School Science

VOL. II]

APRIL, 1902.

[No. 2

THE AMERICAN PHYSICS TEACHER'S OPPORTUNITY.*

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This opportunity is first the opportunity of every teacher of youth, the opportunity in some measure to guide, to instruct, to form the leaders, intellectual, moral and industrial, of the next generation of men; the opportunity to be in the general onward and upward movement of the human race, which we must still believe to be in progress, however much we may occasionally be disheartened by revelations of our slow advance—the opportunity to be in this development active and intelligent factors, not mere individuals of the crowd swept on by forces unvalued and unperceived. This great opportunity, and with every great opportunity comes a great duty, the duty of proving equal to the opportunity, is one appealing to the moral as much as to the intellectual side of our nature, and we see at once why it is that the public more or less distinctly classes us teachers with the clergy and requires of us, with reason, much of the same purity and elevation of life which it is accustomed to look for and to find among religious teachers. Indeed, the professions have often been united in the same man, and are still so united. Moreover, with the great decline in mere authority of office, which the religious profession has suffered during the last century, while the teaching profession has had no such loss of prestige, but has, on the contrary, gained immensely in the range and amplitude of means at its disposal—with this condition of things in the world of religious and secular

*Read before the New York Physics Club, March 15, 1902. Slight changes have been made in the paper since the reading.

instruction, the school or college teacher of the present generation cannot but find before himself a larger opportunity and upon himself a larger duty than fell to the lot of his predecessors.

Holding to this high ideal of our profession, we should not greatly care to what particular rank in our hierarchy we have individually been assigned, provided each one of us finds in his place work suited to his talents. If it be true, as I believe it is, that a man's first duty is to himself, it is also true that he can discharge this duty most largely, most honorably and most happily by service to other men; not by stunting himself, not by self-denial for its own sake, but by the fullest development of his powers under the stimulus of an eager ambition intelligently directed to worthy ends.

As teachers of physics, and especially as American teachers of physics, we have an opportunity to assist in the great and difficult labor of adapting a noble but refractory material to the purposes of general education. Physics is a severe study. In spite of the prestige which it has acquired by such achievements as the determination of the constituents of the sun's envelope, or the discovery and application of the Roentgen rays, not to mention more recent wonders, in spite of the immense and universally applauded usefulness of physics applied to industrial arts, in spite of the fondness which many children show for electrical devices, the fact remains that the real study of physics attracts and holds permanently the attention of few, of few even among scholars. This is true the world over. Physics is first cousin to mathematics and close kin to manual labor, a family connection as honorable as one could desire, but scarcely genial. Can we make it attractive without impairing its character? If we can do so, we should; for the sound popularity of a worthy object is a power for good. Our task, if we attempt it, will certainly be a difficult one, and, in my opinion, the time will not come within the next few thousand years, if it is ever to come, when the heart of the ordinary human being will warm as readily to the study of the impersonal as to the study of the personal. In a recent number of the *New York Nation* there was a long review of a biography of Pasteur. It gave a good account, with considerable historical detail, of the state of knowledge concerning the action

of right-handed and left-handed crystals, of like chemical composition, on plane-polarized light, at the time when Pasteur began the study of such crystals, a study soon attended by brilliant and important discoveries. Now, I feel very sure that most readers of the *Nation* omitted or passed very hastily over this passage, significant as it was; but I feel still more sure that very few who read on to the passage which described Pasteur's controversy with a fellow savant, as to whether a hen can take anthrax, failed to read all that was told on the subject. Pasteur affirmed, in the presence of Colin, that fowls "do not take anthrax." Colin maintained the contrary, and, in response to the challenge of Pasteur, undertook to produce a hen having this disease. He failed, and, finally acknowledging his previous error, declared now that fowls *cannot* take anthrax. Pasteur now affirmed that although fowls *do not* take anthrax under ordinary conditions, they *can be made* to take the disease. This Colin denied; but Pasteur, knowing the normal temperature of a fowl's body to be somewhat too high for the germination of anthrax, cooled a hen in water and then successfully inoculated her with the disease.

I have dwelt somewhat upon this sketch of Pasteur's activities because it has a certain lesson for us, not merely the lesson that a controversy between men is more interesting to the general reader than the solution of an important problem in pure physics, for to dwell much upon this fact might be discouraging, but rather the lesson that it is possible, by means of anecdotes concerning the great men of science, to invest them with a human interest which will be more likely to lead the ordinary student to study their work for the sake of the men than to divert him from a study of the work by undue attention to personalities. I agree entirely with a suggestion recently made by President G. Stanley Hall, that we should make more of the "heroölogy" of science. The general reader who has attained a glimpse of the keen and sportive spirit of Pasteur in the incident of his adversary and the hen will, perhaps, be tempted to turn back to things passed over before and try to understand what such a mind found interesting in crystals and polarized light. Brief biographies of great scientific men are becoming common nowadays, and such books as Cajori's *History of*

Physics are of great assistance. Let us make the most of all such legitimate aids to further our work. But, after all, I cannot look for any very great change, any revolution, of spirit of the average boy toward physics as a result of such a policy on the part of teachers. The simple fact is that, from the point of view of the school-boy, the great men of science have lived very dull lives. Very few of them ever killed anybody. Their victories were victories of the spirit, impossible to represent by means of the "biograph." Born such a date; died such a date; worked on physics all the time between. On such a day, under such and such conditions, was struck by an idea, from the effects of which he never recovered. That is the way the record will seem to run for most of the great worthies. Such a life is beautiful in its serenity, in its purity, in its elevation, in its ultimate usefulness. It is a happy life; it is a better type of heavenly existence than the eternal playing upon a harp would be for most of us. If we can get boys to feel for one moment the charm of such a life, they will be the better for it all their days. And we can do this for most boys if we really feel the charm ourselves; more surely, if we can exemplify in our own lives a little of what we admire in those of our own great teachers.

But, after all, says plain common sense and common experience, physics carried beyond the mere externals is work, and the average boy is not to be hypnotized into a permanent love for work by gazing at any picture of men who worked because they liked to work. Sooner or later, very soon indeed, we have to face the question whether it is worth while to try to take an ordinary class of boys beyond these pleasing externals.

Occasionally we meet some grave authority whose advice is for the negative of this question; not explicitly, of course; not wittingly, perhaps; very few people ever advise what seems to themselves a superficial treatment of any study. But we find such a man as President G. Stanley Hall saying this:* "The normal boy in the middle teens is often a walking interrogation point about ether, atoms, nature of electricity, X-rays, motors of

*At the meeting of the New England Association of Colleges and Preparatory Schools, Oct. 12, 1901.

many kinds, with a special gravity of mind toward frontier questions where the great masters know as little as he. He would like to see hundreds of demonstrative experiments made in physics and the liberty to repeat most of them himself, without being bothered about mathematics." "He is essentially in the popular science age. He wants great wholes, facts in profusion, and very few formulæ." Now, President Hall is a thoughtful man, a man to be listened to. He speaks in this instance with deliberation and with especial reference to and criticism of the kind of physics teaching which is now common in the schools of New England, the kind of physics teaching which is due in great measure to the efforts of Harvard College to build up in the schools a peculiar system of physics study; a system including as its most original feature a laboratory course of work, mostly quantitative, for performance by pupils. Most of you are doubtless familiar with the general features of this course, which, by the action of the National Educational Association and the Middle States College Admission Board, has now attained a national prominence, and all of you are, I hope, interested in the question, the doubt, or, rather, the criticism and condemnation which President Hall directs toward it. For myself, I welcome this criticism, as I do any intelligent, candid criticism of the system of physics teaching, which I have labored many years to develop and to promote, but which I consider still on trial, still in a state of evolution, still in need of criticism and of suggestion from all who have at heart the great purpose of bringing forth and establishing in American schools the best system of elementary physics teaching that the world can show. To share in this work, by adding to our present practice whatever it needs, by putting out from our present practice which should not be retained, is the great opportunity of the American physics teacher of this generation.

Now, the proposition of President Hall as to what a boy in his middle teens wants, is, in my opinion, all true; but I do not draw from it quite the same conclusion which President Hall draws. Behind his minor proposition, which I do not dispute, there seems to lie in his mind the major proposition that whatever a boy in his middle teens wants he ought to have, and this proposition I

am not prepared to accept. Why is either of these propositions peculiarly true of the middle teens? Boys still younger want "great wholes." Are their desires always safe counselors? Boys or men much older want "great wholes," which they are not willing to work for, which they in some way hope to get without bothering over details. It was only the other day that I received a round-about request from a very wealthy man, who had not found it convenient to go through college, for the name of some book or books that would enable him to get the latest results of physical advance without too much bothering over formulas. The demand for a royal road to knowledge is very old but is still unsatisfied.

But if the argument of President Hall in the passage which I have quoted is not conclusive, his contention may nevertheless be true? If it is unwise to give a boy everything that he desires, it is still more unwise to keep from him everything that he desires. Let us consider the proposed course of study, or instruction, or illumination, or gratification, whatever may be the best name for the experience which President Hall recommends for the boy, on its merits. Granting that the interest of the boy might be maintained through an extended course of such sensations and impressions as President Hall imagines for him, is not our proper inquiry, what would be the state of his mind at the end of the course? What would he really know? What would he be able to do? In what respect would he be more useful to himself or to the world after his experience? Would he have at the end anything more than a broad impression of having seen and heard a great many things, an impression vague, confused, in many respects false, not to be depended on? Somehow, as I try to imagine what the suggested course would be, how it would be managed and how it would result, I think of the nursery, of children eager, importunate, restless, seizing any toy within reach, playing with it a moment, then demanding another; I think of mothers or nurses distracted, of chaos and ennui and utter weariness at the end. It is possibly necessary for children to live this kind of life for a year or two, but must they live it till they reach the "middle teens?" If so, why not longer? When should they begin to have discipline with their mental activities?

But let us take another passage from President Hall's remarks. He says: "But boys of this age want more dynamic physics. Like Maxwell, when a boy, they are interested chiefly in the 'go' of things; those with aptitudes for physics want and need wide acquaintance first with tops, kites, and other physical toys, then with clocks, dynamos, engines, machinery, with some experience in running it and using tools; in looking into, taking apart and putting together almost anything that will go." The word "dynamic," as used in this passage, does not, I take it, have a technical meaning, but only a general significance implying some kind of "go." The whole observation just quoted is sound enough as descriptive of some boys; but it does not follow that it is the proper function of a school course of physics to meet those needs and wants of the boy, which are here set forth. If Maxwell's example teaches us anything for our guidance in this case, it teaches us that the boy "with aptitudes for physics" will pick up such knowledge as that here indicated without school instruction. As I remember the story of his boyhood, he used to go about among workmen asking the "go" and the "particular go" of any, to him, new thing. In these days of countless cheap mechanical toys, must we call on the school to furnish tops, kites and clocks for the boy to experiment with? As to dynamos and engines, the school can reasonably do something. I recommended some years ago three school exercises in the "assembling" of the parts of certain electrical instruments or machinery, and I am glad to see that makers of apparatus now advertise the materials needed for such exercises. But I have never seen my way to go very far in this direction, which soon takes us into the province of manual training rather than of physics proper. Manual training is an excellent discipline. I wish that every boy might have opportunity and encouragement to use the ordinary simplest tools of the wood worker and the metal worker. One of the great advantages of laboratory work in physics is this, that it does give a considerable amount of the same kind of discipline that the workshop gives. But how far can we afford to go in replacing physics by manual training, in minimizing the general and theoretical of our instruction, and magnifying the special and empirical? I may seem disposed to answer

or prejudge this question by the form in which I have put it; but I consider it to be a real and open one, especially for those schools which do not send many boys to college, schools in which the average scholarly ability of the pupils for abstract views and general principles is probably lower* than in the distinctively preparatory schools. This difference of natural endowment has been often ignored in important discussions. It was completely ignored, for example, in the Report of the Committee of Ten. One of the opportunities and the duties of the American physics teacher, recognizing the difference between schools to which I have just alluded, is to work out an answer to the question, still a question in spite of the unanimous opinion of all the conferrees of the Committee of Ten, what differences, if any, there should be in the physics courses of the two great classes of secondary schools. I believe that the necessary differences will not prove to be great. I hope that they will reduce to nothing; but I must at present wait for the verdict of experience. In France, perhaps in Germany, such a question would be settled by the government, by some bureau or some minister. In America we must hammer out the answer by patient labor of individual teachers and by discussion in voluntary assemblies like this one of yours.

But I must return to President Hall, whom I have been neglecting for a few minutes, and I wish now to quote from him one sentence of which I strongly approve. It runs thus: "Moreover, exactness comes relatively late in the development of the youthful mind as it did in that of the race, long after interest in general principles and especially forces." I find some evidence of a desire on the part of school teachers to introduce refinements, or perhaps I should say complications, of apparatus which would be eminently appropriate in a college course on physical measurements, but which are, in my opinion, out of place in the laboratory work of the school. Out of place because they are expensive, troublesome to set up and care for, and, under the conditions prevailing in school work, perhaps even less accurate than the much simpler apparatus which they replace. For example, some teach-

*The reference here is especially to the so called high school or "English High Schools" which many cities maintain side by side with "Latin Schools," the latter receiving nearly all of the pupils who look forward to a college course.

ers have a great dislike for the common spring-balance, and I must admit that, as often put on the market, it is scarcely an instrument of precision. Nevertheless, its quickness of action and the ease with which it is cared for and stored recommend it very strongly for work in which the main emphasis should be on the principle involved in the exercise rather than on the precision of the numerical result. For the use of beginners in determining specific gravity, I had rather, if need be, take the trouble to paste a piece of paper over the inaccurate scale of the spring balance and mark a new and better scale on this paper than provide a scale-pan balance with a set of weights. It is true that in skillful hands the latter will give more precise results, but it will take a longer time. And in the hands of the beginner the result may be no more accurate than that obtained with the spring-balance. The boy who will not, or cannot, with one of the ordinary 250 gm. spring-balances, corrected as to scale, get within 1 gm. of the correct weight of a 100 gm. object, is a boy who would be very likely to abuse a scale-pan balance and miscount or lose the weights. In a later course, when he has gradually become used to the handling of apparatus, he may well determine specific gravities with the scale-pan balance and make correction for the buoyancy of the air; but not at first. Another example: many of you are familiar with an exercise on the bending of wooden bars, in which a simple magnifying index is used as a means of measuring the deflection. The suggestion was lately made to me to replace this crude contrivance by the micrometer-screw and electrical contact method familiar in university laboratories. Now, I confess that students using the lever index often get very bad results; but why? Because they misread the magnifying power of the index, or neglect fractions of millimeters on the scale over which the index passes; in short, because they make simple, boyish blunders and are, some of them, unwilling to take pains. Would they do better with the more complicated and expensive apparatus? I doubt it. A boy who will misread a millimeter scale will miscount the number of turns of a micrometer screw. Moreover, the tables of any ordinary school laboratory, with a class of any considerable size in operation, tremble so much that the delicacy of an elec-

trical contact would be quite thrown away, and the sounder would be in a state of continual chatter during any attempt at a proper setting of the contact screw. Of course, some boys would be interested for a time by the electrical device and might try to make the best use of it; but the kind of interest in physics which can be stimulated only by electrical contrivances is hardly worth rousing at all. It is, no doubt, often the case that the beginner, finding his results inaccurate, is disposed to blame the apparatus and to think either that physics is not the exact science he has always heard it called or that he is not getting the genuine thing. When the teacher finds the boy in this state of mind, he should examine the apparatus and his own conscience, and consider whether the pupil has a real grievance, as he may have. If there is any serious fault of the apparatus which the boy has not been told of; if there is anything treacherous about it, like a screw which ought to be tight and is not, or a weight which is incorrectly marked, the teacher should spare no reasonable pains to make the thing right for the future. But if it appears, as it often will appear, that the trouble all lies in the fact that the boy has been, quite unconsciously perhaps, blundering and shirking, then it is the teacher's opportunity to impress upon the mind of that boy, kindly and sympathetically, but unmistakably, the truth that physics is not a science or an art by means of which blindness and laziness escape their natural consequences, but rather a field of experience in which these qualities are overtaken, with peculiar certainty, by their legitimate but unwelcome offspring. For though it is a mistake to make accuracy of performance the foremost consideration in elementary work, the pupil will himself find something lacking in his discipline and grow dissatisfied if he is not held to a conscious effort toward such accuracy as the apparatus at command will fairly yield.

There is one other particular in which, I fear, some teachers of my acquaintance are making a mistake, namely, the comparative neglect of qualitative experiments at the lecture table. I feel called upon to protest so often against what I believe to be the great wastefulness of qualitative laboratory courses for school pupils that I am in some danger of being misunderstood and

being quoted in opposition to qualitative experiments generally. The fact is that I attach very great importance to such experiments in what I believe to be their proper place, the lecture-room, and I take great pains with such experiments. I suppose that some teachers think they have not time for such work, feeling, perhaps, that they must bend all their efforts to the accomplishment of those things which appear prominently in examinations for admission to college. It is quite possible that we who conduct such examinations ought to change our practices of interrogation somewhat and try to make a knowledge of qualitative experiments more important in our tests. I am satisfied that real economy of effort in teaching as well as in learning requires much attention to such experiments. For example, it is a great mistake to undertake to teach Ohm's law without first giving an exhibition of the electromotive force of a battery in open circuit by means of the condensing electroscope. No voltmeter which looks to the pupil just like an ammeter and is, in fact, dependent on *current* for its action, will serve the purpose of initial enlightenment; it will rather deepen confusion. Of course, pupils can be trained to a mechanical facility in the use of Ohm's law without having any satisfactory sense of the nature of the factors involved; but such formalism is not what we hope to get from physics.

I made it plain in the first part of this address that I do not expect to see physics become a popular favorite among school studies. It must remain a rather severe study, when thoroughly treated, and perhaps, on the whole, its necessary severity is not to be regretted. If we can get boys to follow a good, stiff course of it to the end in school, with a measure of cheerfulness on their part, feeling that they are getting wholesome discipline and useful information, we need not be greatly disturbed if most of them do not pursue the formal study of it afterward. Let us not think it our duty to proselyte to the life-long prosecution of this science those who have no especial aptitude for it. But, on the other hand, let us not forget that the abolition of unnecessary difficulty, the economy and the attractiveness of efficient methods of presentation and work, are ends to be constantly sought by every

reasonable effort of the teacher. As compared with the teaching of the classics and the teaching of mathematics, the teaching of physics, especially by the method we are following, is a new art. Often a teacher will find that a slight variation of form in the statement of a proposition or the description of an experiment will make all the difference between success and failure. Every year I find my copy of the laboratory manual used by my lowest class scarred with new inscriptions put down under the stimulus and inspiration of new experience with old problems, and when this ceases to be the case I shall suspect that I am getting too old to teach. Regard for form, not only of thought and of work, but also of personal carriage and of speech is a duty of every teacher, and perhaps teachers of science, with their minds occupied to the full by the matter of a robust and growing body of knowledge, are somewhat less regardful of this duty than teachers of other things, the classics for example.

In the development and perfecting of himself as a teacher, the school man will find scope enough for his energies. It is not enough for him to know his text book or his laboratory manual. Writers of text books and of manuals sometimes err, and the teacher must be able to make correction. Books of a few years back get out of date. The newspapers and magazines are constantly filled with strange stories, sometimes true and sometimes not, of wonderful things done or to be done in science. The teachers should read, and read intelligently, with an open mind watched over by an enlightened skepticism. He should know, too, who are the writers to be depended on and where their opinions are to be found. If the school teacher of physics, regarding himself as one of a great body enlisted in the noble purpose of making the teaching of physics of the greatest possible good to the youth of our land and ultimately to the youth of the world, does all the things which have been suggested in this paper, will he have time for what is commonly called original research? Regretting, as I must, to differ in opinion from my friend Professor Nichols in regard to this matter, I must answer, no. Much as I admire the suggestiveness of Professor Nichols' address, delivered, I think, before this club, I can hardly believe that one

teacher in fifty will find it practicable to carry out even the least formidable of his proposed investigations. Original research, successful and profitable original research, requires rare qualities of combined enterprise, insight and patience, and an atmosphere different from that of the school. It requires specialization, absorption in the enthusiasm of the pursuit for what, in the end, will probably attract the attention of very few. "Does any one read your articles?", a distinguished chemist asked me a few years ago, "I don't think anybody ever reads mine." The joy of research is mainly in the doing, and this joy is for comparatively few minds. The same kind of joy, and perhaps quite as wide a fame, may come to one by the mere exercise of his energy and inventiveness in the perfecting of devices for successful laboratory work. The thrill which comes to a man who, after many fruitless efforts, has made a label stick where it would never stick before, is not so very different in kind from that of the man who has carried some research to a successful conclusion.

But what of "duty to science" and high ideals generally? Prof. Ladd, of Yale, is right when he says in a recent number of *The Forum*, using words which I cannot now exactly recall, that no one owes a "duty to science," that duty is to mankind. Some men, says Professor Ladd, can best serve mankind by following out their instincts and exercising their talents for high research; but others can serve best in other ways. If the school teacher has the real fever for research in his veins, a mad passion for squandering months and years in the endeavor to find out something about, let us say, the thermal conductivity of metals or the resistance of galvanic cells, by all means let him give his passion free swing, provided he can do so without neglecting his primary duties. His labors will probably be, to use the happy phrase which the barber who lavished his professional zeal on me this morning applied to his own handiwork, "genteel, harmless and not too conspicuous." That, at least, is what I find to be true of the majority of my own efforts at original research. But let no school teacher feel that his profession requires him to do this kind of work. He will be most happy, most useful and most respected in doing zealously the thing he can do best.