letters

A new pastime—calculating alpha to one part in a million

[In August (page 18) we reported on a theoretical calculation by Armand Wyler that yields a value for the fine structure constant agreeing with the best experimental measurement to one half part per million (one third the standard deviation). The report stated that the probability is very small to get such good agreement if one were just to play with numbers. Here are some readers who can successfully dispute this claim.]

Experimental value[1]

$$\alpha^{-1} = 137.03611 \pm 0.00021$$

Wyler's value[2]

$137.036082 = 2^{19/4}3^{-7/4}5^{1/4}\pi^{11/4}$

My values

$137.035938 = 2^{-19/4}3^{10/3}5^{17/4}\pi^{-2}$

$137.036163 = 2^{-13/4}3^{17/4}5^{2/3}\pi^{5/4}$

$137.036120 = 2^{2/3}3^{7/3}5^{11/3}\pi^{-7/2}$

$137.036007 = 2^{5/3}3^{-8/3}5^{5/2}\pi^{7/3}$

$137.036289 = 2^{8/3}3^{3/4}5^{-1/2}\pi^{8/3}$

References

1. T. F. Finnegan, A. Denenstein, D. N. Langenberg, Phys. Rev., in press.
2. A. Wyler, Acad. Sci. Paris, Comptes Rendus *269A*, 743 (1969).

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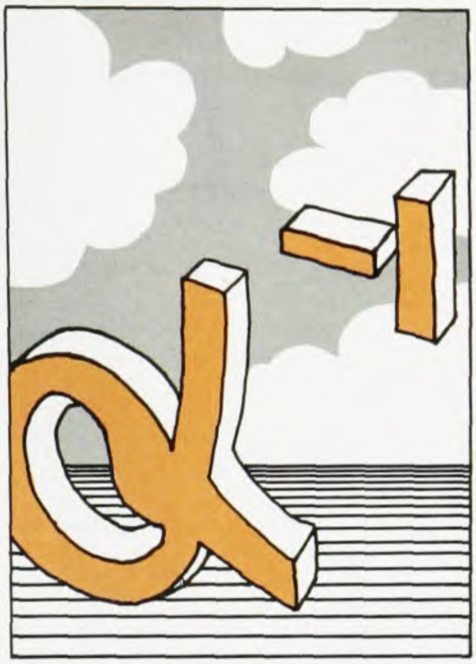
The editor comments: Roskies explained to us that he programmed a 360-91 computer to search through all combinations of powers of 2, 3, 5 and π with exponentials between -5 and $+5$ and having a dominator of 1, 2, 3 or 4. The program was to find those combinations that fall within one standard deviation of the experimental value of α. The program ran in less than 30 seconds and found that besides Wyler's there were five other polynomials that performed equally as well.

Another reader, Ivar Giaever (General Electric Research and Development Center, Schenectady) points out to us that

$$(5/2)^{1/2}(2)^{2/3}e^4 = 137.03597 \text{ (within a standard deviation)}$$

and E. D. Reilly, Jr calls attention to a paper he presented at the January APS meeting this year where he showed that



$$4\pi^3 + \pi^2 + \pi = 137.03630 \text{ (also within a standard deviation)}.$$

And finally there is the following analysis of the situation:

The report in "Search and Discovery" stated that Wyler's theory might well be correct, because if you just play with numbers such as

$$(2^{19}3^{-7}5\pi^{11})^{1/4} = 137.03608$$

the probability is very small indeed for obtaining the fine structure constant

$$\alpha^{-1} = 137.03602\ (\pm 1.5 \text{ ppm})$$

Surprisingly, it is not: The question simply is how closely we can approximate α^{-4} by playing with integral powers of 2, 3, 5 and π. In other words, we have to find integers x, y, z and t such that

$$(1-\delta)\alpha^{-1} < (2^x3^y5^z\pi^t)^{1/4} < (1+\delta)\alpha^{-1}$$

where $\delta = 1.5 \times 10^{-6}$. This can be written as

$$-4(\log\alpha + \delta) < x\log 2 + y\log 3 + z\log 5 + t\log\pi < -4(\log\alpha - \delta)$$

This formula has a very simple geometrical significance: The integers x, y, z, t, form a unit lattice in a four-dimensional space. The expression $x\log 2 + y\log 3 + z\log 5 + t\log\pi$ represents a three-dimensional surface in that space, and the distance between the two limiting surfaces is

$$8\delta[(\log 2)^2 + (\log 3)^2 + (\log 3)^2 + (\log \pi)^2]^{-1/2} = 5.4 \times 10^{-6}$$

by elementary geometry. Therefore, we expect to find, on the average, one lattice point inside the slab, within any three-dimensional area of size 185 000. This is the volume of a sphere of radius 35.

It follows that one could be surprised if he finds a solution for $xyzt$ whose distance from the origin (or from any given point) is *much smaller* than 35. In Wyler's formula however, the distance is

$$(19^2 + 7^2 + 1^2 + 11^2)^{1/2} = 23$$

a number quite comparable to the radius of the sphere expected to contain one lattice point. Thus, we cannot discard the possibility that Wyler's result is a mere numerical coincidence, of the same kind as

$$\pi = 31^{1/3}\ (+67 \text{ ppm}).$$

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The editor comments: Some theorists have told us they feel the above findings weaken the interest in Wyler's calculations. Wyler himself feels that the difference is that his formula is derived from a theoretical formalism which is related to the physical world—the conformal group 0(4,2) which is the natural invariance group of Maxwell equations.

No teaching jobs?

I would like to bring to the attention of those physicists who are considering careers in secondary education (Robert Clark, May, page 9) the possibility that programs like those at The University of Texas at Austin and The University at Wyoming will take them from the frying pan into the fire.

Sections of The University of Wyoming's brochure describing their "Insti-

tute for PhD Scientists Trained in Research Who Are Interested in a Career in Secondary or Elementary Schools . . ." have the familiar tone of the hard sell. For example, concerning money: "In many [high-school] districts the salary scale is competitive with university salaries. School principles [sic!] have salaries in excess of the average full professor and District Superintendent salaries are in excess of those of the average university Dean." This sounds very good to any physicist who went into physics because of the high salaries of physicists.

Concerning job opportunities, the brochure describes the program at The University of Texas at Austin which has "sought vacancies for science advisors, specialists and teachers throughout the state of Texas . . . [and] the project has had remarkable success." Presumably secondary schools in Texas and Wyoming as well as in other areas will be begging for such people. "NEVER BEFORE [their caps] have the secondary schools of the US had this opportunity. Millions of dollars have been spent by the National Science Foundation on trying to upgrade teachers—all this would have been saved if competent, creative men and women had been attracted to the school systems in the first place." It is perhaps at this point that the physicist contemplating such a change should feel some doubts. If millions have been spent on trying to upgrade teachers then we should have many upgraded teachers around already. Maybe there aren't even many places requiring high-school physics, math or science teachers. When I asked a high-school teacher (working for an EdD in math in New Jersey *while purposely keeping his high school job*) in the New Jersey area, I was assured that the supply of high-school teachers in New Jersey is more than adequate. Furthermore, a PhD coming from such a program would not be greeted with open arms by the New Jersey high-school districts. I have a vivid memory of television news coverage of a high-school teachers' convention in Chicago recently. The topic of the newscast was jobs for new graduates from the teaching schools. The comments of those searching for jobs had a sadly familiar sound. The conclusion: The demand of the early and middle 1960's for more high school teachers has largely been met.

As for future teaching demands, Allan Cartter (*Science*, April 9, 1971) has some interesting recent estimates for the 1970's and 1980's based, among other things, on recent declining birth rates. Rather than go into detail, I strongly recommend that the physicist interested in high-school teaching read the entire article himself. The physicist considering a new career has an obligation to himself to look into the future of this career as best he can.

At best there is certainly merit in a program that tries to salvage the careers of physics PhD's. Many of us who were attracted by the job and excitement of physics see physics slipping from our grasp. Some of us hope to find a similar joy and excitement in new careers, perhaps in medical physics or environmental science (see *Saturday Review*, May 1, 1971 for estimates of its future), perhaps even high-school science teaching. But at worst such a retraining program is self serving, requiring degreed, warm bodies to qualify for the NSF money they receive. Incidentally, this trait is not too different from that of some graduate physics programs which are still sending brochures and notices for college and university bulletin boards in order to attract students into graduate physics at their school.

I can best summarize my point by referring to my notes taken at the poorly attended (but excellent) employment workshops conducted by Raymond Sears at the recent New York APS meeting. I wrote: "re: changing jobs—look before you leap."

Robert D. McConnell
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Clark comments: Although I am most sympathetic to many of the views expressed by Robert McConnell and agree wholeheartedly with his conclusion that individuals should ". . . look before they leap" into secondary education, I must differ with many of his points.

At the outset it should be made clear that the primary purpose of the original letter was to inform physicists, who had either accepted or were considering accepting offers to teach in Texas secondary schools, of the availability of the more flexible Jamison Bill mode of certification.

I feel the most important point raised in McConnell's letter is the question of the magnitude of the present demand for the talents of capable physicists in US secondary schools.

My own experience in this regard has been most encouraging. During the past spring we have had very little difficulty in locating over 40 school systems who were interested in hiring capable physicists with advanced degrees for positions this fall. These school systems included Texas public school districts and private schools throughout the US. Most of these positions were listed in the AIP Placement Service summaries in February and May. Since our efforts were necessarily limited in extent, this number should be interpreted as a lower bound on the total number of positions available.

My personal conclusions have been reinforced by the most recent NEA research report[1] on teacher supply and demand which concludes that

> ". . . the teacher supply is generally adequate, but shortages of beginning teachers are expected to continue in secondary school mathematics, special education, vocational-technical courses, industrial arts and some secondary school sciences."

One of the most interesting aspects of the report is that the authors considered the number of science teachers to be in "short supply" and projected a shortage of 2592 for the 1970–71 year. In the field of mathematics the demand was even greater with a projected national shortage of 3900 teachers and the report that 13 of the largest 67 school systems were having "extreme difficulty" in filling mathematics positions. It is of further interest that 7 of the 67 systems had found it necessary to employ "persons with substandard qualifications" in sciences, and 10 systems had the same problem in mathematics.

Although the results of the NEA survey for the 1971–72 year will not be available until August, our limited experiences, described above, indicate that the needs described in the NEA report had not yet been fully met by this spring.

An important lesson that might be learned from the data presented in the NEA report is that the talents of physicists may often be most valuable to secondary schools in meeting their needs in mathematics education. The importance of this lesson is reinforced by the relatively small number of schools whose demands can justify an instructor who teaches physics full time and by the intensity of the economic problem for physicists whose backgrounds are closely associated with mathematics.

Even when the numerical shortages end, there will continue to exist a challenge for the improvement of the quality of secondary-school science and mathematics education and a large number of openings will continue to be filled each year on a competitive basis.

Although I would not presume to speak for the University of Wyoming, I do think that McConnell's long-distance judgment that their program may be "self serving" may reflect in part the tremendous stress that the present economic crisis has brought to bear on all of us.

Reference

1. "Teacher Supply and Demand in Public Schools," Research Report 1970-R14, National Education Association, Washington, D.C. (1970).

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Clock paradox rebuttals

The article in the September issue (page 23) by Mendel Sachs on the clock paradox has evoked a flood of letters to the editor, many of which take issue with the author's position on the basis of theory or experimental evidence. We have already received more letters than we can publish. A representative sampling will appear in this department in the near future.

—Editor

Scales of ionicity

A most interesting paper, "The Chemical Bond and Solid-State Physics" (February, 1970, page 23 by J. C. Phillips) was recently discussed by Linus Pauling (February 1971, page 9). I would like to add a further comment on the ionicity of chemical bonds, an important topic to chemists and physicists alike.

Phillips defines a scale of ionicity, f_i, for binary solid compounds, AB, as

$$f_i = C^2/(E_h^2 + C^2) \qquad (1)$$

where C is the average ionic energy gap and E_h the covalent energy gap. The total energy gap is given by $E_g^2 = E_h^2 + C^2$, and E_g and E_h are evaluated from spectroscopic data. The values of f_i so calculated are shown to accurately divide AB solids into those with 4-fold coordination ($f_i < 0.785$) and those with 6-fold coordination ($f_i > 0.785$).

If a simple molecular orbital calculation is made for an *isolated* AB molecule, containing a pair of valence electrons, an energy gap between the bonding MO and the antibonding MO can also be calculated. The wave function is taken as

$$\Phi = (\Psi_B + \lambda\Psi_A)/(1 + \lambda^2)^{1/2} \qquad (2)$$

and, ignoring overlap,

$$E_g^2 = (q_B - q_A)^2 + 4\beta^2 \qquad (3)$$

where q_B is the coulomb integral on atom B, the β is the exchange integral between A and B.

Clearly $(q_B - q_A)$ corresponds to the ionic energy gap and β^2 to the covalent energy gap, as used by Phillips. However, if we now calculate the ionicity of the bond, as defined by the net charges on A and B,

$$f_i' = (1 - \lambda^2)/(1 + \lambda^2)$$

$$= (q_B - q_A/[(q_B - q_A)^2 + 4\beta^2]^{1/2} \qquad (4)$$

This ionicity, which has a clear meaning within the limitations of the model, is the square root of the ionicity given by Phillips.

Obviously the ionicity scale, f_i', will also divide the binary solids into four-