AN ELEMENTARY STUDY OF PHYSICAL UNITS

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"In order to get the fundamental unit of time, mass, and length, we must multiply a unit of mass by a unit of length. L *For example, if we buy a certain thing and get a foot pound, this is known as the fundamental unit of time."*

This was an answer in reply to the question why the units of mass, length and time are called fundamental units, and was one of a number no less absurd given by pupils of high school grade in a recent examination.

For several years, I have examined papers from about a thousand pupils annually, in which the proper use of units was a feature in the examination, and have found in many cases the crudest ideas, while in schools where the subject was well taught, the answers were a credit to both the teacher and pupil.

I have no reason to suppose that those whose examination papers came under my inspection showed less appreciation of the meaning and use of units than the average; and if so, our schools are lacking in the inculcation of that definiteness which is so important a feature of scientific education. Any teacher who is not aware that the pupil's mind is likely to be exceedingly hazy if not hopelessly befogged in this matter has probably been content if the proper numerical answer to the problem was given and has not insisted that the unit of measurement be also given. But what is the use of being able to apply any number of formulae if when the figures of the answer are obtained it is not known whether the answer is expressed in terms of watts or ohms, or of feet or hours?

It is with the hope that the suggestions I make may be of value to teachers that this article is written; and in the first place the teacher needs to realize two facts: first, that the subject of units is difficult; second, that the subject of units is easy. It is difficult if approached in an abstract manner; it is easy if taken up properly, in a concrete form, with constant application of common sense, frequent returns to general principles and abundant illustrations, especially if these illustrations are emphasized by absurd questions.

The very best beginning in the subject is, I believe, the asking of such absurd questions as, "How many feet old are you? How many years heavy are you? How many pounds tall are you?" These questions are at once seen to be nonsense; and the pupil by a very few judicious questions will be brought to explain that we cannot measure age by feet or weight by years or height by pounds.

The idea of a unit is thus arrived at. Everything that is measured must be measured in some unit, and, furthermore, must be measured in the right unit. Occasionally the unit is not expressed, as for instance when a boy on being asked his age says he is twelve, since in this case there is no possibility of his meaning tweive days, or twelve weeks, or twelve months. When two units are involved one of these units is frequently left out. If butter is said to be sixty cents, one knows that sixty cents a pound is meant; if hay is said to be seventeen dollars, the quantity indicated, though not expressed, is a ton. In the case of potatoes and vegetables, unfortunately, the measure for approximately the same money value is now pecks where a few years ago it was bushels. Nothing, it is easily made plain to the pupil, can be measured without a unit to measure by and this unit, though sometimes understood, is commonly expressed.

The first illustration given will show that at least three different units of measurement are necessary. We must measure length in the proper units which may be inches, feet and miles, or meters and kilometers; we measure mass in pounds and tons or grams and kilograms; we measure time in seconds, weeks and years.

Length, mass and time are independent of each other; the unit of one cannot be derived from the unit of another; we can express pounds in terms of grams, but we cannot express pounds in terms of seconds. This the pupil can easily see and if he is then told that all physical measurements can be expressed in terms of one, two, or three of these units, he can understood why they are the foundation units, the fundamental units of physics.

The simplest combination of units is involved in velocity. Here again the asking of absurd questions is a very excellent method for getting at the units involved. Ask how many feet a pound, or how many tons an hour, or how many hours a mile a train moves; and the pupil will be prepared for the question how many miles an hour or how many feet a second and will see that velocity involves length and time, and involves them in a certain manner.

The unit of velocity, then, is unit length in unit time. Any unit of length may be used and any unit of time. For instance, an inch in a century, or a mile in a second might be chosen as the unit of velocity. In physics the common English unit is a foot per second and the common French unit a centimeter per second. A name might be given to such a unit; a foot per second might be called a velo, but no special name is usually employed for the unit, since it is easy to speak of a foot per second.

It is not simple folly to elicit by questions that one can no more tell the mass of a ball by knowing how fast it moves than one can tell the name of the boy who threw it. Absurd illustrations such as this will bring out the fact that velocity involves length and time and these units alone.

While velocity involves length and time in the simplest possible manner, acceleration involves the same