Measurement

Measuring Things

Physics is based on the measurement of physical quantities.

Each quantity is defined in terms of a *standard* and assigned a *unit*.

- A *unit* is a unique name assigned to measures of a quantity. (.e.g. The meter (m) is the unit of measure for the quantity length).
- The *standard* corresponds to exactly 1.0 unit of the quantity.

A *unit* and its *standard* can be defined in any way we want to. But, it is important to do so in such a way that scientists around the world will agree on their *sensibility* and *practicality*.

Because there is an abundance of physical quantities, organising them is problematic. But not all quantities are independent of each other (e.g. speed $= \frac{length}{time}$). Thus, we only pick a number of physical quantities such as length and time to be *base quantities*, and we assign standards to these alone. Other physical quantities are then defined in terms of these base quantities, base standards and units. Speed, is defined in terms of the base quantities length and time and their base standards and is assigned the units metres per second.

Base standards must be *accessible* and *invariable* (unchanging). The demand for precision in science and engineering pushes us to aim first for invariability. We then make great efforts to duplicate these base standards so that they are accessible to those who require them.

The International System of Units

In 1971, the 14th General Conference on Weights and Measures picked 7 quantities to be base quantities, forming the basis of the International System of Units (*SI* or the *metric system*):

Base quantity	***SI base unit***	***Unit Symbol***
Electric current	Ampere	*A*
Mass	Kilogram	*kg*
Length	Metre	*m*
Time	Second	*s*
Thermodynamic temperature	Kelvin	*K*
Amount of substance	Mole	*mol*
Luminous Intensity	Candela	*cd*

Scientific notation and prefixes for SI Units

Very large/small quantities are encountered in physics. These are expressed using *scientific notation*.

A number in *scientific notation* is expressed as a *product* of a *number between 1,* and an *exponent (certain power) of 10*, for example, 3.45×10^3.

The power is determined by the number of digits the decimal point must be moved to obtain the new number (between 1 and 10) from the original number (which is in the above case 3450). This can be written more briefly as 3.45 E3.

Prefixes are assigned to very large and very small measurements. Each prefix represents a certain power of 10. Attaching a prefix to an SI unit means multiplying by the associated power of 10.

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

The bold/highlighted prefixes are the most frequently used.

Changing units

Units in which a physical quantity is expressed can be changed using the *chain-link conversion.* This involves introducing a conversion factor in such a way that the unwanted units are cancelled out. If you introduce a conversion factor in such a way that the unwanted units don't cancel, invert the factor and try again. The units obey the same algebraic rules as variables/numbers.

Example: Converting minutes to seconds

$$2 \text{ min} = (2 \text{ min})(1) = (2 \cancel{\text{min}})(60\text{s}/1\cancel{\text{min}}) = 120\text{s}$$

Significant Figures and Decimal Places

Decimal places are simply the number of digits after the point. 0.85 has 2 decimal places.

Significant figures are *NOT* the number of decimal places. Suppose a question provides a set of data. Note the number of significant figures present in the data piece with the lowest number of significant figures. This is the number of significant figures you are to give the answer to the question to.

Significant figures are non zero digits unless:

- They occur between non zero digits .e.g. the 0 in 305 is significant.
- The occur after a decimal point, representing a more precise answer .e.g. 29.00m.

When rounding to a certain number of significant figures of decimal places, if the leftmost of the digits to be discarded is 5 or more, the last remaining digit is rounded up, otherwise it remains how it is.

Length

The meter is the length of the path travelled by light in a vacuum in 1/299792458th of a second.

Time

One second is the time taken by 9129631770 oscillations of the light (of a specified wavelength) emitted by a caesium-133 atom.

Mass

The kilogram is defined in terms of a platinum-iridium standard mass kept near Paris. For measurements on an atomic scale, the atomic mass unit, defined in terms of the atom carbon-12 is usually used.

Density

The density ρ of a material is the mass per unit volume:

$$\rho = \frac{m}{v}$$

Bibliography

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