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Short Communication

The international system of units: some major shortcomings and remedies

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Abstract

The paper draws attention to some serious deficiencies in the International System of Units (SI), pertaining to the expression of some important physical quantities, and to further difficulties arising from the adoption of somewhat arbitrary solutions for these problems. Proposals are made for the solution of the problems of the SI through the introduction of a few new names of units and the omission of some existing names of units.

Key words: SI units, engineering measurements, engineering communication.

1. Introduction

The International System of Units (SI) is based on seven fundamental units, referred to as base units, and two supplementary units[1] (See Appendix I). All quantities in science and technology can be expressed in terms of units derived from the aforementioned units. Several of the derived units have special names and other units have complex names derived from those of the base units and of other units with special names, in a manner that reflects the physical nature of the quantity that each unit is used to express.

However, owing to historical reasons, certain defects have crept into the system and, perhaps because of inadequate attention to important details pertaining to the use of units in measurement, there is substantial imbalance and inadequacy in the

assignment of special names to units. Some of the defects have been dealt with in a rather irregular manner, and the solutions have led to more problems than they sought to eliminate.

In this communication, attention is drawn to the need for a systematic approach to the solution of some of the problems of the SI and proposals are made for the elimination of some of the major shortcomings.

2. The defects

The base unit for mass, the *kilogramme* (symbol *kg*), derives its name and the symbol from the CGS unit *gramme* (symbol *g*). The prefix kilo (symbol *k*) is the one used to represent 1000 in the SI. As a result of this, the larger units for the expression of mass are formed as multiples of the gramme, by attaching prefices to the name *gramme*, instead of as multiples of the base unit. The same is true with the smaller units which are formed as submultiples of the gramme.

This method of naming multiples and submultiples of the base unit of mass deprives the user of the SI of one of its basic advantages : In any unit with a complex name containing the unit of mass as its first item, as in *gramme per metre cubed* or *megagramme per second*, the name does not immediately suggest the relative magnitude of the unit compared to the corresponding fundamental unit derived from the base units.

The use of units such as the *megagramme* and *gigagramme* for the expression of large values of mass has failed to receive popular acceptance and the *tonne* (which is not a proper SI unit but one permitted for use with the SI units) and its multiple *kilotonne* are used instead. The permission of the use of the unit *tonne* and its multiples has not helped in solving the problem relating to the kilogramme and has only made it possible for the use of two names (the gramme and the tonne) where one well selected name for the unit of mass would have done.

There are no special names for the fundamental units of area and volume. The SI does not, in general, recommend the use of the prefices centi, deci, deca and hecto; and, as a result, the ratio between the proper successive units of area is 1 000 000 (as in the case of the *square metre* and the *square millimetre*) and that between successive units of volume is 1 000 000 000.

In order to overcome the difficulty caused by the absence of special names for the units of area and volume, additional names have been permitted for use with the SI units. Large areas are expressed in *are* and *hectare* (= 100 are) and small volumes are expressed in *litre* and its submultiple, the *millilitre*. It should be noted that the *are* is a *square decametre* and the *hectare* is a *square hectometre* and that the *litre* is a *cubic decimetre* and the *millilitre* is a *cubic centimetre*. Thus the units based on the prefices *centi, deci, deca* and *hecto* have unconsciously been introduced into the system.

Even the introduction of the 'permitted' units *are, litre,* etc. has not helped solve the problem that the ratio between successive units of area and volume is large. The expression of areas smaller than a square metre and volumes larger than a cubic metre may, and in fact do, sometimes involve an awkwardly large number of numerals or the use of a decimal multiple expressed in numerals (as in 34 500 m^3 or $34 \cdot 5 \times 10^3$ m^3 or 0·000 034 5 km^3 or $34 \cdot 5 \times 10^{-6}$ km^3).

The problems caused by the absence of special names for the units of area and volume also affect the expression of quantities such as specific volume (volume per unit mass), specific surface (area of surface per unit mass), volume flow rate, and fuel consumption (volume per unit distance travelled).

Section modulus (unit, *metre cubed*), second moment of area (unit, *metre to the power four*), and diffusivity (unit, *metre squared per second*) are quantities which occur very frequently in Civil and Mechanical Engineering. The range of magnitudes over which these quantities occur is rather wide and the use of special names for these units would be useful. It may not be necessary to have special names for all three of these units and it may be possible to solve a part of the problem by assigning special names for the units of area and volume ; however, it should be noted that a *metre squared* is not physically the same thing as a *square metre.*

It is interesting to note that of the eighteen units with special names, eight are used exclusively in Electrical Engineering and another two exclusively in Light. Two of the newly added names relate to Nuclear Physics. Two of the units are dimensionally the same. (The *hertz* and *becqueral* have the dimension of an inverse second. These two units, however, are used for expressing physically distinct quantities). The *siemens* is the inverse of an *ohm.* It may also be added that the unit *var* is permitted within the SI, in addition to the *volt ampere,* to express the product of current with voltage, although the absence of the unit *var* is not likely to lead to any serious ambiguity.

A number of units which are permitted for use along with SI units are unnecessary and are at times in conflict with the consistency of the SI. The units *revolution, degree, minute* and *second,* for the measurement of plane angle need to be continued for a long time until a major revision is made in the teaching of geometry and related subjects. The unit *revolution* is nondimensional and can be avoided in the name of units. (Rotational speed is satisfactorily expressed in *inverse second* instead of in *revolutions per second*). The units *day, hour* and *minute* and the *week, month* and *year* of the Gregorian calendar will continue to be used for expressing time for an unlimited period, and there is visibly no possibility of preventing people from using these units.

The *diopter* (equal to an *inverse metre*) is used in Light and is a useful unit. It could be adopted for use wherever the *inverse metre* occurs or may be replaced by a more suitable name. The *electronvolt* and the *atomic mass unit* will continue to be used until workers in the related fields are persuaded to use the proper SI units. The units of mass *tonne* and the *metric carat* can be eliminated : the metric carat is a particularly unsatisfactory unit as it is not a decimal multiple of the kilogramme. The unit *tex* for linear density is again avoidable. The unit of pressure *bar* is unnecessary after the introduction of the unit *pascal* ; and the *bar* has the unsatisfactory feature that it is 100 000 times a *pascal*, and the mixing of these two units in one's work could lead to careless errors. (If the bar were 1000 or 1 000 000 times the Pascal it would have been a kilopascal or a megapascal and would have fitted into the system). The unit of energy *watt hour* is not a satisfactory unit, but it may be some time before it could be eliminated from popular use.

3. Some solutions

The name of the base unit for mass should be changed. If the name *grav* which has been suggested some time ago were adopted with a suitable symol (say *gv*) the units *gramme* and *tonne* could, respectively, be replaced by *milligrav* and *kilograv* (symbols *mgv* and *kgv*).

The unit for area may be named *euclid* (symbol *Ed*), in case the name *pythagoros* sounds too long. The units *are* and *hectare* would be replaced by the *kiloeuclid* (symbol *kEd*) which will be a tenth of a *hectare* and ten times an *are*.

The unit for volume could be named after Boyle, if the name *archemedes* is too long. The unit *boyle* (symbol *Bl*) and its multiples and submultiples will replace the *litre* and its submultiples and the more cumbersome units such as the *cubic decametre* (symbol dam^3).

The units for section modulus and second moment of area can be the *euclid metre* and the *euclid metre squared*, respectively. On the other hand, these quantites may be expressed by units with special names, if necessary.

The unit for diffusivity needs a special name since *metre squared* is physically not the same as *square metre*. This unit may be named after Prandtl who has made major contributions to the study of diffusion of momentum and of heat (Pr $= m^2 s^{-1}$).

It may be advisable to omit either the name *ohm* or the name *siemens* as the units are merely reciprocals of each other. The *inverse second* is a more general unit for the representation of time rate and may be represented by a unit with a special name. It may be worth considering whether the special name *bacqueral* is necessary for representing activity of a radioactive substance or the *inverse second* (or its equivalent with a special name) could be used for expressing this quantity and the time rate of other nondimensional quantities.

The present proposals, if adopted, will help in eliminating certain inconsistencies within the SI, especially in matters relating to the use of prefices, and in reducing the number of 'permitted' units which really do not belong to the SI.

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Reference

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Appendix I

The SI units

All units are given with the name of the unit followed within parentheses by the symbol and the name of a quantity which the unit is used for expressing.

The base units : metre (m, length) ; kilogramme (kg, mass) ; second (s, time); ampere (A, electric current) ; kelvin (K, thermodynamic temperature) ; mole (mol, amount of substance) ; candela (cd, luminous intensity).

The nondimensional supplementary units : radian (rad, plane angle) ; steradian (sr, solid angle).

Derived units with special names : hertz (Hz = 1/s, frequency) ; newton (N = kg. m/s^2, force) ; joule (J = N.m, work) ; watt (W = J/s, power) ; pascal (Pa = N/m^2, stress) ; volt (V = W/A, electric potential) ; coulomb (C = A.s, charge) ; farad (F = C/V, electric capacitance) ; ohm (Ω = V/A), electric resistance) ; siemens (S = A/V, electric conductance) ; henry (H = V.s/A, inductance) ; weber (Wb = V.s, magnetic flux) ; tesla (T = Wb/m^2) magnetic flux) ; lumen (lm = cd.sr, luminous flux) ; lux (lx = lm/m^2, luminous flux density) ; becquerel (Bq = 1/s, activity of radioactive substance) ; gray (Gy = J/kg, absorbed dose) ; degree Celsius (°C, customary temperature).