earned. I chafed every single year of the six I spent earning my degree. Had I graduated earlier, I would certainly have been less competitive in the job market. But creating the nationwide standard for advanced degrees that I propose will lessen the time invested in obtaining a PhD for everybody without penalizing anybody for getting out earlier. And if postdoctoral positions are eliminated, young scientists will not be cruelly teased into hoping things will work out when there just are not enough jobs to go around.

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As a former high-energy physicist who went on to medical school, I am well aware of the difference in the market for MDs and for physics PhDs. I feel that Wallace Mannheimer (December 1992, page 114) is mistaken in attributing this market difference entirely to the fact that admissions to medical schools are strictly limited. The majority of physicians are not in medical schools, training other physicians, but rather are out in the community in private practice, treating patients. They are thus providing people with a necessary service for which those people are willing to pay well. By contrast, the only way that physicists in some subfields, such as elementary-particle physics or cosmology, can earn a living is by teaching at a university and thus training even more particle physicists and cosmologists. This phenomenon leads to an exponentially growing number of particle physicists and cosmologists, and as Thomas Malthus noted, an exponentially growing population will soon outgrow the resources available to support it.

If physics is to survive, it will be necessary for physicists not only to practice some form of "professional birth control" but also to emphasize the *practical* contributions that physics can make to society. We cannot expect the taxpayers to continue to graciously hand over billions of dollars for devices like the Superconducting Super Collider just because particle physics is an interesting (if somewhat esoteric) intellectual exercise. I suspect that the general public would be more supportive of a Department of Energy that devoted more resources to achieving independence from imported foreign oil and less to futile searches for squarks, gluinos and Higgs bosons.

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Davisson–Germer: Not Just Skin Deep

Philip Best (April 1993, page 91) wrote about what he described as the failure of most current physics textbooks to give a correct interpretation of the famous Davisson–Germer experiment (on the scattering of low-energy electrons incident normally on a monocrystal of nickel) that first exhibited quantitatively the wave property of electrons. His objection was that (with only one exception known to him) these texts describe the experiment as a case of Bragg scattering in a three-dimensional structure, whereas the angular disposition of the diffraction spots is in fact explained by atomic spacings within the surface layer of atoms only. However, the totality of the results cannot be explained in terms of surface scattering alone. The text to which Best refers with approval[1] does discuss this at length, and there are other available texts that make it clear that the explanation of the results of the experiment involves scattering by at least several layers of atoms below the surface, even though the penetration into the crystal by low-energy electrons is small.[2]

However, drawing attention to other textbooks would not warrant a letter to PHYSICS TODAY. What does call for some comment is Best's description of the analysis that Clinton Davisson and Lester Germer themselves made of their results. According to him, "Davisson and Germer assumed considerable penetration of the electron into the crystal and so used the Bragg law to describe their results." This is far from the case and could be read as imputing to them a very limited understanding of the physics of the scattering process. In fact they understood it in considerable detail and discussed it in terms of Laue scattering rather than Bragg scattering. In their first full report on their experiments[3] they emphasized that the basic relation between electron energy and scattering angle is indeed describable in terms of scattering by parallel lines of atoms in the surface layer of the crystal. They recognized, however, that there is a significant though limited involvement of other layers of atoms, close to the surface; were this not the case, an electron diffraction peak would always change in direction as the bombarding voltage (and hence the electron wavelength) was changed. This latter behavior did occur for electrons diffracted off at close to grazing angles (where layers of atoms beneath

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the surface would have little chance to contribute). However, in other cases the direction remained unchanged, but the intensity went through a maximum for a particular voltage, as one would expect from the requirement of a constructive phase relationship between scatterings from different atomic layers. As Davisson and Germer pointed out, every diffraction maximum based on scattering from a space lattice also corresponded to a possible peak due to scattering from a line grating of surface atoms. In their summary of all their results they identified several peaks due to a single layer of surface atoms and a larger number of others due to scattering by a space lattice. These latter peaks gave the first indications that the scattering angle was not necessarily quite what one would predict from a knowledge of the electron wavelength *outside* the crystal.

It is true that in subsequent experiments Davisson and Germer did deliberately explore Bragg scattering from the planes of atoms parallel to the crystal surface.[4] By studying the regular reflection of electrons incident on the crystal surface at angles other than 90°, they were able to compare their results with the theoretical predictions based on a refractive index for electron waves entering a crystal,[5] and found substantial agreement. All this, of course, is old and well-established history. The only point I would wish to make is that except for the initially mysterious phenomenon of a refractive index for electron waves entering a solid, Davisson and Germer had a full and realistic picture of what was going on in their experiments, whereas Best's brief comments about their analysis might be taken to suggest otherwise.

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Did Privilege Blunt Soviet Scientists' Politics?

My attention was attracted by the letter from Eugene M. Chudnovsky and Alex Vilenkin that appeared under the headline "Soviet Scientists' Apolitical Past" (December 1992, page 11). I know the authors in person and I took an interest in the problem they touched upon. However, as I read through the letter, I realized that it is quite biased: The main point of the letter is not a proper analysis of past apolitical behavior, but only that former Soviet scientists neither deserve nor need individual financial support.

How can an apolitical past be related to current support? I by no means wish to get into an argument with Chudnovsky and Vilenkin. My only goal in this letter is to let Western readers, especially young people, know the truth about the situation of Soviet physicists and their attitude toward politics.

Soviet physicists were patriots and played an important role in strengthening their country's defense potential, just as their American and English colleagues did in *their* countries. Andrei Sakharov never blamed himself for his participation in this work. On the contrary, he was proud that his efforts promoted the creation of thermonuclear weapons for his country. Igor Kurchatov also contributed essentially to this program. They, like many hundreds of other physicists, did their job not because they were bought with "privileges," as Chudnovsky and Vilenkin state, but only out of their sense of duty. And what enormous privileges are these authors jabbering about? Kurchatov's "privilege" was that he did not live till 60 and died of a heart attack. My "privilege" was that in addition to my main salary of 500 rubles per month, I got 350 more as a member of the Academy of Sciences. But I had neither "cars with drivers" nor "dachas." As far as I know, neither did more prominent scientists such as Lev Landau, Vladimir Fock, Igor Tamm and Isaak Pomeranchuk. Once I heard a story about Pomeranchuk calling the head of a canteen seeking help in getting a pound of rice for his sick wife.

And now about politics. Chudnovsky and Vilenkin claim that Soviet scientists' "freedom of thought rarely went beyond discussions around the kitchen table, while objectively they were supporting the regime by their complacent behavior." However, physicists such as Fock and Moisey Markov struggled for the scientific truth contained in quantum mechanics and relativity, both general and special, against strong attacks from orthodox Marxist philosophers who charged them with idealism. When a powerful anti-Einstein article was prepared for publication in *Pravda*, Kurchatov succeeded in stopping it. Weren't conferences on physics and philosophy held in Kharkov and Kiev at which the ideas of quantum mechanics were defended? Those conferences were very important in legalizing quantum mechanics and relativity at Ukrainian universities. It is surprising that Chudnovsky and Vilenkin, educated at Kharkov University, have forgotten that.

And how can we forget the courage of the great physicist Peter Kapitsa, who literally pulled Landau from the hands of Lavrenty Beria, the head of the Soviet secret police? Was that not politics? Was it not an act of heroism that preserved Landau for science throughout the world? I cannot help recalling the courageous talks of Mikhail Leontovich, Tamm and others against electing Trofim Lysenko and his myrmidons to the Academy of Sciences. Note also that during the hard times of *Lysenkovshina* Kurchatov opened a biological division at his institute in which genetics was studied, and that the geneticist Nikolai Timofeev-Ressovsky gave talks at the seminar held by Kapitsa and at other physical meetings. Incidentally, let me mention the dissident Yuri Orlov. Many physicists supported him, and the academicians Abram Alikhanov, his brother Artemii Alikhanian and Pomeranchuk helped him to get a job at Yerevan and backed up his election to the Armenian Academy of Sciences.

Perhaps all this is not sufficient for Chudnovsky and Vilenkin, and they would like to demand more martyrs for the sake of science. But is it not enough that the brilliant physicist Lev Shubnikov was shot dead by a firing squad, and such talented physicists as Matvey Bronshtein, Vadim Gorski and Lev Rosenkiewicz also were killed?

But here let me step aside from the Soviet reality and get into a more general problem of politics and science by addressing the case of Galileo. Only Bertolt Brecht condemned Galileo for not struggling against the church and not dying like Giordano Bruno. You see, that made Brecht's play about Galileo look more spectacular! Most of us, however, have another opinion. And not only do we have it, but so did Einstein and David Gilbert. Einstein said: "He [Galileo] needlessly got into the lion's jaws, going to Rome to fight priests and other intriguants. I do not think I could attempt something