ellipse would continue in this direction; but since the frequencies differ, the ellipse slowly revolves. Conversely, from the revolution of an ellipse, we should infer a difference of frequency in the two component vibrations. So it is suggested that the two slightly different frequencies in the light sent out by ignited sodium are due to an elliptic motion in the molecule in which the elliptic orb slowly revolves; this suggestion has not yet been carried so far as to specify any hypothetical cause for the revolution of the ellipse.

These two examples, both due to eminent English physicists, may serve to illustrate the method by which, if I am not mistaken, we are not unlikely to learn much as to the structure of molecules and atoms. We must not expect rapid progress. Even comparatively simple hypotheses may require, for their due examination, the invention of new mathematical methods. And useful hypotheses are rare: like the finding of buried treasures, they are not to be counted on. But, since Prout's hypothesis has rendered us its final service, new hypotheses must be devised, competent to guide us further on our way. Let us hope that, before this city again honors our Association with its invitation to meet here, American chemists and physicists may have had some honorable share in such new advance.

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*PAST AND PRESENT TENDENCIES IN ENGINEERING EDUCATION.**

THE present status of engineering education in the United States is the result of a rapid evolution which has occurred in consequence of opinion as to the aims and methods of education in general. These changes of opinion, whether on the part of the public or on the part of educators, together with the resulting practice, may be called tendencies. All progress that has occurred is due to the pressure of such views or tendencies; hence a brief retrospect of the past and contemplation of the present may be of assistance in helping us to decide upon the most advantageous plans for the future.

Thirty years ago public opinion looked with distrust upon technical education. Its scientific basis and utilitarian aims were regarded as on a far lower plane than the well-tried methods of that venerable classical education whose purpose was to discipline and polish the mind. What wonderful changes of opinion have resulted, how the engineering education has increased and flourished, how it has influenced the old methods, and how it has gained a high place in public estimation are well known to all. The formation of this Society in 1893, its remarkable growth, and the profitable discussions contained in the three volumes of its transactions, show clearly that technical education constitutes one of the important mental and material lines of progress of the nineteenth century.

Engineering courses of study a quarter of a century ago were scientific rather than technical. It was recognized that the principles and facts of science were likely to be useful in the everyday work of life and particularly in the design and construction of machinery and structures. Hence mathematics was taught more thoroughly and with greater regard to practical applications, chemistry and physics were exemplified by laboratory work, drawing was introduced, and surveying was taught by actual field practice. Although engineering practice was rarely discussed in those early schools, and although questions of economic construction were but seldom brought to the attention of students, yet the scientific spirit that prevailed was most

*Presidential Address before the Society for the Promotion of Engineering Education at the meeting in Buffalo, N. Y., August 20, 1896.

praiseworthy and its influence has been far reaching.

This scientific education notably differed from the old classical education in two important respects: first, the principles of science were regarded as principles of truth whose study was ennobling because it attempted to solve the mystery of the universe; and second, the laws of the forces of nature were recognized as important to be understood in order to advance the prosperity and happiness of man. The former point of view led to the introduction of experimental work, it being recognized that the truth of nature's laws could be verified by experience alone; the latter point of view led to the application of these laws in industrial and technical experimentation. Gradually the latter tendency became far stronger than the former and thus the scientific school developed into the engineering college.

The very great value of laboratory experiments, and of all the so-called practical work of the engineering school of to-day, is granted by all. Principles and laws which otherwise may be but indistinct mental propositions are by experimentation rendered realities of nature. The student thus discovers and sees the laws of mechanics, and is inspired with the true scientific spirit of investigation. It should not, however, be forgotton that if such practical work be carried beyond the extent necessary to illustrate principles it may become a source of danger. The student of average ability may pass a pleasant hour in using apparatus to perform experiments which have been carefully laid out for him, and yet gain therefrom little mental advantage. Especially is this true when the work assumes the form of manual training, which, however, useful in itself, is properly considered by many as of too little value to occupy a place in the curriculum of an engineering college.

The tendency toward the multiplication of engineering courses of study has been a strong one, especially on the part of the public. This has resulted in a specialization that, as a rule, has not been of the highest advantage to students. In some institutions this has gone so far that the student of civil engineering learns nothing of boilers and machines, while the student of mechanical engineering learns nothing of surveying or bridges. The graduate is thus too often apt to lack that broad foundation upon which alone he can hope to build a successful career.

The development of the scientific school into the engineering college has been characterized throughout by one element of the happiest nature, that of hard work and thoroughness of study. The numerous topics to be covered in a limited time, their close interrelation, and the utilitarian point of view, have required many hours per week and earnest work by each student in preparation for each exercise. The discipline of hard and thorough work is one whose influence can be scarcely overestimated as a training for the duties of life, and in every university it is found that the activity and earnestness of the neighboring students is a source of constant stimulus to those of other departments. Thus scientific and engineering education has tended to elevate the standard and improve the methods of all educational work.

The length of the course of study in engineering colleges has generally been four years, and whatever tendencies have existed towards a five-years' course have now for the most part disappeared. With higher requirements for admission, particularly in English and in modern languages, a reduction of the length of the course to three years may possibly be ventured in the future, particularly if the long summer vacation be utilized for some of the practical work, as indeed is now the case in several institutions.

There has been and now is a strong tendency toward a reduction in the length of the college year. While formerly forty or forty-two weeks were regarded as essential, the process has gone on until now some colleges have but thirty or thirty-two weeks, a reduction of nearly twenty-five per cent. having been effected in twenty-five years. Undoubtedly the long vacation is utilized to great advantage by the majority of students in actual work, yet the fact remains that it is not good business economy to allow the buildings and plant of a college to lie idle for so large a part of the year. It is perhaps possible that in the future the summer schools may be so developed that the work will be practically continuous throughout the year, thus giving to students the option of completing the course either in three or four years.

The report of the committee on requirements for admission, which will be presented later in the session, sets forth many facts which show the tendencies now existing. Almost without exception a higher standard is demanded, both that students may enter with better mental training and that more time may be available in the course for technical subjects. While the general line of advance is toward an increase in mathematics and in modern languages, there is also found, particularly in the central states, a demand for broader training in science. It has already been pointed out that our early engineering schools were strong in scientific training, and that the tendency has been to replace this by industrial applications. If the requirements for admission can be extended to include the elements of chemistry and physics, with some botany or zoology, the engineering student will enter with broader views, a keener power of observation and a scientific spirit that will greatly increase his chances for success in technical studies.

The general increase in requirements for admission tends to raise the average age of the student. It is now usually the case, owing to the greater length of time needed in preparatory work, that the average age of the classical student is one year higher than that of the engineering student; or the former has had one more year of training than the latter. One more year of training means much as an element for success; one more year in age means an increase in judgment which is of the highest importance for a proper appreciation of the work of the course. The older men in a class usually do the best if not the most brilliant work, and after graduation their progress is the most satisfactory. It thus appears that all tendencies that raise the age of entrance are most important ones and deserve hearty encouragement.

Having now considered some of the general elements and tendencies in engineering education it will be well to take up the program of studies, especially in regard to those subjects that are common to all technical courses. The three volumes of the Transactions of this Society contain many carefully prepared papers and interesting discussions which enter into questions of detail concerning nearly all topics in the curriculum. Here, however, can only be noted briefly the main lines of development and the indications for future progress.

Mathematics is undoubtedly the most important subject in all courses of engineering study, and it has been demanded for years that it be taught with great thoroughness. This demand has been not more completely in the independent engineering colleges than in the engineering courses of the universities. Much, however, remains to be done in this direction, and probably it cannot be satisfactorily accomplished until a change in method has been effected. The fundamental element in the change of method must be, it seems to me, in a partial abolition of the formal logic of the text-books and an introduction of historical and utilitarian ideas. Mathematics is a tool to be studied for its uses, rather than for its logic or for discipline that it can give; hence let its applications be inculcated frequently and not be systematically kept out of view. If the student gains the impression that his mathematical exercises are merely intended to train the mind his interest and his progress will usually be slow. If, however, he learns what mathematics has done in the past, how it joins with mechanics to explain the motions of the distant planets as well as to advance the material prosperity of man, there arises an interest and a zeal that helps him to overcome all difficulties.

The great advantage of numerical exercises in all branches of pure and applied mathematics, and the deplorable lack of good preparation in arithmetic, have been expressed by many educators. In numerical computations the average engineering student is weak in spite of the numerous exercises in his practical work. To remedy this defect better instruction in arithmetic is demanded in the common and high schools, while in engineering colleges the teachers of mathematics should constantly introduce numerical work and insist that it be done with a precision corresponding with the accuracy of the data.

Next in importance to mathematics comes mechanics, the science that teaches the laws of force and motion. In most institutions the rational is separated from the applied mechanics and often taught by the mathematical department. Probably less improvement has resulted in the teaching of rational mechanics during the past quarter of a century than in any other subject. That mechanics is an experimental science whose laws are founded on observation and experience is often forgotten, and the formal logic of the text-books tends to give students the impression that it is a subsidiary branch of mathematics. The most interesting history of the development of the science is rarely brought to the attention of classes, and altogether it appears that the present methods and results are capable of great improvement.

It should not be overlooked, however, that in recent years the so-called absolute system of units has been introduced into mechanics and is now generally taught in connection with physics. Here the pound or the kilogram is the unit of mass, while the unit of force is the poundal or the dyne. Although this system possesses nothing that is truely absolute, it has certain theoretical advantages that have commended its use, notwithstanding that no practical way of measuring poundals has been devised except by the action of the force of gravity on the pound. Engineers have continued to employ the pound weight as the unit of force, and the calculations of the physicist must be translated into the units of the engineer before they can be understood. The student of rational mechanics thus has the difficulty at the very outset of two systems of units, and great care should be taken that each be thoroughly understood and the relations between them be clearly appreciated by application to many numerical problems. In view of these and other difficulties and of the novelty of the subject in general, it appears that some engineering colleges do not give to rational mechanics as much time as its importance demands.

Physics in some colleges is taught by a course of five or six exercises per week, extending over a year, while in others the elements are required for admission and the regular course is correspondingly abridged. The marvelous development of electrical theory and practice has naturally tended to make this the most important topic in the course, sometimes indeed to a material abridgment of mechanics, acoustics, thermodynamics and optics. Considering how great is the importance of each branch of physics and the advances that are made every year in new directions, it may also be concluded that more time can be profitably given both to theory and to experimental work. Physics is a fundamental subject whose principles and results are of constant application in every walk of life, and a student who thoroughly covers a well arranged course has gained a mental discipline and a scientific habit of mind that will be of greater value than the technical details of a purely engineering specialty.

Undoubtedly the most powerful tendency in engineeeing education has been in the direction of the development of those special technical subjects which may be grouped under the name of Construction and Design. In civil engineering this has led to plans for railroad, water supply and bridge construction ; in mechanical engineering to engine and machine design; in mining engineering to projects for mine plants, and in electrical engineering to the design of dynamos and motors. These courses have been demanded by the public and by the students themselves, and have been often elaborated to an extent beyond the best judgment of teachers of engineering. To the extension of such courses there is no limit, but it is a question whether the process has not already gone too far. For instance, it would not be difficult to arrange a course of twenty or thirty exercises on water pipes in which should be discussed all the methods of manufacture and processes of laying cast-iron, wrought-iron lap-welded, steel-riveted and wooden mains, together with a comparison of their relative economies under different conditions in different parts of the country. These lectures, however, would plainly be of such a technical nature that the advantage to the student would be slight; they would give valuable information, but little training.

In all courses in construction and design the practical limit seems to be reached when the exercises are of such a nature as to give more information and little scientific training. The aim of all education, and of engineering education in particular, should be to render the student conscious of his mental power and sure of applying it with scientific accuracy so as to secure economy of construction. Fundamental principles are hence more important than the details of a trade, and all exercises in design should be arranged so that the student may think for himself rather than blindly copy the best practice of the best engineers.

The subject of applied mechanics, which occupies an intermediate place between rational mechanics and the work in design, has been so differentiated that the mechanics of materials is now almost the only topic common to all engineering courses. The strongest line of development has here been in the introduction of testing machines and in the making of commercial tests. This work is of high value, although it may be doubted if the use of one or two large testing machines is as advantageous as that of many smaller ones which are designed especially to illustrate principles. The student of the present day enjoys, however, advantages that were unknown a quarter of a century ago, and the marked progress in applied mechanics from both the scientific and technical point of view is a source of congratulation.

English and modern languages are generally called culture subjects, and it is well known that of all the topics in the engineering course these are the ones in which students have the least interest. The great importance to an engineer of being able to clearly and correctly write his own language can scarcely be overestimated. Further it may be said that no engineer can hope to attain eminence unless he can read German and French literature. These opinions have long been held, and furthermore it has been recognized that engineering students and graduates are often lacking in that general culture which the world demands as one of the conditions of success. Great improvements have been made in the methods of teaching English and modern languages, and probably still greater ones are yet to result. In the ideal engineering colleges of the future perhaps these subjects will be required for admission, as is now done at least by one institution, but at present they must generally be taught. The main line of improvement to secure better results will be, it seems to me, in partially abandoning the idea of culture and placing the instruction upon a more utilitarian basis. If English be regarded as a means to an end instead of linguistic drill; if the aim of teaching French and German be to read fluently the language of to-day instead of laboriously to decipher the meaning of the poets of centuries ago, true zeal on the part of the student will arise and a truer culture will result.

At the close of the college course the student presents a thesis showing his ability to apply the principles and rules of engineering in the investigation or design of a special problem. The tendency has been strong to abandon subjects which involve mere description or compilation, and to insist upon those that will require the student to exercise his own powers. Thus the value of the work to the student has been greatly increased, and the theses of each class are a source of stimulus to the following ones. Although the view held by some that theses should be monographs setting forth important conclusions of original investigations is one that can not in general be realized, it is a gratification to note that each year a few theses are produced which are sufficiently valuable to warrant immediate publication.

The formation of engineering clubs among students for the discussion of the details of professional work is one of the most important tendencies of recent years. No exercise is so valuable to a student as one entirely originated and performed by himself, and the preparation of a paper which is to be presented to and criticised by his fellows ranks highest of all among such exercises. Recently there has been forced upon my notice a remarkable activity in the three engineering clubs of a certain engineering college, more than fifty papers having been read discussed during the year by a total of about three hundred and fifty students, besides a number of others read before the mathematical club. In meetings of this kind the scientific and economic questions under discussion in the engineering journals receive a detailed attention which the professor in the class room often finds it impossible to give, while the advantage to students in expressing themselves in debate is very great.

Occasional lectures to classes by practicing engineers have been introduced in many institutions during the past decade, and with uniformly good results. In engineering education there is no conflict between theory and practice, and every professor cordially welcomes distinguished engineers to explain their great structures and achievements to his classes. It is an inspiration to students to see and hear those men who have so successfully applied sound science to economic construction, and whose influence has been uniformly to elevate the standard of the profession.

After four years of work the engineering student receives his degree and is ready to commence the actual work of life. What the letters are that designate the degree is a matter of small importance. Moreover, if we examine the lists of the alumni who graduated ten or fifteen years ago, the conviction arises that their particular course of engineering study has not been an absolute factor in determining their actual lines of engineering work. It is found that graduates in civil engineering are engaged in mining, in machinery and in electricity, and that graduates in other courses are employed upon work in which they received no especial technical instruction. Thus it appears also that the particular course of engineering study is not so important a matter as students and the public generally suppose. In fact, a young man thoroughly grounded in fundamental principles and well trained how to apply them has almost an equal chance for success in all branches of engineering practice.

Looking now over the field of tendency thus briefly outlined it is seen that there has been ever present a powerful impulse towards specialization, to which, indeed, nearly all others have been subordinated. This has demanded a higher standard of admission, great thoroughness in all fundamental subjects, and a rigid adherence to scientific methods. Engineering education has had an active part and healthy growth; it now enjoys the respect and confidence of the public, and its future is sure to be more influential than its past. It is not specialization that has caused its success, but rather the methods which specialization has demanded. Those methods have resulted in imparting to students zeal and fidelity, a love of hard work, a veneration for the truths of science, and a consciousness of being able to attack and overcome difficulties; these elements of character are, indeed, the foundation of success in life.

Looking now forward into the future it is seen that in our efforts for the promotion of engineering education a wide field for work still lies open. The student should enter the engineering college with a broader training and a more mature judgment. The present methods of instruction are to be rendered more thorough and more scientific. In particular the fundamental subjects of mathematics, physics and mechanics are to be given a wider scope, while the languages and the humanities are to be so taught as to furnish that broad, general culture needed by every educated man. In general let it be kept in mind that education is more important than engineering, for the number of men who can follow the active practice of the profession will always be limited. Hence let it be the object of engineering education to influence the world in those elements of character that the true engineer possesses, so that every graduate may enter upon the duties of life with a spirit of zeal and integrity, with a firm reliance upon scientific laws and methods, and with a courage to do his work so as best to conduce to the highest welfare of his race and his country.

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AN OZARK SOIL.

CENTRALLY located on the Ozark Plateau, in the southwestern portion of the State of Missouri, there is a tract of very hilly country, underlain by Lower Carboniferous limestones and noted for its exceedingly stony soil. It comprises a portion of the counties of Stone and Barry, and is bounded on the north and west by the gently undulating plateau country commonly known as the 'crest of the Ozarks;' on the south and southeast by the escarpment of the Lower Carboniferous strata which bounds the broad basin-like valley of White river, and on the northeast by the outcrop of the Ozark Series. This small geographic district is characterized by ridges which are from 200 to 300 feet in height, yet so narrow that often two ridges and two valleys are required to make a mile. It is to the soil which covers these steep narrow ridges that I wish to call attention.