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ENGINEERING LABORATORIES.

BY R. C. CARPENTER, ITHACA, N. Y.

It is the object of the present article to point out how an Engineering Laboratory can be equipped for a comparatively small expenditure.

In discussing the subject I shall confine myself purely to the educational features and will not consider the laboratory as a place for investigation or solution of advanced engineering problems. I may also be permitted to say that there are few colleges in America, perhaps in the whole world, in which students, as a rule, gain sufficient culture, or indeed have sufficient time to undertake the work of investigation of engineering problems, in an undergraduate course. It is only in those courses where a great number of graduates are to be found that problems of research have any legitimate home.

The undergraduate laboratory should be equipped so as to demonstrate in a practical and convincing way the principal laws or facts that the student must master in order to finish his course. Its course of instruction should be such as to require systematic work of the student, teach him how to observe, how to use apparatus, how to deduce conclusions from his mass of data and finally how to make a neat and systematic report of his work.

Having that object in view, the best methods or means of execution remain to be sought. In this respect two courses will be open, one, which at first may seem simpler and better, consists in laying out on a single schedule all the experiments that can possibly be performed by the students, with the apparatus at command. Students are assigned to these various experiments as they report for duty.

The other consists of a course in which are put the more important experiments; every student to take in turn each experiment. In laying out a system of such work it will be necessary to have a series of independent experiments for each term, so that the order in which they are taken is immaterial.

From personal experience I am positive that the latter is the only way to successfully conduct an engineering laboratory, unless you are possessed of an almost infinite equipment, an unlimited patience, and an entire disregard of order, and even then a great number of students, working in as many lines, would be certain to cause vexation, delay or trouble in some direction. Besides all this the amount accomplished by an individual student is generally small, since a large part of his time has to be devoted

to preparation, looking up apparatus, and in finding people willing to lend.

By arranging for a certain definite number of experiments each day, which are sufficient for all the students reporting that day, and repeating these day by day until each student has performed each experiment, the conditions are not only more favorable for systematic orderly work, but a minimum amount of apparatus will be required and more efficient and better directed instruction can be given. In such a case the apparatus is easily kept where needed and in good order, and the student can devote the required time purely to the experimental work. I will not deny that the work of preparation and of looking up apparatus is of benefit to the student, but it is not experimental work and should have a place in some other part of the curriculum.

I hope I may be excused for devoting so much time to this discussion, but I feel that it is an important matter, and vital to the subject of the article. In the physical or chemical laboratory I believe that the best results are obtained by the first system, since working apparatus is portable, experiments quickly arranged and the results more definite and constant in character, and the same system is likely to be applied to engineering, thought not being given to the facts, that engineering constants are seldom more than coefficients, and the value is affected by the method used in testing. In many engineering experiments the method is of equal or greater importance than the results.

For the reasons just stated I would advise a limited number of experiments each term and require each student to take the course as laid out. I am positive that the better instruction obtained will more than offset any loss due to the want of selection.

The nature of these experiments must depend upon the apparatus, but I will, however, refer to a course which might be pursued in case the equipment was extremely small. Suppose, first, the course to be in civil engineering, in which case the laboratory work will relate principally to strength of materials and hydraulics, field work and astronomy, the two latter will not, however, be included in this laboratory course. The apparatus needed might be certainly as much as could be purchased, but one testing machine of 50,000 pounds capacity, arranged for testing in tension, compression and transverse, a cement testing machine, a small drop of 100 pounds falling ten feet, and a wooden beam twenty feet long and four by eight inches in dimensions, will be found to be sufficient apparatus to keep four experiments, two men at each, in operation the entire time. The cost of such apparatus will probably not exceed \$1,000 and possibly might be less.

The experiments that might be performed are almost infinite in variety in the line of strength of materials, and the students could not only obtain skill but also valuable knowledge respecting the properties of materials.

Some of the most interesting experiments are performed with little or no apparatus, as, for instance, by loading a beam in different ways and studying the effect on the elastic cam produced by the load in various positions.

For hydraulics, little is needed but what can easily be made by resident mechanics, excepting tanks and weighing scales. Weir notches and hook gauges are readily made and ensure materials for an almost endless variety of experiments.

Small water motors and pumps are quite inexpensive, so that probably for \$500 an equipment that will give six experiments and keep twelve men at work constantly can be had. If a student could spend six hours a week, which is about the amount required to complete a single experi-

ment and write a complete and satisfactory report, there would be found outlined, as above, sufficient for three terms or one year's work.

For mechanical engineers the field must be broadened out so as to include the various classes of prime movers, engines, boilers, gas engines, etc.; but in this case as in the other, with a few small pieces of apparatus, and a few accurate measuring instruments, a great number of useful and valuable experiments can be performed.

For the purpose of investigation and study, a tool or machine rejected for inefficiency or wear by the owners, will often serve as good a purpose as a new machine. The results obtained often point out a line of practice which should not be followed, and this becomes an enduring lesson on the student's mind.

I have elsewhere endeavored to point out in detail methods of performing engineering experiments, and I wish to call to mind here my emphatic opinion that so far as educational results are concerned, the equipment required need not be so expensive that it cannot be furnished in any college of engineering in the country. It is, perhaps, hardly necessary to remark that a little apparatus, employed to advantage, is of more benefit than a large collection used merely to adorn a cabinet or to advertise a college. My own experience leads me to believe that no species of instruction is of as much value to the student as that in which he participates, and knowledge obtained by "feeling" it out, by proving by actual experiment, remains with one and is more readily at command than that obtained purely through the senses of sight and sound.

This leads me to place a high value on this species of instruction, but above and aside from all this is the fact that engineering is an art, founded on imperfect applications of the science of mechanics; all that we get in this line, every engineering truth, must be proved, if not originated, by the laborious processes which are first taught in an engineering laboratory; and he who would advance his profession must be skilled in all that relates to observation and investigation.

ANIMAL BIOLOGY IN HIGH SCHOOLS AND COLLEGES.

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No one, at the present day, questions the importance of animal biology in the curriculum of all well conducted high schools and colleges as well as in the better endowed universities and professional schools. The question is rather, how may this be accomplished? That there is a sad lack of competent instruction in these branches, even in schools that make it their business to educate teachers, cannot be denied.

The need is only too apparent but the laboratory method is not way the to remedy the defect in our smaller colleges and high schools, because it is beyond their financial ability to secure it.

This obstacle may, however, be overcome to a certain extent by the use of the stereopticon and lantern slides which may be had at a cost that is within the reach of any school board. The price of stereopticons has, within the past few years, been materially reduced and the quality greatly improved, so that now a good working lantern with suitable accessories for projecting photo-micrographs on the screen, for ordinary class work, may be had for a

sum as low as fifty dollars. Then again the process of reproducing histological subjects has of late been so developed that they may be had from almost all dealers in school supplies at a nominal outlay. Very little has, however, been written upon this method of illustrating lectures on physiology and hygiene in our public schools and it is with this in view that I have undertaken the present article.

I have no hesitancy in saying, at the outset, that a better understanding of the histology of tissues can be imparted to a greater number of students in a given space of time by this means than can be obtained by the laboratory method. I do not desire to be understood as decrying the *practical working laboratory*. Where time and equipment are sufficient no better method can be had for studying biology in all its phases, but where either of the above essentials is lacking the lantern becomes a valuable substitute, and even where the laboratory method is employed I have found the lantern a very valuable adjunct in imparting a general knowledge of the subject. As a method of illustrating didactic lectures on histology I consider it far ahead of charts. In its use the matter of "personal equation" is reduced to the minimum, and it carries a more vivid impression of the original tissue because of the fact that it is a photograph. In the use of the lantern the educated senses are appealed to and valuable time saved that in the laboratory method is spent in learning the technique of the microscope which in after years is of little avail unless the individual continues in practical Laboratory work. If the object sought is the making of microscopists and original investigators then use the laboratory method combined with the lantern for class demonstration, but if time or equipment is a desideratum the lantern will be found to be fully adequate for good class instruction. Ten years' experience as a teacher of biology leads me to speak thus positively on this question. Trained in the best German laboratories I naturally followed their methods when I began teaching. Gradually the lantern was introduced to illustrate didactic lectures. At first use was made of the oxyhydrogen lime light for projecting actual tissues upon the screen. Many valuable specimens were lost by overheating. Various cells were introduced to prevent this, but they shut off the light to such an extent as to minimize the result desired to be obtained. I was led to substitute solar light for the lime light, but the uncertainty of the results led to its abandonment in favor of photomicrography, and now with an inexpensive oil lantern better results are obtained by this process than formerly with the most expensive stereopticons, under the most favorable conditions. I make my own photomicrographs and find it a delightful recreation. In past years I used to keep on hand an extensive cabinet of microscopic slides for reference. These have latterly been discarded for the photomicrographic negative. My custom now is to photograph all points of especial value as I am studying and file the negatives away for future use. But little time is required for the work when one has a dark room handy which is fitted up for it.

The objection has been offered to photomicrography in that it only reproduced the slides in light and shade. To overcome this objection I have invented a process by which it is possible to reproduce the original stains of the microscopic slide in the lantern positive, in double stain if necessary, and that without hand-painting as was formerly required.

In conclusion let me reiterate that by adopting the lantern and photomicrography the subject of animal biology may be successfully brought before the classes of our high schools and colleges, now debarred from its study by lack of suitable equipment.