Writing Numbers in Technical Documents

Perhaps you think these comments are pedantic. Some may be. But scientific reports, written or spoken, should reflect the precision of the experiments. Numbers and values submitted to editors or presented at meetings are sometimes hardly better than "umpteen zillion" or "every so often."

—Vernon Booth
Communicating in Science

Celia M. Elliott
Department of Physics
University of Illinois
cmelliott@illinois.edu

Physics is a quantitative science. Thus, numbers must be represented in a way that ensures a reader interprets them correctly. To make sure that we're all speaking the same quantitative language, rules have evolved about how numerical values are presented in writing.

Learn the rules, and hew to them witlessly.

Let's define our terms

A *number* (872) is a scholarly convention to define the size of something that has been measured, calculated, or counted

The special characters that represent numbers are *numerals* (8, 7, and 2)

87.2 is a *quantity**

*unless it appears in a table, where it is a *value*

Follow two fundamental rules for expressing numerical quantities

1. **Use a number style that conveys information unambiguously**

A realistic quantum simulator involving a hundred-thousand interacting spins that could be constructed in a few years has the potential to explore outstanding theoretical issues in condensed matter physics.

2. **Maintain the style consistently throughout the text**

In this example, a reader might interpret “hundred-thousand” as a range (100 to 1000), a collection of one hundred 1000-spin sets, or a single number (100 000).

Fortunately, we have standard rules about the expression of numbers in scientific writing to avoid ambiguity and to ensure that a reader assigns the same meaning to a number that the writer intended.

Numbers <10 are *usually* written as words

Spell out cardinal numbers *one* to *nine* for things that are *counted*

- two-state quantum system
- nine separate experimental runs
- three-body problem

Spell out ordinal numbers *first* to *ninth*

- first occurrence
- second question
- seventh data run

"Zero" is usually written as a numeral

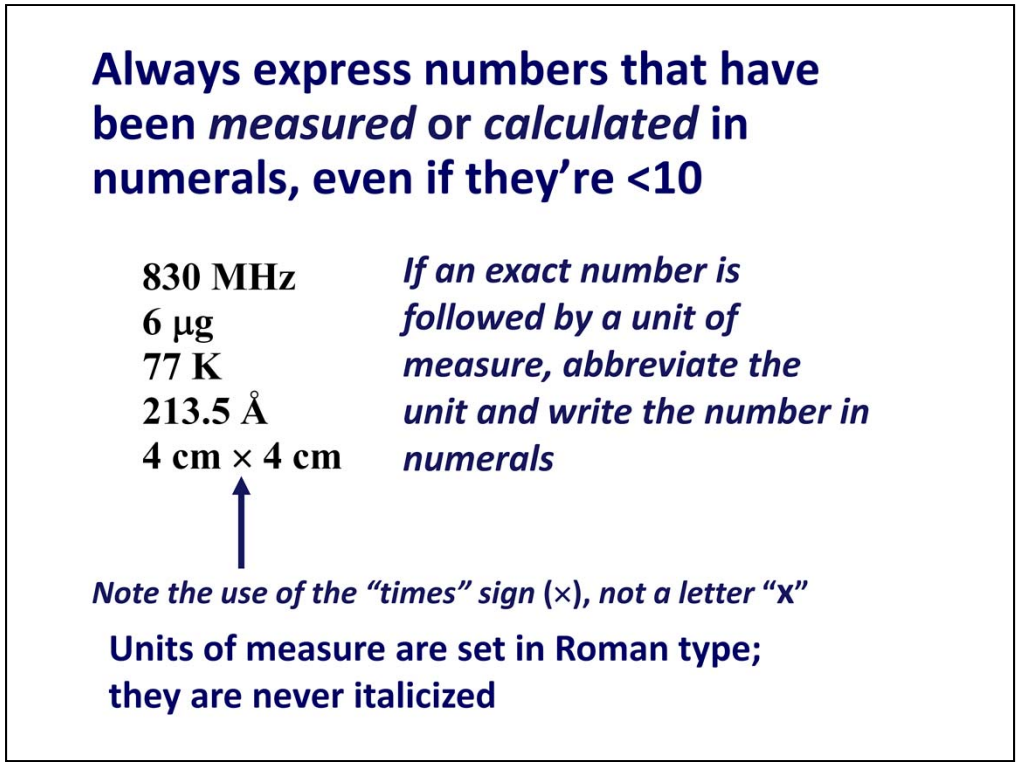
- the x and y axes intersect at 0

Numbers are written as words ***only*** for quantities that have been counted. If the number is the result of a measurement or a calculation, it ***must*** be expressed in numerals.

Numbers >9 are written in numerals

- Use numerals for quantities >9 for things that have been *counted*
  - 18 months
  - 128-processor Paragon® supercomputer
  - $2.1 million
    - write out *million*, *billion*, *trillion* in words
- Use numerals for ordinal numbers greater than *ninth*
  - 50th anniversary
  - 21st century

REMINDER: Numbers are written as words ***only*** for quantities that have been counted. If the number is the result of a measurement or a calculation, it ***must*** be expressed in numerals.



Note that the unit of measure is given after each number, and the "times" symbol is used instead of the letter *x*.

To obtain the times symbol, use the "insert symbol" function in MS Word or PowerPoint, or type \times in LaTeX.

To avoid awkward breaks that maroon the number at the end of a line of text (e.g., 7 mm) and the unit at the beginning of the next line, as in this example, train yourself to type a nonbreaking space between all numbers and units. Do it every time until it's automatic.

A *physical quantity* is the product of a *numerical value* (a pure number) and a unit

1 852 m (nautical mile)

133.322368 Pa (1 torr)

Symbols (usually Latin or Greek letters) for physical quantities are italicized in text

The force, *f*, varied between 15 pN and 17 pN.

The electric potential, φ, is 12 V.

It is important to set letters used to symbolize physical quantities in italics to distinguish them from the rest of the text.

In typography, "Roman" text is straight up and down, like this text, and italics text is *slanted*, like *this*. "Roman" refers to the text style, not the font or typeface name (e.g. Helvetica, Times, Century Schoolbook).

Note that abbreviations for units are never italicized.

A space is *usually* inserted between a number and the unit of measure

Examples:

77 K, 250 kJ, 10 μm, 4 T

Use a non-breaking space to keep the number and the unit on the same line

Word—123Crtl+Shift+Spaceunit or Ω

TeX—123~unit

Do not use an intermediate space in a *few* exceptions:

70% , $100k, 15°, 45°C

Note that the degree symbol (^{0}) is used only for temperatures in the Celsius or Fahrenheit ranges. The SI unit, kelvin (K), is an absolute unit, not a "degree" based on some arbitrary scale. Thus, writing "°K" or "degrees Kelvin" is incorrect.

Some older papers may show temperature as °K, but that use was changed by The General Conference on Weights and Measures (French: Conférence générale des poids et mesures - CGPM) in 1967.

Note also that units are abbreviated when they describe a quantity that has been calculated or measured.

The US is gradually adopting European style in breaking 000s

- **According to IUPAP, a comma (,) should no longer be used to separate numbers having more than four digits into groups of three digits**
  - **12 578 896 *NOT* 12,578,896**
  - Ideally, narrow or half spaces should be used
- **Be sure to use non-breaking spaces to avoid having part of the number marooned on a separate line**

Some subdisciplines of physics are adopting the change faster than others; you'll see numbers presented both ways.

Approximate numbers follow the same rules as exact numbers

Same guidelines as exact numbers

Approximately 50 000 discrete events were recorded.

Approximately one sample in seven had to be discarded because of poor adherence of the thin film to the silicon substrate.

Do not abbreviate a unit that follows an approximate number

tens of kilohertz
thousands of volts
several millimeters

Very large approximate numbers are written as numerals followed by the word *million*, *billion*, or *trillion*

The renovation of the microanalysis laboratory will cost $3.7 million and take nearly four years.

Overall, NSF funding increased by $372.5 million to $4.789 billion, an 8.4-percent increase over the previous year. *

***Avoid awkward line breaks like this one**

The indefinite article preceding a number is chosen based on what the number sounds like when it is spoken

Again, train yourself to insert a non-breaking space between the number and the word to avoid awkward line breaks.

Mathematical operations are expressed in numerals

a factor of 4
a probability approaching 0
3 × 3 matrix
6 orders of magnitude

Fractional numbers written as decimals *must* have a zero preceding the decimal point

~~.3 cm~~ 0.3 cm

A sentence may not begin with a number expressed in numerals

~~35~~ experimental runs were made.

Thirty-five experimental runs were made.

~~75-~~mm holes were drilled in the sample.

~~Seventy-five-~~mm holes were drilled...

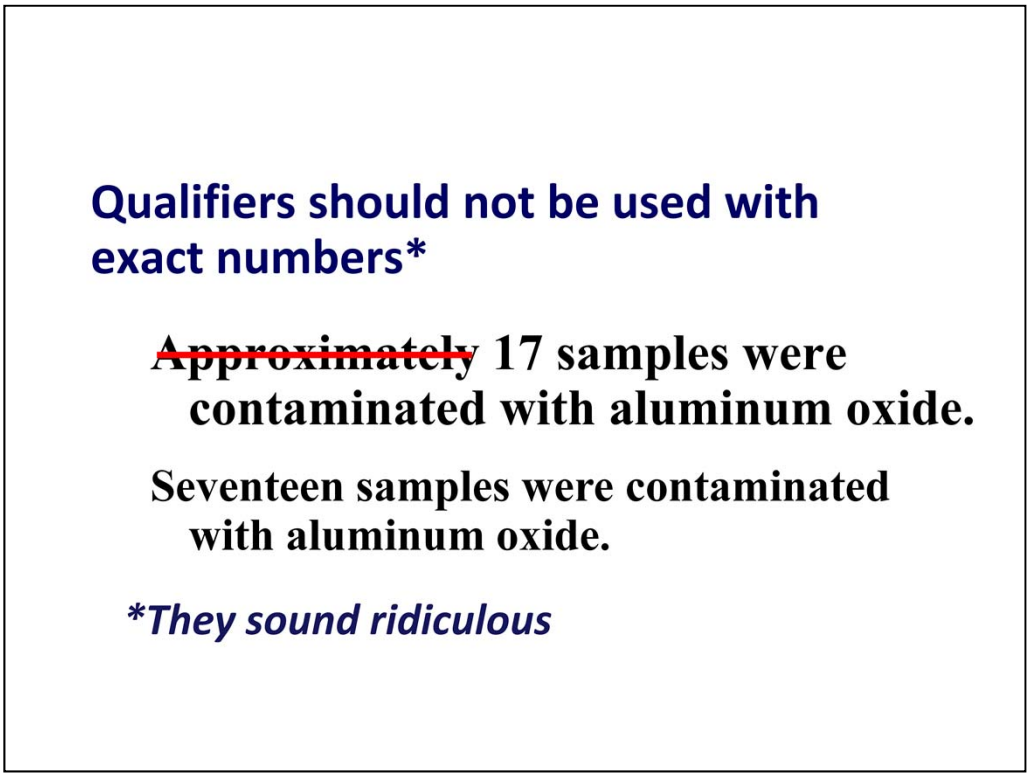
Holes 75 mm in diameter were drilled…

Double penalties attach for beginning a paragraph, a figure caption, or a title with a number expressed in numerals

Notice that the example “Seventy-five mm holes were drilled...,” which attempts to observe the “don’t begin a sentence with a number expressed in numerals” rule, is tantalizingly ripe for misinterpretation.

Is it 70 holes, 5 mm in diameter each?

Is it 75 holes, 1 mm in diameter each?
Or is it some indeterminate number of 75-mm holes that were drilled in the sample?



In general, *all* wimpy qualifiers should be avoided in scientific writing—be specific and quantitative.

The American author Mark Twain had some strong opinions about qualifiers; he was particularly opposed the the profligate use of "very." His advice—every time you are tempted to write "very," substitute "damn." Then your editor will remove all the damns for the sake of propriety, and your writing will be much improved.

Heed Mark Twain.

Numerals for quantities <10 are used in special cases

Names of parts of anything printed

Chapter 2, Vol. 3, No. 7, Fig. 4, Eq. 8
Table IV, Section 6.3.7, 2nd ed.

Locations

Row 3, Area 51

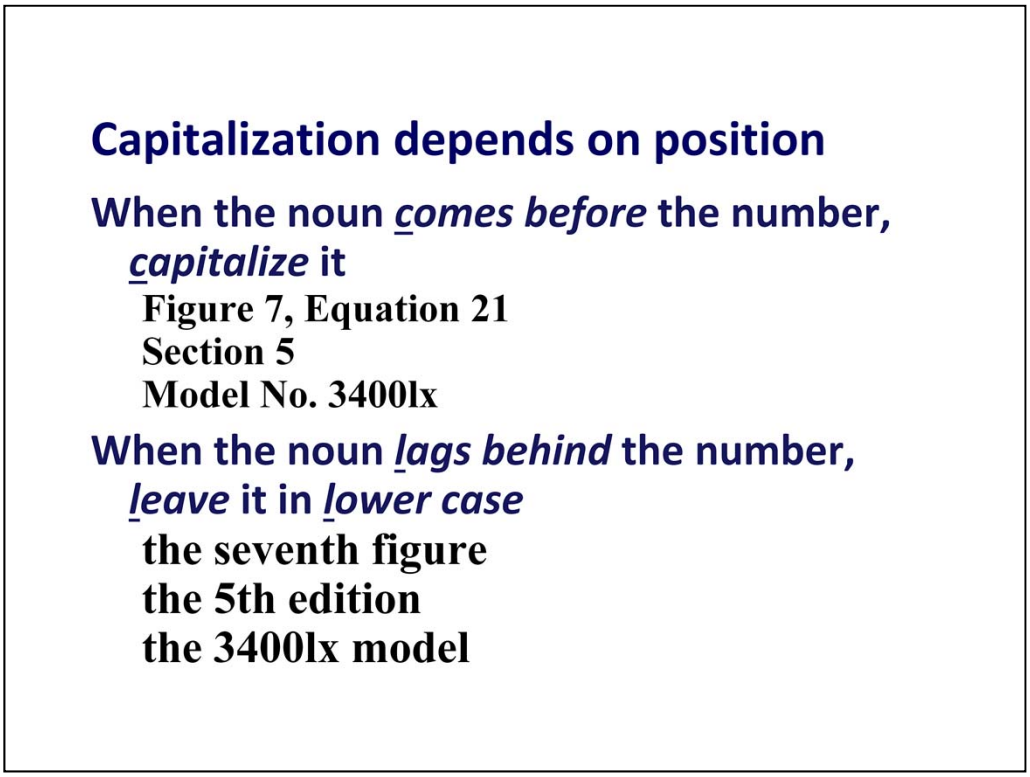
Time

17 ms, 5 s, 3 min—except days, months, years, and centuries (they're counted)

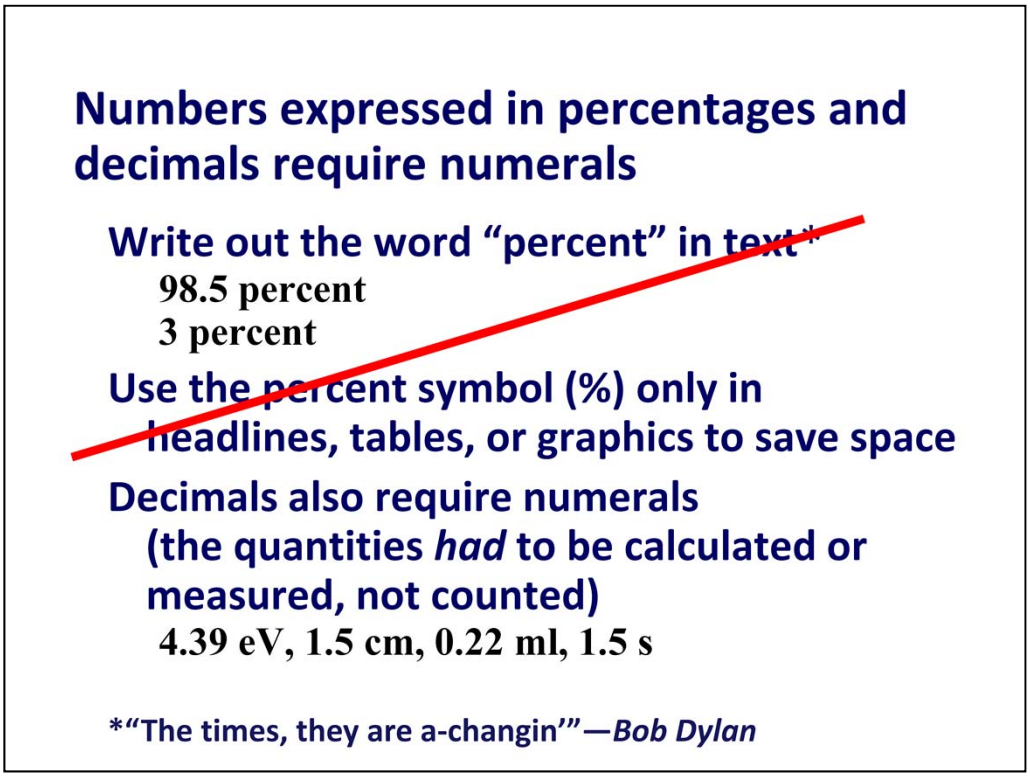
Money

$0.26 per unit, $1.3 billion
($100k and $13M okay for informal writing)

Note that "k" (kilo) is *always* written lower case when it means "thousands."



If the number comes after the noun, the phrase is treated as a title and is capitalized accordingly.



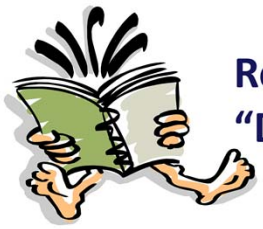
*Although the "rule" is that "percent" should be written out in running text, usage is evolving, and the % sign appears more and more frequently in physics papers. Although Ms. P is loath to abandon a principle, she thinks this fight is probably lost and reluctantly abandons the rule.

Reminder: Any physical quantity that has been measured or calculated must be expressed in numerals.

Use numerals to express ratios

The ratio of epoxy to pigment should be 15 to 2.

"1:4" is read "one to four" and *means* "one out of five"



Read Vernon Booth's chapter on "Dubious Ratios"

Highly recommended reading: Vernon Booth, *Communicating in Science: Writing a scientific paper and speaking at scientific meetings*, 2nd edition (Cambridge, UK, Cambridge University Press, 1993).

Avoid ambiguous ratios

"three times more than" =
"four times as much as"

A hasty reader may interpret "times more than" to mean "times as many as"—
avoid this ambiguity!

The footprint of our device is ***one-fourth smaller*** because of our integrated heating and cooling system.

The results are ***10 times smaller*** than expected.

Forming the plural of a number written in numerals

- Plurals of single-digit numbers are formed by adding an apostrophe plus an *s*
  - "Binary code comprises 1's and 0's."
- Plurals of numbers >9 are formed by adding only the *s—no apostrophe*
  - Boeing 767s
  - expressed in 100s

Hyphenating numbers

Hyphenate numbers and units of measure *only* when they form a modifier that describes something else

The beam diameter is 25 µm.

The 25-µm beam provides excellent resolution.

Hyphenate numbers 21 through 99 when they are written as words

Forty-five days is the maximum the unit should be used without replacing the J17 filter.

More than you ever wanted to know about hyphenation:

http://people.physics.illinois.edu/Celia/Lectures/Dashes.pdf.

Fractions and —*fold* numbers

Mixed integers and fractions are always written in numerals

2½ years, 3¼ percent

Hyphenate fractions written as words

two-thirds, three-quarters, one-fourth as many

Hyphenate "fold" numbers when written in numerals (numbers >9)

20-fold
100-fold

Do not use hyphens when written as words

threefold
sevenfold

Writing ranges of numbers requires special rules

Use an en dash (–), not a hyphen (-)

1985–1993; pp. 11–18; 4.38 eV–4.54 eV

Include all numerals to ensure accuracy

1348–1458, not 1348–458

Include the units of measure for both quantities in the range

$400–$600; 10 µm × 20 µm

The electron-beam sculpting technique was used to fabricate superconducting nanowires having widths of <8 nm and lengths of 30 nm–50 nm.

For more information on the difference between hyphens and dashes in scientific writing, see http://people.physics.illinois.edu/Celia/Lectures/Dashes.pdf.

A dash means "to" or "through," *not* "between"

Use *to* or *through* instead of a dash with negative numbers to avoid confusion

with temperatures of –5–25°C
(is the second number "+25°C" or "−25°C"?)

Do not use *from* or *between* before a range; it's meaningless

from 1993 to 1997 *not* from 1993–1997
between 11 and 17 *not* between 11–17

Express adjacent numbers in a combination of words and numerals to avoid confusion

15 4-mg doses	fifteen 4-mg doses
30 20-mm samples	thirty 20-mm samples
18 6-hour runs	eighteen 6-hour runs

In these examples, the numbers that express quantities that have been counted (doses, samples, runs) are expressed in words

Never write two adjacent numbers in numerals; use a combination of numerals and words to avoid ambiguity and mistakes in interpretation.

Use correct descriptors

For quantities that are *measured*

less than, ***more*** than, ***amount*** of

"Less than 10 percent of the solution …"

For quantities that are *counted*

fewer than, ***greater*** than, ***number*** of

"Fewer than half of the samples …"

For *dimensions*

smaller than, ***larger*** than

Use "more than"—not "over"—to indicate the larger of two quantities

Keep the number and the unit or the thing it is describing on the same line of text

"Joseph Lykken attempted to lower the string scale to the vicinity of 10^{-17} cm, the TeV scale."

"In a 1995 paper, James Hurrell noted the marked similarity between the spatial patterns in surface air temperature trends during the previous 30 years and the winter-to-winter . . ."

To recap...

Use numerals for physical quantities that have been measured or calculated

Write out in words quantities <10 that have been *counted*

Observe standard conventions to ensure that your reader interprets numbers as you intended

Celia M. Elliott
Department of Physics • University of Illinois
cmelliot@illinois.edu

Recommended References:

***The AIP Style Manual*,** 4th ed.
http://www.aip.org/pubservs/style/4thed/toc.html

The Chicago Manual of Style, 15th ed. (University of Chicago Press, Chicago, 2003).

Scientific Style and Format: The CBE Manual for Authors, Editors, and Publishers, 6th ed. (Cambridge University Press, New York, 1994).