

literate public. If we can share with everyone the excitement of our discoveries, there will be a greater understanding of the function of science. Perhaps only then will we no longer be asked why we do what we do, but instead why we cannot do more of what we do.

The physics community is neither childish nor naive. We are (or as our original letter pointed out, should be) aware of the dynamics of employment and funding. In the past, these have had long-term cycles that adversely affected the health of the physics profession. We ignore these at our peril.

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9/87

I would like to comment on the recent articles concerning the supply and demand of physics research manpower. In the June 1986 issue of *PHYSICS TODAY*, there was much discussion and hand-wringing about the decline in PhD production and the possibility of a "shortage" of PhDs. Let me point out that there is no shortage of PhDs in physics nor is one likely to emerge in this century. The reasons are as follows:

▷ Employment in physics is volatile. For example, during 1969–76, most of the opportunities evaporated. Consequently many people trained in physics found it necessary to retrain and become engineers, physicians, taxi drivers or television repairmen. Another consequence was that many young people wisely chose to avoid the study of physics. No direct mention of these events was made in the June 1986 issue.

▷ Military research is volatile. The emphasis on new weapon development depends on the national mood and on the Administration in power. Both can change abruptly. Yet many physics PhDs are currently employed in military research.

▷ Research funding is limited. Bruce Schechter (April 1986, page 32) points out that "it is vital that the most talented young graduates who elect university careers obtain support for their research," but that "the trends in funding, however, run in the opposite direction." Obtain the number of viable university jobs by dividing the total available funding in "small scale" research by \$100 000. Since most university administrators seem to expect such a level of external funding from their faculty, this calcu-

lation is reasonable. Based on such arguments, it appears there is a surplus of physicists.

▷ A surplus of physicists may be deliberately created. A situation may develop analogous to the one in engineering. D. E. Marlowe, executive director of the American Society for Engineering Education and past president of the American Society of Mechanical Engineers, wrote the following in an article, "Engineering Education: Issues and Answers," in *Mechanical Engineering* (December 1980, page 26): "We may have to create a deliberate surplus in the late 1980s and a pool 'holding' of 'postdocs' in the early 1990s to properly meet the nation's requirements for high-technology engineering in the 1990s."

▷ A current surplus of PhDs is suggested by the fact that about half of the new PhDs take postdoctoral positions. As for more experienced PhDs, many are in soft money positions. As Malcolm R. Beasley and Lawrence W. Jones (June 1986, page 36) indicated, it is in the interest of the universities to make "these positions dignified and rewarding, with reasonable long-term job security," which implies that these positions are now undignified and unrewarding, and have poor job security.

I conclude with two suggestions. Those faculty advisers who seek to behave ethically should inform potential graduate students of the historical aspects of physics employment and unemployment. And if a shortage of PhDs develops, let us alleviate it by recruiting those who abandoned physics for medicine, engineering, carpentry or other fields due to lack of opportunity in the 1970s.

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7/86

SDI: When Defenses Turn Offensive

There is a hidden assumption underlying many published discussions on the merits of SDI. Simply stated (and in the language of physics), defensive and offensive weapons are presumed to be independent degrees of freedom whose consequences can be independently calculated. This assumption may lead to seductively "obvious" conclusions, for example, "How can anyone be against a defensive system that increases our own safety without threatening the safety of others?" This presumed separability is a forced and artificial distinction. Arguments based on this distinction are immediately suspect, and may indeed have

serious consequences.

One difficulty with presuming a "decoupling" is subsequent, unintended imbalances of power. A good example may be found in the history of the aircraft carrier. During World War I, the airplane was used to gather intelligence, and as such was viewed primarily as a defensive weapon. After the war, many people experimented with modifying battleships to carry and launch airplanes for land and sea reconnaissance. The aircraft carrier, large and lumbering, was viewed purely as a defensive platform unlikely to be an offensive threat. Indeed, under the terms of the Washington Naval Treaty of 1922 battleships could be traded in for aircraft carriers as a way of "disarming" the world powers. However, a small change—the addition of bombs attached to the aircraft—catapulted the purely defensive aircraft carrier into an extremely powerful offensive weapon, one we had encouraged Japan to build. America nearly lost the war in the Pacific by placing its trust in the independence of these two modes of waging war. Thus, the first problem with assuming a decoupling between offense and defense is to underestimate how quickly these roles can be reversed.

The fact that these roles could be interchanged might lead one to believe that offense and defense are manifestations of the same underlying phenomenon, and that treating them separately obscures the true "symmetry" of the problem. Consider two adversaries A and B, armed with offensive weapons (guns). These weapons and their rough equality of strength dictate a particular style of warfare—for example, ambush is an effective strategy. Consider the consequences when A invents bulletproof clothing. By any standard, bulletproof clothing cannot by itself cause harm. It is a defensive weapon designed solely to increase the personal safety of the wearer. But what a difference it makes! Now A can attack B directly, with no fear for his life and able to absorb as many bullets as may come his way. He can move boldly and with a much broader range of available tactics; the same gun is now a much more effective offensive weapon purely through the addition of a defensive technology. Considering whether A would be generous in victory, or whether B might shift the balance by inventing penetrating bullets, shows once again that the tradeoff between offense and defense is illusory.

The real question is not the offensive or defensive nature of the weap-

on, but are we safer with or without SDI? The answer demands a thoughtful and mature examination of the intertwined political, economic, technical and strategic issues. Unduly simplifying the problem by seeing distinctions where none exist can have grave, perhaps fatal, consequences.

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3/87

Physics Takes the Witness Stand

Certain objectives of the article "Forensic Physics of Vehicle Accidents," by Arthur C. Damask (March 1987, page 36), are very valuable. However, as one who has spent 40 years performing basic research on collision of solids and human impact trauma, I strongly disagree with certain of his views and also would like to elaborate on some additional important topics:

▷ Credibility is the principal attribute of an expert in any court, particularly in litigation involving vehicular impact and resultant trauma. I agree that attendance in brief courses is not a suitable qualification, but neither is a PhD, even one in the general area of expertise and granted by a respected university, unless competence has been demonstrated.

▷ The most crucial qualification of an expert is experience and judgment. It takes a seasoned scientist to evaluate the weight of frequently conflicting physical evidence.

▷ The best credential of an expert is a continuous successful research effort in collision dynamics and trauma, documented by peer-reviewed archival publications. Many consultants have published no research papers, while others exhibit publications that were subjected to either scant review or none at all. Some recent papers are based on invalid representations of a system or on totally arbitrary assignments of physical parameters that change results by many orders of magnitude; some also fail to account for crucial phenomenological processes or boundary conditions.

▷ Damask suggests that more physicists should enter the area of collision litigation, which he claims to now be dominated by "a few good engineers." I strongly disagree with this position. Accident reconstruction demands an intimate knowledge of the mechanics of rigid and deformable bodies and material behavior under dynamic loading. Physicists abandoned this domain as a research area many decades ago and turned it over to the

engineering profession, which has advanced it substantially. There is currently no coherent effort by the physics community to reclaim this field, and research efforts in collision and trauma analysis are published in engineering rather than physical journals. Due to this discrepancy in exposure and development, I believe that engineers are in a much better position to be qualified as experts in accident litigation.

▷ The huge fees accruing to an expert representing one side in such litigation present an additional obstacle to developing a completely detached representation of the most probable accident scenario. In many cases, opposing experts draw contradictory conclusions from the same facts. This confuses the jury, discredits the profession and detracts from the value of such testimony. Ideally, experts should be hired by the court, as often occurs in Europe.

▷ Damask takes pride in the court acceptance of computer programs in accident litigation. There may be substantial legal grounds on which to question the propriety of this procedure. One cannot cross-examine programs, only their originators. Since expert consultants are generally not familiar with the total software development and often only input the code used, only the group that created the program can properly say whether the code itself should be questioned. Because code development often takes many years and involves many contributors, it is impractical or impossible to document accuracy and applicability. Programs such as CRASH and various others detailing occupant motion under collision conditions specifically warn the user that the results represent only a state-of-the-art effort; furthermore, utmost care is required in their employment.

▷ Investigations of collision trauma and its mitigation are best accomplished by a team of medical specialists and engineers; the foundation of experimental head injury investigation in the US was laid by the combined efforts of Elihu S. Gurdjian, an MD, and Herbert Lissner, an engineer. However, there is currently considerable disagreement concerning the mechanical dosage that the living human can tolerate, both for the whole body and for individual parts. These values are constantly being revised, indicating doubts concerning their accuracy and validity. This uncertainty and other disagreements about biomechanical approaches make it necessary that one use the utmost caution in developing conclusions and virtually obviate the

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