1.1 Introduction

The determination of physical constants and the definition of the units with which they are measured is a specialised and, to many, hidden branch of science.

A quantity with dimensions is one whose value must be expressed relative to one or more standard units. In the spirit of the rest of the book, this section is based around the International System of units (SI). This system uses seven base units[1] (the number is somewhat arbitrary), such as the kilogram and the second, and defines their magnitudes in terms of physical laws or, in the case of the kilogram, an object called the "international prototype of the kilogram" kept in Paris. For convenience there are also a number of derived standards, such as the volt, which are defined as set combinations of the basic seven. Most of the physical observables we regard as being in some sense fundamental, such as the charge on an electron, are now known to a relative standard uncertainty,[2] u_{r}, of less than 10^{-7}. The least well determined is the Newtonian constant of gravitation, presently standing at a rather lamentable u_{r} of 1.5×10^{-3}, and the best is the Rydberg constant ($u_{\mathrm{r}} = 7.6 \times 10^{-12}$). The dimensionless electron g-factor, representing twice the magnetic moment of an electron measured in Bohr magnetons, is now known to a relative uncertainty of only 4.1×10^{-12}.

No matter which base units are used, physical quantities are expressed as the product of a numerical value and a unit. These two components have more-or-less equal standing and can be manipulated by following the usual rules of algebra. So, if $1 \cdot \mathrm{eV} = 160.218 \times 10^{-21} \cdot \mathrm{J}$ then $1 \cdot \mathrm{J} = [1/(160.218 \times 10^{-21})] \cdot \mathrm{eV}$. A measurement of energy, U, with joule as the unit has a numerical value of U/J. The same measurement with electron volt as the unit has a numerical value of $U/\mathrm{eV} = (U/\mathrm{J}) \cdot (\mathrm{J}/\mathrm{eV})$ and so on.

[1]The **metre** is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second. The **kilogram** is the unit of mass; it is equal to the mass of the international prototype of the kilogram. The **second** is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom. The **ampere** is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length. The **kelvin**, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. The **mole** is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol." When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles. The **candela** is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

[2]The relative standard uncertainty in x is defined as the estimated standard deviation in x divided by the modulus of x ($x \neq 0$).