letters

We clearly must limit the number of physicists, and we can only do this by limiting the number of physicists produced. This means cutting down graduate enrollments. Let us look at what is happening in this area now.

Applications to graduate school are certainly dropping at a rapid rate; after all, physics majors are not stupid! Enrollments, however, are not as closely tied to applications as they are to support. While financial cutbacks have undoubtedly reduced enrollments somewhat, it is also apparent that admissions standards have often been lowered to compensate for the even more drastic drop in applications. Thus as the job market tightens, we actually lower the quality of our students. Some schools supplement their dwindling crop of applicants by importing quantities of foreign students, mainly from Asia. This is grossly exploitative, and I anticipate the day when some developing country will discover that it has more particle theorists than it has computer programs to write, or, more to the point, more physicists than competent engineers.

Even if financial restrictions and reduced applications do have a major corrective effect on the production of new physicists, it can hardly be satisfactory to predicate our year-to-year graduate policies on the vagaries of congressional support and the undergraduate rumor mill. If graduate enrollment in physics is to be controlled, let it be controlled by physicists, not by politicians and newspapermen.

I propose that the American Institute of Physics establish an accreditation board for graduate programs in physics. This board would set minimum standards for graduate programs, thereby greatly discouraging the proliferation of under-staffed and under-equipped programs that even now goes on. It could also set minimum admission and graduation requirements.

An essential feature of any such policy is that it ensure a degree of stability to graduate programs in a widely fluctuating era. This, and the need to control graduate student enrollments, can be accomplished by requiring a minimum faculty-student ratio in the accreditation standards. Doing so would also inhibit the tendency of some popular departments to admit more outstanding students than they can possibly do justice to, while leaving the dregs to others. A particularly important feature of using a faculty-student ratio as an accreditation standard is that it is flexible; if needed, it can be adjusted to meet projected manpower needs, which is the only mechanism I know of that can affect graduate enrollments before, rather than after, the situation changes.

There is a common fear that this proposal, like any other, is sure to provoke; perhaps we will overcompensate and create a shortage of physicists. I think this would be virtually impossible. The number of jobs that physicists can fill is far greater than the number that only a physicist can fill. The number of physicists needed is much smaller than the number employable, a fact emphasized by recent articles in *physics today* that show how much further afield physicists have gone than the usual peripheral fields of engineering, applied math, and computing. That we, despite the fantastic flexibility of our field, have been able to generate a glut is ample testimony to the necessity of strong corrective measures.

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Reply to Mumford

It is regrettable that in the face of an attack on physics and technology by Lewis Mumford, the editor of *physics today* in the December 1970 issue chose to surrender positions that can be easily defended. The malaise of our times is due to an almost complete lack of social and economic planning by our national leaders (none of whom are scientists or engineers). The supercilious attitude toward material things by humanists like Mumford is endemic with people who are themselves well fed, well housed, and have superior medical care that they take for granted, and none of which would be possible without modern science and technology. People like Mumford are also apparently incapable of understanding the simple fact that the primary drive of a scientist is for an understanding of nature, a spiritual and creative drive of the same kind that impels a humanist.

Regardless of the fact that describing Descartes as a positivist is simply incorrect, if the development of physics from Galileo to our day is positivism,

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then more power to it! But in fact, positivism, and in particular logical positivism, has had less influence than it deserves. This philosophical school advocates a logical analysis of scientific concepts and the avoidance of meaningless questions. It has helped to clear much metaphysical fog.

Finally, it is amazing to find you deprecating the use of mathematical methods in science. Without this, physics would be impossible, as has been known since the discovery of the laws of strings by Pythagoras. It is true that in some sciences at some periods qualitative methods may be sufficient, as in the case of Darwin. But Darwin was followed by Mendel, and who will deny the mathematical nature of modern genetics? And biophysics and biochemistry, insofar as physics is a component, must eventually be highly mathematical. In sum, science and technology are being used as a convenient scapegoat by those who refuse to see the real causes of the distress of our day.

A. V. Bushkovitch
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The editor comments: There was no intent in the December editorial to deprecate the value of mathematics. There is, of course, an immense advantage in being able to formulate the significant questions in a field of study in mathematical terms. But unfortunately there is too often an overreaction in the form of the attitude that unless a field of study is able to use mathematics it isn't really science. The result has been that frequently people in the "softer" sciences mistakenly try to employ mathematical approaches to problems for which the methods of Darwin would be more appropriate. See the late William Feller's views on this point (Scientific Research **4**, No. 3 24 (3 February 1969)).

How Neptune was discovered

For the sake of historical accuracy I would like to correct two minor points in the excellent article by John S. Rigden ("Reshaping the Image of Physics," October, page 48).

The English mathematician John Adams who calculated the location of Neptune prior to its discovery was not an undergraduate at the time he worked on this problem. Having already graduated at Cambridge as Senior Wrangler in 1843, he commenced work on the Uranus problem (part time!) arriving at his first results in 1845.

The often-referred-to "small discrepancy" that Bouvard noticed in Uranus's position was, in fact, substantial if measured against what was then detectable. In 1820 the error in Uranus's position was about 21 seconds of arc, which is approximately an order of magnitude larger than other effects that had been observed (such as stellar aberration and stellar parallax).

Indeed, the full story of the discovery of Neptune is one of the most dynamic and human stories in the entire history of physics. It is a shame that time has buried this tale so deeply. Congratulations to Rigden for giving it a moment's breath out in the open.

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What is modern physics?

Your March issue, devoted to physics for the nonscience major, carried a review (page 75) in which my recently published college text, *Introductory Physics, a Model Approach*, was compared with Leon Cooper's very excellent *An Introduction to the Meaning and Structure of Physics*. I should like to question reviewer Thomas Von Foerster's unspoken assumptions as revealed in his comments about my "slight" treatment of modern physics and his suggestion that my book was better suited to high-school courses.

▶ What is "modern physics"? Most authors and the reviewer appear to consider relativity, quantum theory, subnuclear particles, and symmetry principles to be essential ingredients of modern physics. While I agree that these are the important topics in current research, it is also a sad fact that their very abstract nature—the remoteness of their models from common experience—makes them exceedingly difficult for laymen to grasp. I have therefore looked beyond these specific areas and propose that operationalism, together with the awareness that models are not truth, characterizes 20th-century physics in a deeper way than relativity.

▶ What distinguishes "high-school" from "college" physics for nonscience students who avoided taking physics in high school because of disinterest, fear, or lack of time? The students are in college and have never had physics before. Should they ". . . stand, perhaps in awe, before the 'cathedral-like' structure of physics," as Von Foerster expects from Cooper's text? Or is it better that they ". . . feel at home in the structure of physics," as Von Foerster describes the aim of my book? Both of these objectives are undoubtedly worthwhile, but, "feeling at home" would seem to come before "standing in awe" if students are to understand rather than merely being impressed. This is especially true for the many students—50% in some of my classes—who hold an active hostility toward science because its technological applications can so easily be used for evil purposes. A