value out of whatever technical work he does during that summer. Only men who spend their summers in engineering work are being discussed here. Those who elect to guard beaches or sell brushes in the Adirondacks *when other jobs are open* belong to the same group of students that are taking engineering because they are handy around machinery.

Look at the matter this way: By electing to go to college we have taken four years out of our lives and invested them in acquiring an engineering education. This should be considered in making all subsequent decisions concerning this education. How are we to exploit this four year investment so as to make ourselves the best possible engineers? Certainly the experience of a surveying camp, which at Davis includes work in highways and railroads, mapping, astronomy, building layout, bridges, canals, land subdivision, geodesy and general camp life cannot be exchanged on equal terms with a summer at specialized, uncorrelated and ineffectual sub-engineering work. We are not so naive as to ignore financial aspects of a summer's recess. But let us remember that our educations, besides an investment of years, cost someone, our families and society in general, upwards of five thousand dollars. The one hundred fifty dollars that represents total camp costs is an unimportant three per cent additional investment that increases the value of the product by at least one fifth. The student who went to camp and did not learn as much engineeering in the eight weeks than he did in any one year on the campus missed the boat.

The argument of financial need is met easier than some people think. Professor Davis, founder of Michigan's surveying camp system, left a fund from which loans are easily obtainable for those students desiring to attend camp. The Department of Geodesy and Surveying assists in arranging a means of transportation to its camp in Wyoming. Looking at it economically or professionally the answer to the question, "Shall I go to camp?," is emphatically, "Yes!" No decision you will make will ever provide you more engineering education per day.

Applied Mechanics

by
J. ORMONDROYD
Professor of Engineering Mechanics

MECHANICS is the science whose field is the description of the motion of physical bodies. The science of mechanics would seem to be of great interest and use to the engineer whose task is to combine physical bodies into stationary and moving groups which are useful to mankind. Yet many practicing engineers refer to these sciences scornfully as "theories." The student has a right to ask the question, "Are the branches of the science of mechanics actually used in industry?" The answer, of course, is, "Yes."

The most essential activity of any engineer is quantitative prediction. An engineer deals with ideas, specifications, blue prints; he doesn't build bridges or machines; he indicates how they are to be built to function satisfactorily. He is always asked "how much"—how much the structure will weigh, how big it will be, how well it will sustain its loadings, how much it will cost, when it will be finished, and so on. He is expected to give specific, quantitative answers to questions like these before a single mechanic puts one hand on any piece of material.

The only method for correct prediction that man has ever discovered is based on experience. All we can do is to observe what can and does happen and remember it. If our observation is keen and accurate and our memory is good concerning the action of a given combination of physical bodies, then we can safely and successfully predict what a similar combination will do in the future.

Of all the different situations which may confront an engineer, only a limited number can be included in his past, personal experience. The time honored methods of "cut and try" engineering are based on this paucity of personal experience. By them a successful structure is achieved by successive approximations. But this takes time—it costs money—it expends enormous amounts of personal energy. By this method the individual builds up his experience at the expense of delaying the successful outcome of the action demanded at the beginning of the process.

Most of the defects which show up in the course of such a "cut and try" process could be predicted on the basis of the accumulated and recorded experience of other men.

Mechanics is the recorded experience of thousands of men gathered through the last three hundred years. It is not the mere description of the millions of individual situations which were observed in the past. It is the highly distilled essence of all those situations. A few laws gained by experience, a finite number of convenient definitions and the symbolic language of elementary mathematics are all that one needs to learn to gain possession of this treasure of practical experience. Naturally, merely reading the recorded statements of laws, definitions and mathematical processes does not put one in possession of them —they must be gotten by actively using them.

The practical purpose of the "theories" of engineering mechanics is to avoid, as much as possible, the expense, time and energy consumed in experimenting with each individual problem as it arises. With the use of mechanics the experiments can be carried out on paper. Where experiments must be carried out on actual structures, properly applied mechanics permits us to direct those experiments in such a way as to give us the greatest results with the least expense.

There are many problems in engineering for which the mechanical sciences give complete and easily used answers. Every draftsman using a handbook is applying these obvious answers to his designs and drawings, for a handbook is merely a convenient collection of the mechanical laws and experimental results obtained in the past.

A more spectacular use of mechanics is found in those fields where experimentation is absolutely necessary. There are three general situations in which experimenting is needed. First, in situations where we have actual gaps in our factual knowledge of the processes involved in the operation of the machine to be built. Second, where a structure or machine is so complicated that the recorded experience, although possibly adequate, can only be applied with overwhelming difficulty. Third, where the structure or machine is so unique and expensive that no chances can be taken.

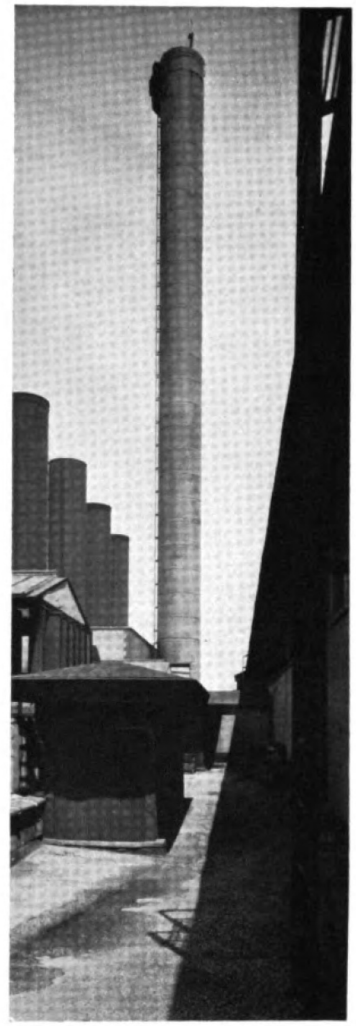
By using mechanical principles in their most general form (dimensional analysis) we can follow a simple, quick and cheap procedure of testing models of the structures in question. Model testing is very effective when used with a clear understanding of the relationships between the test results on the model and the behavior of the actual structure. The model test results must be translated to suit the dimensions of the prototype (the actual structure). Without the mechanical principles needed to make this translation, model testing becomes misleading and dangerous.

Model tests were first used in the field of Hydro-dynamics to measure resistance offered to bodies moving through fluids. This problem is typical of a large class of problems which deal with the effects of various types of friction. The details of frictional resistances acting on bodies moving in various surroundings have resisted successful detailed description to such an extent that actual cases which are not exceedingly simple must be studied experimentally. The resistance to the motion of ships through water to airplanes and dirigibles through the air are all studied today by the use of models. All questions of efficiency in machines are studied by the experimental methods. The efficiencies of turbine blades and nozzles, and of pumps and blowers are successfully measured on models, thus avoiding disastrous disappointment in the actual performance of the prototypes. This type of model testing represents the intelligent reaction to the first typical situation mentioned above in which we are confronted by an actual hiatus in our detailed knowledge.

Good examples of the second situation mentioned above in the use of models for important structures are the numerous models built of the mounting for the 200-inch telescope. Of these models the most interesting and useful was the 1/30th scale model of the mounting built of celluloid. This model was used for angular deflection tests and indicated the existence of deformations which could not be predicted by the usual mathematical methods. This structure, an unsymmetrical frame, could be and was submitted to well-known methods of analysis for deflections. But these led to such complicated expressions that the designers were lost in the maze of details. The model tests were the only way out.

The third situation is illustrated in the design procedure of large bridges, large dams, floating dry docks and dirigible frameworks. These structures cost millions of dollars, they are usually different in many respects from previous structures in the same field, and most important of all, their failure in service means danger to human life. Small scale models costing many thousands of dollars and many months to build are considered cheap for the purpose they serve.

Experiments and tests on actual structures become fruitful likewise when directed by the dictates of mechanics. No test is worth its cost unless it is preceded by a definite theory based on the laws of mechanics. A wrong theory, if it is specific in its predictions, is better than none; since a preconceived idea of what may happen makes the tester look for definite results. These either materialize or they do not, the test information becomes clear cut; the theory is either justified or definitely disproved. In either case the next move is distincly presented to the experimenter.



Electric Light and Power
Models of large structures provide an economical test.

An engineer may build his own experience from the ground up for himself. Or he may use the experience of the world's great thinkers and experimenters as a foundation on which to rear his personal experience. If he follows the second course he has great men for his assistants. If he follows the first course he works alone—and life is short.