Tutorials / Surveys

Typesetting mathematics for science and technology according to ISO 31/XI

Claudio Beccari

Abstract

Mathematicians set mathematics into type differently from physicists and engineers; the latter require some particular tricks in order to satisfy ISO 31/XI and to distinguish similar symbols that have different meanings. The LaTeX 2ε commands to implement such tricks are shown and explained.

1 Introduction

As D.E.Knuth points out very well in *The TeXbook* [7], the strength of TeX and its derived dialects (among which LaTeX 2ε outclasses all others) lies in the ability to typeset beautiful mathematics; the variety of symbols, the shape of the operators, the spacing, both vertical and horizontal, the sizes of first and second order sub and superscripts make (La)TeX the best software available today for typesetting mathematics. Of course (La)TeX does a wonderful job also with plain text, tables, cross referencing, indexing, and so forth, but other programs may perform well with the latter tasks; what other programs really cannot do is the excellent work with mathematics; all this is not surprising since TeX was created by a mathematician for typesetting mathematics, first of all in his own books.

In this paper I do not discuss how to typeset mathematics, since (La)TeX takes care of most of it; very seldom the author needs minor corrections of a formula, and when this happens it is usually to correct some spacing when slanted operators are too close or too far away from the symbols they precede or follow, so that the slanting shape of the operator requires some degree of manual intervention in order to fix the spacing. Several such cases are dealt with both in *The TeXbook* and in Lamport's LaTeX Handbook [8].

Nor do I discuss the aesthetics of a typeset formula, where several factors should follow one another in such a way that the formula profile is as smooth as possible, without valleys and peaks. Typesetting a complicated formula requires both mathematical knowledge and a sense of aesthetics, but requires also, especially in didactic books, that the relevant parts of the formula are highlighted in the proper way coming to a compromise between readability and abstract typesetting rules.

I will discuss here those few tricks that physicists and engineers, *not mathematicians*, must know in order to satisfy the international regulations and to distinguish similar symbols with different meanings and, ultimately, in order to cope with the ISO regulations [1] and the recommendations issued by the International Union of Pure and Applied Physics (IPU) [6].

2 Upright and sloping letters

The main and possibly the only difference between "mathematical" vs. "physical" mathematics lies in the use of upright and sloping letters. Scientists and technologists (should) use upright letters much more often than mathematicians.

In math mode LaTeX 2ε chooses normal letters from the "math italics" alphabet, which includes also the Greek lowercase ones. Both Latin and Greek letters have a sloping shape, the former being in italics, the latter just sloping to the right with a slope angle that matches the one of the italics characters. Just the uppercase Greek letters (by default) are upright, but it would be very easy, although unusual, to set them with a sloping shape because they appear in the "math italic" font, and in all the "text italic" and other "slanted" fonts.

In the following I will call "roman" the upright shape and "italic" the one that TeXies are used to associate with math italics. The choice of the word "roman" is not chance, since sans-serif characters are not suited for physical mathematics because several signs are not easy to distinguish in the absence of serifs: compare I and l for example; you cannot tell which one is "upper case I" and which one "lower case l".

Sans-serif upright characters may be used in technical and/or physical texts in order to mark objects that cannot be confused with mathematical symbols, for example for the names of points in the description of geometrical figures, technical objects, experimental setups, and the like. Therefore sans-serif upright letters never appear in a mathematical formula of a physicist or an engineer, while mathematicians use sans-serif fonts to represent certain structures in category theory.[1] As a partial exception, sans-serif *sloping* uppercase letters are allowed to indicate tensors of the second rank, but this is the

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[1] Thanks to the reviewer for this information; although he/she does not specify it, nevertheless I suppose that they are sans-serif *sloping* fonts.

only exception mentioned in the IPU recommendations [6] and stated in the ISO regulations [1, clause 11-10.14] for using sans-serif fonts.

2.1 Italic symbols

According to the ISO regulations and the IPU recommendations, italic symbols should be used only to denote those mathematical and physical entities that may assume different values, typically those symbols that play the role of physical variables, but also those physical "constants" that are not really constant, because better measuring techniques may produce updated values.

Among such constants there is for example the elementary electric charge (the charge of the proton) $e = 1.602 \cdot 10^{-19}\,\mathrm{C}$, that is considered constant until better measures will add other significant digits; the same holds true for such constants as the velocity of light c, the Planck constants h and $\hbar$, the Boltzmann constant k, and so on.

Every physical variable is represented by *one* italic letter with as many modifiers as needed such as subscripts, superscripts, primes, etc. [6, clause 1.2.1]. There are a few exceptions to this rule, represented by the dimensionless parameters (such as the Mach number, the Euler number, and so on) that are specified with a two-letter symbol by the ISO regulations [2]; for example the Mach number is represented by Ma, the Euler number by Eu; when such two-letter symbols are used, equations must be written with special care so as to make sure that Ma does not represent the product of the physical variables M and a. For the names of the nuclides, that may consist of two letters, see the next section.

In pure mathematics two- or three-letter names are used in applications such as, for example, the name of the Galois field with n elements[2] that is represented with $\mathrm{GF}(n)$. But such applications are not substantially different from what the ISO regulations say about the names of special functions [1, clauses from 11.11.1 to 11.11.21].

In the domain of Computer Science as well as in Electronics authors and typesetters make frequent use of multiletter symbols,[3] but this tradition is evidently in contrast with the ISO and IPU statements and should be abandoned.

Sub and superscripts must be set in italics when they represent physical quantities or mathematical variables [6, clause 1.2.2] otherwise they should be set in roman type; for example: C_T, where T represents "temperature"; M_i, where i is a summation index; but R_E where 'E' distinguishes an object such as the "emitter".

2.2 Roman symbols

Any other symbol that was not dealt with in the preceding subsection must be set in roman font; the list of such "roman" entities is surprisingly long and, unfortunately, little known although ISO regulations and IPU recommendations are quite clear on this subject.

1. Numbers must be set in roman type (LaTeX 2ε does this by default).
2. Numerical constants must be set in roman type; this is perhaps the most neglected rule, but it applies to $\mathrm{e} = 2.718\,281\,8\ldots$, the base of natural logarithms, to the "imaginary unit" that mathematicians and physicists call 'i', while most engineers call 'j', and so on. The ISO regulations [1, clause 11-8.1] allow both symbols for the imaginary unit, but both must be set in roman type. The reason behind this is to avoid confusion between the base of natural logarithms and the elementary electric charge, between the imaginary unit and the instantaneous current i or the instantaneous current density j whose symbols are recommended by the IPU [6, sections 7.5 and 8.5].

   Anybody can notice that 'e' and 'i' or 'j' are universally typeset in italic font in both mathematical and physical or technological texts; this observation gives a measure of how much the rule I am speaking about is ignored, at least by physicists and engineers.

   The same rule should apply to numerical constants represented by Greek letters, such as $\pi = 3.141\,592\,6\ldots$, but it is necessary to get by with it because it is difficult to have both the upright and the sloping Greek fonts; fortunately enough the frequency of such symbols (except π) is not high. If both upright and sloping Greek fonts were available, an upright π should indicate the numerical constant "3.1415...", while a sloping π should indicate the physical constant "3.1415... rad" corresponding to the angle of 180°.
3. Physical units must be set in roman type with the additional requirement that a line break cannot take place between the measure and the unit of measure. In order to emphasize the unitary nature of a physical constant, the measure and the unit of measure should be separated by an unbreakable *thin* space, rather than by a regular interword (unbreakable) space. Besides

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[2] Thanks again to the reviewer for pointing out this topic.

[3] Please notice the difference between the *symbol* of a physical quantity and the *name* of an operator or a function.

being quite reasonable, this point copes with the high penalty that TEX introduces in a formula within a product of terms; if TEX has to break a formula across lines, it does so close to a binary or a relation operator (although very reluctantly), not within the product of terms, and a physical quantity *is* the product of the measure times the unit of measure.

4. Mathematical operators indicated with letters must be set in roman type; LATEX 2ε already does this for a number of predefined operators, such as 'lim' or 'sin'. The package amsmath adds some more predefined operators, but, most important of all, it adds a couple of commands for using other operators. We will discuss this topic in a following section.

   It is worthwhile to mention that operators do not require that their argument be enclosed within parentheses if the operand is made up of no more then two objects (2π being counted as one object), but proper spacing is required on both sides; so you simply write $\sin\omega t$ and do not need to write $\sin(\omega t)$, but you should write $\sin(2\pi ft)$; in any case parentheses are required when a formula contains several operators with their arguments.

5. The names of special functions such as 'erf' (error function), or 'Ei' (exponential integral), or 'E' (incomplete elliptic integral of the second kind), ..., are treated by ISO 31/XI the same as the names of operators [1, clauses from 11.11.1 to 11.11.21] and should be typeset in roman type, although their argument(s) must always be indicated within parentheses. See the following sections for what concerns the definition of new operators.

6. A particular operator, the operator of differentiation, should be set in roman type, but under the LATEX 2ε point of view, it should behave differently from other operators as concerns spacing. The use of roman type for the differential operator is another example of a highly neglected rule, albeit the ISO regulations [1, clause 11-5.15] are explicit on this point.

   The "house style" of the majority of publishing companies, where the differential operator is a common italic '*d*', was evidently set up under the influence of the tradition of pure mathematical typesetting before the ISO regulations were published; now many years have elapsed since their publication so that the ISO regulations should be widely applied, and it is surprising (it surprises me, at least) that, while the modern world is so attentive to international standards, this particular one is almost completely neglected.

   The ISO prescription and the IPU recommendation concerning the differential operator are not illogical, since in physical and technological mathematics it is essential to distinguish different mathematical objects within a formula, taking into account the nomenclature recommendations for physical quantities; it is really necessary to distinguish 'd' from '*d*' when the latter indicates one of the many physical quantities whose symbol is recommended to be *d*: thickness, diameter, relative density, lattice plane spacing, degeneracy of vibrational mode, etc.

7. Sub and superscripts that do not represent physical quantities or mathematical variables should be set in roman type; the amsmath package makes available the command `\text` for setting in roman type any word or sentence within mathematics, also in sub and superscripts. In general, though, the problem is to distinguish the type of sub and superscripts in order to decide how they should be typeset. In the books I wrote I estimated that more than two thirds of the subscripts I used had to be set in roman type, while the absolute majority of superscripts were mathematical expressions; although just a few books have no statistical value, the experience I gained allows me to say that this percentage of roman subscripts should be considered typical, so that roman subscripts are almost the default case in physics and technology.

8. Chemical symbols coincide with the names of the nuclides if they carry proper sub and superscripts; with respect to typography, particles and quanta are treated as the nuclides. They are made up of one or two letters and must be set in roman type [6, section 4]; chemical equations are in general quite complicated so that for setting into type a book on chemistry it is better to use specialized packages; the last one that was described in *TUGboat* [10] is an excellent example; the *LATEX Companion* [9] describes another package ChemTEX [11] for the same purpose.

   For simpler chemical formulas that do not require the graphic facilities of LATEX 2ε, the author can typeset chemical equations with the usual math commands provided he/she remembers to switch to roman type for the symbols of the chemical elements.

9. Roman numbers are seldom used in physics and technology, although they find their way in

chemistry where they may represent the spectrum of a z-fold ionized atom or, in superscript position, the oxidation number; in both cases they are set in roman type [6, clause 4.5].

Roman numbers used for enumerated lists or for numbering front matter pages do not pertain to mathematics; they are generally set according to the publishing house style. As a matter of personal taste, in these situations I prefer small-caps roman numerals to italic ones.

3 Other typesetting recommendations

While typesetting "physical" mathematics it is convenient to remember that scientific and technical papers have a worldwide readership and the observance of the ISO regulations and IPU recommendations is essential for making one's text easily understood by readers of different language and culture. Here are some hints:

1. The decimal separator is the "decimal comma" in the rest of the world [6, clause 3.2] and the "decimal point" in the English speaking countries; it is necessary to be consistent with this rule and to avoid mixed separators (see the following point).
2. Before and after the decimal separator digits may be grouped in triplets separated only by a *thin space*, not by commas (USA) or lowered or raised points (Europe) [6, clause 3.5]; in general Europeans are more used to the North American habit of dividing triplets with commas, than North Americans with European habits. In both cases a professional typesetter of a scientific or technical text uses only thin spaces so as to avoid the trouble of interpretation to readers of different cultures. Triplets may be avoided when before or after the decimal separator there are just four digits: that is, you should write USD 1900 (or $1900) preferably to USD 1 900, while writing USD 1,900 should be absolutely avoided: in Europe it means "one US dollar and 90 cents"!

   In this paper the North American decimal separator is being used all over; for Europeans I recall that the point in the role of the decimal separator is allowed only in numerical constants written within a (section of a) programming language.
3. When a number is less than unity in absolute value, this should be explicitly indicated with a 'zero' preceding the decimal separator [6, clause 3.2]; therefore it is necessary to write 0.123 and −0.456 in place of .123 and −.456 respectively.
4. The International System of Units (SI) [3] is the only legal system of units to be used in those countries that undersigned the specific bill. In practice the SI is the only system of units accepted by the scientific community, although engineers do it more readily than physicists; the latter sometimes indulge in using one of the old cgs systems, more for the possibility of skipping some constants in the formulas dealing with electromagnetic phenomena, than for a real need of using centimetres/centimeters and grams.

   The SI establishes the symbols for the fundamental and derived units and the legal decimal prefixes; some non-SI units keep their value, while some others are "outlaw". In any case every legal or accepted unit has its own symbol and only that symbol must be used; you write 3h 12min 45s, not 3hrs 12mins 45secs; you write "a conductance of 25 mS", not "a conductance of 25 m℧".
5. The symbols of the physical units are *symbols*, not abbreviations, therefore they must never carry the abbreviation point after them and do not change in the plural [6, clause 2.1.2] so that it is correct to write 7.25 cm while it is wrong to write either 7.25 cm. or 7.25 cms with the abbreviation point or with the plural of the symbol.

   Unit symbols must always be used when they accompany the measure and they must be set after the measure; the full spelled name (with lower case initial even if the unit has an uppercase symbol) should be used in the text when preceded by general specifications such as "several", "few" or when the unit of measure is called by name; you write "electric bulbs are labeled with the operating voltage in volts and the power rating in watts", not "electric bulbs are labeled with the operating voltage in V and the power rating in W".

   As for the plurals of the unit names (not of the unit symbols that are invariant as mentioned above), every language has its own rules and every country its own regulations; beware not to use a plural form of another language.[4]
6. Proper scientific prose does not use the physical quantity symbols in text mode, it rather uses the full spelled name possibly followed by the symbol; you write "space s and time t are the only physical quantities necessary to deal with

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[4] This is not a common problem in English speaking countries, but it is a problem in other countries where English plurals are often used.

kinematics", not "s and t are the only physical quantities necessary to deal with kinematics".

7. Connected to the previous item, the scientist and the engineer should choose the correct names for physical quantities; the IPU recommendations [6] offer a very wide nomenclature list in English and French for virtually every quantity of interest in pure and applied physics; for every quantity a preferred literal symbol is indicated and the names of the quantities should be used in a consistent way, rather than inventing new names and new symbols for old objects simply because of specialized technical jargons.
8. The physicist's and the engineer's equations are relationships between physical quantities; the latter are groups made up of a first term that represents the measure, and a second term that represents the unit of measure; although they are not commutative, they behave as factors of a multiplication. The mathematical operations performed on physical quantities operate in the usual way on the numerical parts and in an algebraic way on the units of measure, giving rise in some instances to derived units. If a physical equation contains a physical constant not represented by a symbol, this constant must contain both elements: measure and unit of measure. You write $Z_0 = 377\,\Omega/\sqrt{\epsilon}$, not $Z_0 = 377/\sqrt{\epsilon}$.

   For the same reason it is not necessary, or better, it is definitely wrong to write the units of measure after a coherent physical equation; see also the next item.
9. Measure equations should be absolutely avoided in professional scientific texts; measure equations were somewhat popular before the SI was universally adopted; now they should not be used any more. They survived in those countries where the "English system of units" is being used, but, since scientifically speaking this traditional system of units is "illegal",[5] measure equations have no reason to be used any more.
10. Since every physical quantity is a group formed by the measure and the unit of measure, it is wrong to specify the unit of measure after the symbol of a physical quantity; you write "a periodic function of period T", not "a periodic function of period T seconds".
11. Physicists seem to like the powers of 10; engineers prefer the decimal prefixes established by the SI. Such prefixes, representing positive and negative powers of 1000 (in addition to several that represent the first few positive and negative powers of 10), cover an extremely wide range, from 10^{-18} to 10^{18}, so that powers of 10 can be easily avoided. When choosing the right prefix it is necessary to remember that integer values of the measures are preferred and that zeroes just after the decimal separator should be avoided; you write 32 pF rather than 0.032 nF. This rule holds true everywhere, except in tabular formats where the unit of measure is specified in every column-head and is valid for all the table entries of that column [3, section 4].
12. Connected with the previous item there is the question of the number of significant digits; while leading zeroes (between the decimal separator and the first nonzero digit) are allowed only in tables, trailing zeroes should be avoided unless they are significant because they carry information on the measure precision: in physics 7.25 m is different from 7.250 m because the former quantity is precise to ±0.5 cm while the latter, to ±0.5 mm. Therefore physicists and engineers should be careful to use just the number of significant digits (inclusive of the trailing zeroes) that are compatible with the experimental or technological data they are referring to.
13. I need not emphasize that prefixes as well as units of measure should be spelled correctly, paying particular attention to uppercase and lowercase letters and to the operators between units; nevertheless the following errors are quite common: 'K' (kelvin) in place of 'k' (kilo); 'M' (mega) in place of 'm' (milli) or vice versa; 'mμ' (milli-micro) in place of 'n' (nano) [6, clause 2.2.2]; 'u' in place of 'μ'; 'hz' and 'db' in place of 'Hz' and 'dB'; '°K' in place of 'K'; 'kwh', 'KWH', 'KWh', 'kw/h' (awful!) in place of 'kWh' (or even better 'kW h' — notice the thin space); 'kc' (kilocycles) in place of 'kHz' or, at least, even if it is not fully SI, 'kc/s' (kilocycles per second).

   Decimal prefixes should be attached to the following unit without interposing any space; compound units may have a thin space between them or (exceptionally) a raised dot [6, clause 2.3.1]; either separator is mandatory when units may be confused with prefixes; positive or negative powers refer to the unit *inclusive of its*

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[5] The United States was one of the last countries to adopt the SI in the late fifties, but even after four decades have elapsed, in that country the SI seems to have difficulties in replacing the traditional units.

decimal prefix; negative powers, although allowed, are preferably avoided: '$\mathrm{kW\,h}$' is better than '$\mathrm{kW \cdot h}$' and better than 'kWh'; '$\mathrm{m/s^2}$' is better than '$\mathrm{m\,s^{-2}}$' and both mean something different from '$\mathrm{ms^{-2}}$' (meters per square second versus the inverse of square milliseconds) [6, clause 2.2.3].

14. As mentioned above, the math italic typeface is used for normal variables and roman typeface is used for letters and "adjectives" that do not represent variables. Other typefaces are seldom used; the IPU recommendations [6] state that sloping sans-serif characters may be used for second rank tensors and boldface italic characters for vectors (lowercase) and matrices (uppercase).
15. Currency units are not part of the SI, and are standardized by other regulations [5]; they are generally made up of three uppercase letters, the first two of which are the two-letter code for the nation while the third one is the initial of the currency name; therefore you write USD, not US$, for a text that should be read abroad, and keep the symbol $ just for the national readership — after all, many countries use the dollar as the national currency (besides the United States, there are Canada, Australia, Hong Kong, and many others), but in general they are not equivalent to one another; the same holds true for the UK pound £ and the Italian lira,[6] whose international symbols are GBP and ITL respectively.

    In contrast to other units, currency units precede the monetary value but the rule of the unbreakable thin space keeps its validity. Trailing zeroes such as 'USD 1900.00' may be required in order to specify also the unit submultiples for legal and/or commercial purposes.

4 LaTeX 2ε new commands

Here I will describe some very simple LaTeX 2ε new commands intended to help in the typesetting of "physical" mathematics. In general I will use the command `\providecommand*`. This instruction behaves just as `\newcommand*` except that it defines the new command only if it is undefined; if the command already existed the new definition is silently ignored. In this way if you make yourself several packages that include such definitions, the new commands are defined just once and you do not have to be concerned about anything else; on the contrary if you use `\newcommand*`, you receive error messages when LaTeX 2ε executes them if the command being defined already exists, and if you use `\renewcommand*` the error messages show up the first time LaTeX 2ε executes it. I prefer the asterisk form because I get better diagnostic messages in case I forget some closing brace.

1. Some commands for special units and a prefix are very handy; the following definitions are valid both in text and in math mode:

   ```
   \DeclareMathAccent{\ring}%
             {\mathalpha}{operators}{"17}
   \providecommand*{\angs}%
   {\ensuremath{\smash{\mathrm{\ring A}}}}
   \providecommand*{\ohm}%
           {\ensuremath{\mathrm{\Omega}}}
   \providecommand*{\degree}%
                       {\ensuremath{^\circ}}
   \providecommand*{\celsius}%
         {\ensuremath{\mathrm{^\circ C}}}
   \providecommand*{\micro}%
                           {\ensuremath{\mu}}
   ```

   The first declaration adds the ring accent in math mode; LaTeX 2ε has the `\r` command for the ring accent in text mode, but in math mode the ring accent is missing so that it is necessary to define it. At the present state of the LaTeX 2ε art, mathematical signs, letters, accents, ..., are taken from the traditional knuthian cm fonts, and accents are set over the accented letter, especially a capital one, a little too high; with the dc fonts accented letters are made up of just one glyph and the positioning of the accent has been carefully adapted to each letter by the font designer. Maybe in the future, when new 256-glyph math fonts are available, the position of the accents will be more precise. This is why I introduced the `\smash` command in the definition of the ångström unit,[7] otherwise in text mode a line containing such a unit would force some interline leading, resulting in a nonuniform line spacing. The chance of interfering with the previous line descenders is small but not zero. See the following paragraph.

   The `\ring` command is useful not only for setting the unit symbol 'Å', but also for setting

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[6] The UK pound and the Italian lira have similar symbols: £ and £; attentive people notice that the UK pound symbol has one stroke across, while the Italian lira has two strokes, but if you ask Italians, the great majority don't notice the difference.

[7] The ångström unit is tolerated by the SI in the specialized field of light and optics; the name of the unit, in contrast to other SI units derived from personal names containing diacritics, maintains its diacritics [3, annex A, clause 6.3.1] [4, section IV.2].

a variety of 'physical' variables in telecommunications when they refer to the analytical signal.

The remaining definitions introduce handy commands for common units that may be used in both modes thanks to the `\ensuremath` command. There is a drawback with these definitions, that is the newly defined units are set in roman medium upright type everywhere and do not change family or series in text mode.

The `\ohm` definition is a little redundant,[8] because `\Omega` by default is defined as a symbol, not as a letter, so that with LaTeX 2ε it is not subject to the change in the math version (either normal or bold); but if you redefine it or use a package where it is redefined as a letter from the `\mathnormal` alphabet, the above definition guarantees that the unit Ω is set in roman type anyway.

2. The following macro lets you set the units, whichever they are, in roman type, both in text and math modes, with the proper unbreakable thin spacing:

```
\providecommand*{\unit}[1]{%
              \ensuremath{\mathrm{\,#1}}}
```

   When you use `\unit` in text mode, of course, you must not leave any space between the measure and the `\unit` command.

3. Numerical constants represented by Latin letters may be treated by the following macros:

```
% The number 'e'
\providecommand*{\eu}%
               {\ensuremath{\mathrm{e}}}
% The imaginary unit
\providecommand*{\iu}%
               {\ensuremath{\mathrm{j}}}
```

   In the imaginary unit definition a physicist would probably substitute 'j' with 'i', but this is not the point, because the above definition is just an example of how the imaginary unit should be defined. A more sophisticated definition might refer to math operators (see below) so that proper spacing is left around such letters (especially around the imaginary unit). In several sciences, though, a common expression is the combination of 'e' raised to some imaginary power; if you use 'j' for the imaginary unit, its descender butts against the 'e' irrespective of what definition you use (and in practice this occurs even if you stick to the tradition of using italic fonts); this is one of the rare occasions where the typesetter should correct the almost perfect setting performed by TeX.

4. LaTeX 2ε provides an internal command for setting text superscripts, but we need commands that let you set sub and superscripts with the proper math sizes; the package amsmath provides the command `\text` for setting text in math mode, and this command chooses the right size according to the sub or superscript commands. Here I introduce a couple of commands that are good for single word sub and superscripts:

```
\providecommand*{\ped}[1]{%
              \ensuremath{_\mathrm{#1}}}
\providecommand*{\ap}[1]{%
              \ensuremath{^\mathrm{#1}}}
```

   These definitions, that work in both modes, can be handy also for setting text superscripts such as 2nd, 3rd. The names are abbreviations of the Latin words *pedex* and *apex* that refer to the foot or the head position respectively.

5. The LaTeX 2ε package amsmath provides a couple of commands for *using* a sequence of letters as an operator; they are `\operatorname` and `\operatornamewithlimits`; here I introduce a couple of new commands that *define* new operators.

   But before going on, it is better to recall a couple of details about operators. (La)TeX deals with two kinds of operators: the "log-like" and the "lim-like" ones; the former treat subscripts and superscripts as regular ones, that is (La)TeX sets them in smaller size at the right and lowered or raised respectively, while the latter accept sub and superscripts as limits, so that in math display mode subscripts are set underneath the operator and superscripts above it.

   Moreover (La)TeX sets spaces at the left and at the right of the operator in different ways according to what kind of mathematical object falls close to the operator; such different spacings are described in detail in chapter 18 of *The TeXbook*. Therefore to set perfect (physical) mathematics it is advisable to define operators in the proper way, but owing to the two kinds of operators it is necessary to specify in the definition whether sub and superscripts should be used as limits or not:

```
\providecommand{\newoperator}[3]{%
       \newcommand*{#1}{\mathop{#2}#3}}
\providecommand{\renewoperator}[3]{%
     \renewcommand*{#1}{\mathop{#2}#3}}
```

---

[8] In any case, even if `\ohm` was simply `\let` to `\Omega`, it would be shorter to spell and clearer to understand.

Here the first argument is the operator name, the second is its full description and the third is the TeX declaration `\limits` or `\nolimits`. A couple of examples are necessary: according to the ISO regulations the integer part of a decimal number is called "ent" [1, clause 11-4.15], so that the following definition is required

```
\newoperator{\ent}%
                 {\mathrm{ent}}{\nolimits}
```

According to the ISO regulations [1, clauses 11-8.2 and 11-8.3] the real part and the imaginary part of a complex number are "Re" and "Im", not $\Re$ and $\Im$; therefore we need the following redefinitions:

```
\renewoperator{\Re}%
                  {\mathrm{Re}}{\nolimits}
\renewoperator{\Im}%
                  {\mathrm{Im}}{\nolimits}
```

6. The differential operator must be treated in a slightly different way, because it is a special operator that requires different spacings on the left and on the right; moreover being made up of just one letter, it is necessary to use a little TeX trick in order to guarantee that its mathematical axis lines up properly. The differential operator should be spaced as an operator on the left, while on its right it should receive different spacings, and in particular it should not be spaced from its argument. A possible way of achieving this result is to define it as an operator that contains a negative spacing on the right; in order to cope with possible exponents some tests must be performed along the line and this requires some low level TeX programming.

```
\makeatletter
\providecommand*{\diff}%
      {\@ifnextchar^{\DIfF}{\DIfF^{}}}
\def\DIfF^#1{%
        \mathop{\mathrm{\mathstrut d}}%
            \nolimits^{#1}\gobblespace}
\def\gobblespace{%
            \futurelet\diffarg\opspace}
\def\opspace{%
        \let\DiffSpace\!%
        \ifx\diffarg(%
            \let\DiffSpace\relax
        \else
            \ifx\diffarg[%
               \let\DiffSpace\relax
            \else
               \ifx\diffarg\{%
                   \let\DiffSpace\relax
               \fi\fi\fi\DiffSpace}
```

With respect to (total and partial) derivatives it might be useful to define some commands (with the order as an optional argument) by means of the usual `\providecommand*` construct:

```
\providecommand*{\deriv}[3][]{%
    \frac{\diff^{#1}#2}{\diff #3^{#1}}}
\providecommand*{\pderiv}[3][]{%
                \frac{\partial^{#1}#2}%
                    {\partial #3^{#1}}}
```

The first *optional* argument is the derivative order, the second is the function being derived, and the third the derivation variable. Partial high order mixed derivatives require a more sophisticated definition, or direct setting with the `\frac` command.

With the help of these new commands it becomes very easy to typeset the following equations with the assurance that spacings are right and the differential operator is correctly set in roman type; a sample of source code follows each equation.

$$a\frac{\mathrm{d}^2 y}{\mathrm{d}x^2} + b\frac{\mathrm{d}y}{\mathrm{d}x} + c = f(x)$$

(`a\deriv[2]{y}{x}+...`)

$$\frac{\mathrm{d}(\log y)}{\mathrm{d}x} = \frac{1}{y}\frac{\mathrm{d}y}{\mathrm{d}x}$$

(`\deriv{(\log y)}{x}=...`)

$$\mathrm{d}z(x,y) = \frac{\partial z}{\partial x}\,\mathrm{d}x + \frac{\partial z}{\partial y}\,\mathrm{d}y$$

(`...=\pderiv{z}{x}\diff x+...`)

$$\mathcal{L}[f(t)] = \int_{0-}^{\infty} \mathrm{e}^{st} f(t)\,\mathrm{d}t$$

(`...\eu^{st}f(t)\diff t`)

7. The prefix "femto" (that stands for 10^{-15}) turns out to be rather frequent in microelectronics where it is generally used as a prefix for the unit 'farad'; the couple 'fF' requires some kerning so that the lowercase 'f' does not butt against the uppercase 'F'; up to now[9] the available math fonts do not consider this couple for implicit kerning information, therefore the typesetter should remember to insert an italic

---

[9] At the time of writing, the latest version of dc fonts is 1.3 and has a date of June 1996; this release of the dc fonts copes with many new kernings that take place with SI decimal prefixes, but this doesn't help much in math mode because here cm fonts are used; their latest version was refined in 1992, but the latest available source METAFONT files on the CTAN archives carry the date of June 1995; let's hope that the new math fonts with 256-glyph encoding will be available soon.

correction between the lowercase 'f' and any uppercase non-slanting-left-side letter that follows; examples: 'fF' (`f\/F`), 'fW' (`f\/W`), 'fH' (`f\/H`), but 'fA' (`fA`).

At present a `\femto` macro would solve the kerning problem, but in the future such kernings should find their way into the very definitions of the various fonts that are used in math mode.

5 Examples

In addition to the examples shown in the previous section, I report here some more examples where the various features described above show the difference between 'mathematical' and 'physical' equations. Between parentheses you find the source code for some relevant part of the example.

1. The Euler equation involves the five most important mathematical constants:

   $$\mathrm{e}^{\mathrm{j}\pi} + 1 = 0$$

   (`\eu^{\iu\pi}`)

   Actually in this case, as pointed out in the previous section, the typesetter should introduce a small correction to the spacing:

   $$\mathrm{e}^{\,\mathrm{j}\pi} + 1 = 0$$

   (`\eu^{\,\iu\pi}`)
2. A component list:

   $$\begin{array}{ll} R_\mathrm{B} = 2.2\,\mathrm{k\Omega} & R_\mathrm{F} = 180\,\mathrm{k\Omega} \\ h_\mathrm{ie} = 1.5\,\mathrm{k\Omega} & h_\mathrm{fe} = 100 \\ C_\mathrm{E} = 3.3\,\mathrm{nF} & R_\mathrm{C} = 4.7\,\mathrm{k\Omega} \end{array}$$

   (`R\ped{C}=4.7\unit{k\ohm}`)
3. The equations of a common emitter stage with a feedback resistor on the emitter:

   $$\begin{aligned} I_\mathrm{b} &= (1/h_\mathrm{ie})(V_\mathrm{b} - V_{R_\mathrm{E}}) \\ V_{R_\mathrm{E}} &= (1 + h_\mathrm{fe})R_\mathrm{E} I_\mathrm{b} \\ V_\mathrm{c} &= -h_\mathrm{fe} R_\mathrm{C} I_\mathrm{b} \end{aligned}$$

   Notice in particular the term V_{R_E} whose LaTeX source code is (`V_{R\ped{E}}`).
4. A table

Stub length in mm	Decay time in ns
0.04	798.72
1.20	19 836.07
2.28	17 356.74
3.36	15 468.04
3.96	14 747.75

   (`14\,747.75`)
5. An equation with complex variables:

   $$\mathrm{Re}[F(\sigma + \mathrm{j}\omega)] > 0 \qquad \forall\,\sigma > 0 \text{ and } \forall\,\omega$$

   (`\renewoperator\Re{\mathrm{Re}}{\nolimits}`)
6. Some text with physical quantities: "The heat sink with a thermal resistance θ_sa of 3.3 °C/W is supposed to maintain the temperature below the transistor maximum junction operating temperature when it operates in an environment at 60 °C."
   (`$\theta\ped{sa}$ 3.3\unit{\celsius/W}` `60\unit{\celsius}`)
7. Use of ångströms: a wave length of 5500 Å (`5500\unit{\angs}`).

6 Conclusion

I have been using the above commands for several years; before the advent of LaTeX 2ε I had put together similar commands for LaTeX 2.09, but the difference lies simply in the easier way of defining them with the new version of LaTeX. With the help of such commands I have found it very simple to cope with the ISO regulations and IPU recommendations at the point that now I feel somewhat handicapped if I have to write anything scientific on a computer where the LaTeX implementation is lacking such commands.

At the same time they are so few and simple that I did not consider the possibility of making up a short package file (where the documentation and the insertion driver would be much larger than the useful lines) to be submitted to the CTAN archives. Anybody can copy such commands from paper and/or use them as guidelines for making one's own set of useful commands, possibly performing better than the simple ones that I suggested.

But, most important of all, I warmly suggest to pay attention to the international regulations and recomendations; the results are worth the little extra effort.

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◇ Claudio Beccari
Dipartimento di Elettronica
Politecnico di Torino
Turin, Italy
`beccari@polito.it`