which a driver pushes vertically downwards on a moving cart is an inactive force, the vertical pull of the earth on a railway train which moves along a level track is an inactive force.

An active force is said to do work and the amount of work done in a given time is equal to the product of the force and the distance that the body has moved in the direction of the force.

This is taken almost verbatim from the text-book on "Elementary Mechanics" which was recently used with a freshman class in one of our best technical schools (only 126 pages of the text were covered during the excessively short time allotted to this subject) *and 43 per cent. of the class at the time of the final examination (counting the 20 per cent. who were so hopelessly deficient that they were not allowed even to try the final examination) were so deficient in physical imagination, or power of perception, or whatever one may prefer to call it, that they blindly calculated that the man was doing nearly twice as much work as the mule in the following problem:*

A cart moves northwards with a velocity of 6 feet per second, a mule pulls northwards on the cart with a force of 90 pounds, and a man exerts on the cart a downward force of 150 pounds. At what rate is work done by the mule and at what rate is work done by the man?

To have named the part of his body the man used in pushing down on the cart might have stimulated the perceptive powers of the dullest members of the class; indeed the instruction during the term did resolve itself many times into things as unreservedly elemental as this; but have we not a right to expect our students, at least at examination time when their greatest effort is put forth, to be able to handle abstract (!) problems like this of the hard-working cart driver and his pampered mule?

SCIENTIFIC PERCEPTION

I was greatly pleased to see Professor Swain bring up Sir William Hamilton's ideas, seventy years old. Perhaps your readers will welcome an idea from William Whewell which is also seventy years old. It is almost the only idea I was able to find years ago when I read the "Philosophy of the Inductive Sciences," but it is a creditable thing to have produced one idea; indeed, it would be a creditable thing in our time even to adopt ideas! Whewell says that ideas of perfect precision are a paramount possession (the four p's are Whewell's; he might well have omitted at least one of them as I do in the paraphrase). Nothing is so essential in the acquirement of real knowledge of physical things as the possession of precise ideas, not indeed because a perfect precision is necessary as a means for retaining knowledge, *but because nothing else so effectually opens the mind for the perception even of the simplest evidences of a subject.*

(In the final examination in elementary mechanics above referred to, the following note was appended to one of the questions:

A redundant or wrongly used word in answer to this question will be graded zero,

and a day or two after the examination a member of the faculty (*not* a professor of mathematics) quoted this note in derision, as if the only precision were numerical precision! May the shade of William Whewell protect us!)

In order to be able to define in a general way the perceptive phase of the physical sciences, let me distinguish two chief results of the scientific activity of the nineteenth century, namely, (1) an accumulated mass of fact, under which heading I would include all of the details of applied science, for indeed the most important and compelling facts that have been accumulated by the sciences are the facts which are incorporated in the settled doings of men, and (2) an established mode of thought and inquiry which may be designated, using a suggestive phrase of Bacon's, as "A new engine, or a help to the mind corresponding to tools for the hand." Here is an idea three hundred years old!

We continually force upon the extremely meager data which are obtained directly through our senses an interpretation which in its complexity and penetration would seem to be entirely incommensurate with the given data, and the possibility of this forced interpretation depends upon the use of two complexes, (*a*) a logical structure, that is to say,

a body of ideas and conceptions which operates for perception, and (*b*) a mathematical structure, which, in many cases, but by no means in all, supervenes and leads easily to an elaborate conclusion. These two complexes do indeed constitute a new engine which helps the mind as tools help the hand, and if the first (the perceptive phase of physical science) were insisted upon in our technical schools with approximately the same emphasis as pure mathematics, our students would not be so ridiculously perverted by mathematical superventions as to calculate that a two-horse-power steam engine would be required to drive a *willing* mule. But such is the earlier stage of technical education as it is to-day!

PHYSICS TEACHING AT FAULT

The fault, however, seems to me not to lie to any great extent with our teachers of mathematics. Their mode of presenting their subject is, I believe, in a general way correct, but I am firmly convinced that our mathematical courses at present include a great many topics which might well be omitted, and a thorough drill in descriptive geometry should certainly be included. I believe that too much time is devoted to the study of pure mathematics in our technical schools and too little time to the study of elementary physics and chemistry. It is certainly a fact, however, that a large number of our college and university teachers of physics are anything but enthusiastic as teachers, and the subject matter which they place before their students is certainly not up to the requirements of modern technical education. A real fault, as it seems to me, may be charged against our teachers of physics.

In the discussion of engineering education before the American Institute of Electrical Engineers on January 24, 1908, a great deal was said concerning the place of mathematics in technical education; and the exacting character of technical education, which is associated in most men's minds with the teaching of mathematics, was emphasized as important. In the old days mathematics was indeed the only scientific study which could be made definite and exacting. Nowadays, however, nearly every technical subject which is taught in the engineering school can be made as exacting as mathematics and, above all, the elementary sciences of physics and chemistry have been reduced to a basis which enables these sciences to be presented in a way which, in my opinion, must soon entirely revolutionize technical education. I believe that our engineers and many of our engineering professors fail to realize the change which has taken place in the teaching possibilities of elementary physics in the last ten or fifteen years, and therefore we find these men still expecting our teachers of mathematics to lift themselves and a large superstructure by pulling on their boot straps, these faithful teachers being held responsible for the most serious faults which underlie technical education. Let the heads of our technical schools look rather to their teachers of physics, demanding of them the best that modern science teaching can give, and allowing them the necessary time to accomplish what is desired.

ELEMENTARY PHYSICS TEACHING NECESSARY

I do not think we can look to our teachers of mathematics to establish the simple logical structure of physical science.

Nothing is more completely established in psychology nowadays than that ideas can not be formed out of the clear sky, as it were. They must be built of stuff, and *the rational study of the physical sciences especially in its earlier stages is the transformation of simple intimate knowledge into general ideas.* All elemental knowledge, such as the knowing how to throw a ball, how to ride a bicycle, how to swim, or how to use a tool, is locked in the marginal region of the mind (the region of reflexes) as a very substantial but very highly specialized kind of intuition, and the problem of the teaching of elementary physical science is the problem of how, by verbal and concrete suggestion, to drag this material into the field of consciousness, where it may be transformed into a generalized logical structure having traffic relations with every department of the mind. *An abstract treatment of the principles of elementary physics tends, more than anything else, to inhibit the influx of this elemental knowledge from the marginal regions into the field of consciousness and results in the building up of a*