The international system of physical units[1)]

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Not all physical phenomena by far can be rationally described in terms of the international system of units (the SI system). In this respect, it is a *retrograde step* as compared with the Gaussian CGS system. In mechanics, in the study of thermal phenomena, and in all branches of physics that are not directly connected with the study of electricity, the two systems are equally justifiable and differ from one another only by the size of the units of fundamental physical quantities.

The situation is different in the case of electricity. Here, the Gaussian CGS system is, in fact, the *absolute system* based on three fundamental units, namely, those of length, mass, and time. Electrical phenomena are introduced into this system through Coulomb's law. Magnetic units are introduced through the requirement that electric and magnetic fields must have *the same dimensions*. The result of this is that a coefficient, called *the electrodynamic constant* and having the dimensions of velocity, appears in the system of units. This coefficient has a clear physical interpretation and is equal to the velocity c of light in a vacuum.

Although the SI system is also an *absolute system*, a fourth, purely electric and independent quantity is introduced into it, namely, the electric current. The unit of current in this system is the ampere, which has become established in the practice of electrical measurements purely as a result of historical accident. This approach leads to the appearance of *two dimensional constants* in the electrodynamic equations. In the SI system, these constants are

$$\varepsilon_0 = \frac{10^7}{4\pi c^2} \approx 8.854 \cdot 10^{-12}\ \mathrm{F/m},$$
$$\mu_0 = 4\pi \cdot 10^{-7} \approx 1.256 \cdot 10^{-6}\ \mathrm{F/m}.$$

They are artificially introduced and do not have the direct physical interpretation of "genuinely physical quantities" such as velocity, charge, electric field, magnetic field, and so on. Moreover, their numerical values are difficult to remember and are inconvenient in practical calculations. Only the combination $c = 1/\sqrt{\varepsilon_0 \mu_0}$, i.e., the velocity of light in vacuum, is a truly physical quantity.

The introduction of the dimensional constants ε_0 and μ_0 forces us to distinguish, *even in vacuum*, between the electric and magnetic fields **E** and **H** and the inductions **D** and **B**, since they are then related by $\mathbf{D} = \varepsilon_0 \mathbf{E}$, $\mathbf{B} = \mu_0 \mathbf{H}$. This is unnatural. Ever since the development of the Lorentz electron theory, it has been firmly established that it is sufficient to specify *one* vector **E** and *one* vector **H** to characterize the electromagnetic field in a vacuum. The subdivision of the electric field in a vacuum into **E** and **D** and the magnetic field into **B** and **H** is an artificial and unnecessary complication. It arose in the nineteenth century in the elastic theory of the ether in which it was considered that there was no fundamental difference between the ether (vacuum) and ordinary material media. This lost all its meaning when it was established that the mechanical ether did not, in fact, exist. However, the Giorgi electrotechnical system of units was founded at the beginning of this century on this obsolete idea, and has now become the basis for the SI units. The quantities ε_0 and μ_0 in the Giorgi system (and initially in the SI system as well) were, in fact, termed the *permittivity* and *permeability* of vacuum. They were subsequently redesignated as the "electric and magnetic constants." However, this change of name cannot hide the essence of the matter. The quantities ε_0 and μ_0 have remained, as before, foreign to the study of electricity and to physics as a whole. They not only introduce difficulties in the teaching of the subject, both orally and in writing, but can also lead, and have done so, to incorrect ideas about the origin of electric and magnetic fields.

In the case of material media, the SI system introduces the unnecessary subdivision of permittivity and permeability into the *relative* ε and μ and the *absolute* $\varepsilon_{\mathrm{abs}}$ and μ_{abs}. The latter are entirely superfluous.

In the SI system, the dimensions of the vectors **E**, **D**, **B**, and **H** are all *different*. Moreover, it is clear from the foregoing that, even in the prerelativisitic electrodynamics, a necessary requirement which any physically rational system of units had to satisfy was that the vectors **E** and **D** had to have the same dimensions. The dimensions of **B** and **H** also had to be the same. Relativity theory has strengthened this requirement. It shows that the subdivision of the electromagnetic field into electric and magnetic fields is purely *relative*, i.e., it depends on the choice of the reference frame. It turns out that **E** and **B** can be combined into a single antisymmetric tensor of rank four, and the vectors **D** and **H** can be represented by another single tensor. Since the components of a given tensor must all have the same dimensions, it is *almost essential* for the four vectors **E**, **B**, **D**, and **H** to have the same dimensions. This is not so in the SI system, and *dimensional factors* have to be introduced into it in order to ensure that the components of these tensors do, in fact, have the same dimensions. The Gaussian CGS system, on the other hand, does satisfy this condition even though it was developed well before the advent of the theory of relativity. In this respect, the SI system is no more logical than, say, a system in which the length, width, and height of an object are expressed not only in terms of different units but have different dimensions as well.

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One of the requirements which the SI system had to satisfy when it was originally put forward was that all calculated quantities should appear directly in the units in which existing measuring devices were calibrated, i.e., in amperes, volts, and so on. There is no dispute about the convenience of this in practical calculations. However, this convenience has to be paid for dearly, namely, by organic defects in the system of units. For physicists, including physics students, the most important goal is the understanding of the physics of natural phenomena and the establishment of the relationships between them, i.e., the system of equations in the simplest and most natural form, free from artificial quantities such as ε_0, μ_0 and all the other ballast that is so characteristic of the SI system. On the other hand, conversion in numerical calculations from a particular set of units to the practical units such as amperes, volts, and so on is not particularly difficult even though it may not be desirable.

The SI system of units is not widely used in scientific papers and monographs or in scientific seminars, conferences, and schools of physics. It is hardly ever used in the teaching of theoretical physics. General physics is still taught in terms of the CGS system of units in leading physics institutes, whereas the introduction of the SI system into higher educational establishments has encountered considerable opposition. The reason for all this is not the innate conservatism or inertia of physicists, but the fact that the SI system suffers from *fundamental defects*. Even Sommerfeld, a most authoritative physicist who originally initiated the introduction of the SI system into physics, had doubts as to the usefulness of the SI system in atomic physics. Finally, the SI system is completely unacceptable in quantum electrodynamics and the physics of elementary particles.

The SI system was introduced as the *preferred* system into science, teaching, and the national economy without convincing justification. At least temporarily, it coexisted with other systems of units, including the CGS system in physics. However, the situation has now changed.

The Forty-Third Meeting of the Permanent Commission on Standardization of the Council for Mutual Economic Aid[2)] (CMEA) approved a new standard for physical units, namely, STCMEA 1052-78 in place of RS 3472-74. This new standard was proposed by the Soviet Delegation to the Permanent Commission and states, in particular, that:

"The standard does not extend to units used in scientific studies and in applications of a theoretical nature in natural philosophy, or units of quantities expressed on arbitrary scales."

"1.7. The teaching process (including all textbooks and teaching aids) must be based in all educational institutions on the application of SI units and units that are defined as admissible in Sections 3.1, 3.2, and 3.3."

The CGS system of units is not included among the admissible systems.

It is thus clear that *different systems of units*, including the CGS system, are admitted into science in the case of theoretical studies although a sharp dividing line between theoretical and nontheoretical work cannot always be drawn. On the other hand, all instructions must be given exclusively in the SI system. The only admissible textbooks are those written in the SI system. These are the main points in the above standard and, although they have been adopted, they are not acceptable for the following reasons.

1. They tend to increase the gap between theoretical and applied studies.

2. They increase the gap between science and the teaching of science.

3. The exclusion of the CGS system from all instructional activities will make it difficult for students and future physicists to use the enormous (and better) physics literature written in terms of CGS units.

4. The transition to teaching in terms of the SI system will unusually complicate the teaching of fundamental physical disciplines for which the SI system is unsuitable.

5. This transition will necessitate the reissuing of existing physical literature in SI editions. This will not only be time-consuming but, in most cases, will give rise to a deterioration in quality.

The CGS system should be restored to physics not merely temporarily but permanently because its advantages compared with the SI system are indisputable from the physical point of view. This applies not only to teaching but also to the publication of scientific and instructional physical literature, at least for physicists. It applies not only to theoretical physics but to physics in general. Modern general physics is just as fundamental as theoretical physics. In any case, it is increasingly becoming theoretical, so that a sharp dividing line can no longer be drawn between them. This approach to systems of units should be retained at least until a unified system of physical units free from the disadvantages inherent in the SI system is developed.

The foregoing should not be taken as suggesting that the CGS system should be the only system in physics. The units of length, mass, and time are chosen arbitrarily in this system. It is often more convenient to use "natural units" whilst retaining all the advantages of the CGS system. For example, the system of atomic units introduced by Hartree is of this kind. Another example is the system of units used in quantum electrodynamics, in which the velocity c of light in a vacuum and Planck's constant $\hbar$ are assumed to be dimensionless and equal to unity, and so on.

Finally, we must briefly consider terminology. Our Committee of Standards tends to replace established physics terminology without any real reason with new and inferior terms.

For example, *electrical induction* (electrical induc-

[2)] Also known as Comecon.

tion vector) has been replaced with *electrical displacement* even though, in magnetism, the old designation, *magnetic induction*, has been retained. This upsets the terminological symmetry in the teaching of electricity and magnetism. The new designation, "electrical displacement," is in no way better than the old "electrical induction."

The *polarization* of a medium (or polarization vector) has been replaced with the awkward *polarizability*.

The familiar "atomic weight" and "molecular weight" have been replaced with "atomic mass" and "molecular mass," respectively. The new terminology is in no way better than the old because these quantities are *dimensionless*. Within the range of validity of the principle of equivalence of inertial and gravitational masses (and we know of no departures from this principle), dimensionless "weights" and "masses" are identical quantities.

There are many other examples.

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