III. General style

A. GRAMMAR AND PUNCTUATION

Scientific writing is not exempt from the rules of good grammar, usage, and punctuation, although scientific conventions may modify some rules. Standard, authoritative references like Strunk and White's *The Elements of Style*[1] and *The Chicago Manual of Style*[2] can be invaluable, even to scientific writers with much experience.

Good punctuation is an aid to clarity. Wrongly placed punctuation may introduce ambiguity into a sentence, or even change the sense. Excessive punctuation is as undesirable as too little punctuation. A good working rule is that, if someone familiar with the subject has to reread a sentence in order to understand it, the sentence probably needs more punctuation—or rewriting. Keep in mind that the journals of the Institute and its Member Societies are read by many for whom English is not a native language. It should be impossible to misunderstand a properly written, properly punctuated, sentence.

The following rules for grammar and punctuation have special application to scientific writing.

1. Commas

(1) A comma goes before "and" or "or" in a series of three or more:

Sn, K, Na, and Li lines are invisible.

(2) Write dates as follows, without commas:

23 March 1989

(3) Separate superscript reference numbers by commas (but use a dash to indicate a range of numbers):

Recent studies of carrier-transport phenomena[6,7,9–11] have revealed...

(4) Do not represent decimal points by commas:

1.0 (not 1,0)

Place decimal points on the line:

1.0 (not 1·0)

(5) Numbers with four or fewer digits on either side of the decimal point are closed up and unpunctuated:

1200 4620.010 24.0032 cm

Numbers with five or more digits on either side of the decimal point are written with spaces instead of commas:

12 000 6 427 020 24.077 094 3 cm

Conflict with the European convention of using commas instead of decimal points is thereby avoided.

2. Numbers

(1) In general, use words for numbers up to ten:

one equation third

two-dimensional tenfold

Use numerals for numbers above ten:

11 equations 13th 11-fold

There are exceptions:

(a) For consistency, use numerals for all the numbers in lists containing numbers above *and* below ten:

"Groups of 8, 52, and 256 particles...."

(b) Numbers used as nouns are almost always numerals:

sample 2, counter 4, ratio of 3:5, values of 0 and 1 (or values of zero and unity).

(c) The dimensions of matrices should be given in numerals:

2×2 matrix

(d) The number before a unit of measure is always written in numerals:

6 V

(2) Decimal points should never be left "naked":

.03 (correct style is 0.03)

106. (correct style is 106 or 106.0, whichever is meant)

3. Quotation marks

(1) Place quotation marks after commas and periods, before colons and semicolons:

... the "whistlers,"... the "whistlers":

Use double quotation marks, as shown. Single quotation marks should be used only within material already enclosed in double quotation marks.

(2) New or special usage calls for quotation marks around the word or phrase in question—but only at its first appearance:

> The resonance is an extra tunneling channel, or "window," in the barrier. Tunneling electrons with total energy $E + E_r$ will always be able to see the window, but do not necessarily exit through it.

(3) Do not use quotation marks around standard nomenclature. Write

The nearest-neighbor distance taken from...

instead of

The "nearest-neighbor" distance...

(4) Do not use quotation marks to set off symbols from straight text. Write

Constants a and b are given by...

instead of

Constants "a" and "b"...

1. William Strunk, Jr. and E. B. White, *The Elements of Style*, 3rd ed. (Macmillan, New York, 1979).
2. *The Chicago Manual of Style*, 13th ed. (University of Chicago, Chicago, 1982).

4. Possessives

The following forms are correct:

When Smith and Green's theory[26] is applied...

When the Smith–Green[26] theory is applied...

5. Plurals

(1) To form the plural of numbers, add s:

Since the late 1950s much work has...

(2) For symbols add 's:

x's, K_x's.

The singular form may serve as a plural, however:

Values for various M_r...

and

Values for various M_r's...

are both permissible.

(3) For abbreviations add 's:

LCAO's.

6. Parentheses

(1) A sentence in parentheses inserted into another sentence does not end with a period inside the closing parenthesis:

This is clearly not the case (see Fig. 2), so that our initial conjecture would appear to be correct (compare, however, with results of Jones at nonzero temperatures).

An isolated sentence or two in parentheses has a period *inside* the closing parenthesis, and begins with a capital letter:

Equation (58) represents the effect of the magnetic anisotropy. (Note that T_c was defined for zero field and zero magnetic anisotropy. A generalized definition for nonzero field is implied.)

(2) Use square brackets for a parenthetical remark that already contains parentheses:

Recall that the susceptibility [see Eq. (A4)] receives a Curie term.

(3) Pairs of parentheses should surround the letters or numbers used to label the elements of enumerative lists:

The three remaining cases are (a) isotopic, (b) nearly elastic, and (c)polar optical scattering.

(4) Always use parentheses in citations of equations and parts of figures:

In Eq. (13) In Fig. 4(a)

Keep the parentheses intact in multiple citations:

In Eqs. (13), (14), and (16)
[not (13, 14, 16)]

In Eqs. (3a)–(3c)
[not (3a–c)]

In Figs. 4(a) and 4(b)

[not 4(a,b)]

In Figs. 2(a)–2(c)
[not 2(a–c)]

(5) Do not use parentheses in reference citations:

Scott *et al.*[2]
[not Scott *et al.*(2)]

In Ref. 5
[not Ref. (5)]

7. Spelling and hyphenation

Spelling and hyphenation in scientific writing are often controversial points of style. For nonscientific words *Webster's Third New International Dictionary*[3] is still the principal authority (*Webster's Ninth New Collegiate Dictionary* is a convenient abridgment). If a word has alternative spellings (for example, analog or analogue), choose the preferred form (analog) given in Appendix B. Recommended spellings for scientific words not found in standard dictionaries (for example, bandwidth) and correct spellings of words frequently misspelled (for example, parametrize) are also listed in Appendix B.

Some general guidelines for spelling follow.

(1) The tendency in scientific spelling is to avoid the hyphen when it does not serve a useful purpose. Words that formerly were hyphenated have now in considerable numbers become either one word or two. Thus, compound nouns such as

buildup	cutoff	output
crossover	knockout	setup

are usually spelled as one word, and nouns such as

t channel	α particle	p type
δ function	x ray	s wave

are spelled as two words. For exceptions, see Appendix B.

(2) Words with prefixes and suffixes are usually "closed up" (spelled without hyphens):

multivalent nonradioactive stepwise

There are important exceptions, however:

(a) If closing up would produce a double letter, hyphenate instead: non-negative, semi-infinite. For particular exceptions to this exception (for example, unnecessary, coordinate) see Appendix B.

(b) If the prefix or suffix is added to a proper noun, symbol, or numeral, hyphenate: non-Fermi, pseudo-P, di-MeB, 12-fold.

(c) Italic-letter chemical prefixes and suffixes are hyphenated: *cis*-dimethylethylene, dimethylnitrosamine-d_6. Number prefixes are also hyphenated: 1,2-dimethylbutylene.

3. *Webster's Third New International Dictionary*, unabridged, 3rd ed. (G. & C. Merriam, Springfield, MA, 1986), and *Webster's Ninth New Collegiate Dictionary* (G. & C. Merriam, Springfield, MA, 1985).

(d) If the prefix or suffix is added to two or more words, hyphenate them all: non-time-independent, quasi-free-electron, free-electron-like.

(e) If closing up would change the meaning, hyphenate: un-ionized, re-solved.

(3) "Self" words, "free" words, and "half" words are usually hyphenated:

self-consistent	half-width
divergence-free	half-life

(4) Modifiers made up of two or more words are usually hyphenated:

Bridgman-grown sample	x-ray analysis
thin-film results	6-keV data

When such hyphens forestall ambiguity, they are essential:

In contrast to the many-gauss dipolar lines...
Given the wrong-signature points...

But omit the hyphen (i) when the first word of the modifier is an adverb ending in -ly (rapidly increasing attenuation), or (ii) when the modifier is a predicate adjective ("The samples were Bridgman grown...").

(5) Do not use British spellings. Write, for example,

analyze (not analyse)	liter (not litre)
center (not centre)	meter (not metre)
color (not colour)	program (not programme)

Proper names are an exception: International Centre for Theoretical Physics.

8. Mathematical English

(1) Punctuate all equations, in running text and in display, according to their function in the sentence. Compare

(a) If $x = 1$, the Regge-pole model is...

with

(b) If $x = 1$ is taken to be a limiting condition...

In case (a) the equals sign of the equation acts as the verb of a subordinate clause ("If x equals 1, the..."). In case (b) the same equation acts as a noun.

(2) If a subordinate clause ends with a symbol or number, the ensuing main clause should begin with a word:

If $a = b$, then c holds too.

is more readable than

If $a = b$, c holds too.

(3) Avoid starting a sentence with a symbol or number, especially when the preceding sentence ends with a symbol or number. For example, change

$\rho b(\omega)$ is the density of states in branch b. c_b, the coupling constant of Eq. (1), can be shown to be proportional to q_2, and...

to

Here $\rho b(\omega)$ is the density of states in branch b. The coupling constant c_b of Eq. (1) can be shown...

(4) Do not place commas or parentheses around a symbol or expression if it immediately follows the noun that defines it:

The relaxation time T_i can...

The local approximation $\epsilon' = 2t + \omega_p u^2$ gave values for...

But add commas or parentheses if another phrase intervenes:

The relaxation time with no magnetic field, T_0, and with a magnetic field, T_h, can...

The local approximation determined by Watt ($\epsilon' = 2t + \omega_p u^2$) gave ...

(5) Nonrestrictive clauses are introduced by "which" and set off by commas:

The $K = 0$ component, which does not influence the band shape, gives rise to...

Without commas, this sentence could be misread to mean that there is more than one $K = 0$ component, one of which does not influence the band shape.

Restrictive clauses are usually introduced by "that" and are not set off by commas:

The data that we have accumulated can be used for a determination of...

(6) Dangling participles are always awkward and sometimes misleading. A clumsy sentence such as

Substituting Eq. (5) in Eq. (6), the thermal conductivity becomes $\frac{1}{3}kNVL$.

is easily improved:

Substituting Eq. (5) in Eq. (6), we obtain $\frac{1}{3}kNVL$ for the thermal conductivity.

or:

Substituting Eq. (5) in Eq. (6) gives $\frac{1}{3}kNVL$ for the thermal conductivity.

9. "I," "we," and impersonal constructions

(1) The old taboo against using the first person in formal prose has long been deplored by the best authorities and ignored by some of the best writers. "We" may be used naturally by two or more authors in referring to themselves; "we" may also be used to refer to a single author and the author's associates. A single author should also use "we" in the common construction that politely includes the reader: "We have already seen... ." But never use "we" as a mere substitute for "I," as in, for example, "In our opinion...," which attempts modesty and achieves the reverse; either write "my" or resort to a genuinely impersonal construction.

(2) The passive is often the most natural way to give prominence to the essential facts:

Air was admitted to the chamber.

(Who cares who turned the valve?) But avoid the passive if it makes the syntax inelegant or obscure. A long sentence with the structure

The values of ... have been calculated.

is clumsy and anticlimactic; begin instead with

I [We] have calculated...

(3) "The author(s)" may be used as a substitute for "I [we]," but use another construction if you have mentioned any other authors very recently, or write "the present author(s)."

(4) Special standards for usage apply in two sections of a paper: (i) Since the abstract may appear in abstract journals in the company of abstracts by many different authors, avoid the use of "I" or "we" in the abstract; use "the author(s)" or passives instead, if that can be done without sacrificing clarity and brevity. (ii) Even those who prefer impersonal language in the main text may well switch to "I" or "we" in the acknowledgments, which are, by nature, personal.

10. Capitalization

(1) The preferred style is to capitalize adjectives and nouns formed from proper names:

Gaussian Hamiltonian Ohmic

But there are four kinds of name-derived nouns that are always lower case:

(i) units of measure (gauss, amperes),
(ii) particles (fermion, boson),
(iii) elements (einsteinium), and
(iv) minerals (scheelite, fosterite).

(2) Lower-case symbols and abbreviations are never capitalized in titles or headings or at the beginning of a sentence. It is better, however, to begin a sentence with a word. Change

ac Stark effects in the multiphoton ionization of atomic sodium were studied by Keynes *et al.* for...

to

Keynes *et al.* studied ac Stark effects...

(3) Single words or phrases introduced by a colon never begin with a capital letter:

We obtained values for two parameters: the quantum cyclotron radius and the Debye shielding radius.

If a colon introduces a complete sentence, the first word may be—but need not be—capitalized:

We are led to the following conclusion: The fast electron mode represents an unloading of excess excitons formed during excitation.

or

We are led to the following conclusion: the fast electron mode...

But if a colon introduces more than one sentence, always capitalize the first word:

Our experience with diamond suggests several conclusions bearing on future XPS studies: First, surface contamination can contribute substantially to the observed spectra. Second, available calculations of the density of states within a valence band are not directly useful for qualitative results. Third,...

(4) Do not capitalize

column 4	curve B	sample 1
counter 12	model 4A	type 4A

On the other hand, the prominence gained by capitalization befits

Appendix A	Lemma 2	Table 1
Corollary 1	Paper H	Theorem 1

Capitalize only the name in

Avogadro's number	Debye temperature
Bohr radius	Ohm's law

Note the following particular cases:

Fermi's "golden rule"
general theory of relativity
second law of thermodynamics

(5) The words Addendum, Comment, Communication, Letter, and Note are capitalized only when they denote a specific section of a journal, as opposed to, say, someone's informal remark or private letter; the words article, paper, and report are never capitalized.

(6) Protected trade names must be capitalized: Nichrome, Plexiglas.

(7) Small capitals are used for computer programs (ABACUS, QUAD) and for ionization states in atomic spectroscopy (Fe III). Note the difference between Fe III and Fe(III) and between He I and He I.

Indicate small capitals with a double underline in black pencil.

11. Abbreviations

(1) The abbreviation for a single word is usually a clipped form of the word, lower case, and unpunctuated:

av for average const for constant

The abbreviation for a phrase is usually an acronym, capitalized, and unpunctuated:

MO for molecular orbital
BCS for Bardeen–Cooper–Schrieffer

See Appendix D for particular exceptions.

(2) Abbreviations invented by the author or not widely known outside the author's specialty (see Appendix D) should be defined the first time they occur in manuscript, and should be used sparingly:

Two-photon resonant (TPR) third-harmonic generation has been reported in cesium, thallium, and stron-

tium. In this paper we examine the special problems associated with TPR third-harmonic generation in metal vapors.

[14]Robert S. Cantor and Peter M. McIlroy, J. Chem. Phys. **90**, 4423–4430(1989), referred to as CM.

In long papers, such abbreviations should be redefined occasionally. An abbreviation introduced (and defined) in the abstract or in a figure caption or table should be defined again when it first appears in the body of the paper. This practice protects readers interested only in the text of the paper and readers who scan only the abstract, figures, and tables.

(3) Do not use abbreviations as mathematical variables. Such abbreviations as RRR for residual resistivity ratio or KE for kinetic energy may be used in text; but if they enter into mathematical expressions, they are almost as awkward as full words, and should be replaced with conventional symbols such as r_R or E_k.

(4) Use the standard abbreviations Eq., Fig., Ref., and Sec. or their plural forms before numbers:

In Eq. (3)	In Refs. 6–8
In Figs. 4 and 5	In Sec. II

But use the whole word even before a number if the word begins a sentence:

Equation (3) thus represents...

(5) For standard journal title abbreviations, see Appendix G.

12. Symbols for nuclides

Journals of AIP and its Member Societies follow the recommendations of the Symbols, Units, and Nomenclature (S.U.N.) Commission of the International Union of Pure and Applied Physics on the symbols to be used for nuclides and their states. The mass number is shown as an anterior superscript:

^{14}N

A posterior superscript can indicate either a state of ionization:

Ca^{2+}

or an excited state:

$^{110}Ag^{m}$, $^{14}N^{*}$

A posterior subscript is used to indicate the number of atoms in a molecule:

$^{14}N_2$.

B. SYMBOLS AND UNITS

A *physical quantity* is the product of a *numerical value* (a pure number) and a unit. Symbols for physical quantities are printed in italics, while symbols for units are printed in roman type.

Organizations such as the International Organization for Standardization (ISO) and the International Union for Pure and Applied Physics (IUPAP) have drawn up lists of recommended symbols for commonly encountered physical quantities.[4,5] Authors are encouraged to consult these sources and to use recommended symbols in their papers unless there are special reasons to deviate.

In the interests of good communication, authors should employ units that are accepted for use in the International System of Units (*Système Internationale*, SI). The SI includes seven *base units*, several *derived units* with special names, and certain other acceptable units. Table IV shows the base units, the derived units, and other acceptable units and their symbols.

To ensure uniformity in the use of the SI unit symbols, ISO and other international bodies give certain recommendations.

The product of two or more units may be indicated in either of the following ways:

$N \cdot m$ *or* $N\ m$

A solidus (an oblique stroke, /), a horizontal line, or negative exponents may be used to express a derived unit formed from two others by division:

m/s, $\frac{m}{s}$, or $m \cdot s^{-1}$

The solidus must not be repeated on the same line unless ambiguity is avoided by parentheses. In complicated cases negative exponents or parentheses should be used:

m/s^2 *or* $m \cdot s^{-2}$ *but not* $m/s/s$

$m \cdot kg/s^3 \cdot A$

or

$m \cdot kg \cdot s^{-3} \cdot A^{-1}$

but not

$m \cdot kg/s^3/A$

Compound prefixes, that is, prefixes formed by the juxtaposition of two or more SI prefixes, are not to be used.

For example,

1 nm *but not* 1 mμm

A prefix should never be used alone.

For example,

$10^6/m^3$ *but not* M/m^3

Names and symbols should not be mixed in a unit expression.

For example,

mol/L *or* mole/liter

but not

mol/liter *or* mole/L

A complete list of units of measure with their symbols (or abbreviations) is given in Appendix C.

4. *Units of Measurement*, ISO Standards Handbook 2 (International Organization for Standardization, Geneva, Switzerland, 1982).
5. E. Richard Cohen and Pierre Giacomo, *Symbols, Units, Nomenclature and Fundamental Constants in Physics* [International Union of Pure and Applied Physics, Document IUPAP-25 (SUNAMCO 87-1), 1987].

TABLE IV. SI base units, derived units, and other acceptable units and their symbols.

SI base units.

Quantity	SI unit	
	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

SI derived units with special names.

Quantity	SI unit			
	Name	Symbol	Expression in terms of other units	Expression in terms of SI base units
frequency	hertz	Hz		s^{-1}
force	newton	N		$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C		$s \cdot A$
electric potential, potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Celsius temperature	degree Celsius	°C		K
luminous flux	lumen	lm		$cd \cdot sr$
illuminance	lux	lx	lm/m^2	$m^{-2} \cdot cd \cdot sr$

TABLE IV (*continued*).

SI derived units with special names admitted for reasons of safeguarding human health.

	SI unit			
Quantity	Name	Symbol	Expression in terms of other units	Expression in terms of SI base units
activity (of a radionuclide)	becquerel	Bq		s^{-1}
absorbed dose, specific energy imparted, kerma, absorbed dose index	gray	Gy	J/kg	$m^2 \cdot s^{-2}$
dose equivalent, dose equivalent index	sievert	Sv	J/kg	$m^2 \cdot s^{-2}$

SI supplementary units.

	SI unit	
Quantity	Name	Symbol
plane angle	radian	rad
solid angle	steradian	sr

Units in use with the International System.

Name	Symbol	Value in SI unit
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3 600 s
day	d	1 d = 24 h = 86 400 s
degree	°	$1° = (\pi/180)$ rad
minute	′	$1' = (1/60)° = (\pi/10\,800)$ rad
second	″	$1'' = (1/60)' = (\pi/648\,000)$ rad
liter	l, L	$1\ L = 1\ dm^3 = 10^{-3}\ m^3$
metric ton	t	$1\ t = 10^3$ kg

TABLE IV (*continued*).

Units used with the International System whose values in SI units are obtained experimentally.

Name	Symbol	Definition
electronvolt	eV	(a)
unified atomic mass unit	u	(b)

[a] The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 volt in vacuum; 1 eV = $1.602\,19 \times 10^{-19}$ J approximately.

[b] The unified atomic mass unit is equal to (1/12) of the mass of an atom of the nuclide ^{12}C; 1 u = $1.660\,57 \times 10^{-27}$ kg approximately.

Units sanctioned for use with the International System.

Name	Symbol	Value in SI unit
nautical mile		1 nautical mile = 1 852 m
knot	kn	1 nautical mile per hour = (1852/3600) m/s
angström	Å	1 Å = 0.1 nm = 10^{-10} m
are	a	1 a = 1 dam^2 = 10^2 m^2
hectare	ha	1 ha = 1 hm^2 = 10^4 m^2
barn	b	1 b = 100 fm^2 = 10^{-28} m^2
bar	bar	1 bar = 0.1 MPa = 10^5 Pa
gal	Gal	1 Gal = 1 cm/s^2 = 10^{-2} m/s^2
curie	Ci	1 Ci = 3.7×10^{10} Bq
roentgen	R	1 R = 2.58×10^{-4} C/kg
rad	rad	1 rad = 1 cGy = 10^{-2} Gy
rem	rem	1 rem = 1 cSv = 10^{-2} Sv

SI prefixes.

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{18}	exa	E	10^{-1}	deci	d
10^{15}	peta	P	10^{-2}	centi	c
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	μ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{2}	hecto	h	10^{-15}	femto	f
10^{1}	deka	da	10^{-18}	atto	a