SCIENCE

FRIDAY, JANUARY 7, 1910

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SOME REFORMS NEEDED IN THE TEACHING OF PHYSICS [1]

LAST year's decision of the council of the American Association shows clearly the desirability of distinguishing between the work of the various sections and that of the more technical, scientific societies which meet in conjunction with the association. By leaving the presentation of special papers on research topics to the American Physical Society our section will in future pay more attention than heretofore to the discussion of general topics and by joint sessions with other sections strengthen the, in recent years, somewhat neglected ties between physics and allied sciences. There is an abundance of general subjects from which to choose.

For example, during the past few years a renewed interest has been shown, especially by high school teachers, in the teaching of physics—leading in the course of events to the so-called "new movement among physics teachers," new only in so far as it is an organized effort to improve the teaching of the subject in the high schools.

Your speaker has followed this movement with great interest, hoping that some definite reform might be accomplished by it; but it must be admitted that, as far as actual improvements in those high schools, where such improvements are most needed, are concerned, the progress has been very, very slow. The strongest censure which

[1] Address of the vice-president and chairman of Section B—Physics. American Association for the Advancement of Science, Boston, 1909.

can be made is that, while there is no lack of criticism in a general form, as: "The course is too mathematical," or "The course contains too many topics" no clear-cut, definite proposition for reform has yet been made. For example, we have waited in vain for an answer to the question: "Which mathematical relation should be omitted?" or, "Which topics seem superfluous?" Most of the better high school teachers have not changed their course. Why should they do so? We have statistical data showing that over 90 per cent. of the students in the larger Michigan high schools, after having taken physics, which is a required study, declare that they would elect the subject if allowed free choice. But doubtless statistics could also be produced showing the opposite effect upon students in other schools and under other teachers.

There has been considerable hesitancy on the part of the college professor to interest himself in this question; but within the last year or two a change has taken place, and it is a hopeful sign that section B is to have a discussion on educational problems during this week. Let us hope that some positive results may be reached. The decision as to how physics should be taught rests finally with those men who know the subject, understand the spirit of our science and for this reason are the only judges of its characteristic educational value. Leaving the discussion of the teaching of physics in our high schools to our session on Friday, I wish to speak upon a subject seldom touched upon in our former discussions: "The Teaching of Physics in our Colleges and Universities."

Many of us have heard the amusing remark: "The worst teacher is the college professor," a remark which always meets with the hearty approval of unripe high school teachers and arouses an unfortunate antagonism, instead of leading to a helpful cooperation between college and high school men. No matter how much importance we attribute to the new movement or to such a sweeping statement as the one just mentioned, may not we college professors in the end be held responsible for the conditions in the high schools? Or to be specific: "May not the preparation which we give future teachers be faulty?" and "May not our own teaching be capable of improvement?" I believe both these questions should be answered in the affirmative.

1. My first proposition is then: The system of the teaching of physics in many of our colleges and universities is more adapted to train professional physicists than future high school teachers. I take for granted that the two should receive a different training, a statement with which many of you will doubtless not agree. For my own part, I believe that the ideal high school teacher is one who has passed through a complete and thorough graduate course. However, we are not talking about ideals, but about conditions which actually confront us. At the present time the great majority of our high school teachers do not go beyond graduation, and I would deplore any attempt to crowd so much physics into the undergraduate course, that the physicist whom we may finally turn out lacks the general culture which an undergraduate course should give. We can hardly demand that an undergraduate spend more than from 20 to 24 semester hours in the department of physics, even if he expects to teach the subject in the high school.

In many of our institutions an elementary course is given, requiring the knowledge of very little mathematics. After passing this the student is turned loose on advanced studies, often highly specialized mathematical courses. By the time of graduation he will have lost a general grasp of the subject which he might have had before, but probably never acquired.

We should emphasize more problem work in connection with the elementary course. An utter helplessness of many higher classmen in attacking elementary problems is not unusual. The laboratory work given with the elementary course is frequently quite insufficient, and a somewhat advanced course, not in special lines, but covering the whole field, will do an untold amount of good. Finally there should be a general review of the whole subject from a higher point of view than is possible in the elementary course. Calculus might be a required study for this. At this point subjects might be taken up which have been omitted in the first course, the treatment could be more thorough and more exact. I believe that the introduction of such an advanced course would also have a good influence upon the first course. Now we feel too much under an obligation to present as large an amount of information as can be crowded into two semesters. If we know that those who are interested in our science can obtain a knowledge of the less common phenomena later on, these might be omitted at first and the elementary course could be made more thorough in what it teaches. Several text-books on university physics contain so much material and a good deal of it presented from such an advanced point of view, that they can not be covered the first year. The more difficult topics might well be reserved for such a course as I propose. Finally, every teacher of physics should be acquainted with the history of his science. The gross ignorance among some physics teachers of the development of physical theories and of the work of the intellectual giants, to whom mankind is indebted for its present civilization, is appalling.

A course of study, as outlined, would not require more than 24 semester hours. I might add that, where time allows, I would advise future physics teachers to take also a course in meteorology, a short course in dynamo-electric machinery and an elementary course in instrument-making, all of which might properly be given in the physics department. It is my firm belief that such a graded course will produce teachers to whom we may leave without hesitancy the question as to how physics should be taught in the high school. I have nothing to say about those people whom an incompetent school board appoints, though they had never more than a one-year's elementary training. We university teachers can certainly not be held responsible for their failure. What a pity that we can not prevent such men and women from experimenting upon our children.

It is a hopeful sign that from year to year a larger number of students stay with us after graduation or return during summer school to pursue graduate studies. It shows a slowly growing recognition of the fact that teaching is a profession and that professional knowledge in the chosen line of work is necessary even for high school teachers. Such knowledge can only be acquired by graduate work in this line, *i. e.*, in our case, in physics. An undergraduate course, as outlined above, is certainly not antagonistic to this spirit; yes, may it not raise the standard of our graduate work?

I am fully aware of an objection to my scheme and appreciate its force. You may ask: "Do you wish to prevent the professor in the small college, where the main object is to train teachers, from giving any graduate work?" I must admit, though very reluctantly, that such is the case, provided that the college in question is unable to furnish a sufficiently large instructional staff. If it is a question between one or two graduate courses and a general review course, I believe the latter should be given. While it may be more interesting and profitable for the professor to teach the advanced subjects, he should subordinate his personal wishes to the efficiency of the college. If he be fortunate enough to discover an exceptional man, is it not best for the latter to go to an institution affording larger facilities for his future work, to an institution where close contact with a number of investigators will stimulate and inspire him? Such a student will always remain loyal to his old college professor and be proud of being a graduate of an institution which has given him a thorough fundamental training.

2. As was suggested in the earlier part of the paper, not alone the college curriculum of the future high school teacher is being criticized, but also our teaching. We must admit that there is and always will be room for reform. The best we can do is to apply remedies after we have been shown clearly just where the trouble lies. In education we should not apply patent medicine, invented to cure general debility. Therefore we will not talk about methods. It would be an unfortunate condition, ending in stagnation, were all university professors forced to teach according to certain pedagogical rules which suppress individuality and kill spontaneous enthusiasm.

I shall be specific and state my second proposition thus: "We are far from being unanimous in the use of certain terms and frequently employ the same term to designate two entirely different physical quantities." This means that we do not pay enough attention to the very things which make physics so valuable as a training of the mind, namely, clearness of thinking and accuracy of expression.

Let me cite the most flagrant cases:

a. What is pressure? In every-day usage it is a force, pure and simple, as illustrated by the classic problem: How large a pressure is exerted upon a vertical wall by a beam leaning against it? Leaving this interpretation entirely out of consideration, is pressure the force, acting upon unit area, or, the force per unit area, *i. e.,* a force divided by an area? In other words: Has pressure the dimensions of a force or not? Both definitions are doubtless taught, but if we assume the former to be correct, then in our formula

$$F = PA$$

A does not represent an area, but the *number* of units of area upon which the force acts. Of course I assume that P stands for pressure.

But if we do this, we get into trouble when we discuss the work done upon or by a gas. For in the equation

$$W = PV$$

the V would no longer represent a volume, but a length. In fact, as soon as we speak of the action of a gas, we discard the force and substitute for it the abstract concept of the proportionality factor P between force and area. This abstract idea, which most of us call pressure, is nevertheless a real physical quantity.

I believe the greatest difficulty to the beginner in physics arises at the very moment when he is confronted with such an abstract physical quantity, *e. g.,* acceleration. He feels suddenly the solid ground slipping away from under his feet and regains confidence only after he has manipulated this quantity again and again in the solution of problems. So it is with pressure; we can not blame the student for trying to hold on to his old friend, the force, as long as he possibly can.

Clifford says: "When that which we do not know how to deal with is described as made up of things we do know how to deal with, we have that sense of increased power which is the basis of all higher pleasures." We should keep this always in mind in the presentation of our subject, but should not go so far in our wish to arouse this higher pleasure in the student as to make incorrect statements as the one that the pressure coefficient P is a force, and the other quantity A in our first equation an area. Let us be consistent and use the term "pressure" only for one physical quantity, and not for two or even three. In modern education we find too much a tendency to introduce kindergarten methods in the high schools; keep them out of the college.

b. In surface-tension phenomena we have a very similar case, since the force is expressed here by the equation

$$F = Tl.$$

The capillary constant T is usually called "surface tension," but we may read in the same book which gives this definition, that the weight of a liquid is balanced by the surface tension. The latter statement, though consistent with ordinary usage, does not agree with the former definition. All the preceding arguments in favor of accuracy and uniformity in our teaching apply in this case.

It is true, it is a hard task to teach students a new meaning of a word which they have been in the habit of using in a different, or at least in a much broader sense. But are we not successful in making them distinguish between mass and weight, though the same difficulty arises in this case? It is well known that the importance of the law of conservation of energy was not fully appreciated, until the new term "energy" with its definite present physical meaning was introduced and we stopped talking about the conservation of force.

c. In the chapter on Heat we find several inconsistencies. Every physicist knows perfectly well that the term "absolute temperature" refers to temperature measured on the thermodynamic scale. Nevertheless, we call the zero of the constant volume hydrogen thermometer the absolute zero and we call temperatures, measured from this point and by this thermometer, absolute temperatures. We even refer to any gas thermometer, no matter whether of constant volume or constant pressure, in defining absolute temperature. There seems to be no other remedy but to invent a new name, a tempting task for a philologically inclined physicist. Do not let us make light of our trouble because these different temperature scales agree so very closely. They are different. A man has not discovered the north pole even if he came within a few miles of it.

d. Another example occurs in the common expression of quantity of heat as

$$H = cM(t_2 - t_1).$$

The factor c is usually called "specific heat." It is really the "heat capacity of the substance" in question and is taken as unity for water under standard conditions. But it is not a pure number. It has definite dimensions, while "specific heat," defined as the ratio of the heat capacity of the substance to that of water, *is* a pure number; in other words, the relation between these two thermal quantities is exactly similar to that between density and specific gravity. We distinguish very carefully between the latter two, even where the numerical value would be the same.

This numerical equality has done more than anything else to befog our minds about the true nature of a physical quantity. Next in importance comes our inheritance of terms from old, long discarded theories. Think of such terms as "specific heat" which is not heat at all, or "electromotive force" which is no force. A discussion of all misfitting names would, however, lead us too far from the subject under consideration.

e. Though I do not wish to tire you by an enumeration of all examples of inconsistency in our teaching, I can not pass by in silence a case where our lack of accuracy introduces the most serious difficulties. It is the indiscriminate use of "lines of force," not alone for "lines of intensity," but also for "lines of induction." These two are very different things, as well in electrostatics as in magnetism, and neither the intensity nor induction is a force.

Let us consider a magnet and the field surrounding it. According to the old theory of action at a distance there is no magnetic disturbance anywhere in the space about the magnet, until we introduce a magnetic pole. Then, it is true, we have a force between magnet and pole. But this theory has long been overthrown. We know now that at every point of a magnetic field there exists a certain disturbance, call it a stress, if you please, whose magnitude and direction are given by the intensity of the field at that point. Moreover, the intensity of the magnetic field has nothing to do with a force, except that we may *measure* it by the force acting on pole strength m according to the equation, defining intensity H

$$F = Hm.$$

It is usually stated that the lines of force show the direction of the intensity, and their number through unit area, drawn at right angles to the direction, represents the magnitude of the intensity.

The use of a misleading name is not my main objection. The trouble begins at this point. After having used lines of force as synonymous with lines of intensity, it is serenely asserted that the cutting of lines of force produces an induced electromotive force in a conductor. You know that the magnitude of this electromotive force does not depend upon the intensity, but upon the rate with which the lines of induction are cut.

Only very few text-books give the correct expression for the induced electromotive force as

$$E = Blv.$$

To write H instead of B in this formula is radically wrong. The *numerical* value of E will be correct, provided the medium is air. The dimensional formulæ for the left and right hand sides of the equation balance only if we use B. Every experiment in electromagnetic induction is an example of the correctness of this statement. We all teach that the intensity of the field is analogous to a stress, the induction to a strain in an elastic medium, both being connected by the equation

$$B = \mu H.$$

No one would tolerate such a confusion of stress and strain in mechanics.

The historical development of lines of force is very interesting and explains to a certain extent the origin of our troubles. Faraday introduced the lines of force, but not in the sense of lines of intensity. Many quotations from his writings might be given, all showing that he meant by lines of force what I have called lines of induction. For example he says:[1]

> I have not referred in the foregoing considerations to the view I have recently supported by experimental evidence that the lines of force, considered simply as representants of the magnetic power, are closed curves, passing in one part of their course through the magnet and in the other part through the space about it. *These lines are identical in their nature, qualities and amount, both within the magnet and without.*

It is true, Faraday also speaks of lines in connection with field intensity, but here he uses various terms. Thus he writes:[2]

[1] Faraday, "Researches," Vol. III., p. 417.

[2] "Researches," Vol. I., p. 411.

I have used the phrases *lines of inductive force* and *curved lines* of force in a general sense only, just as we speak of lines of magnetic force.

He does not represent field intensity by lines.

Maxwell, however, changed the meaning by calling Faraday's lines of force lines of induction and using the term lines of force for lines of intensity only.

And we? We use the words sometimes in Faraday's sense, sometimes in Maxwell's sense. We introduce them when speaking of field intensity and later on make the glaring mistake of asserting that the induced electromotive force is measured by the cutting of lines of force. The American Institute of Electrical Engineers has proposed to call the unit of magnetic intensity the "gauss"; it seems to be a general understanding, judging from papers appearing on magnetic subjects, that it is also the unit of induction. Personally I prefer to discard the troublesome term altogether, but it may be that it has become so familiar to the scientist and is so generally used in engineering practise, though usually there in the meaning of lines of induction, that it is too late to abolish it altogether. If we must keep the lines of force in our text-books, let us use them in one sense only. We should certainly stop confusing our students about the real nature of these two totally different quantities.[3]

I hope to have proven that we lack in the presentation of several topics that accuracy of expression of which in general the physicist can be justly so proud, and that greater uniformity in the use of certain terms is very desirable. Our ideas as to the fitness of proposed names for the quantities in question as well as to the choice of definitions, may be widely different. Your speaker clearly realizes that there is ample room for discussion and that the sporadic attempt of a single scientist to correct the apparent faults in our teaching can not better the conditions appreciably.

[3] See also a paper by Professor Patterson, "Michigan Technic," 20, No. 2, p. 35, 1907.

Reforms of a lasting nature can be accomplished and the desired result reached in shortest time, only, if definite propositions be made by a committee consisting of a number of representative physicists. With their influence behind a reform movement of this kind we shall soon reach practical unanimity.

In conclusion, let me assure you from my own experience that it is not an extremely difficult matter to teach the student to make these fine distinctions between different physical quantities. It is true, it requires some deep and accurate thinking; but the result has always been that in the end the subject has become clearer to the student and, as I have been assured, even more interesting.

K. E. GUTHE

THE EVOLUTION OF INTELLIGENCE AND ITS ORGANS[1]

WE recognize two very distinct types of physiological functions: (1) activities concerned with the inner working of the bodily mechanism—nutrition, internal regulation, etc.—and called vegetative or visceral functions; (2) activities concerned with the adjustments of the body to outside, or environmental influences. These we call somatic functions.

These reaction types are, of course, always intimately related and interdependent; nevertheless, as we ascend the scale of animal life the history of the evolution of both structure and function shows a progressive elaboration of each of these

[1] Address of the vice-president and chairman of Section F—Zoology. American Association for the Advancement of Science, Boston, 1909.