OCR A Level Physics

Your notes

Physical Quantities & Units

Contents

Physical Quantities

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What is a Physical Quantity?

- Speed and velocity are examples of physical quantities; both can be measured
- All physical quantities consist of a numerical magnitude and a unit
- In physics, every letter of the alphabet (and most of the Greek alphabet) is used to represent these physical quantities
  - These letters, without any context, are meaningless
- To represent a physical quantity, it must contain both a numerical value and the **unit** in which it was measured
  - The letter *v* is used to represent the physical quantity of velocity (or speed)
  - The letter *V* can be used to represent volume, potential or voltage
- The units provide the context as to what *v* or *V* refers to
  - If *v* represents velocity, the unit would be $\mathbf{m\ s^{-1}}$
  - If *V* represents volume, the unit would be $\mathbf{m^3}$
  - If *V* represents voltage, the unit would be **V**

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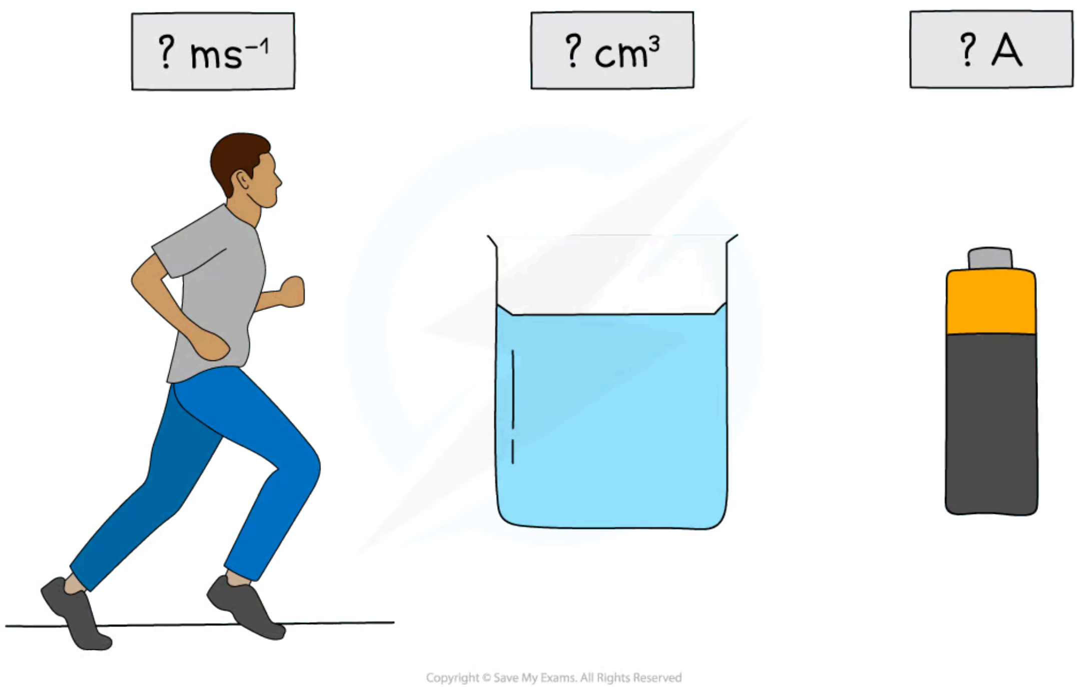

All physical quantities must have a numerical magnitude and a unit

Examiner Tips and Tricks

The same letter in the Greek or English alphabet can often refer to a different quantity depending on its context in Physics. Make sure you understand what each variable in every equation is before you use it, in order to avoid confusion.

Estimating Physical Quantities

- There are important physical quantities to learn in physics
- It is useful to know these physical quantities, they are particularly useful when making estimates
- A few examples of useful quantities to memorise are given in the table below (this is by no means an exhaustive list)

Estimating Physical Quantities Table

QUANTITY	SIZE
DIAMETER OF AN ATOM	10^{-10} m
WAVELENGTH OF UV LIGHT	10 nm
HEIGHT OF AN ADULT HUMAN	2 m
DISTANCE BETWEEN THE EARTH AND THE SUN (1 AU)	1.5×10^{8} m
MASS OF A HYDROGEN ATOM	10^{-27} kg
MASS OF AN ADULT HUMAN	70 kg
MASS OF A CAR	1000 kg
SECONDS IN A DAY	90000 s
SECONDS IN A YEAR	3×10^{7} s
SPEED OF SOUND IN AIR	300 ms^{-1}
POWER OF A LIGHTBULB	60W
ATMOSPHERIC PRESSURE	1×10^{5} Pa

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Worked Example

Estimate the energy required for an adult man to walk up a flight of stairs.

Answer:

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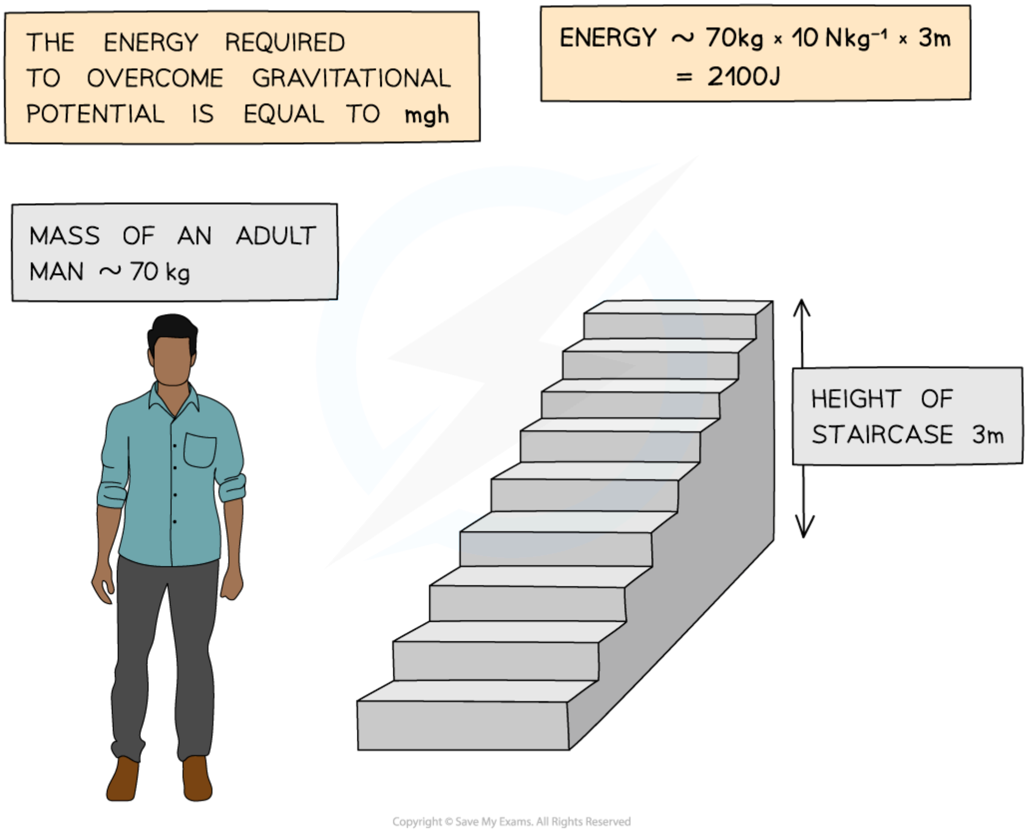
THE ENERGY REQUIRED TO OVERCOME GRAVITATIONAL POTENTIAL IS EQUAL TO mgh
ENERGY ~ 70kg × 10 Nkg⁻¹ × 3m = 2100J
MASS OF AN ADULT MAN ~ 70 kg
HEIGHT OF STAIRCASE 3m
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SI Units

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SI Base Quantities

- There is a seemingly endless number of units in Physics
- These can all be reduced to six base units from which every other unit can be derived
- These six units are referred to as the SI Base Units; this is the only system of measurement that is officially used in almost every country around the world

SI Base Quantities Table

QUANTITY	SI BASE UNIT	SYMBOL
MASS	KILOGRAM	kg
LENGTH	METRE	m
TIME	SECOND	s
CURRENT	AMPERE	A
TEMPERATURE	KELVIN	K
AMOUNT OF SUBSTANCE	MOLE	mol

Examiner Tips and Tricks

You will only be required to use the first five SI base units in this course, so make sure you know them!

Derived Units

- Derived units are derived from the seven SI Base units
- The base units of physical quantities such as:
    - Newtons, **N**

- Joules, **J**
- Pascals, **Pa,** can be deduced

- To deduce the base units, it is necessary to use the definition of the quantity
- The Newton (N), the unit of force, is defined by the equation:
  - Force = mass × acceleration
  - $N = kg \times m\,s^{-2} = kg\,m\,s^{-2}$
  - Therefore, the Newton (N) in SI base units is $\mathbf{kg\,m\,s^{-2}}$
- The Joule (J), the unit of energy, is defined by the equation:
  - Energy = ½ × mass × velocity^2
  - $J = kg \times (m\,s^{-1})^2 = kg\,m^2\,s^{-2}$
  - Therefore, the Joule (J) in SI base units is $\mathbf{kg\,m^2\,s^{-2}}$
- The Pascal (Pa), the unit of pressure, is defined by the equation:
  - Pressure = force ÷ area
  - $Pa = N \div m^2 = (kg\,m\,s^{-2}) \div m^2 = kg\,m^{-1}\,s^{-2}$
  - Therefore, the Pascal (Pa) in SI base units is $\mathbf{kg\,m^{-1}\,s^{-2}}$

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Homogeneity of Physical Equations & Powers of Ten

Your notes

Units

- In Physics, every quantity has an appropriate unit
  - It is important that the correct unit is applied to that quantity

Table of Units

Quantity	Unit
Angle (θ)	Degrees
Distance (d) Displacement (s) Wavelength (λ) Radius (r)	m
Area (A)	m^2
Volume (V)	m^3
Mass (m)	kg
Speed/Velocity (v)	$m\ s^{-1}$
Acceleration (a)	$m\ s^{-2}$
Density (ρ)	$kg\ m^{-3}$
Pressure (P) / Stress (σ)	Pa (Pascals)

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Pressure (P) / Stress (σ)	Pa (Pascals)
Frequency (f)	Hz (Hertz)
Time (t)	s (seconds)
Angular frequency (ω)	rad s^{-1} (Radians per second)
Force (F)	N (Newton)
Moment	N m
Momentum (p)	kg m s^{-1}
Energy (E) Work Done (W) Work Function (ϕ)	J (Joules)
Power (P)	W (Watts)
Intensity (I)	W m^{-2}

Current (I)	A (Amperes)
Resistance (R)	Ω (Ohms)
Resistivity (ρ)	Ω m
Electric Charge (Q)	C (Coulomb)
Electric Field Strength (E)	$N\,C^{-1}$
Electric Potential (V) Gravitational Potential (V_g) Potential difference (ΔV) E.m.f. (ε)	V (Volts)
Capacitance (C)	F (Farads)
Temperature (T)	°C or K (Celsius or Kelvin)
Specific Heat Capacity (c)	$J\,kg^{-1}\,°C^{-1}$ or $J\,kg^{-1}\,K^{-1}$
Specific Latent Heat (L)	$J\,kg^{-1}$

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Gravitational Field Strength (g)	$N\ kg^{-1}$
Magnetic Field Strength (B) Magnetic Flux Density (B)	T (Tesla)
Magnetic Flux (ϕ)	Wb (Webers)
Magnetic Flux Linkage	Wb turns
Activity (A)	Bq (Becqueral)
Decay Constant (λ)	s^{-1}
Amount of Substance (n)	moles
Parallax Angle (p)	arcsecond
Luminosity (L)	W
Hubble's Constant (H_0)	$km\ s^{-1}\ Mpc^{-1}$
Acoustic Impedance (Z)	$kg\ m^{-2}\ s^{-1}$

- A unit to the power of −1 ($^{-1}$) means 'per' eg. per metre = m^{-1}
  - If this is to the power of −2 or above, this means 'per' quantity squared eg. per unit area = m^{-2}
- Units of constants will be given on the data sheet
- There are a few cases when values have no units, these are:
  - When the value is calculated from a trigonometric function eg. cos(ωt)
  - Ratios, where both quantities have the same units eg. v / c
  - A number of something eg. number of molecules

Examiner Tips and Tricks

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> Not all exam questions will provide the unit, and a mark is often allocated for this in a calculation. Always write your answer in SI units, unless stated otherwiseNot checking units carefully when calculating values from a graph or table is very common mistake. Make sure to check the units on the axes and if they match the equation you are using.

Homogeneity of Physical Equations

- An important skill is to be able to check the homogeneity of physical equations using the SI base units
- The units on either side of the equation should be the same
- To check the homogeneity of physical equations:
  - Check the units on both sides of an equation
  - Determine if they are equal
  - If they do not match, the equation will need to be adjusted

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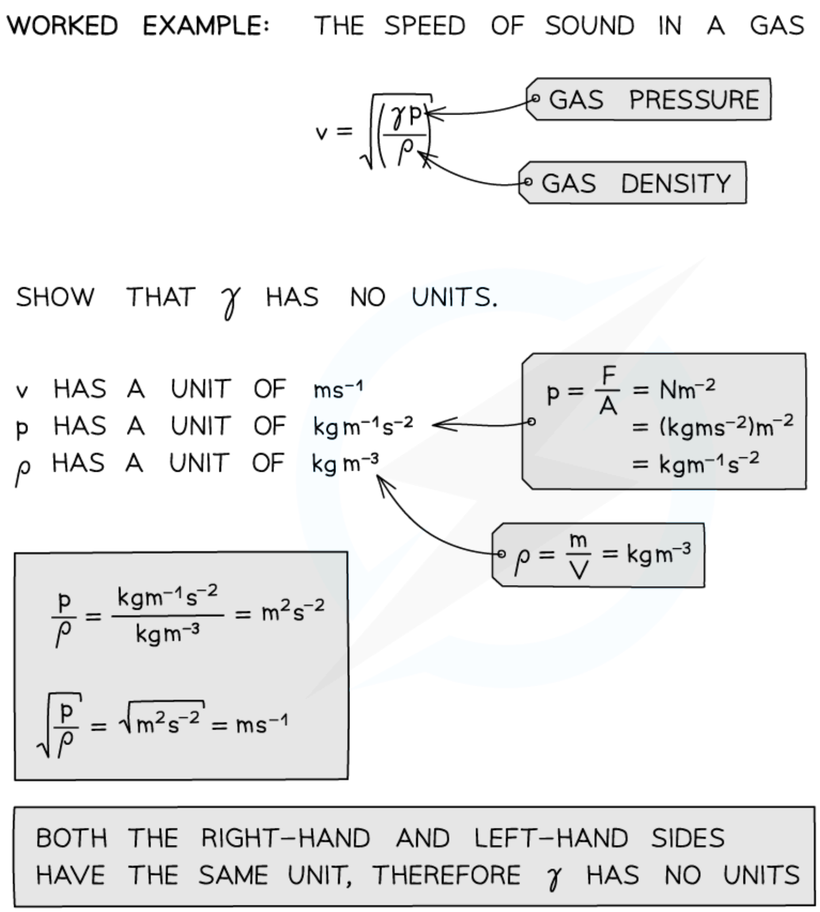

How to check the homogeneity of physical equations

Powers of Ten

- Physical quantities can span a huge range of values
- For example, the diameter of an atom is about 10^{-10} m (0.0000000001 m), whereas the width of a galaxy may be about 10^{21} m (1 000 000 000 000 000 000 000 m)
- This is a difference of 31 powers of ten
- Powers of ten are numbers that can be achieved by multiplying 10 times itself
- It is useful to know the prefixes for certain powers of ten

Powers of Ten Table

Prefix	Abbreviation	Power of ten
Tera–	T	10^{12}
Giga–	G	10^{9}
Mega–	M	10^{6}
Kilo–	k	10^{3}
Centi–	c	10^{-2}
Deci–	d	10^{-1}
Milli–	m	10^{-3}
Micro–	μ	10^{-6}
Nano–	n	10^{-9}
Pico–	p	10^{-12}

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Examiner Tips and Tricks

You will often see very large or very small numbers categorised by powers of ten, so it is very important you become familiar with these as getting these prefixes wrong is a very common exam mistake!

There is also a power of ten known as a Femto– (f) which is equal to 10^{-15}, knowledge of this is not required according to the OCR specification, however, it has been known to crop up occasionally so make sure you are aware of the Femto (f) too!

Labelling Graphs & Tables

Your notes

Graph & Table Labelling Conventions

- There are specific conventions for labelling physical quantities in columns of data in tables and on graph axes

Table Conventions

- When labelling table headings, the symbol is presented first, then a forward slash and the unit
  - e.g. Current with unit Amps – ***I* / A**
- The general convention for tables:
  - The **independent variable** goes in the column on the left
  - The **dependent variable** goes in the column on the right
- Sometimes, powers of tens are also included with the unit, such as t / × 10^2 s
  - This means the column of data has been divided by 100 to save repeating lots of zeros in the table
  - If the values of *t* in the table or axes on the graph are 1, 2 and 3, the actual values obtained for *t* are 100 s, 200 s and 300 s
- Any processed data (eg. averages) should be in columns to the far right
- All units should be in the table headings, **not** in the body
- Any raw data should be recorded to the resolution of the measuring instrument
- All data of the same type must be recorded to the **same** number of **decimal places**
- An example table and graph is shown below for a Velocity v Time graph:

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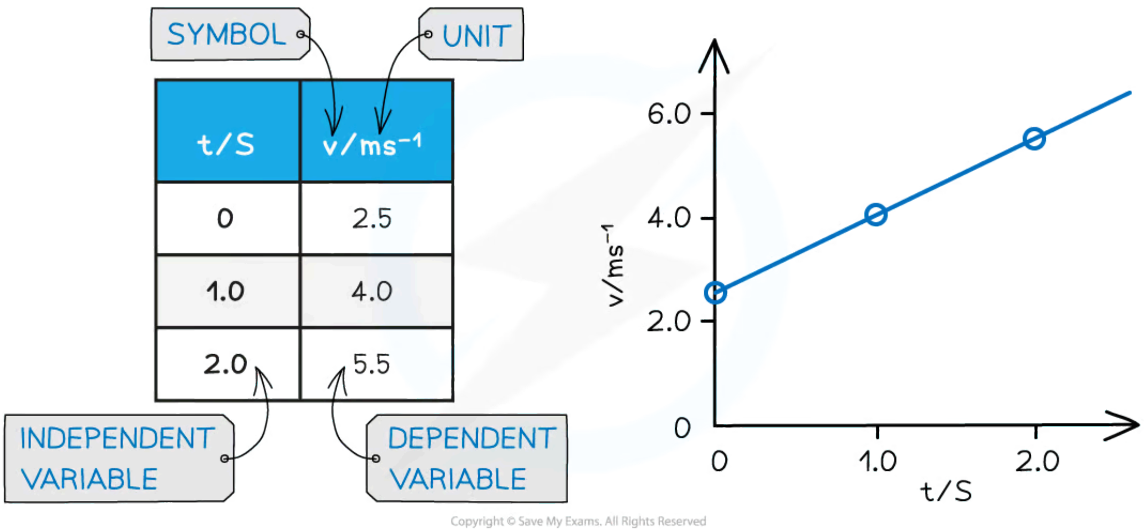
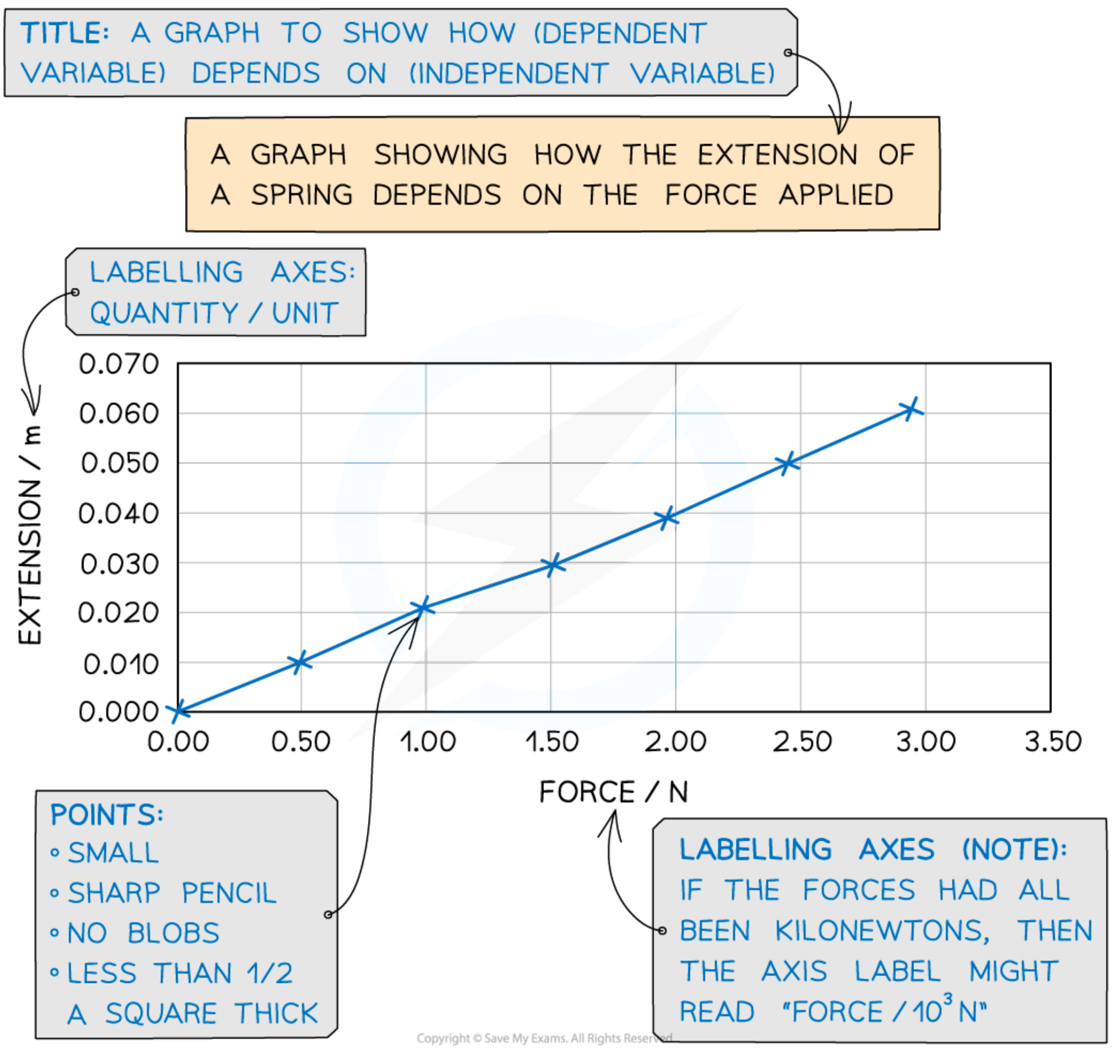


The convention for labelling tables and graphs

Graph Conventions

- When labelling graphs:
  - The independent variable should be plotted on the x-axis
  - The dependent variable should be plotted on the y-axis
- Each axis should be labelled with the quantity and unit, separated by a forward slash just like the table headings
- The graph must cover over 75 % of the space provided
  - This means either axis does not always have to start at 0
- The only exception to this is that a y-intercept must always be read from an axis that starts at x = 0
- A suitable scale must be used for each axis to provide this (in steps of 1, 2, 5 or a multiple of 10)
- When calculating a gradient, draw a triangle that covers at least 75 % of the data points
- Similar to table headings, powers of tens may also be included with the unit on the axes labels, such as ***t* / × 10^2 s**
- The data points should be made with a small sharp pencil
  - The general convention is to put an 'x' instead of a dot, as this is clearer to see on graph paper

- A line of best fit should have roughly equal points on either side and should not be forced through the origin
  - It must also be a thin line that is clear, drawn using a straight edge or ruler



An example of a correctly labelled and plotted graph

Examiner Tips and Tricks

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One way to remember which axis is labelled with the independent and dependent variable is that the word 'independent' is a longer word and therefore 'sinks' to the bottom axis (the x axis)

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