Physics Today

Europe's Educational Edge

Daniel Zwanziger, Tannie Stovall, Don Olliff, and Chiara R. Nappi

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surveyed experimental progress toward establishing the existence of the Wigner crystal. One of the key signatures of such a crystal is nonlinear conductance, which presumably arises from the depinning of the crystal from the host lattice. As Khurana pointed out, it may be useful to draw parallels with earlier work on the depinning of the charge-density wave in quasi-one-dimensional solids. However, the compounds in which the charge-density waves may be depinned by a weak electric field were incorrectly identified.

A charge-density wave (a weak periodic modulation of the electron density) is accompanied by a periodic lattice distortion whose wavevector matches the diameter of the Fermi surface. The periodic potential opens up a gap at the Fermi surface. In certain low-dimensional solids, the gain in electronic energy from gap formation offsets the cost in lattice strain energy when the temperature is below a critical value, so that the charge-density wave is stable. The existence of charge-density waves in solids was first demonstrated in the late 1960s by John Wilson, Frank DiSalvo and S. Mahajan.[1] The structural evidence for charge-density wave formation in the transition-metal dichalcogenides ($NbSe_2$ and TaS_2) was carefully argued in their paper, which strongly influenced the work of later investigators, including us. The dichalcogenides are layered compounds with quasi-two-dimensional electronic properties. For reasons that are not completely understood, the charge-density waves are *very strongly pinned* to the host lattice, and there is no evidence (so far) that collective motion of the waves is possible in these layered compounds.

In 1974 Jean Rouxel and coworkers synthesized the trichalcogenide $NbSe_3$. This remarkable compound has a linear-chain morphology and an electronic dispersion that is quasi-one-dimensional. A charge-density wave spontaneously forms in $NbSe_3$ at 142 K, followed by a second one at 59 K. Around this period, we were inspired by a prescient remark by John Bardeen that "sliding Fröhlich" conductivity could exist in quasi-one-dimensional metals. In experiments starting in 1975 we found that at all temperatures below 142 K, the linear conductivity at the microwave frequency 10 GHz is significantly larger than at zero frequency. We also observed that the conductivity increases dramatically in the presence of a weak dc electric field (10 mV/cm). We interpreted these results as reflecting, respectively, collective forced oscillation of the pinned charge-density wave and depinning of the wave from the host lattice.[2]

Khurana also mentioned the phenomenon of noise generation when nonlinear transport occurs. The existence of voltage oscillations ("narrow band noise") accompanying charge-density wave motion in $NbSe_3$ was reported by Robert Fleming and Charles C. Grimes[3] in 1979.

These three unusual transport phenomena—nonlinear conductivity in a weak dc field, excess conductivity at microwave frequencies, and noise generation—are now accepted as the key signatures of charge-density wave motion. To date, all compounds that display these properties [$NbSe_3$, TaS_3, NbS_3, $(TaSe_4)_2I$ and $K_{0.3}MoO_3$] have a linear-chain structure.[4]

In his article in the same issue of PHYSICS TODAY (page 25), Bardeen also referred to the properties of $NbSe_3$. In addition to the quantum tunneling model proposed by him, classical models also have been quite successful in explaining the remarkable transport properties of these solids.[5]

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Europe's Educational Edge

Chiara R. Nappi's comparison of mathematics and science education in the US and Europe (May 1990, page 77) contains many perceptive observations and much valuable analysis. I have recently returned from a visit to the physics and mathematics departments at the University of Rome, Italy, and I can confirm her observation that women are better represented there than in the corresponding departments at American universi-

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ties. There are of course many reasons for the poor performance on physics tests of Americans in general compared with other nationalities, and of American women and minorities in particular. However, I believe that Nappi has put her finger on one important cause that it is in our power to change. She calls attention to the elective system in American high schools, which allows the vast majority of high school students to avoid studying physics entirely, as well as the more advanced parts of high school mathematics. This choice, made by students at an immature age, effectively closes the door to a scientific career, much to the detriment of women and minorities, whose choice may well be determined by stereotypes. In Europe, on the other hand, the required core curriculum in secondary schools keeps this door open longer for everyone.

I would like to point out that the same policy error is repeated in the US at the college level. I had the good fortune to attend an excellent American liberal arts college that had a core curriculum in the humanities and social sciences. It was rightly considered that a graduate of the college was not a well-rounded man (it was an all-male college) if he had not read 100 or so required authors, such as Homer, Sophocles, Dante, Montesquieu and Milton. However, in science, the student was allowed to choose two courses from among the four sciences of biology, chemistry, geology and physics. As a consequence of the most common choices, the typical "well rounded" graduate had never studied the conservation of energy or Newton's law of gravity at either the high school or college level. This remains true of most American PhDs.

Nowadays the core curriculum is being reintroduced at many American colleges. But I am not aware of any college where an integrated core curriculum in the sciences is required. This would comprise an integrated several-semester sequence designed to provide a recognized minimum knowledge in the sciences and including biology, chemistry, Earth science and physics. It would be a stimulating challenge for scientists to design an integrated science course sequence and write the appropriate textbooks. The rationale for mixing elective courses in the sciences with a core curriculum in the humanities is that by an in-depth exposure to any part of science, one learns "the scientific method." However, no scientist I have ever met believes this rationale justifies a policy that leaves the student completely ignorant of one or

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more basic sciences. Those of us who are scientists in academia share a responsibility to introduce a curriculum in which we do believe.

To return to the broader issue raised by Nappi, that of science education at the high school level, I would like to point out that those of us who teach in colleges and universities can in fact exert considerable leverage over high school policy. If properly applied, this leverage may effect rapid change in American high school curriculums despite—or rather because of—the decentralized nature of the American educational system. American high schools are, quite rightly, extremely sensitive and responsive to whether their graduates are admitted to selective colleges. If a minimum knowledge in all the sciences were made a requirement for admission to college, we may be sure that a general science curriculum would be rapidly introduced in American high schools and would be studied by college-bound students at least. This would provide a much needed improvement in American scientific literacy. Moreover one might expect women and minorities to be the major beneficiaries, because their representation in the college population is not nearly as bad as it is in the sciences.

Nappi also raises the important matter of the quality of secondary school science teachers. As she points out, in Europe secondary school teachers are generally university graduates with a specialty in the subject that they teach, whereas in the US this is often not the case. Here again the colleges, especially the more prestigious ones, can provide the lead and exert leverage. By requiring of entering college students a minimum level of performance in all the sciences, we will reward those high schools with core curriculums in the sciences whose faculties are properly trained and academically effective. Of course it would not be fair to college applicants to implement such a policy in any one college instantly; it should be phased in over a period of, say, four years. When scientifically well-trained high school students are rewarded by increased college admissions, the market value of the many devoted and inspiring science teachers, whose efforts are not now sufficiently recognized and rewarded, will be correspondingly increased, making the high school science teaching profession more attractive. In the long run, an effective science education policy at the college level will encourage future college students to study science and, after graduation, to join in the valuable task of science education in the elementary and secondary schools.

Daniel Zwanziger
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7/90 *New York, New York*

I take issue with Chiara R. Nappi's contention that courses "are not made unnecessarily intense and demanding in European schools" and therefore "all students can handle them better." In France 25% of all high school graduates in science take four years to complete their last "three" years—and this after a certain amount of "weeding out" of marginal elements that leaves in the scientific fields only a small fraction of the 40% of the total population who qualify to continue to college-level training. In view of the fact that all French students who successfully complete their secondary education are entitled to free college training, this is not surprising. It seems to me that the situation is roughly the same in most of Europe. Sure, those students who are left in the scientific fields can handle the scientific courses better, but it is not because they are less intense and demanding.

Neither are the centralized educational systems in Europe social equalizers. The fact is that the much smaller proportion of the population who get to do college-level studies are for the most part members of what can only be called the middle and upper classes. Judging from my own experiences of having been born poor and having been educated in the United States and of having lived in Europe most of the last quarter of a century, working-class people have greater opportunities for education in the US than in Europe, in spite of the fact that European systems on the surface can seem fairer.

I do agree that Afro-Americans would probably produce more scientists if they were educated in Europe. As I see it there are two important, self-reinforcing factors that mitigate against Afro-Americans' becoming scientists. These are the relative lack of scientific culture in the Afro-American community and the negative expectations felt by Afro-Americans from the larger community, as Nappi points out. In Europe, at least for the moment, only the first factor is operative. This is mostly why I chose to educate my two Afro-American sons in Europe.

Tannie Stovall
7/90 *Paris, France*

Chiara R. Nappi's commentary on the percentages of women and minor-

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ities ready for calculus at the end of high school reminded me of Wilt Chamberlain's remark that had he known he had such an innate advantage for athleticism, he wouldn't have wasted so many thousands of hours practicing.

Socialization may be of some use in explaining lower participation rates in high school math by some groups in the US, but it no more *excuses* not taking math than it does getting pregnant, becoming involved with drugs or violent crime, or totaling cars while drunk. If one listed the things American high schoolers have to deal with, math might be among the more threatening to their self-images. But when so many of the other things on the list involve a far greater risk of immediate negative consequences as a result of irrational decisions, it's hard to understand avoiding math.

The most serious drawbacks of our high school mathematical education may stem from problems further along: Hardly any of the students with four years of high school math end up getting PhDs, and of those who do, only 18% get grants to help them in the process. Years of headlines about the majority of junior faculty in this country being from abroad have done little to shift the attention of universities from installing computer networks to altering the mix of students to whom they give graduate degrees. The fact that Japan has about half again as many researchers in high-temperature superconductors has not prompted the sort of outpouring of Federal subsidies for graduate education that came after Sputnik, even though Japanese electronics manufacturers are a far more serious threat to the economy.

DON OLLIFF
11/90 *Oxnard, California*

NAPPI REPLIES: I fully agree with Daniel Zwanziger's letter.

In response to Tannie Stovall, I would reiterate that my point was that the more gradual and systematic approach to math and science teaching adopted in European schools makes these subjects more accessible than the "hit and run" approach used in American schools does. This opinion is shared by many American educators and researchers. (See the report on the National Science Teachers Association's new curriculum in PHYSICS TODAY, October 1990, page 87.) It may be the case that the French school system has its own problems, but surely concentrating all the physics or algebra in a one-year crash course would only make it worse.

In considering the question of the schools as social equalizers, I will concentrate on my experience of having been born and educated in Italy. In Italy, all schools are virtually free, from nursery school (for children above three years of age) to college (where the enrollment fee, which is very small compared with American standards, is waived in case of hardship, and students from low-income families are eligible for scholarships). The quality of education is controlled at the state level and, to a very good approximation, is independent of the specific school district: Schools are financed by the state, the curriculum is the same all over the country, and all teachers have to pass the same state exam.

Finally, returning to the issue of women in math and science (as well as in any other profession), women in Italy get paid maternity leave. This fact, together with the availability of affordable day care at a charge that depends on the family income, helps to explain the high percentage of women in scientific professions and in the job market in general, and is of invaluable importance especially to low-income families. (For a description of the similar positive effects of day care at Argentinian universities, see Akhlesh Lakhtakia's letter in PHYSICS TODAY, December, page 94.)

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3/91 *Princeton, New Jersey*

Physics Deported at Portland State

The pages of PHYSICS TODAY have reported that one-third of US high schools do not offer physics.

Now a US university is suspending its bachelor's degree program in physics.

The Oregon state system of higher education is currently being decimated—in the literal meaning of that term—by mandated budget cuts. In reacting to this mandate, Portland State University has proposed to eliminate its undergraduate programs in applied science. Also marked for suspension is the undergraduate program in physics.

I challenge physicists to consider the implications of a *university* not offering a major in physics!

While I am not employed at Portland State—I work over a hundred miles away, at the University of Oregon—I am horrified by the contempt this shows for one of man's highest intellectual achievements. I am disgusted by the mentality that seems to want more VCRs but doesn't give a thought to knowing how they work!

Currently both the City of Portland and the State of Oregon are attempting to build upon the core of electronics and high-technology industries in the Willammette Valley. Perhaps the administrators of these entities should be made aware of the message being sent by the elimination of physics from a university curriculum.

Further information on this matter can be obtained from the appropriate agency administrators; addresses may be obtained by contacting the office of Governor Barbara Roberts, 254 State Capital, Salem OR 97310, phone (503) 378-3111.

PAUL ENGELKING
2/91 *Lowell, Oregon*

Religion and Science: Worldviews Collide

The participants in your forum on physics literacy (November 1990, page 60) discussed various barriers to public understanding of science in general and physics in particular. I was surprised that none of your panelists mentioned one of the biggest problems a significant fraction of the public has with science: It conflicts with their religion. Gerald Holton, in outlining parts of a typical layman's scientific world picture, did state that the layman believes that "the pattern of cause and effect works most of the time, but incomprehensible and magical things do occasionally intervene."

All too often, when engaged in a discussion of some scientific topic with people who have no scientific training, I am unable to keep the discussion purely scientific because they insist on dragging in the subject of religion. To these people, religion is an integral part of their view of nature and it is meaningless to attempt a discussion of science without involving religion.

Usually such people inject religion into the dialogue whenever biological evolution or the age of the Earth is touched upon. When this happens it is useless to continue the conversation: Science is necessarily wrong, since it contradicts their dogmatic beliefs.

I wish I had a constructive suggestion to make here. It will probably make some readers uncomfortable for me to say this, but the truth is that certain religious beliefs may be barriers to the general population's understanding of science.

TERRY SMITH
12/90 *New Market, Alabama* ■