Topic One: Physics and Physical Measurement

Orders of Magnitude

In the physical world, many quantities are too large or too small to write down on a piece of paper using the "normal" number system. We therefore commonly use scientific notation in Physics. It is sometimes useful to get an idea of the approximate size of a quantity without needing to know the exact number. For this, we can use a concept known as "order of magnitude" The order of magnitude of a quantity is simply the power of 10 in the scientific form notation. We either state quantities "to the nearest order of magnitude" – ie. to the nearest power of 10 – or we express ratios of quantities as differences of orders of magnitude.

Worked example:

(a) State the (rest) mass of an electron to the nearest order of magnitude (get data from data book or text)

(b) State the ratio of the rest mass a proton to that of an electron as a difference of orders of magnitude

Solutions

(a) the mass of an electron to the nearest order of magnitude is 10^{-30} kg (mass = 9.11×10^{-31} kg – this rounds to 1×10^{-30} kg or simply 10^{-30} kg)

(b) $\frac{m_p}{m_e}=\frac{1.673\times10^{-27}}{9.11\times10^{-31}}=1.8\times10^{4}\approx10^{4}$

Quantities

A physical quantity has a unit and a magnitude. The unit describes the nature of the quantity and the magnitude, the size. Some quantities, called vector quantities, also have direction (those for which direction has no meaning are called scalar quantities). Certain units are defined by quantities that exist in reality and remain constant. Such units are called fundamental units. All units can be derived from fundamental units. Hence the set of all units comprise fundamental (or base) units and derived units. Fundamental units on their own are sufficient to define all quantities.

Common Quantities and their Units

Example T1.1 – complete the table

Fundamental or Derived

Vector or Scalar

Quantity	Quantity Symbol	Unit Symbol	F/D	V/S
Mass				
Length				
Time				
Current				
Temperature				
Force				
Displacement				
Speed				
Acceleration				
Pressure				
Potential difference				
Resistance				
Energy				
Charge				
Velocity				
Power				
Frequency				

Example T1.2

Show that the kilowatt hour (kWh) and the joule (J) are both derived from the same fundamental (or base) units

Prefixes

It is convenient to express very large or very small quantities using prefix multipliers. The common multipliers used are as follows:

Example T1.3 – complete the table

Name	Multiplication factor	Example -	conversion to S.I. units (using scientific notation)
nano (n)	10^{-9}	300nm =	
micro (μ)	10^{-6}	0.6 μs =	
milli (m)	10^{-3}	500 mV =	
centi (c)	10^{-2}	0.3 cm =	
kilo (k)	10^{3}	101 kPa =	
mega (M)	10^{6}	23.4 MN =	

Uncertainty and Error

A random uncertainty is an unpredictable and largely uncontrollable uncertainty. Examples include human reaction time and other forms of human measurement. Random uncertainties can be reduced by taking the average of repeated measurements.

A systematic error is an error that occurs on all measurements. An example is a zero error on a newton meter (spring balance). Systematic errors can often easily be detected on a graph of the measurements versus a related (dependent) variable – the whole curve, for example, will be this error distance too high – and will miss the origin when it should pass through it. Systematic errors are not reduced by taking repeated measurements.

Precision and Accuracy

An accurate instrument is one whose graduations correspond to the true quantities. For example the 1m mark on a ruler corresponds correctly (accurately) to a length of 1 metre, if the ruler is accurate.

The maximum uncertainty in reading an instrument is generally taken to be half a division on the graduation of the instrument. For example, if a metre ruler has 1mm graduations, the maximum uncertainty in recording a length is 0.5mm

A precise instrument is one that has a very fine graduation – so it records measurements to within a very small uncertainty. For example, a ruler with 1mm graduations is less precise than a ruler with 0.5mm graduations (but it may be more, or less, accurate)

Calculation of Uncertainties

If quantities are multiplied together (e.g. F = ma) or divided (e.g. speed = distance/time) then the percentage (or fractional) error of the product (e.g. of F) is obtained by adding the percentage (or fractional) errors of the individual errors,

If quantities are added or subtracted (e.g. perimeter = length + length + width + width) then the absolute (actual) error is obtained by adding the absolute error for each measurement.

Significant Figures

In Physics, numbers representing quantities have implied uncertainties. The uncertainty corresponds to half the next significant digit on the number. For example, 45 N $\Rightarrow 45 \pm 0.5$ N. 45.67 N $\Rightarrow 45.67 \pm 0.005$ N

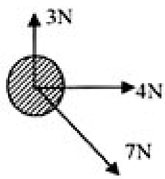
Vector Quantities

A vector quantity is a quantity that has both size (magnitude) and direction. In Physics, vector quantities are represented using arrows. The length of the arrow represents the magnitude of the quantity and the direction of the arrow, the direction of the quantity. Solving vector problems can then be done either using mathematical geometry or scale diagrams.

Unlike scalars, which are just treated like numbers when added, direction must be taken into account when adding vector quantities. They are added by summing head-to-tail vectors, then either by direct measurement of scale drawing or by using geometry. The vectors are drawn, in any order, the head of one joining the tail of the next. The resultant vector is the vector that joins the tail (start) of the first vector to the head (end) of the last vector. Any vector can be considered as a sum of several vectors. It is common and useful to consider single vectors as two perpendicular vectors. These are called component vectors. The process of splitting a vector into two perpendicular components is called resolution (vector has been resolved). The process of combining two or more vectors into a single vector is called vector summation (finding the resultant vector).

Example T1.4

(a) A 5kg mass has forces acting on it as shown in the diagram. By scale diagram, or otherwise, find the resultant force acting on the mass:



Note: The diagram is not drawn to scale
The 3N force is perpendicular to the 4N force
The 7N force is at 45° to the 4N force

(b) Resolve the weight of a 25kg mass on a slope at 30° to horizontal into components parallel and perpendicular to the slope.

(c) Find the resultant speed of a man walking due East at 1.3 m/s across a flat lorry trailer if the lorry is moving due north at 3.2 m/s