SOME ASPECTS OF TECHNICAL EDUCATION WITH
ESPECIAL REFERENCE TO THE TEACH-
ING OF PHYSICS.

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Among the gigantic strides of human progress of the nineteenth century and up to the present time, it is safe to say that the greatest has been along scientific lines. In the dawn of the twentieth century we find ourselves in the midst of the greatest industrial activity and development that the world has ever seen. Science and invention have placed vast resources at our command. The material wealth of every country is being developed; railroads are built; mines are opened; towns are established; commerce is encouraged. Every effort is put forth to make living less costly and more comfortable.

Until the last few years the province of American manufacturers was to supply the domestic wants of this country. When the output exceeded that demand, collapse came from over production. Now our markets are broadening; our opportunities are increasing; our resources are being developed beyond our requirements, and increasing population demands increased occupation and production. Trade and territorial relations have been established in the Orient, and we are destined to secure our fair proportion of the commerce of that thickly populated and now rapidly opening section of the globe.

Under these pressing conditions of expanding industries and new markets throughout the world, an aggressive competition must necessarily follow. The skilled artisans and the accomplished merchants of the Old World will not willingly surrender their trade or prestige. We may accept complacently the popular estimate of our superiority in natural resource and inventiveness, but we are confessedly not their equals in trained skill and tried experience in that field which they have held so long.

It is not alone, however, in meeting competition in foreign markets that a successful field for educated labor and industrial

* An address delivered before the Physics Section of Central Association of Science and Mathematics Teachers, Nov. 25, 1904.

training is offered. The marvelous strides made in our own country in manufacturing of all kinds, in electrical, mechanical, civil, mining, chemical and fire protection engineering reveal an unprecedented demand for technically trained engineers. We are, therefore, able to comprehend some of the broad and diversified fields of usefulness and profit which are open to young men who will properly fit themselves for the commercial and industrial arts. It is to supply this broad material sphere of activities with capable men that so many technical schools have recently been established throughout the country. There has been nothing in our national history more significant or more distinctive than the origin, growth and the amazing development of these institutions of learning.

The purpose of this paper is not to discuss, to any extent, the ideal course of study for students to pursue in such institutions, but rather to consider more closely certain phases of their preparation which is to fit them for an engineering education.

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In the engineering courses of today we try to combine, in four years, professional training with research and culture. This, however, is difficult to do, for while the professional work is reasonably complete, culture is at a minimum and research crowded to the wall. The subject of law requires three solid years for professional training alone. Three or four culture years go with this and are surely none too many. The same requirement should eventually be made for engineering. A college of engineering cannot turn out a finished engineer in four years, since there are many things besides engineering which go to the making of a real engineer. Of all professional men, he should be an individual of broad, general culture, because of the very nature of his profession and of the constantly increasing scope of his activities in all departments of life. A certain amount of culture must be given before the student enters the technical school, and here is the weak point of our present day training. Students come to the College of Engineering before they

know how to study, and much of the time is spent in acquiring that systematic habit of work which they should have brought with them. While we cannot prepare a student within four years to become an engineer and also a man of broad general culture, we can show him in that time the line of his professional advancement and can see him well started in that direction before he receives his degree. We can give, in the college course, something of the methods and results of advanced research. In any subject, the advanced work has a higher culture value than elementary work.

The one subject in which we find the entering students to Armour Institute of Technology woefully deficient is English. The teacher, however, may not be wholly to blame in this matter, for it seems to be the prevalent feeling among students about to take up an engineering course that the study of English is of little importance. Teachers of High School English inform me that it requires more than ordinary effort to interest the pupils of their classes who are contemplating engineering courses. This is a sad state of affairs, and if these students could have presented to them the opinions of our great engineers on this subject, I am sure it would have a salutary effect. The chief engineer of one of our large electrical concerns recently told me of a young man employed in one of the main departments whose failure to be promoted to the highest position in his department was due to his lack of knowledge of the English language. That too much stress cannot be laid upon this all important, but sadly neglected subject, is the opinion of all successful engineers today.

Prof. John Perry, whose opinions always claim our closest attention and for which we have the profoundest respect, expresses himself as follows: "Well equipped schools of applied science are getting to be numerous, but I am sorry to say that only a few of the men who leave them every year are really likely to become good engineers. The most important reason for this is that the students who enter them usually come from the public schools; they cannot write English; they know nothing of English subjects; they do not care to read anything except the sporting news

in the daily papers; they cannot compute; they know nothing of natural science; in fact, they are quite deficient in that kind of general education which every man ought to have."

While this state of affairs in England is much to be deplored, let us congratulate ourselves that such a criticism is altogether too severe to be applied to our own system of preparatory teaching.

Realizing the importance of the study of English to the engineering student, the Armour Institute of Technology has recently inaugurated the system of requiring laboratory notebooks and bulletins to be presented to the English department for criticism and correction. At least once a term, the head of each of the engineering departments submits to the Professor of English, for his criticism, a set of papers taken from the regular work of that department in the Sophomore, Junior and Senior years. These papers are corrected and returned to the student, and the Professor of English has the authority to cause any student deficient in English to report him for special work in that subject. All graduating theses are submitted to the Department of English for criticism before they are presented to the Executive Committee of the Faculty for final judgment.

The subject, however, of the most importance to the student contemplating a course in engineering is Physics. When we remember that engineering, in all of its branches, is only the application of the principles of Physics, we can realize how necessary it is for a thorough and practical foundation in that subject. It has been one of my duties for the past five years to examine the students in Physics and to pass upon their laboratory notebooks for admission to the College of Engineering. I have, in that time, examined the work of approximately a thousand students from high schools and academies in nearly every state in the Union. While the preparation, in general, has been very satisfactory, I have made a few observations of points upon which more emphasis should, perhaps, be laid by high school teachers in preparing students for the study of engineering.

In the first place, I find many of our Professors of Engineering complaining that too little stress is laid upon the subject of

Mechanics. While it is true, that in the interim between the completion of the study of Physics in the high school and the taking up of the College Physics, the student forgets many of the principles he has learned, there are certain fundamentals upon which he should be so thoroughly drilled that he will never forget them. Especially in Dynamics does the teacher of Engineering Physics find his pupils either poorly prepared or their memories exceedingly faulty. Much valuable time would be saved the instructor if his pupils could bring with them a clear idea and conception of the Units of Force, Units of Work, and the subjects of Acceleration, Rate of Change of Momentum, Impact and Energy. In connection with the above, I will add the subject of Angular Velocity, which is of great importance to the mechanical engineer, and the fundamental ideas of which should be given in the Preparatory Physics.

In the second place, if there is one general topic more than another in the study of Physics which should receive extraordinary attention and upon which the student should receive special drill, it is that of Units. In the general term I include, of course, Electro-magnetic Units, Units of Heat, Units of Force and Units of Work. The engineering student makes constant use of these from the beginning of his Sophomore year until he graduates. It seems unjust that the instructor in College Physics should be compelled to curtail the time for his regular work in order to explain what the student should have brought with him from the high school, yet this is only too true, and on behalf of our engineering instructors I suggest that more drill and more problems be given in dealing especially with the Units of Force and the Units of Work.

Furthermore, a subject upon which emphasis should be laid and which some textbooks fail to mention in any way is that all-important engineering principle of Moments of Forces. Other subjects of especial moment to the engineer are Composition and Resolution of Forces, Friction, Elasticity, Efficiency and Mechanical Advantage of Machines, Boyle's Law, Fluid Pressure and Heat Energy. An abundant use of simple practical problems is thoroughly recommended for the above subjects. It is only by the

varied application of the principles of Physics to practical problems that the student can acquire that firm grasp of ideas which comes from constant use.

Two other subjects of vital importance, and of which the high school student usually has little or no knowledge, are Simple Harmonic Motion and Moment of Inertia. While it is impossible to treat these subjects from a mathematical point of view, the physical conception should at least be given.

Another very important desideratum is a more intimate connection between the studies of Mathematics and Physics. While students are able to use and manipulate the physical formulae in the majority of cases, they fail to give to them the proper physical interpretation. However, as another paper has been prepared on this subject, I shall not enter into a detailed consideration of the question.

It is true that many high school teachers seems to undervalue the importance of the study of Mechanics. Nevertheless, it is a fact that it is the backbone of an engineer's college training. It is only with a thorough grounding in the fundamentals of this subject that the student can take up the studies of his college course without grim discouragement and possibly failure staring him in the face. To the ordinary pupil, this branch of Physics is usually uninteresting and difficult, and the teacher should exert his greatest effort to conduct his classes in a way that will interest and, at the same time, impress upon them its unusual importance. The instructor should also remember that it is upon his skill and ability in devising practical experiments in the laboratory that the students' thorough grasp of the principles finally depends.

The immediate aim of instruction in Physics should be to give the power and the habit of using physical knowledge. The enthusiastic and observant teacher will encourage his pupils to see and think about physical phenomena and physical devices which are outside of the class-room. If the pupils are sufficiently interested to bring to the teacher their observations from a visit to a machine shop, factory, power station, electric light plant, steel works, car shops, or even from their daily walk or ride to

school and recognize any of the principles they have learned, then the teacher may well feel satisfied.

In connection with the laboratory work in Physics, there is one feature, the growing tendency of which is gladly welcomed, and that is the plotting of curves and graphical methods in general. The importance of this practice cannot be overestimated in connection with technical work. The use of cross-section paper should be extended to every experiment that will permit of its use, and care should be taken that the pupil thoroughly understands its meaning. I remember, some years ago, one of the experiments I gave, to illustrate the plotting of a curve, was that of the pendulum, where the string was lengthened a number of times and the time in seconds for the swing of each successive length was taken. These were plotted with the times as ordinates and the lengths as abscissae. It was not, however, until the times and square roots of the lengths were plotted, giving a straight line, that the students fully appreciated its meaning.

A feature of laboratory work, in which it seems there is room for improvement, is in arranging and devising experiments so that the student may not know the outcome beforehand. It is always the natural tendency for the student to turn either to his tables, or some other place of reference, and anticipate the result. It is surprising sometimes to know what remarkable and accurate results are obtained by students which, with the apparatus at their command, the instructor knows to be well nigh impossible, barring accident.

I have known students, with the aid of a string, a lead ball and an ordinary watch, to determine, after repeated trials, the value of gravity accurately to two decimal places, and by measuring the circumference and diameter of an ordinary wheel, to determine the value of π to five decimal places. While the temptation on the part of the student to do this is great, in many experiments, especially those in Mechanics, there are many occasions where it can be prevented.

Attention may be called here to the fact that the student too often fails to clearly recognize the connection between a definition, or statement of a law, and the result of an experiment. A

student, for example, who has taken two different masses connected by a string passing over a pulley and has determined the moving force, the mass moved and the acceleration, certainly is in a better way to clearly grasp the meaning of Newton's second law of motion than the student who accepts it as a mere convention. Again, let me suggest, in this connection, as thorough a drill on practical problems as time will allow. Not a few of the candidates for admission to our College of Engineering are able to give every definition and state every law and principle within the covers of the textbook, but are utterly at sea in knowing how to apply these principles they have memorized so well. It is gratifying to state, however, that there seems to be a general tendency throughout the country for instructors in Physics to be less spectacular and more practical in their teaching; to pay more attention to the great underlying laws of nature, rather than its beauties. So many students, upon completing the study of Physics, seem to feel like a laborer who has finished his task and sat down to rest. They heave a sigh when they find they have passed the subject and immediately proceed to forget it. The teacher who can instill into his pupils a *continual desire* to investigate and master the energies and forces of nature is as powerful an engineer as the builder of the greatest bridge or the mightiest man of war.

The young man of today should be impressed with the fact that this is a scientific age and that scientific methods enter into all branches of business and departments of industry. No matter what his plans for the future may be, let him understand that whatever vocation he may choose, his scientific training will contribute in no small way to his success in that particular department of activity. Let us, then, as sponsors for his early training, assist him in laying a strong, practical, scientific foundation, so that he may go forth to do battle with the world equipped with the weapons of modern warfare, and not "with the shield and sword of an ancient gladiator."