About the International System of Units (SI) Part IV. Writing, Spelling, and Mathematics

Gordon J. Aubrecht II, Ohio State University, Columbus and Marion, OH
Anthony P. French, Massachusetts Institute of Technology, Cambridge, MA
Mario Iona,a University of Denver, Denver, CO

This is the fourth part in a series of notes that will help teachers understand what SI is and how to use it in a common-sense way. This part contains information about spelling, pronouncing, and manipulating symbols.

1. Spelling
a. The names of units (see Tables I and II, Part III)1 (including those named for persons) are to be written with small letters. (The two-word unit “degree Celsius” is an anomaly.)

b. The plural of a unit name is formed by following the customary rules of English (hertz, lux, and siemens remain unchanged in the plural).

c. Symbols for units named after persons are to be written with first letter capitalized. Symbols for units not named after persons are to be written with small letters. (Note: the non-SI unit liter has both L and l as permitted symbols, but NIST recommends to use only L.) To leave a space between the numerical value and the symbol is recommended by ISO and is generally accepted SI practice.

d. The symbols for the units and prefixes are shown in Tables I, II, and III, Part III. They are truly symbols and not abbreviations. They are not followed by a period (except at the end of a sentence) and do not acquire an “s” in the plural. There are a few irregularities due to the historical development and lack of acceptable alternatives.

(i) There are Greek letters for the symbol for ohm (capital omega, Ω) and for the prefix micro- (μ = 10⁻⁶). The omega can be avoided (in an awkward way) by using the reciprocal siemens (S⁻¹ = Ω). The μ can often be improvised by adding with a pen an upstroke to a typed or printed u; however, the unmodified u should be avoided as meaning micro since it is the symbol for the unified atomic mass unit. U.S. pharmacists have adopted another symbol for 10⁻⁶, mc, which they use frequently in the microgram (mcg). This is not acceptable SI practice in any other context.

(ii) The final vowel of the prefix is often dropped in megaohm to make megohm, and is almost always dropped in kilohm and hectare.

e. In the United States, NIST2 adopted the spelling “meter,” in accord with Webster’s Third New International Dictionary, which is used by the United States Government Printing Office Style Manual. In many other English-speaking countries, the spelling “metre” is preferred, which is based on the Oxford English Dictionary. ISO3 uses “-re”. SI-104 accepts both spellings as correct. There is some linguistic justification for the “-re” spelling, and its use allows a distinction between the unit metre and the measuring instruments, such as a voltmeter. Countries such as Germany and Sweden also use the “-er” spelling. The spelling of liter usually follows the spelling chosen for meter.

f. Unit names and prefixes are to be printed in upright Roman font. (In the physics literature, symbols for quantities are usually printed in italics, which helps in distinguishing for example m for mass and m for meter or milli-.)

2. Pronunciation

There is no absolute agreement as to the pronunciation of the units and prefixes.

Most guides for metric practice have dropped recommendations from recent editions. On the other hand, there is a large consensus for some preferred pronunciations. In choosing a pronunciation, we suggest that one look it up in a dictionary that one considers authoritative. We provide some (possibly controversial) guidance in the tables and text, but there may be valid considerations for other choices, such as knowing the pronunciation of the name of the scientist being honored in the country where the scientist lived.

Some rules seem noncontroversial, but are still not always adhered to; e.g., the accent for all prefixes is to be on the first syllable (e.g., kilo should have the same accent in km as in kg, and be pronounced kil-o-meter).

the questionable part sounds like

yotta gotta
zetta exa
peta pet (a few use a sound as in “peat”)
tera terror (a few use a sound as in “tyranny”)
giga giggle (some use a sound as in “gigantic”; a few use a sound as in “jiggle”)
mega
kilo kill-ing, willow (a few use a sound as in “silo”)
hecto deka
The expression more foolproof, but makes it ambiguous and multiplication dot in changing multiplication or division by "\(a/b\)" the interpretation becomes ambiguous. If there is a multiplication and it is further multiplication or division by "\(a/b\)" the interpretation may exist when the same symbol may mean a prefix or a unit; for example, mN (without space) means millinewton and might be hard to distinguish from m N or even from m-N; write this torque unit as N m or N.m. The \((\times)\) as multiplication sign is not sanctioned in the context of compound unit symbols, although it is used for example in the power-of-ten notation, e.g., \(5 \times 10^3\) or as a symbol in multiplying numbers. (For multiplication after a solidus, see the note following the next paragraph.)

### 3. The algebra of unit symbols

**a. Multiplication**

Multiplication of unit symbols may be indicated by a raised dot (\(\cdot\)), or a space between the symbols. A space of width which may be varying is not a reliable indicator, and ambiguity may exist when the same symbol may mean a prefix or a unit; for example, mN (without space) means millinewton and might be hard to distinguish from m N or even from m-N; write this torque unit as N m or N.m. The \((\times)\) as multiplication sign is not sanctioned in the context of compound unit symbols, although it is used for example in the power-of-ten notation, e.g., \(5 \times 10^3\) or as a symbol in multiplying numbers. (For multiplication after a solidus, see the note following the next paragraph.)

**b. Division**

There are several ways of expressing divisions: horizontal line between numerator and denominator, a slanted line (solidus, \(\slash\)) with numerator and denominator on the same line, or with negative exponents. The symbols (\(\div\)) or (\(\colon\)) are not sanctioned for use in compound unit symbols.  

**NOTE:** After a solidus there should not be any multiplication signs (dot) or division sign (solidus) on the same line, since it makes the expression ambiguous, unless parentheses are used to clarify the intent. There may be several multiplications (factors) in the denominator of a fraction, which is indicated by the solidus, but the unit symbols should be written with a space between them rather than a dot. To illustrate the problem: if one has a fraction \(a/b\) and there is a further multiplication or division by "\(c\)," the interpretation becomes ambiguous. If there is a multiplication and it is written as \(a/(bc)\) most people interpret that as meaning the same as \(a/(b\cdot c)\). When there is division written as \(a/b\cdot c\) it is often interpreted as \((a/b)\cdot c\), which, of course, could also be written as \(a/(b\cdot c)\) or \(a/(bc)\); i.e., it would be written the same as when the last operation was a multiplication by \(c\).

The rule that there should be no more operation signs after a solidus must be rigorously applied to avoid ambiguity. Adding a multiplication dot in changing \(a/b\cdot c\) to \(a/(b\cdot c)\) does not make the expression more foolproof, but makes it ambiguous and is therefore specifically forbidden. These rules for units are the same as the ISO rules for symbols of quantities; however, in dealing with algebraic symbols of quantities, one deals usually with single letter symbols, while with units one deals frequently with a string of letters so that a space between factors is officially required. Ambiguities can always be avoided by using parentheses or negative exponents.

These considerations are important not only during calculations but in the final writing of a compound unit, which is not necessarily written in the simplest form. It may contain certain groups of units that are kept together to illustrate, to some extent, what relationships are involved. Although there are no fixed rules, the most essential aspect of the writing is to avoid ambiguities. A frequent consideration is to write as much as possible in terms of coherent units, which means the mass unit will usually be the kilogram, whether it is in the numerator or denominator, and all other prefixes or power-of-ten expressions are collected in one prefix (or power-of-ten factor), usually at the beginning of the numerator of such a compound unit. For example, the Hubble constant is frequently given in \(\text{km/}(s\cdot\text{pc})\) rather than in \(1/s\).  

**Examples:**  
Use: \(\text{m/s}^2\) or \(\text{m}^2\text{s}^{-2}\) or \(\text{m}/(\text{s}\cdot\text{s})\) or \(\text{m}\text{/s}\text{s}\) BUT NOT: \(\text{m/}\text{s}\text{s}\) or \(\text{m/}\text{s}\text{s}\)  
Use: \(\text{m/kg}/(\text{A}\cdot\text{s})\) or \(\text{m/kg}\cdot\text{A}^{-1}\cdot\text{s}^{-1}\) or \(\text{m kg}/\text{A s}\) BUT NOT: \(\text{m/\text{k}\cdot\text{A/s}}\) or \(\text{m/kg/\text{A/s}}\)

**c. Powers**

In raising a unit with prefix to a power, one has to take into consideration that the prefix is part of the unit and has also to be raised to the same power. **CAUTION:** Although the written form is unambiguous, in reading such expressions aloud, care has to be taken to avoid misunderstanding. For example, in reading an expression like 5 cm\(^2\) one can express that as “5 square centimeters,” but one should avoid reading that as “5 cm squared,” because that is properly interpreted as meaning (5 cm\(^2\)), which has, of course, an entirely different meaning. In converting such expressions with prefixes, for example, to base units, the power-of-ten notation and parentheses are very helpful.

**Examples:**  
1 cm\(^2\) = 1 \((10^{-2}\ \text{m})^2\) = 1\times10^{-4}\ \text{m}^2  
3 \(\mu\text{s}^{-1}\) = (three per microsecond) = \(3/\mu\text{s}= 3\times10^{-6}\ \text{s}^{-1}\) = 3 \(\times 10^6\ \text{s}^{-1}\)  
1 V/(cm = (1 V))/(10^{-2}\ \text{m}) = 10^2\ \text{V}/\text{m}  
5 cm^{-1} = 5 \((\text{cm})^{-1}\) = 5 \((10^{-2}\ \text{m})^{-1}\) = 5\times10^2\ \text{m}^{-1} = 500/\text{m}  

Special care is required in converting non-SI units having prefixes, such as mL, to coherent SI units: 1 mL = 10^{-3}\ (\text{dm}^3) = 10^{-3}\ (10^{-1}\ \text{m})^3 = 10^{-3}\ (10^{-3}\ \text{m})^3 = 10^{-6}\ \text{m}^3.

### 4. A comment on abbreviations

As noted in 1. d. above, unit symbols are not abbreviations. Despite this, many science professionals routinely use abbreviations in their talks and publications. Copy editors sometimes are not aware of the distinction, and sometimes
(even when knowledgeable copy editors identify the misuse) authors insist on the incorrect usage. In many scientific publications today, copy editors have been eliminated and authors supply the articles after making the changes suggested by the referees in TeX, which is directly translated into the printed copy and carries through the author usages, whatever they might be.

In our experience, the most commonly found abbreviation used in scientific talks and papers in place of the proper unit symbol is “sec” for second. We have seen velocity-time graphs published with inconsistent axis labels “v (m/s)” and “t (sec)” on a single graph on numerous occasions. Our purpose here is not to chastise authors who have made this or a similar mistake, but to make TPT readers and authors aware of proper usage for their teaching, talks, and publications.

Some mistaken usage comes from changes in the SI itself. For example, until 1968, common usage was “degree kelvin,” with symbol °K. The 13th CGPM decreed that henceforth it was to be the unit kelvin with symbol K. It is obvious that scientists who grew up using “degree kelvin” may have failed to adopt the change, perhaps bringing their own students back to what was the custom in the past and prolonging the transition as those students pass on that usage to their own students. The 13th CGPM also did away with the name “micron” for micrometer, which usage also persists to the present for similar reasons.

Another source of confusion in units occurs because other professionals ignore international standards. The notorious “cc” for cubic centimeter or centimeter cubed has been used out of habit by medical professionals, but can be misread as “U” (meaning “units” as in, for example, units of blood) if the handwriting is sloppy (I think of the poor pharmacist trying to read my physician’s handwriting; perhaps your doctor’s handwriting is more legible); such a mistake is easy to make. The medical profession has been asking everyone to use the milliliter instead of “cc” to help prevent dosage errors.

Also used in medicine is the mass abbreviation “gm” for gram and “ug” or “ugm” for microgram. All of these can result in dosage errors if misinterpreted, some of which could be life-threatening, for example, reading “ug” or “gm” as mg. Some engineers use “gm” to refer to “gram mass,” as opposed to “gram force.” According to the SI, of course, there is no such thing as a “gram force” and “gram mass” is redundant.

References