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3.2 Physical Quantities

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Introduction

A **physical quantity** is a physical property of an object that can be quantified through measurement.A physical quantity can be expressed as the combination of a number (*typically a real number*) and a unit or combination of units.

For example:
$1.6749275 \times 10^{-27}$ kg (the mass of the neutron)
299792458 metres per second (the speed of light).

Symbols

General: Symbols for quantities generally follow recommendations from ISO/IEC 80000, the IUPAP red book and the IUPAC green book.

For example:

the recommended symbol for the physical quantity 'mass' is m

and the recommended symbol for the quantity 'charge' is Q.

Subscripts and Indices

Subscripts are used for three primary reasons, 1) to simply attach a name to the quantity or 2) associate it with another quantity, or 3) represent a specific vector, matrix, or tensor component.

Name Reference: The quantity has a subscripted or superscripted single letter, a number of letters, or an entire word, to specify what concept or entity they refer to, and tend to be written in upright roman typeface rather than italic while the quantity is in italic.

For example:

E_k or E_kinetic is usually used to denote kinetic energy

E_p or $E_\mathrm{potential}$ is usually used to denote potential energy.

Quantity Reference: The quantity has a subscripted or superscripted single letter, a number of letters, or an entire word, to specify what measurements they refer to, and tend to be written in italic rather than upright roman typeface while the quantity is also in italic.

For example:

c_p or $c_{isobaric}$ is heat capacity at constant pressure.

Indices: These are quite apart from the above, their use is for mathematical formalism, see index notation.

Scalars: Symbols for physical quantities are usually chosen to be a single letter of the Latin or Greek alphabet, and are printed in italic type. They are representative of only a value.

Vectors: Symbols for physical quantities that are vectors are in bold type, underlined or with an arrow above. If, e.g., u is the speed of a particle, then the straightforward notation for its velocity is **u**, $\underline{\mathrm{u}}$, or $\vec{u}$.

Numbers and elementary functions

Numerical quantities, even those denoted by letters, are usually printed in roman (upright) type, though sometimes can be italic. Symbols for elementary functions (circular trigonometric, hyperbolic, logarithmic etc.), changes in a quantity like Δ in Δy or operators like d in dx, are also recommended to be printed in roman type.

For example:

real numbers are as usual, such as 1 or $\sqrt{2}$,

e for the base of natural logarithm,

i for the imaginary unit,

π for 3.14159265358979323846264338327950288...

δx, Δy, dz,

sin α, sinh γ, log *x*

Units

Most physical quantities include a unit, but not all – some are dimensionless. Neither the name of a physical quantity, nor the symbol used to denote it, implies a particular choice of unit, though SI units are usually preferred and assumed today due to their ease of use and all-round applicability. For example, a quantity of mass might be represented by the symbol *m*, and could be expressed in the units kilograms (kg) or pounds (lb).

Dimensions

The notion of *physical dimension* of a physical quantity was introduced by *Joseph Fourier* in 1822.By convention, physical quantities are organized in a dimensional system built upon base quantities, each of which is regarded as having its own dimension.

Base quantities

"Base quantities are those quantities which are distinct in nature and cannot be expressed in the form of other quantities". Base quantities are those quantities on the basis of which other quantities can be expressed. The seven base quantities of the International System of Quantities and their corresponding SI units and dimensions are listed in the following table. Other conventions may have a different number of base units (the CGS and MKS systems of units).

Derived quantities are those whose definitions are based on other physical quantities (base quantities).

Quantity name/s	**(Common) Quantity symbol/s**	**SI unit name**	**SI unit symbol**	**Dimension symbol**
Length, width, height, depth	*a, b, c, d, h, l, r, s, w, x, y, z*	metre	m	L
Time	t, τ	second	s	T
Mass	m	kilogram	kg	M
Temperature	T, θ	kelvin	K	Θ
Amount of substance	n	mole	mol	N
Electric current	i, I	ampere	A	I
Luminous intensity	I_v	candela	cd	J
Plane angle	α, β, γ, θ, ϕ, χ	radian	rad	1

Solid angle	ω, Ω	steradian	sr	1

(Common) Quantity name/s	(Common) Quantity symbol	SI unit	Dimension
(Spatial) position (vector)	**r**, **R**, **a**, **d**	m	L
Angular position, angle of rotation (can be treated as vector or scalar)	θ, $\boldsymbol{\theta}$	rad	1
Area, cross-section	A, S, Ω	m^2	L^2
Vector area (Magnitude of surface area, directed normal totangential plane of surface)	$\mathbf{A} \equiv A\hat{\mathbf{n}}, \quad \mathbf{S} \equiv S\hat{\mathbf{n}}$	m^2	L^2
Volume	τ, V	m^3	L^3

The meaning of the term physical quantity is generally well understood (*everyone understands what is meant by the frequency of a periodic phenomenon, or the resistance of an* *electric wire*). The term *physical quantity* does not imply a physically *invariant quantity*. *Length* for example is a *physical quantity*, yet it is variant under coordinate change in special and general relativity.

The notion of physical quantities is so basic and intuitive in the realm of science, that it does not need to be explicitly *spelled out* or even *mentioned*. It is universally understood that scientists will deal with quantitative data, as opposed to qualitative data. Explicit mention and discussion of *physical quantities* is not part of any standard science program, and is more suited for a *philosophy of science* or *philosophy* program. But students should know how to work and intuitively work with these quantities by understanding and manipulating units, but this is why most courses do not discuss this.