, Federal Register **48**, 19584, 29 April, 1983.

ROBERT O. POHL
Cornell University
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7/83

Role of the teacher

I fully agree with Jerry Finkelstein's belief that the ideas students bring with them to the classroom can furnish a firm starting point from which to develop an understanding of physics (April, page 91).

The teaching of Newtonian physics to Aristotelian minds is a serious problem that has confronted teachers for years. In addition, there is evidence for the persistence of the Aristotelian way of thinking even in adults who have learned Newtonian physics in high school. So my view is that we cannot blame students because they have a predilection for Aristotle's views or a prejudice against Newton's views—they are completely ignorant of these views. But they do express Aristotelian ways of thinking without knowing it and without knowing that they contradict Newtonian physics. In addition, Aristotle's views are at least 2000 years old. Despite our efforts to teach Newtonian physics, we are in trouble because of the persistence of Aristotelian views. The only conclusion I can draw, therefore, is that Aristotle's way is the natural way of thinking, though it has not given birth to the overwhelming developments of physics. If Aristotle had existed in the 17th century along with Newton, or after that, he would have become aware of Newtonian physics and would have contributed to the developments of physics enormously.

So, instead of suppressing the natural way of thinking, we should teach students to express their ideas systematically and lead them smoothly to the laws of physics by making changes whenever and wherever necessary. Otherwise, as Finkelstein says, students will not believe in us.

DILEEP V. SATHE
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8/83

More on problem solving

Mary Meyer enlivened the June issue (page 92) with her lucid discussion of Robert Fuller's article (September, page 43) on problem solving. They and the references they cite call to our attention some superb insights on the consequential structure of applied thought that is science.

I would like to offer, as support to Fuller's expectation that some such attention to the cognitive processing of disequilibrating experiences (discovery and other such perceptions of universally accessible fact which apparently contradict a dominant depiction of reality) offers benefit to science generally and to its teaching.

Permeating science and the cultures that produced it is the hidden assumption that such problems are individual matters—that salvation, as it were, is a private affair. This seems to be true at least in those domains where the fiction of immense individual accomplishment drives personal strivings for fulfillment through dedicated work; physics is a paradigm itself of such fields of endeavor.

But there is a considerable likelihood bordering upon certainty that unapparent mental constructs involving cognitive resonances of long, broad standing among many, many persons are a (the?) basic phenomenon at work in such fields. The incremental nature of the progress of general understanding and the ubiquity of parallel invention hardly contradict this presumption.

If this is true, then one contributor's misery of cognitive dissonance is a vital ingredient of the next one's exultant resolutions. The *sine qua non* for this to be plausible is communication. I would then submit that science arose upon the foundation of universal publication.

The bearing of all this upon those issues discussed by Fuller, then Meyer,