

1 Physical Quantities, Units and Measurement

Preamble

Measurement is a tool that we use in physics a lot. It is difficult to get fully accurate measurements due to how well we can create instruments, control random errors, and other factors. Nonetheless we try to minimise these errors by practising proper measurement techniques. We use measurements to determine physical quantities, and these quantities are communicated with units.

1.1 Physical Quantities

Definition 1.1: Physical Quantity

A physical quantity is a quantity consisting of a **numerical magnitude** and a **unit**.

The numerical magnitude tells us the size of the quantity, and the unit tells us what the quantity is expressed in. Physical quantities can be either a **basic quantity**:

Physical Quantity		SI Unit	
mass	m	kilogram	kg
time	t	second	s
temperature	T	kelvin	K
length	l	metre	m
current	I	ampere	A
amount	n	mole	mol

or a **derived quantity**, which are derived from basic quantities.

1.1.1 Dimensional Analysis

This is not explicitly taught in syllabus, but it is a very important tool to help you if you are stuck in a problem. The main idea is to treat units like **algebraic terms**, and manipulate them accordingly to get the right derived unit for the quantity. Usually, a single unit is written in square brackets [] to avoid confusion with units with multiple letters (e.g. [mol] and [m]).

1.2 Prefixes, Standard Form, and Order of Magnitude

If a number is too large or too small, it will get very annoying to write a lot of digits. That is what prefixes and standard form aim to solve. The former will be written with the unit, while the latter will be written with the numerical magnitude.

A number is expressed in standard form as

$$\underbrace{A}_{\text{base}} \times \underbrace{10^N}_{\text{factor}}$$

where $1 \leq A < 10$ and $N \in \mathbb{Z}$.

A unit can be rewritten with any of these prefixes preceding its symbol:

Prefix	Symbol	Factor	Order of Magnitude
tera	T	10^{12}	12
giga	G	10^9	9
mega	M	10^6	6
kilo	k	10^3	3
deci	d	10^{-1}	-1
centi	c	10^{-2}	-2
milli	m	10^{-3}	-3
micro	μ	10^{-6}	-6
nano	n	10^{-9}	-9
pico	p	10^{-12}	-12

1.3 Scalars and Vectors

Definition 1.2: Scalar Quantity

A scalar quantity has a magnitude but **no** direction.

Definition 1.3: Vector Quantity

A vector quantity has a magnitude and direction.

1.4 Vector Analysis

Vectors can be added by using the trigonometric method or the graphical method.

Equation 1.1: Components

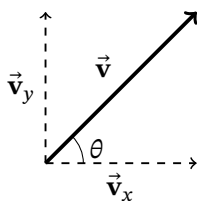
A two-dimensional vector \vec{v} can be broken down into components \vec{v}_x and \vec{v}_y , with magnitudes of

$$\vec{v}_x = v \cos \theta, \vec{v}_y = v \sin \theta$$

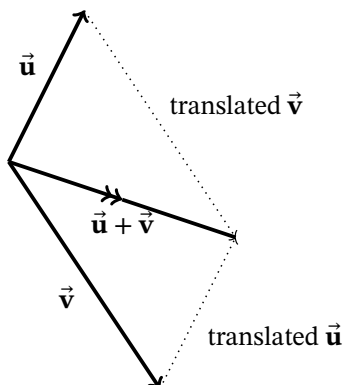
Equation 1.2: Magnitude of Vectors

The magnitude of a vector \vec{v} with components \vec{v}_x and \vec{v}_y is given by

$$|\vec{v}| = \sqrt{|\vec{v}_x|^2 + |\vec{v}_y|^2}$$



Observe that when you add the two components together, they form the vector itself.



1.5 Measurement

1.5.1 Precision and Accuracy

Precision is how well a set of readings of the same physical quantity agree with each other.

Accuracy is how close the set of readings are to the true value.

1.5.2 Measurement of Lengths

Parallax error should be avoided when measuring lengths. In the case of a measuring tape or a metre rule, the object needs to be **in contact** with the measuring instrument.

Vernier Callipers

Accuracy: ± 0.01 cm

1. Check for zero error. This error is Δx .
2. Place the object to be measured at the appropriate measurement site (internal jaws, external jaws, or tail).
3. Slide the vernier scale so that the jaws or tail measure the entirety of the object.
4. On the main scale (with 0.1 cm subdivisions), take the reading that is on or left of the '0' mark of the vernier scale, x_{main} .
5. On the vernier scale (with 0.01 cm subdivisions), read the mark that coincides with a mark on the main scale, x_{vernier} .
6. The measurement is the sum of the reading on the main scale and vernier scale, and then subtracting the zero error, $x - \Delta x$.

Micrometer Screw Gauge

Accuracy: ± 0.001 cm

1. Check for zero error. This error is Δx .
2. Place the object in between the anvil and the spindle.
3. Close the jaws on the micrometer screw gauge until the object is in contact. Turn the ratchet until a 'click' sound is heard.
4. On the datum line (with 0.5 mm subdivisions), take the reading that is on the left of the circular scale, x_{datum} .
5. On the circular scale (with 0.01 mm subdivisions), take the reading that coincides with the datum line, x_{circular} .
6. The measurement is the sum of the reading on the datum line and circular scale, and then subtracting the zero error, $x - \Delta x$.

1.5.3 Simple Pendulum

A simple pendulum is one on the premises that the string is massless, and the bob is a point mass.

Equation 1.3: Period of Simple Pendulum

Using the approximation $\cos \theta \approx 1 - \frac{\theta^2}{2}$, for a reasonably small θ (angle of release),

$$T = 2\pi \sqrt{\frac{L}{g}}$$

