

instituted in order to keep subjects perpetually at work and in poverty we may mention the pyramids of Egypt, the numerous offerings made by the Cypselids, the building of the temple of Zeus Olympius by the Peisistradae, and public works under Polycrates of Samos. Subjects are also kept poor by taxation, as at Syracuse under Dionysius, where in five years the value of the entire private property was paid in."

Three megascience programs for which the public is taxed at the multi-billion-dollar level today are space science, controlled thermonuclear fusion and high-energy particle physics. What benefit to they give to the public? Space science provides satellite television, weather surveillance, spectacular views of the outer planets and, of course, security from surprise attacks by enemy forces. Controlled thermonuclear fusion promises abundant safe nuclear power. Since it doesn't work, the promise of safety is fulfilled. Like Achilles racing with the tortoise, the program forever gets closer and closer to the tortoise without catching it. Some public utilities are having trouble running nuclear fission reactors, so how could they run the much more complicated controlled fusion reactors even if they worked? Still, if the project succeeded it would benefit the public that is taxed to support it.

Now to high-energy particle physics! Like the pyramids of Egypt, that program is of no earthly use to the taxpaying public or to any other branch of science. Its practitioners say that they must "probe deeply into the structure of matter." Isn't it hilarious that the structure of matter that makes the program technically possible is superconductors? That discovery was made by people working on small budgets in laboratory rooms where they could go in and shut the door on program managers.

Sometime we must stop building ever-larger pyramids for the high-energy particle physics community. Why not now? I suggest giving a medal, a prize and perhaps a splendid uniform to all top-level program managers in high-energy particle physics. That is really what they are working for anyway. The facilities should be put on a shutdown ramp over two fiscal years to complete all work now in progress. The funds and personnel would, over those two years, be divided among the first two megascience programs. The rest of the world would think we were on to something and would be totally confused! Actually, we would only be implementing the wisdom of Aristotle!

(P. S. I am working in molecular biology, a program that pays its piper.)

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5/88

SDI: Some Darker Implications

Greg Blonder (January 1988, page 126) has pointed out, through a clever and simple analogy, the subtle mutability between defensive and offensive weapons. However, there is no need for analogizing, since copious examples can be found in the public domain of SDI's "darker side."

On 14 January 1986 the *Los Angeles Times* announced in an editorial that a local "think tank," RDA-Logicon Inc, had concluded from its own research that not only were the high-energy laser systems being planned for SDI extremely potent offensive weapons, they were also capable of rapidly igniting combustible urban materials in sufficient quantities that it appeared possible to catalyze a "laser winter" with the same catastrophic effects predicted to accompany a "nuclear winter."

At the time I was a staff member at the Jet Propulsion Laboratory in Pasadena, and I contacted RDA-Logicon to obtain a copy of the report. I was told that the report had been classified "proprietary" and was not available to the general public. Subsequently I contacted a physicist at Argonne National Labs who had published a paper shortly thereafter in the open literature predicting the laser winter effect. I suggested a collaboration to further refine the technical issues of laser physics, beam propagation and laser winter effects, but I was told in no uncertain terms that the Argonne management had communicated their displeasure upon learning that an employee was investigating such a politically volatile topic, and that further research was officially discouraged.

Apart from a single paper presented at an APS conference last year and personal communications with a private research organization in Los Angeles, I am unaware of any other ongoing investigations along these quite controversial lines, but I would greatly appreciate hearing from any readers who are.

Just prior to President Reagan's March 1983 "Star Wars" speech, the president's science adviser, George Keyworth, and the deputy national security adviser, Robert McFarlane, discussed the possibility of using high-

energy lasers to assassinate leaders like Muammar el-Qaddafi (*Bulletin of the Atomic Scientists*, October 1987, page 20). In light of the APS study of directed-energy weapons (see *PHYSICS TODAY*, May 1987, page 51), I think it's safe to assume that Qaddafi is not losing sleep over this prospect.

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3/88

The Light Quantum, Viewed in Hindsight

Giorgio Margaritondo's article "100 Years of Photoemission" (April 1988, page 66) conveys the false picture that only Einstein's 1905 quantum theory explained the photoelectric effect and that the experiments of Robert Millikan and other physicists confirmed Einstein's theory of light quanta. Although this picture makes sense to a modern reader, it has no foundation in history. It is not true, for example, that Philipp Lenard's discovery of a maximum kinetic energy of photoelectrons (independent of the intensity of light) remained unexplained until Einstein solved the matter. Lenard explained the result by means of a "triggering hypothesis," which was developed by many other physicists and enjoyed general respect. Lenard's result was not considered to be particularly puzzling and certainly not in need of the sort of explanation Einstein could offer. The triggering hypothesis may not seem satisfactory to a modern physicist, but at the time it was regarded as a much better explanation than Einstein's strange alternative.

As to the experimental confirmation of the photoelectric law, one should distinguish sharply between Einstein's equation $E = h\nu - W$ and Einstein's theory. Margaritondo fails to make this distinction and thus claims that about 1916, experiments definitely established the idea of the light quantum. The facts are that Einstein's theory was almost unanimously rejected and that the experiments did not lead to acceptance of the theory. In his celebrated 1916 paper, Millikan argues that the Einstein equation was now verified but that the light quantum theory was "wholly untenable," a view he repeated the following year in his book *The Electron*. Millikan may not have understood Einstein's theory, which he saw as a modification of J. J. Thomson's ether-string theory, but he

was firm in his support of the wave theory of light and in his refutation of localized energy quanta. Finally, the Nobel Prizes to Einstein (1922) and Millikan (1923) do nothing to change this picture. Einstein got his prize not for his *theory* of the photoelectric effect, but, as the Nobel committee was careful to point out, for his *law* of the photoelectric effect. The distinction is significant. Millikan, who in his Nobel address described the photoelectric effect as an as yet not understood "interaction between ether waves and electrons," appreciated this distinction. So should the physicist of today.

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4/88

MARGARITONDO REPLIES: Helge Kragh's criticism misses the target, since my article was not a chronicle of events in the early years of quantum physics. The article presents fundamental contributions of the photoelectric effect to modern physics, in celebration of the first centennial of its discovery. Einstein's use of the idea of the photon to derive the linear frequency law was one of these fundamental contributions. Robert Millikan's work is still remembered not because it proved the linear frequency law, but because Einstein had derived the law using the idea of the photon. In comparison with Einstein's derivation, neither the triggering hypothesis nor Millikan's and the Nobel Prize committee's opinions are relevant to the centennial of Heinrich Hertz's discovery.

The importance of Einstein's derivation stems from its seminal role in establishing the concept of the photon and quantum physics in general. "Establishing" has nothing to do with the majority opinion at that time. Many facts in physics are established before the majority of physicists accept or even know them. For example, we now realize that the results of Georg Bednorz and Alex Müller had established the existence of high-temperature superconductors when these results were known by a very few people, and believed by even fewer. Similarly, we can see that the quantum revolution became irreversible in 1916, even if the contemporary majority opposed it.

As to the distinction between "equation" and "theory," the seminal role of Einstein's theory is not affected by the possibility of obtaining the law with time-dependent perturbation theory and without using the concept of the photon. It was Einstein's derivation that contributed to

the development of basic quantum mechanics, and without basic quantum mechanics we would not have time-dependent perturbation theory.

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Bachelor's Booster

The roundtable on physics research in industry in the February 1988 issue (page 54) was stimulating and insightful. Inevitably, the roles of engineers as well as those of physicists were discussed. In recent years these two groups have become closer, yet some longtime myths and misinformation persist. I was struck by Robert Frosch's perceptive comment that "industrial physicists [with PhDs], who are in with a large number of engineers with bachelor's degrees, are very likely to shine. But whether this happens because of the difference between physics and engineering or the difference between a lot of education and some education isn't clear to me." Later Robert Stratton says, "At least 50% of all electrical engineering degrees are being awarded to noncitizens." Stratton is, of course, referring to PhDs; far fewer than 10% of all bachelor's degrees in engineering are awarded to noncitizens.

It appears to be a common presumption in the physics community that only PhDs are real physicists or electrical engineers. While the doctoral degree is certainly an important component of our educational system, the bachelor's degree remains a very significant one for engineers, and perhaps it should be for physicists too. The well-documented shift in undergraduate enrollment from the physical sciences to engineering over the last decade or more may be in part a reflection of the difference in attitude toward the bachelor's degree between physicists and engineers. This trend has occurred even more strongly among the brightest students than for the general student population. I would also note that data over several years on per capita awards of degrees to citizens in Japan and the United States show a lead for Japan at the bachelor's level and a lead for the United States at the PhD level. Thus it is difficult to make the case that from the standpoint of economic competitiveness the PhD degree is more significant than the BS.

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