A Physical Quantities, Units, and Constants

Physical quantities appear in nearly every aspect of our daily lives. An athlete checks her wristwatch to measure the physical quantity of time elapsed during a race. A doctor employs a thermometer to measure the physical quantity of temperature inside a patient's mouth. A merchant uses a scale to measure the physical quantity of mass for a piece of cheese. A physical quantity is not just a numerical value but needs to include another essential attribute: a unit. Additionally, physical quantities can be scalars, vectors, matrices, and higher dimensional objects. With the inclusion of units, a physical quantity acquires additional behaviors during mathematical operations that a numerical value alone would not have. For example, a physical quantity with a given dimensionality can only be converted between units having the same dimensionality. Likewise, no physical quantities can be added or subtracted unless they have the same dimensionality. Similarly, the arguments of transcendental functions (i.e., $\sin[x]$, $\cos[x]$, $\ln[x]$, $\exp[x]$, …) must be dimensionless quantities.

An essential characteristic of physical quantities is that any given physical quantity can be derived from other physical quantities through physical laws. For example, the physical quantity of speed is calculated as a ratio of distance traveled to the time elapsed. The volume of a box is calculated as the product of three quantities of length: i.e., height, width, and depth. Any physical quantity can be related through physical laws to a smaller set of reference physical quantities. Joseph Fourier originally proposed this idea in his 1822 book *Theorie analytique de la Chaleur* (The Analytic Theory of heat). As the laws of physics become unified, it has been argued that this smaller set can be reduced to simply the Planck length and the speed of light. At the level of theory employed by most scientists and engineers, however, there is a practical agreement that seven physical quantities should serve as fundamental reference quantities from which all other physical quantities can be derived. These reference quantities are (1) length, (2) mass, (3) time, (4) electric current, and (5) thermodynamic temperature[1], (6) amount of substance, and (7) luminous intensity.

A.1 Dimensionality

In the International System of Units (SI), seven reference quantities are used to define seven dimensions whose symbols are given in Table A.1. The dimensionality of any physical quantity, q, can then be expressed in terms of these seven reference dimensions in the form of a dimensional product

$$\dim q = \mathsf{L}^\alpha \cdot \mathsf{M}^\beta \cdot \mathsf{T}^\gamma \cdot \mathsf{I}^\delta \cdot \Theta^\epsilon \cdot \mathsf{N}^\zeta \cdot \mathsf{J}^\eta, \tag{A.1}$$

where the lower case greek symbols represent integers called the dimensional exponents. The dimensionality of any physical quantity can be represented as a point in the space of dimensional

[1]Thermodynamic temperature is an absolute measure of temperature.

Reference Quantity	Dimension Symbol
length	L
mass	M
time	T
electric current	I
thermodynamic temperature	Θ
amount of substance	N
luminous intensity	J

Table A.1: Dimension symbols for the seven reference quantities.

exponents $(\alpha, \beta, \gamma, \delta, \epsilon, \zeta, \eta)$. Physical quantities with different meanings can have the same dimensionality. For example, the thermodynamic quantities *entropy* and *heat capacity* are different physical quantities having the same physical dimensions. Only physical quantities with the same dimensionality can be added. With the operation of multiplication, the physical dimensions form a mathematical group.

There also exists numerous dimensionless quantities of importance, such as *plane angle* which has dimensionality of L/L, or *solid angle* with a dimensionality of $\mathsf{L}^2/\mathsf{L}^2$. It is sometimes necessary to distinquish between these different types of dimensionless quantities. Representing dimensionless dimensionalities requires us to split each dimension exponent into the numerator and denominator exponents. Thus, we redefine our set of dimensionalities to incorporate numerator and denominator exponents,

$$\dim q = \left(\frac{\mathsf{L}^{\alpha_+}}{\mathsf{L}^{\alpha_-}}\right) \cdot \left(\frac{\mathsf{M}^{\beta_+}}{\mathsf{M}^{\beta_-}}\right) \cdot \left(\frac{\mathsf{T}^{\gamma_+}}{\mathsf{T}^{\gamma_-}}\right) \cdot \left(\frac{\mathsf{I}^{\delta_+}}{\mathsf{I}^{\delta_-}}\right) \cdot \left(\frac{\Theta^{\epsilon_+}}{\Theta^{\epsilon_-}}\right) \cdot \left(\frac{\mathsf{N}^{\zeta_+}}{\mathsf{N}^{\zeta_-}}\right) \cdot \left(\frac{\mathsf{J}^{\eta_+}}{\mathsf{J}^{\eta_-}}\right). \tag{A.2}$$

A list of accepted physical quantity names and their corresponding dimensionality symbols are given in Table A.7. When no accepted physical quantity name exists for a dimensionality, the symbol obtained from Eq. (A.2) can be used as the quantity name.

A.2 Unit

Inherent in measuring any physical quantity is a comparison to a previous measurement. What is most useful is the ratio of the new measurement to a previous measurement. For example, an ancient scientist might have used the cubit, an ancient unit of length, to measure the ratio of a large tree trunk's circumference to its diameter. Around 3000 BC in Egypt, a cubit was decreed to be the length of a forearm and hand. So, a scientist could make a string of 1 cubit in length using the distance from the back of their elbow to the tip of their middle finger and then use the string to measure the ratio

$$\frac{l_{\text{circumference}}}{l_{\text{diameter}}} \approx 3.14. \tag{A.3}$$

While another scientist with longer arms might have cut a longer string to be a cubit, the procedure for finding the ratio of a large tree trunk's circumference to its diameter will be the same, and the result is independent of the absolute length of the string used, i.e., independent of the units of length used.

Thus, we begin by representing a physical quantity, q, using the notation

$$q = \{q\} \cdot [q], \tag{A.4}$$

where $\{q\}$ is the numerical value and $[q]$ is the reference unit symbol, i.e., a non-numerical string of characters, usually an abbreviation for the name of the unit.

A.2.1 SI Units

A.2.1.1 Coherent SI Base Units:

The *coherent SI base (reference) units* form a set of seven units, described in Table A.2 and given by the symbols

$$[q]_{\text{CBU}} \in [Q]_{\text{CBU}} = \{\text{m}, \text{kg}, \text{s}, \text{A}, \text{K}, \text{mol}, \text{cd}\}\,. \tag{A.5}$$

A.2.1.2 SI Base Root Units:

A minor complication is that the coherent base unit for mass in SI Units is defined as the kilogram, not the gram. For this reason, we define the set of seven base root units,

$$[q]_{\text{BRU}} \in [Q]_{\text{BRU}} = \{\text{m}, \text{g}, \text{s}, \text{A}, \text{K}, \text{mol}, \text{cd}\}\,. \tag{A.6}$$

with names and symbols are shown in table A.3.

A.2.1.3 SI Base Units:

The set of *Coherent SI Base Units* only includes the seven SI base units given in Table A.2. The larger set of *SI Base Units* includes the Coherent SI Base Units, as well as all decimal multiples of the root units, created using the 20 prefix symbols given in Table A.4 with the root unit names and symbols given in Table A.3. These prefixed and unprefixed symbols form the set, $[Q]_{\text{BU}}$, of 147 SI base units,

$$[q]_{\text{BU}} \in [Q]_{\text{BU}} = \left\{x_L\text{m}, x_M\text{g}, x_T\text{s}, x_I\text{A}, x_\Theta\text{K}, x_N\text{mol}, x_J\text{cd}\right\}, \tag{A.7}$$

where $[Q]_{\text{CBU}} \subseteq [Q]_{\text{BU}}$, $[Q]_{\text{BRU}} \subseteq [Q]_{\text{BU}}$, and x_i indicates that the root unit symbol may be modified with one of the SI prefixes given in Table A.4.

A.2.1.4 Coherent Derived SI Units:

Coherent derived SI units is an infinite set, $[Q]_{\text{CDU}}$, defined as the products of powers of *coherent SI base units*,

$$[q]_{\text{CDU}} \in [Q]_{\text{CDU}} = \{\text{m}^\alpha \cdot \text{kg}^\beta \cdot \text{s}^\gamma \cdot \text{A}^\delta \cdot \text{K}^\epsilon \cdot \text{mol}^\zeta \cdot \text{cd}^\eta\}, \tag{A.8}$$

for all positive and negative integer values of the exponents. Here $[Q]_{\text{CBU}} \subseteq [Q]_{\text{CDU}}$.

	Coherent SI Base Unit		
Base Dimension	**Name**	**Plural Name**	**Symbol**
length	meter	meters	m
mass	kilogram	kilograms	kg
time	second	seconds	s
electric current	ampere	ampere	A
thermodynamic temperature	kelvin	kelvin	K
amount of substance	mole	moles	mol
luminous intensity	candela	candelas	cd

Table A.2: Coherent SI base units for the seven reference quantities.

	Base Root Unit		
Base Dimension	**Name**	**Plural Name**	**Symbol**
length	meter	meters	m
mass	gram	grams	g
time	second	seconds	s
electric current	ampere	ampere	A
thermodynamic temperature	kelvin	kelvin	K
amount of substance	mole	moles	mol
luminous intensity	candela	candelas	cd

Table A.3: Base root unit names and symbols for the seven reference quantities.

SI Prefix Name	x, SI Prefix Symbol	factor	SI Prefix Name	x, SI Prefix Symbol	factor
yotta	Y	10^{24}	yocto	y	10^{-24}
zetta	Z	10^{21}	zepto	z	10^{-21}
exa	E	10^{18}	atto	a	10^{-18}
peta	P	10^{15}	femto	f	10^{-15}
tera	T	10^{12}	pico	p	10^{-12}
giga	G	10^{9}	nano	n	10^{-9}
mega	M	10^{6}	micro	μ	10^{-6}
kilo	k	10^{3}	milli	m	10^{-3}
hecto	h	10^{2}	centi	c	10^{-2}
deca	da	10^{1}	deci	d	10^{-1}

Table A.4: SI prefixes used for the seven reference quantities.

A.2.1.5 Derived SI Root Units:

Derived SI root units are an infinite set, $[Q]_{\mathrm{DRU}}$, defined as the products of powers of *SI base root units*,

$$[q]_{\mathrm{DRU}} \in [Q]_{\mathrm{DRU}} = \{\mathrm{m}^{\alpha} \cdot \mathrm{g}^{\beta} \cdot \mathrm{s}^{\gamma} \cdot \mathrm{A}^{\delta} \cdot \mathrm{K}^{\epsilon} \cdot \mathrm{mol}^{\zeta} \cdot \mathrm{cd}^{\eta}\}, \tag{A.9}$$

for all positive and negative integer values of the exponents. Here $[Q]_{\mathrm{BRU}} \subseteq [Q]_{\mathrm{DRU}}$.

A.2.1.6 Derived SI Units:

Derived SI units are an infinite set, $[Q]_{\mathrm{DU}}$, defined as the products of powers of *SI base units*,

$$[q]_{\mathrm{DU}} \in [Q]_{\mathrm{DU}} = \left\{(x_L\mathrm{m})^{\alpha} \cdot (x_M\mathrm{g})^{\beta} \cdot (x_T\mathrm{s})^{\gamma} \cdot (x_I\mathrm{A})^{\delta} \cdot (x_\Theta\mathrm{K})^{\epsilon} \cdot (x_N\mathrm{mol})^{\zeta} \cdot (x_J\mathrm{cd})^{\eta}\right\}, \tag{A.10}$$

for all positive and negative integer values of the exponents. Here $[Q]_{\mathrm{CBU}} \subseteq [Q]_{\mathrm{CDU}} \subseteq [Q]_{\mathrm{DU}}$ and $[Q]_{\mathrm{BRU}} \subseteq [Q]_{\mathrm{DRU}} \subseteq [Q]_{\mathrm{DU}}$.

A.2.1.7 Derived SI Dimensionless Units:

There also exists dimensionless units, such as the radian, which has units of m/m, or the steradian with units of $\mathrm{m}^2/\mathrm{m}^2$. Representing such units requires us to split each dimension exponent into the numerator and denominator exponents. Thus, we redefine the infinite set of coherent derived SI units to incorporate the numerator and denominator exponents,

$$[q]_{\mathrm{CDU}} \in [Q]_{\mathrm{CDU}} = \left\{ \left[\frac{\mathrm{m}^{\alpha_+}}{\mathrm{m}^{\alpha_-}}\right] \cdot \left[\frac{\mathrm{kg}^{\beta_+}}{\mathrm{kg}^{\beta_-}}\right] \cdot \left[\frac{\mathrm{s}^{\gamma_+}}{\mathrm{s}^{\gamma_-}}\right] \cdot \left[\frac{\mathrm{A}^{\delta_+}}{\mathrm{A}^{\delta_-}}\right] \cdot \left[\frac{\mathrm{K}^{\epsilon_+}}{\mathrm{K}^{\epsilon_-}}\right] \cdot \left[\frac{\mathrm{mol}^{\zeta_+}}{\mathrm{mol}^{\zeta_-}}\right] \cdot \left[\frac{\mathrm{cd}^{\eta_+}}{\mathrm{cd}^{\eta_-}}\right] \right\}, \tag{A.11}$$

for all positive integer values of the exponent numerator and denominators. Using this approach, we represent dimensionless units with an exponent vector using the notation $(\alpha_+ - \alpha_-,\ \beta_+ - \beta_-,\ \gamma_+ - \gamma_-,\ \delta_+ - \delta_-,\ \epsilon_+ - \epsilon_-,\ \zeta_+ - \zeta_-,\ \eta_+ - \eta_-)$. Thus, the radian can be represented by the exponent vector $(1-1,\ 0-0,\ 0-0,\ 0-0,\ 0-0,\ 0-0,\ 0-0)$ and the steradian by $(2-2,\ 0-0,\ 0-0,\ 0-0,\ 0-0,\ 0-0,\ 0-0)$. Dimensionless quantities such as counts, are not derived SI units and can be represented with the exponent vector $(0,0,0,0,0,0,0)$.

Finally, we redefine the infinite set of derived SI units to incorporate numerator and denominator exponents,

$$[q]_{\mathrm{DU}} \in [Q]_{\mathrm{DU}} = \left\{ \left[\frac{(x_L^+\mathrm{m})^{\alpha_+}}{(x_L^-\mathrm{m})^{\alpha_-}}\right] \cdot \left[\frac{(x_M^+\mathrm{g})^{\beta_+}}{(x_M^-\mathrm{g})^{\beta_-}}\right] \cdot \left[\frac{(x_T^+\mathrm{s})^{\gamma_+}}{(x_T^-\mathrm{s})^{\gamma_-}}\right] \cdot \left[\frac{(x_I^+\mathrm{A})^{\delta_+}}{(x_I^-\mathrm{A})^{\delta_-}}\right] \cdot \left[\frac{(x_\Theta^+\mathrm{K})^{\epsilon_+}}{(x_\Theta^-\mathrm{K})^{\epsilon_-}}\right] \cdot \left[\frac{(x_N^+\mathrm{mol})^{\zeta_+}}{(x_N^-\mathrm{mol})^{\zeta_-}}\right] \cdot \left[\frac{(x_J^+\mathrm{cd})^{\eta_+}}{(x_J^-\mathrm{cd})^{\eta_-}}\right] \right\}, \tag{A.12}$$

for all positive integer values of the exponent numerator and denominators. The infinite set $[Q]_{\mathrm{DU}}$, as described by Eq. (A.12), is a complete set of units for all quantities in the physical sciences.

A.2.1.8 Equivalent Units

While all units in the set $[Q]_{\mathrm{DU}}$ have unique derived symbols and names, it should be noted that some are functionally equivalent. For example, a derived physical quantity such as speed in units of $[\mathrm{m} \cdot \mathrm{s}^{-1}]$ can be converted among any of the units below,

$$[\mathrm{m}\cdot\mathrm{s}^{-1}] \equiv [\mathrm{km}\cdot\mathrm{ks}^{-1}] \equiv [\mathrm{hm}\cdot\mathrm{hs}^{-1}] \equiv [\mathrm{dam}\cdot\mathrm{das}^{-1}] \equiv [\mathrm{dm}\cdot\mathrm{ds}^{-1}] \equiv [\mathrm{cm}\cdot\mathrm{cs}^{-1}] \equiv [\mathrm{nm}\cdot\mathrm{ns}^{-1}], \tag{A.13}$$

without modifying the numerical value of the quantity.

A.2.1.9 Special SI Units:

In the SI system, there is a set, $[Q]_{\mathrm{SU}}$, of 22 coherent derived units contained within the $[Q]_{\mathrm{CDU}}$ set that, for convenience, have their own special names and symbols. The 22 special names and symbols and their corresponding coherent derived units are given in table A.5. For example, the coherent derived SI unit: $\mathrm{m}\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}$, used for the derived quantity of force, is given the special name "newton" and replaced with the symbol "N".

A.2.1.10 Special SI Units with prefixes:

The 22 coherent derived units with special SI units have the additional possibility of being modified by SI prefixes to create a set, $[Q]_{x\mathrm{SU}}$, of 462 units. Some of the units in $[Q]_{x\mathrm{SU}}$, however, may not have an equivalent in the set of derived SI units, $[Q]_{\mathrm{DU}}$. That is, $[Q]_{\mathrm{DU}} - [Q]_{x\mathrm{SU}} \neq \emptyset$. For example, the Sievert is equivalent to the coherent derived unit $\mathrm{m}^2\cdot\mathrm{s}^{-2}$, and

$$[\mathrm{Sv}] = [\mathrm{m}^2\cdot\mathrm{s}^{-2}] \subseteq [Q]_{\mathrm{DU}}, \tag{A.14}$$

but the decisievert, [dSv], which is one-tenth of the coherent derived unit $\mathrm{m}^2\cdot\mathrm{s}^{-2}$, has no equivalent unit in the set $[Q]_{\mathrm{DU}}$. That is,

$$[\mathrm{dSv}] = 0.1[\mathrm{m}^2\cdot\mathrm{s}^{-2}] \nsubseteq [Q]_{\mathrm{DU}}. \tag{A.15}$$

On the other hand, the centiSievert, [cSv], which is one-hundredth of the coherent derived unit $\mathrm{m}^2\cdot\mathrm{s}^{-2}$, has an equivalent unit in the set $[Q]_{\mathrm{DU}}$,

$$[\mathrm{cSv}] = 0.01[\mathrm{m}^2\cdot\mathrm{s}^{-2}] = [\mathrm{dm}^2\cdot\mathrm{s}^{-2}] = [\mathrm{m}^2\cdot\mathrm{das}^{-2}] \subseteq [Q]_{\mathrm{DU}}. \tag{A.16}$$

A.2.1.11 Derived Units employing Special SI Units:

With the introduction of special SI symbols, there is the additional possibility of derived quantities with derived units employing a special SI unit. Generally, however, no more than one special SI symbol appears in such a derived unit symbol, and the special SI symbol often appears as a linear term in the numerator. For example, the derived quantity dynamic viscosity can use the derived unit $[\mathrm{Pa}\cdot\mathrm{s}]$ as well as $[\mathrm{m}^{-1}\cdot\mathrm{kg}\cdot\mathrm{s}^{-1}]$. The derived quantity of surface tension can use the derived unit $[\mathrm{N}\cdot\mathrm{m}^{-1}]$ as well as $[\mathrm{kg}\cdot\mathrm{s}^{-2}]$. Additional examples are given in Table A.6.

A.2.2 Non-SI Units:

Several units outside the International System of Units continue to be used in different science and engineering communities. While it is straightforward to include non-SI unit symbols in the same manner as special SI unit symbols, one must avoid symbol and name collisions, particularly as some non-SI unit symbols employ SI prefixes.

A.2.3 Physical constants

It is also possible to use symbols for physical constants as unit symbols, although one has to be careful to avoid symbol collisions. There are conflicts between unit symbols and commonly accepted

Derived Quantity	SI Special Unit Name	Plural Name	Symbol	Coherent Derived SI Symbol
plane angle	radian	radians	rad	(m/m)
solid angle	steradian	steradians	sr	$(\mathrm{m}^2/\mathrm{m}^2)$
frequency	hertz	hertz	Hz	s^{-1}
force	newton	newtons	N	$\mathrm{m}\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}$
pressure, stress	pascal	pascals	Pa	$\mathrm{m}^{-1}\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}$
energy, work, heat	joule	joules	J	$\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}$
power, radiant flux	watt	watts	W	$\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-1}$
electric charge	coulomb	coulombs	C	$\mathrm{s}\cdot\mathrm{A}$
electric potential difference	volt	volts	V	$\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-3}\cdot\mathrm{A}^{-1}$
capacitance	farad	farads	F	$\mathrm{m}^{-2}\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^4\cdot\mathrm{A}^2$
resistance	ohm	ohms	Ω	$\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-3}\cdot\mathrm{A}^{-2}$
electric conductance	siemens	siemens	S	$\mathrm{m}^{-2}\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^3\cdot\mathrm{A}^2$
magnetic flux	weber	webers	Wb	$\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}\cdot\mathrm{A}^{-1}$
magnetic flux density	tesla	tesla	T	$\mathrm{kg}\cdot\mathrm{s}^{-2}\cdot\mathrm{A}^{-1}$
inductance	henry	henry	H	$\mathrm{m}^2\cdot\mathrm{kg}\cdot\mathrm{s}^{-2}\cdot\mathrm{A}^{-2}$
Celsius Temperature	degree Celsius	degrees Celsius	°C	K
luminous flux	lumen	lumens	lm	$(\mathrm{m}^2/\mathrm{m}^2)\cdot\mathrm{cd}$
illuminance	lux	lux	lx	$\mathrm{m}^{-2}\cdot\mathrm{cd}$
radionuclide activity	becquerel	becquerel	Bq	s^{-1}
absorbed dose	gray	grays	Gy	$\mathrm{m}^2\cdot\mathrm{s}^{-2}$
dose equivalent	sievert	sieverts	Sv	$\mathrm{m}^2\cdot\mathrm{s}^{-2}$
catalytic activity	katal	katal	kat	$\mathrm{s}^{-1}\cdot\mathrm{mol}$

Table A.5: The 22 Coherent Derived SI Units with Special SI Names and Symbols.

Derived Quantity	Derived Symbol	Coherent Derived SI Symbol
dynamic viscosity	$\mathrm{Pa \cdot s}$	$\mathrm{m^{-1} \cdot kg \cdot s^{-1}}$
moment of force	$\mathrm{N \cdot m}$	$\mathrm{m^{2} \cdot kg \cdot s^{-2}}$
surface tension	N/m	$\mathrm{kg \cdot s^{-2}}$
angular velocity	rad/s	$\mathrm{m/(m \cdot s)}$
angular acceleration	$\mathrm{rad/s^2}$	$\mathrm{m/(m \cdot s^2)}$
heat flux density, irradiance	$\mathrm{W/m^2}$	$\mathrm{kg \cdot s^{-3}}$
heat capacity, entropy	J/K	$\mathrm{m^{2} \cdot kg \cdot s^{-2} \cdot K^{-1}}$
specific heat capacity, specific entropy	$\mathrm{J/(kg \cdot K)}$	$\mathrm{m^{2} \cdot s^{-2} \cdot K^{-1}}$
specific energy	J/kg	$\mathrm{m^{2} \cdot s^{-2}}$
thermal conductivity	$\mathrm{W/(m \cdot K)}$	$\mathrm{m \cdot kg \cdot s^{-3} \cdot K^{-1}}$
energy density	$\mathrm{J/m^3}$	$\mathrm{m^{-1} \cdot kg \cdot s^{-2}}$
electric field strength	V/m	$\mathrm{m \cdot kg \cdot s^{-3} \cdot A^{-1}}$
electric charge density	$\mathrm{C/m^3}$	$\mathrm{m^{-3} \cdot s \cdot A}$
surface charge density	$\mathrm{C/m^2}$	$\mathrm{m^{-2} \cdot s \cdot A}$
electric flux density, electric displacement	$\mathrm{C/m^2}$	$\mathrm{m^{-2} \cdot s \cdot A}$
permittivity	F/m	$\mathrm{m^{-3} \cdot kg^{-1} \cdot s^{4} \cdot A^{2}}$
permeability	H/m	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$
molar energy	J/mol	$\mathrm{m^{2} \cdot kg \cdot s^{-2} \cdot mol^{-1}}$
molar entropy, molar heat capacity	$\mathrm{J/(mol \cdot K)}$	$\mathrm{m^{2} \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}}$
exposure (x- and γ-rays)	C/kg	$\mathrm{kg^{-1} \cdot s \cdot A}$
absorbed dose rate	Gy/s	$\mathrm{m^{2} \cdot s^{-3}}$
radiant intensity	W/sr	$\mathrm{m^{4} \cdot m^{-2} \cdot kg \cdot s^{-3}}$
radiance	$\mathrm{W/(m^2 \cdot sr)}$	$\mathrm{m^{2} \cdot m^{-2} \cdot kg \cdot s^{-3}}$
catalytic activity concentration	$\mathrm{kat/m^3}$	$\mathrm{m^{-3} \cdot s^{-1} \cdot mol}$

Table A.6: Quantities with Derived Symbols using Special SI Symbols.

symbols for physical constants, e.g., the planck constant and hour (h), or the newton gravitational constant and gauss (G). Table 1 gives a list of suggested symbols for physical constants (giving priority to unit symbols) which avoid collision with accepted unit symbols.

Due of the symbol collision between the euler constant $e = 2.718281828459045\ldots$ *all string representations of numbers using scientific notation should use an upper case* `"E"`, e.g., `6.022140857E+23` instead of `6.022140857e+23`. Since the euler constant is dimensionless, the latter expression could mistakenly be interpreted as the valid equation: $6.022140857 \times e + 23 = 39.36987606000388\ldots$

Quantity	Dimensionality
absorbed dose	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{M} \cdot \mathsf{T}^2)$
absorbed dose rate	$\mathsf{L}^2/\mathsf{T}^3$
acceleration	L/T^2
action	$\mathsf{L}^2 \cdot \mathsf{M}/\mathsf{T}$
amount	N
amount concentration	N/L^3
amount of electricity	$\mathsf{T} \cdot \mathsf{I}$
amount ratio	N/N
angular acceleration	$\mathsf{L}/(\mathsf{L} \cdot \mathsf{T}^2)$
angular frequency	$\mathsf{L}/(\mathsf{L} \cdot \mathsf{T})$
angular momentum	$\mathsf{L}^2 \cdot \mathsf{M}/\mathsf{T}$
angular speed	$\mathsf{L}/(\mathsf{L} \cdot \mathsf{T})$
angular velocity	$\mathsf{L}/(\mathsf{L} \cdot \mathsf{T})$
area	L^2
area ratio	$\mathsf{L}^2/\mathsf{L}^2$
capacitance	$\mathsf{T}^4 \cdot \mathsf{I}^2/(\mathsf{L}^2 \cdot \mathsf{M})$
catalytic activity	N/T
catalytic activity concentration	$\mathsf{N}/(\mathsf{L}^3 \cdot \mathsf{T})$
catalytic activity content	$\mathsf{N}/(\mathsf{M} \cdot \mathsf{T})$
charge to amount ratio	$\mathsf{T} \cdot \mathsf{I}/\mathsf{N}$
charge to mass ratio	$\mathsf{T} \cdot \mathsf{I}/\mathsf{M}$
circulation	L^2/T
compressibility	$\mathsf{L} \cdot \mathsf{T}^2/\mathsf{M}$
current	I
current density	I/L^2
current ratio	I/I
density	M/L^3
diffusion coefficient	L^2/T
diffusion flux	$\mathsf{N}/(\mathsf{L}^2 \cdot \mathsf{T})$
dimensionless	1
distance per volume	L/L^3
dose equivalent	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{M} \cdot \mathsf{T}^2)$
dynamic viscosity	$\mathsf{M}/(\mathsf{L} \cdot \mathsf{T})$
elastic modulus	$\mathsf{M}/(\mathsf{L} \cdot \mathsf{T}^2)$
electric charge	$\mathsf{T} \cdot \mathsf{I}$
electric charge density	$\mathsf{T} \cdot \mathsf{I}/\mathsf{L}^3$
electric conductance	$\mathsf{T}^3 \cdot \mathsf{I}^2/(\mathsf{L}^2 \cdot \mathsf{M})$
electric conductivity	$\mathsf{T}^3 \cdot \mathsf{I}^2/(\mathsf{L}^3 \cdot \mathsf{M})$
electric dipole moment	$\mathsf{L} \cdot \mathsf{T} \cdot \mathsf{I}$
electric displacement	$\mathsf{T} \cdot \mathsf{I}/\mathsf{L}^2$
electric field gradient	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{L}^2 \cdot \mathsf{T}^3 \cdot \mathsf{I})$
electric field strength	$\mathsf{L} \cdot \mathsf{M}/(\mathsf{T}^3 \cdot \mathsf{I})$

Quantity	Dimensionality
electric flux	$L^3 \cdot M/(T \cdot I)$
electric flux density	$T \cdot I/L^2$
electric polarizability	$L^2 \cdot T^4 \cdot I^2/(L^2 \cdot M)$
electric potential difference	$L^2 \cdot M/(T^3 \cdot I)$
electric quadrupole moment	$L^2 \cdot T \cdot I$
electric resistance	$L^2 \cdot M/(T^3 \cdot I^2)$
electric resistance per length	$L^2 \cdot M/(L \cdot T^3 \cdot I^2)$
electric resistivity	$L^3 \cdot M/(T^3 \cdot I^2)$
electrical mobility	$L^2 \cdot T^3 \cdot I/(L^2 \cdot M \cdot T)$
electromotive force	$L^2 \cdot M/(T^3 \cdot I)$
energy	$L^2 \cdot M/T^2$
energy density	$M/(L \cdot T^2)$
entropy	$L^2 \cdot M/(T^2 \cdot \theta)$
fine structure constant	$L^5 \cdot M \cdot T^4 \cdot I^2/(L^5 \cdot M \cdot T^4 \cdot I^2)$
first hyperpolarizability	$L^3 \cdot T^7 \cdot I^3/(L^4 \cdot M^2)$
fluidity	$L \cdot T/M$
force	$L \cdot M/T^2$
frequency	$1/T$
frequency per electric field gradient	$L^2 \cdot T^3 \cdot I/(L^2 \cdot M \cdot T)$
frequency per electric field gradient squared	$L^4 \cdot T^6 \cdot I^2/(L^4 \cdot M^2 \cdot T)$
frequency per magnetic flux density	$T \cdot I/M$
frequency ratio	T/T
gas permeance	$L \cdot T^2 \cdot N/(L^2 \cdot M \cdot T)$
gravitational constant	$L^3/(M \cdot T^2)$
gyromagnetic ratio	$L \cdot T^2 \cdot I/(L \cdot M \cdot T)$
heat capacity	$L^2 \cdot M/(T^2 \cdot \theta)$
heat flux density	$L^2 \cdot M/(L^2 \cdot T^3)$
heat transfer coefficient	$M/(T^3 \cdot \theta)$
illuminance	$L^2 \cdot J/L^4$
inductance	$L^2 \cdot M/(T^2 \cdot I^2)$
inverse amount	$1/N$
inverse amount concentration inverse time	$L^3/(T \cdot N)$
inverse area	$1/L^2$
inverse current	$1/I$
inverse length	$1/L$
inverse luminous intensity	$1/J$
inverse magnetic flux density	$T^2 \cdot I/M$
inverse mass	$1/M$
inverse temperature	$1/\theta$
inverse time	$1/T$
inverse time squared	$1/T^2$
inverse volume	$1/L^3$

Quantity	Dimensionality
irradiance	$L^2 \cdot M/(L^2 \cdot T^3)$
kinematic viscosity	L^2/T
length	L
length ratio	L/L
linear momentum	$L \cdot M/T$
luminance	J/L^2
luminous efficacy	$T^3 \cdot J/(L^2 \cdot M)$
luminous energy	$L^2 \cdot T \cdot J/L^2$
luminous flux	$L^2 \cdot J/L^2$
luminous flux density	$L^2 \cdot J/L^4$
luminous intensity	J
luminous intensity ratio	J/J
magnetic dipole moment	$L^2 \cdot I$
magnetic dipole moment ratio	$L^2 \cdot I/(L^2 \cdot I)$
magnetic field gradient	$M/(L \cdot T^2 \cdot I)$
magnetic field strength	I/L
magnetic flux	$L^2 \cdot M/(T^2 \cdot I)$
magnetic flux density	$M/(T^2 \cdot I)$
magnetizability	$L^2 \cdot M \cdot T^4 \cdot I^2/(M^2 \cdot T^2)$
mass	M
mass concentration	M/L^3
mass flow rate	M/T
mass flux	$M/(L^2 \cdot T)$
mass ratio	M/M
mass to charge ratio	$M/(T \cdot I)$
molality	N/M
molar conductivity	$L^2 \cdot T^3 \cdot I^2/(L^2 \cdot M \cdot N)$
molar energy	$L^2 \cdot M/(T^2 \cdot N)$
molar entropy	$L^2 \cdot M/(T^2 \cdot \theta \cdot N)$
molar heat capacity	$L^2 \cdot M/(T^2 \cdot \theta \cdot N)$
molar magnetic susceptibility	L^3/N
molar mass	M/N
moment of force	$L^2 \cdot M^2/(M \cdot T^2)$
moment of inertia	$L^2 \cdot M$
permeability	$L \cdot M/(T^2 \cdot I^2)$
permittivity	$T^4 \cdot I^2/(L^3 \cdot M)$
plane angle	L/L
porosity	L^3/L^3
power	$L^2 \cdot M/T^3$
power per luminous flux	$L^3 \cdot M/(L \cdot T^3 \cdot J)$
pressure	$M/(L \cdot T^2)$
pressure gradient	$M/(L^2 \cdot T^2)$

Quantity	**Dimensionality**
radiance	$\mathsf{L}^4 \cdot \mathsf{M}/(\mathsf{L}^4 \cdot \mathsf{T}^3)$
radiant flux	$\mathsf{L}^2 \cdot \mathsf{M}/\mathsf{T}^3$
radiant intensity	$\mathsf{L}^4 \cdot \mathsf{M}/(\mathsf{L}^2 \cdot \mathsf{T}^3)$
radiation exposure	$\mathsf{T} \cdot \mathsf{I}/\mathsf{M}$
radioactivity	$1/\mathsf{T}$
reduced action	$\mathsf{L}^3 \cdot \mathsf{M}/(\mathsf{L} \cdot \mathsf{T})$
refractive index	$\mathsf{L} \cdot \mathsf{T}/(\mathsf{L} \cdot \mathsf{T})$
rock permeability	L^2
second hyperpolarizability	$\mathsf{L}^4 \cdot \mathsf{T}^{10} \cdot \mathsf{I}^4/(\mathsf{L}^6 \cdot \mathsf{M}^3)$
second radiation constant	$\mathsf{L}^3 \cdot \mathsf{M} \cdot \mathsf{T}^2 \cdot \theta/(\mathsf{L}^2 \cdot \mathsf{M} \cdot \mathsf{T}^2)$
solid angle	$\mathsf{L}^2/\mathsf{L}^2$
specific energy	$\mathsf{L}^2/\mathsf{T}^2$
specific entropy	$\mathsf{L}^2/(\mathsf{T}^2 \cdot \theta)$
specific gravity	$\mathsf{L}^3 \cdot \mathsf{M}/(\mathsf{L}^3 \cdot \mathsf{M})$
specific heat capacity	$\mathsf{L}^2/(\mathsf{T}^2 \cdot \theta)$
specific power	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{M} \cdot \mathsf{T}^3)$
specific surface area	L^2/M
specific volume	L^3/M
spectral power	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{L} \cdot \mathsf{T}^3)$
spectral radiance	$\mathsf{L}^4 \cdot \mathsf{M}/(\mathsf{L}^5 \cdot \mathsf{T}^3)$
spectral radiant energy	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{L} \cdot \mathsf{T}^2)$
spectral radiant flux density	$\mathsf{M}/(\mathsf{L} \cdot \mathsf{T}^3)$
spectral radiant intensity	$\mathsf{L}^4 \cdot \mathsf{M}/(\mathsf{L}^3 \cdot \mathsf{T}^3)$
speed	L/T
stefan-boltzmann constant	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{L}^2 \cdot \mathsf{T}^3 \cdot \theta^4)$
stress	$\mathsf{M}/(\mathsf{L} \cdot \mathsf{T}^2)$
stress-optic coefficient	$\mathsf{L} \cdot \mathsf{T}^2/\mathsf{M}$
surface area to volume ratio	$\mathsf{L}^2/\mathsf{L}^3$
surface charge density	$\mathsf{T} \cdot \mathsf{I}/\mathsf{L}^2$
surface density	M/L^2
surface energy	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{L}^2 \cdot \mathsf{T}^2)$
surface tension	M/T^2
temperature	θ
temperature gradient	θ/L
temperature ratio	θ/θ
thermal conductance	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{T}^3 \cdot \theta)$
thermal conductivity	$\mathsf{L} \cdot \mathsf{M}/(\mathsf{T}^3 \cdot \theta)$
time	T
time ratio	T/T
torque	$\mathsf{L}^3 \cdot \mathsf{M}/(\mathsf{L} \cdot \mathsf{T}^2)$
velocity	L/T
voltage	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{T}^3 \cdot \mathsf{I})$

Quantity	Dimensionality
volume	L^3
volume per length	L^3/L
volume power density	$\mathsf{L}^2 \cdot \mathsf{M}/(\mathsf{L}^3 \cdot \mathsf{T}^3)$
volume ratio	$\mathsf{L}^3/\mathsf{L}^3$
volumetric flow rate	L^3/T
wavelength displacement constant	$\mathsf{L} \cdot \theta$
wavenumber	$1/\mathsf{L}$

Table A.7: Physical quantity names.