DISCUSSION

PHYSICS, EXACTING BEYOND ALL COMPROMISE

How true the points made by Professor Williams in his recent discussion in SCIENCE,[1] and how forcefully he puts them. Perhaps more forcefully than he intended considering that the one worked-out physical problem which he expects his students to do by ordinary proportion is solved incorrectly! Fifteen years ago when quantum mechanics was first being developed, I was much impressed by a remark of the Göttingen mathematician, David Hilbert, who said, "Physics is becoming too difficult for the physicists." Perhaps it always has been and always will be, but those of us who love the subject will keep on trying anyway.

First let us consider the correct solution to Professor Williams's supposedly elementary problem. It is "Two spheres are charged with a combined charge of 15 esu. If the radii of the two spheres are 10 and 20 centimeters, respectively, what is the charge on each sphere when put to a common potential by touching one sphere to the other?" The solution given says the charge on the little sphere will be 5 esu and that on the larger one 10 esu, on the supposition that the charges divide in proportion to the respective radii.

The correct solution, however, is a matter of some difficulty, quite beyond the scope of the elementary course. The basic theory is presented, for instance, in Jeans's "Electricity and Magnetism," Chapter 4. The charges on the two spheres will be called Q_1 and Q_2 and their potentials V_1 and V_2. Then,

$$Q_1 = q_{11}V_1 + q_{12}V_2$$
$$Q_2 = q_{12}V_1 + q_{22}V_2$$

Let a be the radius of the first sphere, b that of the second and c be the center-to-center distance apart. Then if c is large compared to either a or b, the q's have the values below, approximately,

$$q_{11} = a, \quad q_{12} = 0, \quad q_{22} = b.$$

Hence if the spheres are brought to the same potential, *not by touching them together,* but by keeping them far apart and connecting them with a very fine wire, we shall have $Q_1 = aV$ and $Q_2 = bV$, so the charges will distribute in proportion to the radii and so will be 5 esu and 10 esu for the particular example proposed.

But if the spheres are brought very close together, leading finally to contact, the q's have quite different values, the calculation of which is a matter of rather difficulty theory (see pp. 196–199 of the fourth edition of Jeans) and thus the charges will distribute not in the ratio of $a : b$ but in the ratio of

$$(q_{11} + q_{12}) : (q_{22} + q_{12})$$

which will have a very different value. To avoid the labor of computing the q's for Professor Williams's example let us take one for which the q's are given by Jeans, namely, that in which the first sphere has a radius $a = 7$ cm, while for the second $b = 1$ cm and the center to center distance is $c = 10$ cm. Then the q's are

$$q_{11} = 7.576, \quad q_{12} = -0.814, \quad q_{22} = 1.160$$

instead of

$$q_{11} = 7, \quad q_{12} = 0, \quad q_{22} = 1$$

which are the values when c is very great. The result is that if the potentials are equalized by keeping the spheres at this distance and connecting them with a fine wire, the charges distribute in the ratio 19.5 : 1 which is very different from the value 7 : 1 obtained by one who simply works it out by proportion.

Now what is the moral of this for the student and teacher of physics? After much less than 35 years of teaching I think it is this, that the quantitative side of physics is being much too greatly over-emphasized in the elementary, especially in the introductory liberal arts, course. I hasten to admit my own guilt and to apologize to former students, one and all, if such abasement will help to make my point.

Of course it is a great thing that physical science is so quantitative and that mathematical analysis applied to it is so powerful. We all have heard the one about Lord Kelvin's saying that you don't understand a thing unless you can measure it. And students should try to get a glimpse of this even in the first course, although they can hardly hope to get a real appreciation of it so quickly. But there is altogether too much of the simplified formula, derivation-without-calculus stuff and that is what makes the freshman course so dreary to so many students. In the chemistry course there is hellzapoppin most of the time, but in freshman physics we omit anything violent like an explosion because it is described by non-linear equations. The subject-matter is systematically robbed of its lively vital stuff in order to fit the requirement that the science must be exhibited as a beautiful set of exercises in high-school algebra. Out go all the topics that can't be handled this way, such as friction and lubrication, or how a whistle works, or a host of other interesting topics from everyday life. And in comes a set of polite conventions to make the problem reducible to the standard of mathematics which it is vainly hoped is within the students' grasp, such as the famous "Neglect air resistance" of the traditional projectile problems. Who wants to neglect air resistance in a class of baseball, tennis, ping-pong and golf players? In order to calculate

[1] SCIENCE, 93: 398, 1941.

how far some ball will go in a manner contrary to the facts, but to the physics professors' satisfaction. What the students want to know is roughly, approximately, how much is air resistance, how does it arise, what about streamlining, what about the spin of the ball. Let any professor take a brief vacation from $s = (1/2)at^2 + v_0t$, etc. and tell the boys the "real dope" without formulas but with quantitative connections discussed graphically. Students wake up, eyes brighten, the boys begin to think physics means something. It gets exciting, like chemistry the day the chemistry professor made a big explosion and a lot of red fire right on the lecture table.

In short, I hold the opinion that there is too much attempted mathematical treatment of physics in the beginning course, with resultant cutting out of interesting qualitative descriptions of phenomena, and artificial over-simplifications which make the subject obviously unreal, in order to bring it to the painfully low level of mathematical attainment of college freshmen. The remedy, obviously, is to resume the teaching of mathematics in the secondary schools.

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INCOMPLETE FILES OF CURRENT PERIODICALS IN AMERICAN LIBRARIES

A LETTER[1] from Dr. Stuart Mudd emphasizes the inevitable breaks in continuity of files of American scientific journals in foreign libraries and makes a plea for the preservation of copies in this country to complete these files, when and if foreign libraries can resume their acquisitioning.

Dr. Mudd's plea is admirable. There is need of equal emphasis on the preservation of the continuity of files of foreign journals in American libraries. Unfortunately, shipments are being lost. In several cases at least, ships carrying nearly all the copies of certain issues of European publications destined for American libraries have gone down. Some American libraries have already discovered that issues lost at sea can not be replaced by the publishers. Few, if any, libraries have been able to obtain complete files of foreign periodicals for 1940. Some libraries have arranged for storage in Europe. How far such storage is a safe means of temporary preservation is not yet known.

The outlook may be far worse after the war. English and Canadian libraries, in general, have cancelled subscriptions to German periodicals. These libraries will certainly be eager to complete their files after the war, but it is probable that no copies can be found. Most publishers, both in Germany and the United States, are printing only enough copies to meet the demands of their subscribers. It will probably be quite impossible for all libraries which desire complete sets of German scientific publications of the war period to obtain them after the war.

The fact that many colleges have failed to receive European journals regularly has already proved a hindrance to research. It is very desirable that subscribers who have personal subscriptions to scientific journals and others who have received exchange copies preserve these numbers very carefully. They may be of inestimable value in future years.

The Iowa State College Library has not yet completed all its 1917–18 files of French and German scientific journals. Even the completion of the outstanding *Mathematische Annalen* for 1917 and 1918 was impossible until 1930. Many hindrances to research through lacunae in 1940 periodicals are arising, and the end is not yet.

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IOWA STATE COLLEGE LIBRARY

[1] SCIENCE, April 18, 1941, 93: 376.

THE CONTINUITY OF THE SCIENTIFIC RECORD

WE should indeed, as Dr. Stuart Mudd suggests,[1] keep the written record of scientists' research unbroken, not only in this country but abroad. The destruction of scientific libraries now taking place in the warring countries must be remedied in the days of peace that must eventually follow. Since the first World War there has been introduced upon the scientific scene a new technique, which makes this possible at relatively low cost. This is microfilming, already in use in this country to take from library shelves to the work desk of the scholar or scientist the particular item of literature he wishes, when he wishes it. In the same way, in condensed form, and upon relatively imperishable photographic film, long runs of scientific journals can be provided at a cost comparably equivalent to the original single copy cost. Provided the original copy is available, this can be done in small editions, even as single copies, at the time when the material is needed.

There should, however, in these trying times be clear thinking and decisive action, as Dr. Mudd suggests, so that when the dead hand of war is lifted, science in freedom may continue.

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THE UNIVERSITY OF HAVANA SUMMER SCHOOL

I HAVE recently received a notice of the first summer courses to be given by the University of Havana and it gives me pleasure to call attention to the unusual opportunity which is offered for the first time to American naturalists.

[1] SCIENCE, 93: 376, April 18, 1941.