Physical quantities and units

Magnitudes and units, reasonable estimates, SI base units and prefixes, checking equations for homogeneity, systematic and random errors, precision and accuracy, combining uncertainties, and adding and resolving vectors.

NOTE

How the Pearson Edexcel IAL Physics is examined. There are six units, each its own written paper. Unit 1 (Mechanics and Materials) and Unit 2 (Waves and Electricity) are 1 hour 30 minutes and 80 marks; Unit 4 (Further Mechanics, Fields and Particles) and Unit 5 (Thermodynamics, Radiation, Oscillations and Cosmology) are 1 hour 45 minutes and 90 marks; Units 3 and 6 are the written practical-skills papers, 1 hour 20 minutes and 50 marks. Units 1 to 3 make the AS and Units 4 to 6 the A2 half.

Physical quantities

Every physical quantity is a **numerical magnitude and a unit**. "The length is 3" means nothing; "the length is 3 m" does.

Reasonable estimates

You are expected to know roughly how big things are, so that you can spot an answer that cannot be right.

Note Academy

Quantity	Rough value
Mass of an adult	70 kg
Mass of a car	1000 kg
Walking speed	1.5 m/s
Speed of sound in air	330 m/s
Speed of light	3×10^8 m/s
Atmospheric pressure	1×10^5 Pa
Diameter of an atom	10^{-10} m
Wavelength of visible light	5×10^{-7} m
Power of a domestic kettle	2 kW
Mains voltage	230 V (in many countries)

SI units

Base quantities

Quantity	Unit	Symbol
Mass	kilogram	kg
Length	metre	m
Time	second	s
Current	ampere	A
Temperature	kelvin	K

(Amount of substance, the mole, is added in chapter 15.)

Derived units

Every other unit is a product or quotient of base units. Build them from a defining equation.

Note Academy

Unit	From	In base units
newton, N	$F = ma$	kg m s^{-2}
joule, J	$W = Fs$	kg m^2 s^{-2}
watt, W	$P = W/t$	kg m^2 s^{-3}
pascal, Pa	$p = F/A$	kg m^{-1} s^{-2}
coulomb, C	$Q = It$	A s
volt, V	$V = W/Q$	kg m^2 s^{-3} A^{-1}
ohm, Ω	$R = V/I$	kg m^2 s^{-3} A^{-2}

Homogeneity

An equation is **homogeneous** if every term has the same base units. A correct equation must be homogeneous, but a homogeneous equation need not be correct: numbers such as the $\frac{1}{2}$ in $E_k = \frac{1}{2}mv^2$ have no units, so this test cannot detect them.

TRY IT

Show that $p = \rho g h$ is homogeneous. Left side: pascal is kg m^{-1} s^{-2}. Right side: (kg m^{-3})(m s^{-2})(m) = kg m^{-1} s^{-2}. They match.

Note Academy

Prefixes

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

Be careful with powers: $1\ \text{cm}^2 = 10^{-4}\ \text{m}^2$ and $1\ \text{mm}^3 = 10^{-9}\ \text{m}^3$.

Errors and uncertainties

Systematic and random errors

- A **systematic error** shifts every reading the same way by the same amount or proportion. A zero error on a micrometer is the classic example. Repeating readings does **not** reduce it. Remove it by correcting the instrument or the readings.
- A **random error** scatters readings either side of the true value, for example reaction time with a stopwatch. Repeating and averaging **does** reduce its effect.

Precision and accuracy

- **Accuracy** is how close a result is to the true value.
- **Precision** is how close repeated readings are to each other (small scatter).

A set of readings can be precise but inaccurate: tightly grouped, all with the same systematic error.

Note Academy

Combining uncertainties

Calculation	What to add
$y = a + b$ or $y = a - b$	absolute uncertainties
$y = ab$ or $y = a/b$	percentage uncertainties
$y = a^n$	n times the percentage uncertainty in a

Uncertainties always **add**, even when the quantities are subtracted.

TRY IT

The resistance $R = V/I$ with $V = 6.0 \pm 0.1$ V and $I = 1.50 \pm 0.05$ A. Find R with its uncertainty. $R = 4.0\ \Omega$. The percentage uncertainties are 1.7% and 3.3%, which add to 5.0%. 5.0% of 4.0 is 0.2, so $R = 4.0 \pm 0.2\ \Omega$.

Scalars and vectors

A **scalar** has magnitude only: distance, speed, mass, time, energy, temperature, charge. A **vector** has magnitude and direction: displacement, velocity, acceleration, force, momentum, field strength.

Adding vectors

Draw the vectors **head to tail**. The resultant goes from the start of the first to the end of the last. To subtract a vector, reverse it and add it. For two vectors at right angles, use Pythagoras and trigonometry; otherwise a scale drawing works.

Components

A vector F at angle θ to the horizontal has two perpendicular components:

$$F_x = F\cos\theta \qquad F_y = F\sin\theta$$

The components act together in exactly the same way as the single vector. Problems become easy when you resolve everything along two perpendicular directions and treat each direction separately.

TRY IT

A 50 N force acts at 30° above the horizontal. Find its components. Horizontal: $50\cos 30° = 43$ N. Vertical: $50\sin 30° = 25$ N.

Note Academy