Module 2: Foundations of Physics

Quantities and Units

Quantities are expressed with a value and a unit. There are 6 base units:

Base quantity	Unit
Mass	kg
Length	m
Time	s
Electrical current	A
Temperature	K
Amount of a substance	mol

Other units, such as Newtons, N, and Joules, J, represent **a combination of these base units**. For example, using the equation for force, $F=ma$, you can express Newtons in terms of base units.

$$N = kg\ m\ s^{-2}$$

Another important skill is proving that an equation is **homogeneous**. This means that the units for both sides of the equation are the same.

Quantity	S.I derived unit	Symbol	Written in S.I base units
Energy, Work, Heat	joule	J	kgm^2s^{-2}
Resistance	Ohm	Ω	$kgm^2s^{-3}A^{-2}$
Potential difference, e.m.f	Volt	V	$kgm^2s^{-3}A^{-1}$
Charge	Coulomb	C	As
Force, weight	Newton	N	$kgms^{-2}$
Power	Watt	W	kgm^2s^{-3}
Pressure, stress	Pascal	Pa	$kgm^{-1}s^{-2}$
Frequency	hertz	Hz	s^{-1}

Prefixes

Prefix	Multiple of unit
Pico (p)	1×10^{-12}
Nano (n)	1×10^{-9}
Micro (μ)	1×10^{-6}
Milli (m)	1×10^{-3} (0.001)
Centi (c)	1×10^{-2} (0.01)
Deci (d)	1×10^{-1} (0.1)
Kilo (k)	1×10^{3} (1000)
Mega (M)	1×10^{6}
Giga (G)	1×10^{9}
Tera (T)	1×10^{12}

Estimations—Typical values

Mass of a person	70kg
Mass of a car	1500kg
Height of a man	1.8m
Walking speed	1.5m/s

Errors

Random: Cause readings to be spread about the true value due to the results varying in an unpredictable way. They affect precision.

Caused by	Solutions:
Poor technique	Use a different method or instrument
Equipment not calibrated	
Using the wrong unit	
Zero error - equipment is displaying a measurement when nothing is being measured.	

Systematic cause each reading to be different to the true value by the same amount. They affect the accuracy of your results .

Caused by	Solutions:
Observation error	Take many readings and find an average
Readability	
External effects	

Zero errors caused by the apparatus failing to read zero when it should do (reduced by calibrating equipment)

Uncertanties

Total absolute uncertainty = sum of absolute uncertainties of each measurement

Total percentage uncertainty = sum of percentage uncertainties of each measurement

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Scalars and Vectors

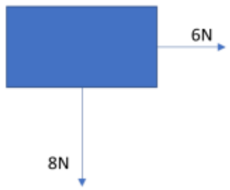
Scalar quantities, such as mass, have a magnitude only.

Vector quantities, such as force or acceleration, have a magnitude and direction.

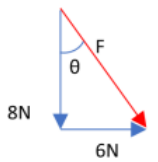
Scalar	Vector
Length/distance, speed, mass, temperature, time, energy	Displacement, velocity, force (including weight), acceleration, momentum

Adding Vectors

Force is a vector quantity, therefore when more than one force is acting on an object you must consider the direction and magnitude when calculating the resultant force.



When forces are at right angles to each other, you can use Pythagoras' theorem to calculate the magnitude of the resultant force and trigonometry to calculate its direction.

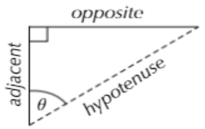


$$F = \sqrt{8^2 + 6^2} = 10N$$

$\theta = tan^{-1}\left(\frac{6}{8}\right)$ = 38.9° from the vertical

This method works for all vector quantities.

For any right-angled triangle where you know two sides, you can work out the size of an angle with one of the formulas below. A handy way to remember them is SOH CAH TOA (



$\sin\theta = \frac{opp}{hyp}$ $\cos\theta = \frac{adj}{hyp}$ $\tan\theta = \frac{opp}{adj}$

Figure 2: SOH CAH TOA for a right-angled triangle.

Resolving Vectors

Resolving a vector into horizontal and vertical components

The components of a vector are perpendicular to each other, so they form a right-angled triangle with the vector.

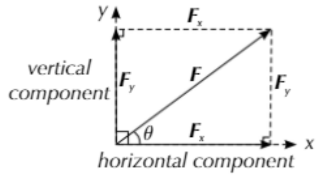


*Figure 4: The vector **F** and its horizontal component F_x and vertical component F_y.*

You just need to use a bit of trigonometry to find the components of the vector in each direction:

You get the horizontal component F_x like this:

$$\cos\theta = \frac{F_x}{F}$$

$$F_x = F\cos\theta$$

...and the vertical component F_y like this:

$$\sin\theta = \frac{F_y}{F}$$

$$F_y = F\sin\theta$$

Tips

Cos 60° = sin 30° = 0.5 (saves time in an exam!)

In these formulae θ is measured from the horizontal

You may be given angles in degrees and radians be sure to know how to change your calculator between the two!

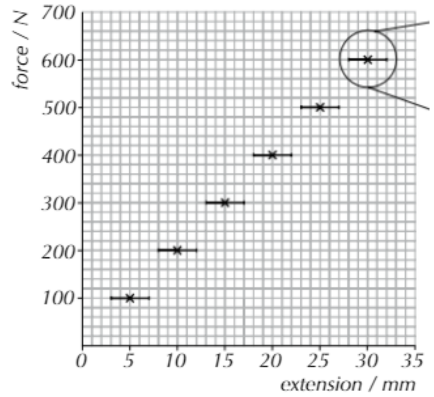
Percentage difference

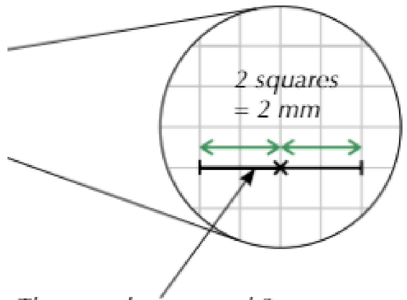
If you know the true value of what you're investigating you can measure the accuracy of your result using **percentage difference**. This is the difference between your experimental value and the accepted value, expressed as a percentage of the accepted value.

$$\text{percentage difference} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \times 100$$

Graphical representations of uncertainties

Error bars : when plotting a graph you show the uncertainty in each measurement by using error bars to show the range the point is likely to lie in. You can have error bars for both the dependant and independent variable





The error bars extend 2 squares to the right and to the left for each measurement, which is equivalent to 2 mm. So, the uncertainty in each measurement is ± 2 mm.