Guide for Metric Practice

Internationally recognized conventions have been established for standard usage of SI units.

Robert A. Nelson

The modernized metric system is known as the Système International d’Unités (International System of Units), with the international abbreviation SI. It is founded on seven base units, listed in table 1, that by convention are regarded as dimensionally independent. All other units are derived units, formed coherently by multiplying and dividing units within the system without numerical factors. Examples of derived units, including some with special names, are listed in table 2. The expression of multiples and submultiples of SI units is facilitated through the use of the prefixes listed in table 3.

SI obtains its international authority from the Meter Convention, signed in Paris by the delegates of 17 countries, including the United States, on 20 May 1875, and amended in 1921. The treaty established the Conférence Générale des Poids et Mesures (General Conference on Weights and Measures) as the formal diplomatic body responsible for ratification of new proposals related to metric units. The scientific decisions are made by the Comité International des Poids et Mesures (International Committee for Weights and Measures). It is assisted by the advice of 10 Consultative Committees specializing in particular areas of metrology. The activities of the national standards laboratories are coordinated by the Bureau International des Poids et Mesures (International Bureau of Weights and Measures), which has its headquarters in Sèvres, France, and operates under the supervision of the CIPM. The SI was established by the 11th CGPM in 1960, when the metric unit definitions, symbols, and terminology were extensively revised and simplified. Today there are 51 member states of the Meter Convention and 16 associates of the General Conference.

The BIPM, with the guidance of the Consultative Committee for Units and approval of the CIPM, periodically publishes a document2 that summarizes the historical decisions of the CGPM and the CIPM and gives some conventions for metric practice. In addition, Technical Committee 12 of the International Organization for Standardization has prepared recommendations concerning the practical use of the SI.3 Some other recommendations have been given by the Commission for Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants of the International Union of Pure and Applied Physics.4 The National Institute of Standards and Technology (NIST) has published a practical guide for the use of the SI.5 The Institute of Electrical and Electronics Engineers (IEEE) and the American Society for Testing and Materials (ASTM) have jointly prepared a metric practice manual6 that has been recognized by the American National Standards Institute (ANSI). The Secretary of Commerce, through NIST, has also issued recommendations for US metric practice,7 as provided under the Metric Conversion Act of 1975 and the Omnibus Trade and Competitiveness Act of 1988. Additional information is available on the Internet at the BIPM8 and NIST9 Web sites.

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Table 1. SI base units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Name</th>
<th>Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td>meter</td>
<td>m</td>
<td>m/m²=1</td>
</tr>
<tr>
<td>time</td>
<td>second</td>
<td>s</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>kilogram</td>
<td>kg</td>
<td>m³/kg</td>
</tr>
<tr>
<td>electric current</td>
<td>ampere</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>thermodynamic temperature</td>
<td>kelvin</td>
<td>K</td>
<td></td>
</tr>
<tr>
<td>amount of substance</td>
<td>mole</td>
<td>mol</td>
<td></td>
</tr>
<tr>
<td>luminous intensity</td>
<td>candela</td>
<td>cd</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Examples of SI derived units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Special name</th>
<th>Unit Symbol</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>plane angle</td>
<td>radian</td>
<td>rad</td>
<td>m²/m²=1</td>
</tr>
<tr>
<td>solid angle</td>
<td>steradian</td>
<td>sr</td>
<td>m²/m²</td>
</tr>
<tr>
<td>speed, velocity</td>
<td>hertz</td>
<td>Hz</td>
<td>m/s</td>
</tr>
<tr>
<td>angular acceleration</td>
<td>rad/s</td>
<td>rad/s</td>
<td>m/s²</td>
</tr>
<tr>
<td>angular acceleration frequency</td>
<td>rad/s²</td>
<td>rad/s²</td>
<td>s⁻¹</td>
</tr>
<tr>
<td>force</td>
<td>newton</td>
<td>N</td>
<td>kg·m/s²</td>
</tr>
<tr>
<td>pressure, stress, work</td>
<td>pascal</td>
<td>Pa</td>
<td>N/m²</td>
</tr>
<tr>
<td>energy, heat</td>
<td>joule</td>
<td>J</td>
<td>N·m</td>
</tr>
<tr>
<td>impulse, momentum</td>
<td>watt</td>
<td>W</td>
<td>V·s</td>
</tr>
<tr>
<td>power</td>
<td>volt</td>
<td>V</td>
<td>J/C, W/A</td>
</tr>
<tr>
<td>electric charge</td>
<td>coulomb</td>
<td>C</td>
<td>A·s</td>
</tr>
<tr>
<td>electric potential, emf</td>
<td>ohm</td>
<td>Ω</td>
<td>W/A</td>
</tr>
<tr>
<td>resistance</td>
<td>siemens</td>
<td>S</td>
<td>A/V</td>
</tr>
<tr>
<td>conductance</td>
<td>weber</td>
<td>Wb</td>
<td>V·s</td>
</tr>
<tr>
<td>magnetic flux</td>
<td>henry</td>
<td>H</td>
<td>Wb/A</td>
</tr>
<tr>
<td>inductance</td>
<td>farad</td>
<td>F</td>
<td>Wb/C</td>
</tr>
<tr>
<td>capacitance</td>
<td>farad</td>
<td>F</td>
<td>Wb/N/C</td>
</tr>
<tr>
<td>magnetic flux density</td>
<td>tesla</td>
<td>T</td>
<td>Wb/m³, N/A-m</td>
</tr>
<tr>
<td>electric displacement</td>
<td>volt</td>
<td>V</td>
<td>J/cm²</td>
</tr>
<tr>
<td>magnetic field strength</td>
<td>ampere</td>
<td>A/m</td>
<td>J/cm²</td>
</tr>
<tr>
<td>magnetic field density</td>
<td>weber</td>
<td>Wb</td>
<td>V·s</td>
</tr>
<tr>
<td>angular velocity</td>
<td>rad/ s</td>
<td>rad/s</td>
<td>A/m²</td>
</tr>
<tr>
<td>speed, velocity</td>
<td>m/s</td>
<td>m/s</td>
<td>m/s²</td>
</tr>
<tr>
<td>solid angle</td>
<td>steradian</td>
<td>sr</td>
<td>m²/m²</td>
</tr>
<tr>
<td>angular acceleration</td>
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<td>s⁻¹</td>
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<td>second</td>
<td>s</td>
<td>s</td>
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<tr>
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<td>hertz</td>
<td>Hz</td>
<td>s⁻¹</td>
</tr>
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<tr>
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<td>Hz</td>
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</tr>
<tr>
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<td>m²/m³</td>
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</tr>
<tr>
<td>work, energy</td>
<td>joule</td>
<td>J</td>
<td>N·m</td>
</tr>
<tr>
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<td>rad/ s</td>
<td>rad/s</td>
<td>m/s²</td>
</tr>
<tr>
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<td>watt</td>
<td>W</td>
<td>V·s</td>
</tr>
<tr>
<td>power</td>
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<td>V</td>
<td>J/C, W/A</td>
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<td>rad/s</td>
<td>A/m²</td>
</tr>
<tr>
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<td>m/s</td>
<td>m/s²</td>
</tr>
<tr>
<td>acceleration</td>
<td>m/s²</td>
<td>m²/s²</td>
<td>m²/m³</td>
</tr>
</tbody>
</table>

Style conventions

Letter symbols include quantity symbols and unit symbols. Symbols for physical quantities are set in italic (sloping) type, while symbols for units are set in roman (upright) type (for example, \( F = 15 \, N \)). A unit symbol is a universal mathematical entity. It is not an abbreviation and is not followed by a period (for example, the symbol for second is \( s \), not sec or s.). Symbols for units with proper names have the first letter capitalized—otherwise unit symbols are lower case—but the unit names themselves are not capitalized (for example, tesla, \( T \); meter, \( m \)). In contrast to unit symbols, the spelling and grammar for unit names have the first letter capitalized—otherwise unit symbols are lower case—but the unit names themselves are not capitalized (for example, kilogram and ampere are used in English, while kilogramme and ampere are used in French, but kg and A are the universal SI symbols). Plurals of unit names are formed according to the usual rules of grammar (for example, kilopascals, henries) with the exceptions lux, hertz, and siemens, which are irregular.³ Unit symbols are not pluralized (for example, 3 kg, not 3 kgs).

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http://physicstoday.org/guide/metric.pdf
The word “degree” and its symbol, °, are omitted from the unit of thermodynamic temperature $T$ (that is, one uses kelvin or $K$, not degree Kelvin or °K). However, they are retained in the unit of Celsius temperature $t$, defined as $t = T - T_0$, where $T_0 = 273.15 \, K$ exactly (that is, one uses degree Celsius or °C).

Symbols for prefixes representing $10^n$ or greater are capitalized; all others are lower case. There is no space between the prefix and the unit. Compound prefixes are to be avoided (for example, pF, not $\mu\mu F$). An exponent applies to the whole unit including its prefix (for example, cm$^3 = 10^{-6} \, m^3$). When a unit multiple or submultiple is written out in full, the prefix should be written in full, beginning with a lowercase letter (for example, mega- or μ). The kilogram is the only base unit whose name, for historical reasons, contains a prefix; names of multiples and submultiples of the kilogram are retained in the unit of Celsius temperature $t$, defined as $t = T - T_0$, where $T_0 = 273.15 \, K$ exactly (that is, one uses degree Celsius or °C).

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### Table 3. SI prefixes

<table>
<thead>
<tr>
<th>Factor</th>
<th>Prefix</th>
<th>Symbol</th>
<th>Factor</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^24</td>
<td>yotta</td>
<td>Y</td>
<td>10^{-4}</td>
<td>deci</td>
<td>d</td>
</tr>
<tr>
<td>10^18</td>
<td>zetta</td>
<td>Z</td>
<td>10^{+3}</td>
<td>centi</td>
<td>c</td>
</tr>
<tr>
<td>10^12</td>
<td>exa</td>
<td>E</td>
<td>10^{-6}</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>10^6</td>
<td>peta</td>
<td>P</td>
<td>10^{-9}</td>
<td>micro</td>
<td>μ</td>
</tr>
<tr>
<td>10^3</td>
<td>tera</td>
<td>T</td>
<td>10^{-12}</td>
<td>nano</td>
<td>n</td>
</tr>
<tr>
<td>10^2</td>
<td>giga</td>
<td>G</td>
<td>10^{-15}</td>
<td>pico</td>
<td>p</td>
</tr>
<tr>
<td>10^1</td>
<td>mega</td>
<td>M</td>
<td>10^{-18}</td>
<td>femto</td>
<td>f</td>
</tr>
<tr>
<td>10^{-1}</td>
<td>kilo</td>
<td>k</td>
<td>10^{-21}</td>
<td>atto</td>
<td>a</td>
</tr>
<tr>
<td>10^{-2}</td>
<td>hecto</td>
<td>h</td>
<td>10^{-24}</td>
<td>zepto</td>
<td>z</td>
</tr>
<tr>
<td>10^{-3}</td>
<td>deka</td>
<td>da</td>
<td>10^{-27}</td>
<td>yocto</td>
<td>y</td>
</tr>
</tbody>
</table>

### Table 4. Units accepted for use with the SI

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Name</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>minute</td>
<td>min</td>
<td>1 min=60 s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hour</td>
<td>h</td>
<td>1 h=60 min=3600 s</td>
<td></td>
</tr>
<tr>
<td></td>
<td>day</td>
<td>d</td>
<td>1 d=24 h=86 400 s</td>
<td></td>
</tr>
<tr>
<td>plane angle</td>
<td>degree</td>
<td>°</td>
<td>1°=π/(180) rad</td>
<td></td>
</tr>
<tr>
<td></td>
<td>minute</td>
<td>'</td>
<td>1'=1/(60)=π/(10 800) rad</td>
<td></td>
</tr>
<tr>
<td></td>
<td>second</td>
<td>&quot;</td>
<td>1&quot;=1/(60)=π/(648 000) rad</td>
<td></td>
</tr>
<tr>
<td>volume</td>
<td>liter</td>
<td>L</td>
<td>1 L=1 dm=10⁻³ m³</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>metric ton</td>
<td>t</td>
<td>1 t=1000 kg</td>
<td></td>
</tr>
<tr>
<td>attenuation, level</td>
<td>neper</td>
<td>Np</td>
<td>1 Np=1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bel</td>
<td>B</td>
<td>1 B=½ ln 10 Np</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5. Non-SI units accepted for use with the SI whose values in SI units are obtained experimentally

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Name</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>energy</td>
<td>electron volt*</td>
<td>eV</td>
<td>$1.602 176 462(63) \times 10^{-19}$ J</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td>unified atomic mass unit*</td>
<td>u</td>
<td>$1.660 384 73(13) \times 10^{-27}$ kg</td>
<td></td>
</tr>
<tr>
<td>distance</td>
<td>astronomical unit**</td>
<td>au</td>
<td>$1.495 970 769(10) \times 10^{3}$ m</td>
<td></td>
</tr>
</tbody>
</table>


### Non-SI units

An important function of the SI is to discourage the proliferation of unnecessary units. However, there are three categories of units outside the SI that are recognized. “Units accepted for use with the SI” are listed in Table 4. As exceptions to the rules, the symbols °, ’ and “ for plane angle are not preceded by a space, and the symbol for liter, L, is capitalized to avoid confusion with the number 1. “Non-SI units accepted for use with the SI whose values in SI units are obtained experimentally” are given in Table 5. The third category, “other non-SI units currently accepted for use with the SI,” consists of the nautical mile, knot, are, hectare, bar, angstrom, and barn.

### References