A Level Physics Edexcel

1. Working as a Physicist

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Working as a Physicist

1.1 SI Units

SI Units

- Everytime a quantity is measured or calculate, it must be quoted with its **units**
- All units in Physics can be reduced to seven base units from which every other unit can be derived
  - These other quantities are called derived units
- These seven units (of which you need to know six) 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

Derived Units

- Derived units are derived from the SI Base units mathematically
- The base units of physical quantities can be deduced, such as:
  - Newtons, **N**
  - Joules, **J**
  - Pascals, **Pa**

- 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 ÷ m^2 = (kg m s^{-2}) ÷ m^2 = kg m^{-1} s^{-2}
  - Therefore, the Pascal (Pa) in SI base units is **kg m^{-1} s^{-2}**

Exam Tip

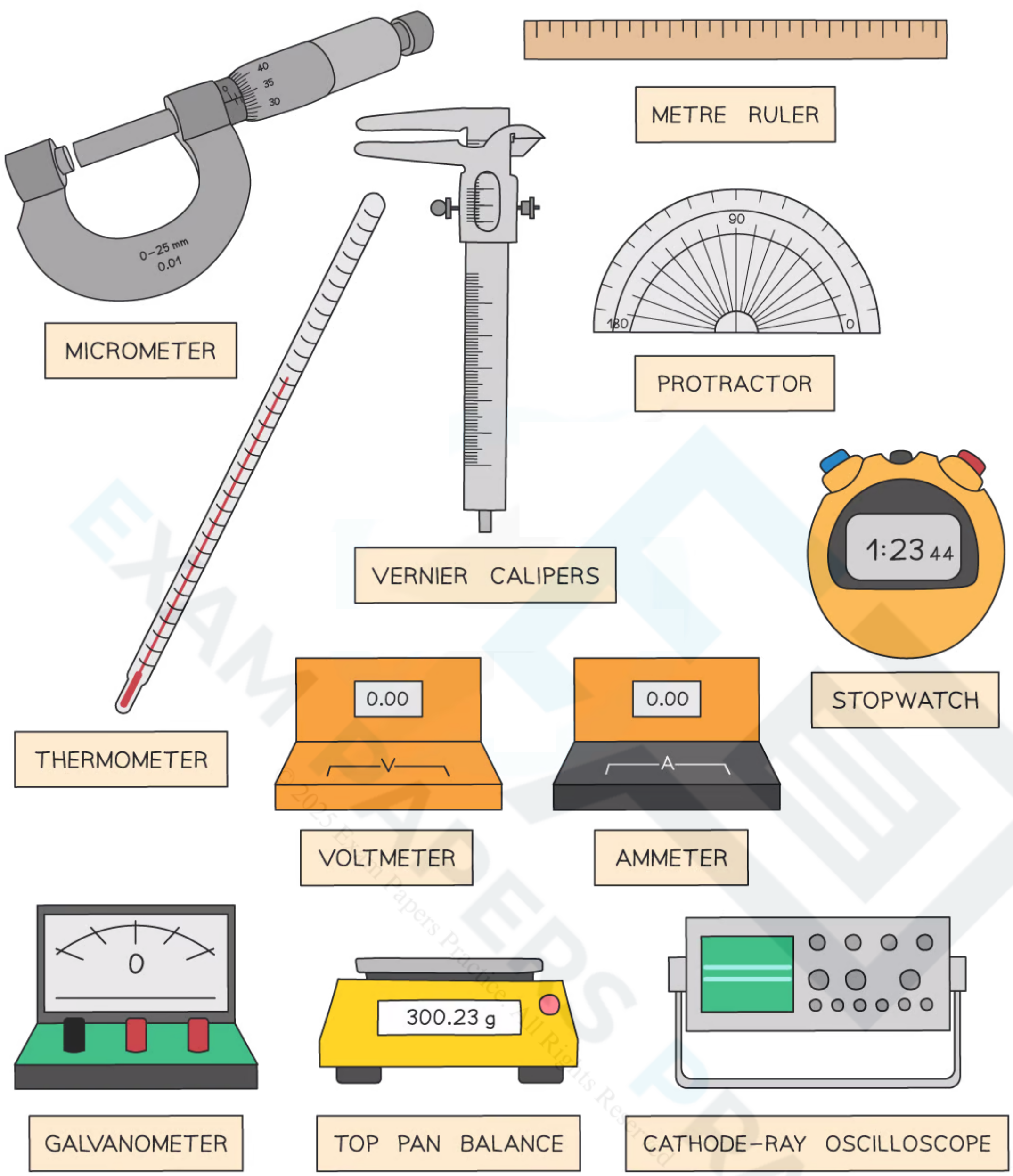
You will only be required to use the first five but be aware of six SI base units in this course, so make sure you know them!

Practical Skills

Using Equipment

- Good practical skills involves choosing the right equipment
- Knowing how to **use** it for a physics experiment is crucial
- When using measuring instruments, it is important to be aware of what each division on a scale represents
  - This is known as the **resolution**
- A list of common apparatus is shown below:

Apparatus	Purpose	Typical Resolution
Metre Value	To measure the Length of an object of moderate length	1 mm
Venier Calipers	To measure short Lengths	0.05 mm
Micrometer Screw Gauge	To measure small values of width, thickness, or diameter	0.001 mm
Top-pan Balance	To measure the mass of an object	0.01 g
Protractor	To measure angles	1°
Stopwatch	To measure periods of time	0.01 s
Thermometer	To measure the temperature of a body	1° C
Voltmeter	To measure the potential difference across a component	1 mV – 0.1 V
Ammeter	To measure the electric current flowing through a component	1 mA – 0.1 A
Oscilloscope	To display waves and measure their frequencies	1 Hz
Laser	To provide a monochromatic source of Light	450 – 650 nm



A selection of apparatus commonly used in physics experiments

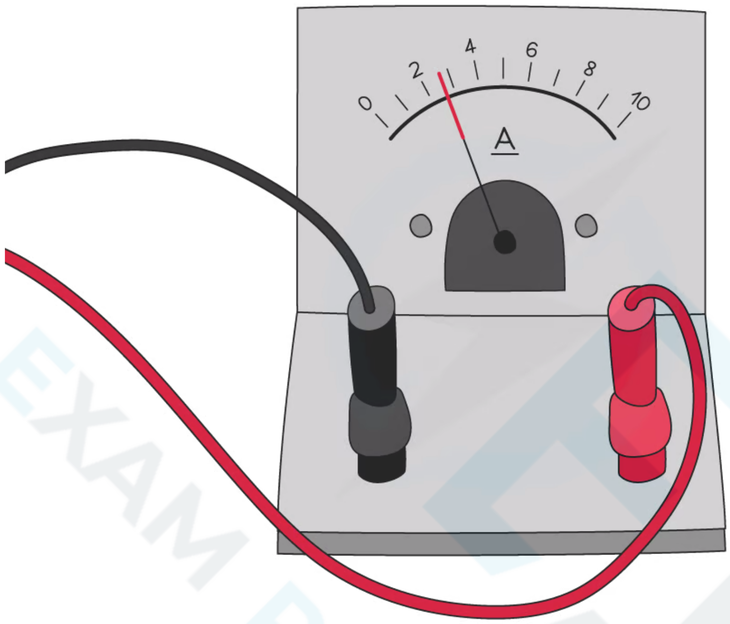
Types of Display

- Scientific instruments can be **digital** or **analogue**

Analogue

- Analogue scientific instruments transfer information through electric pulses of varying amplitude
  - This means they cannot be read easily by a computer

- Analogue instruments are cheaper but they have lower **accuracy** and **resolution**
- They are also more **sensitive**, which can make it difficult to read fluctuating values
  - An analogue display normally involves a pointer which indicates a value depending on its position or angle on the scale



Analogue meter

- The measurements taken on this analogue ammeter are restricted over a range e.g. 0 - 10 A and a resolution of 1 A
- Analogue meters are subject to zero errors
  - This means the marker must be double-checked before each reading. If it is not at zero, then the value but be subtracted from all the measurements
- They are also subject to parallax error
  - Always read the meter from a position directly perpendicular to the scale
- A potentiometer is an example of a sensitive analogue meter

Digital

- Digital scientific instruments translate information into binary (0 or 1) format which can then be read and analysed by a computer
- They are more expensive but have greater accuracy and resolution than analogue instruments
- Digital displays show the measured values as digits
- They're easy to use because they give a specific value and are capable of displaying more precise values

Digital meter

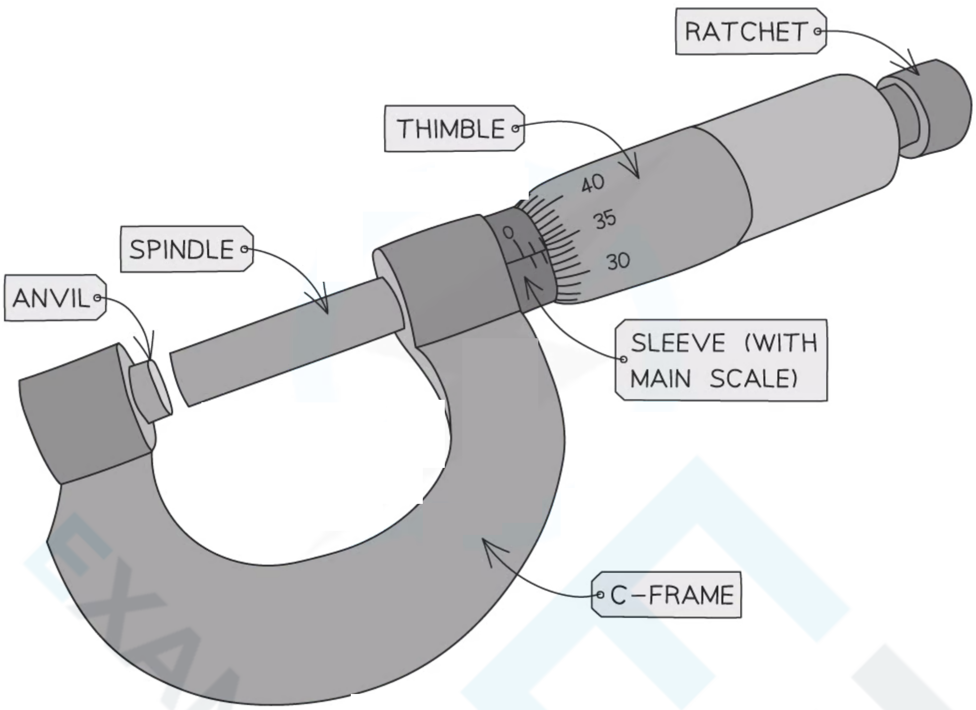
- The measurements taken on this digital ammeter have a much wider range and a resolution of 0.01 A
- Digital meters are also subject to **zero error**
  - Make sure the reading is zero before starting an experiment, or subtract the "zero" value from the end results
- Most digital meters have an auto-range function, this means it can show very low or very high values depending on the readings
  - This saves time selecting an instrument with the correct range and precision for your experiment
- A digital multi-meter is an example of a digital meter

Reading Distances

- Reading distances using calipers or micrometers will be expected for the practical examination

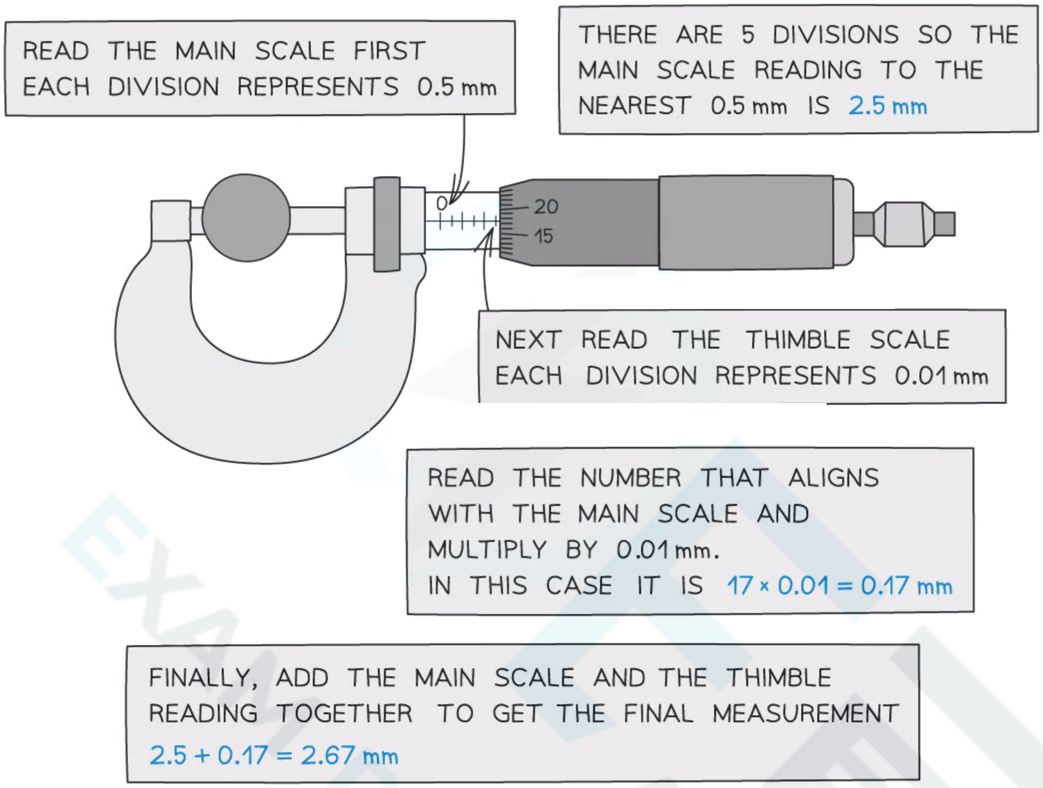
Micrometer Screw Gauge

- A micrometer, or a micrometer screw gauge, is a tool used for measuring small widths, thicknesses or diameters
  - For example, the diameter of a copper wire
- It has a resolution of **0.01 mm**
- The micrometer is made up of two scales:
  - The main scale - this is on the sleeve (sometimes called the barrel)
  - The thimble scale - this is a rotating scale on the thimble



Components of a micrometer

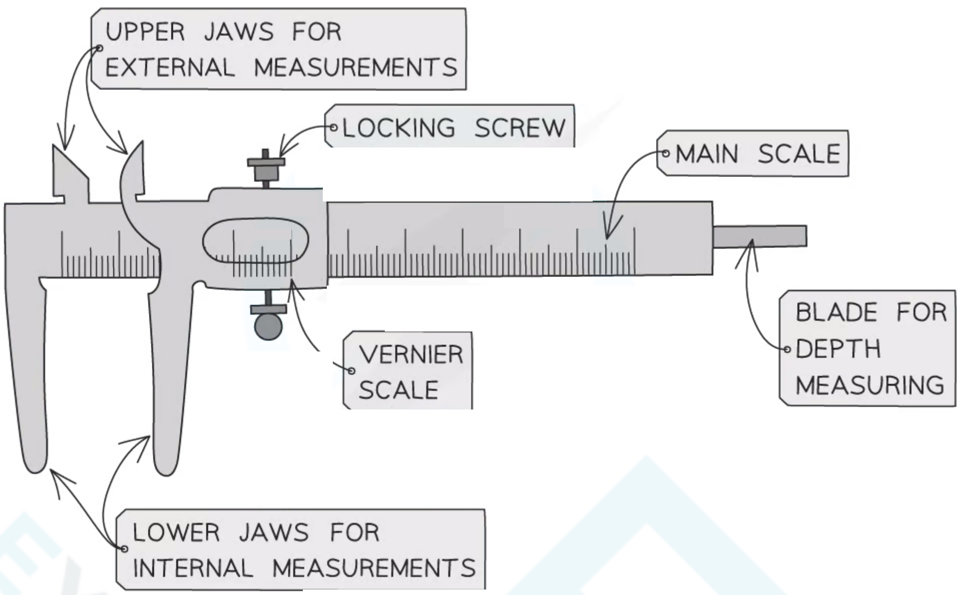
- By rotating the rachet, the spindle and anvil are clamped around the object being measured
  - This should be tight enough so the object does not fall out but not so tight that is deformed
  - **Never** tighten the spindle using the **barrel**, only using the **ratchet**. This will reduce the chances of overtightening and zero errors
- The value measured from the micrometer is read where the thimble scale aligns with the main scale
  - This should always be recorded to 2 decimal places (eg. 1.40 mm not just 1.4 mm)



The micrometer reading is read when the thimble scale aligns with the main scale

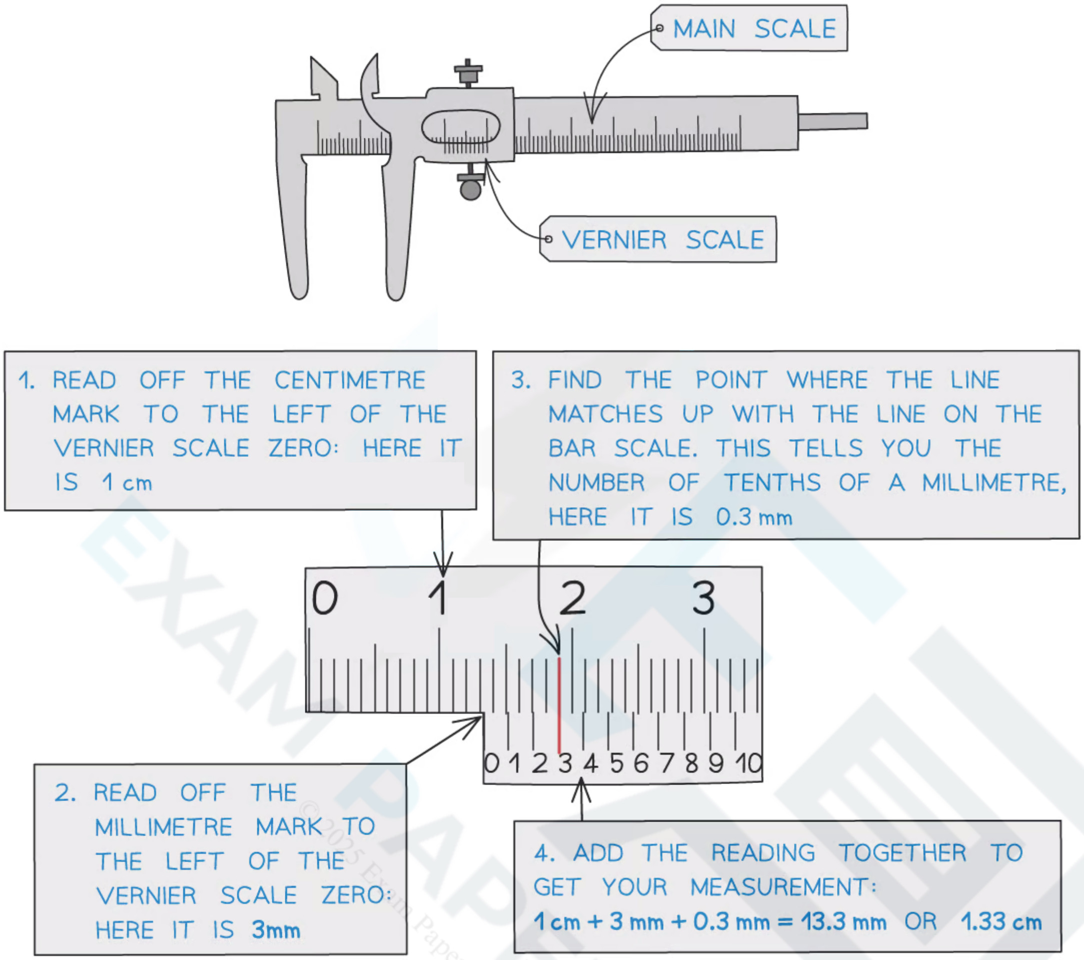
Vernier Calipers

- Vernier calipers are another distance measuring tool that uses a sliding vernier scale
  - They can also be used to measure diameters and thicknesses, just like the micrometer
  - However, they can also measure the length of small objects such as a screw or the depth of a hole
- Vernier calipers generally have a resolution of **0.1 mm**, however, some are as small as 0.02 mm - 0.05 mm
- The calipers are made up of two scales:
  - The main scale
  - The vernier scale
- The two upper or lower jaws are clamped around the object
  - The sliding vernier scale will follow this and can be held in place using the locking screw



Components of a vernier caliper

- The value read from the caliper when the vernier scale aligns with the main scale
    - This should always be recorded to at least 1 decimal place (eg. 12.1 mm not just 12 mm)



The vernier caliper reading is read when the vernier scale aligns with the main scale

- In general, the micrometer has a smaller measuring range than a vernier caliper
- However, the micrometer has a better accuracy (due to better resolution)
- The vernier caliper is quicker to use, whilst the micrometer involves rotating the thimble
  - Therefore, to take many measurements, a caliper would be easier to use

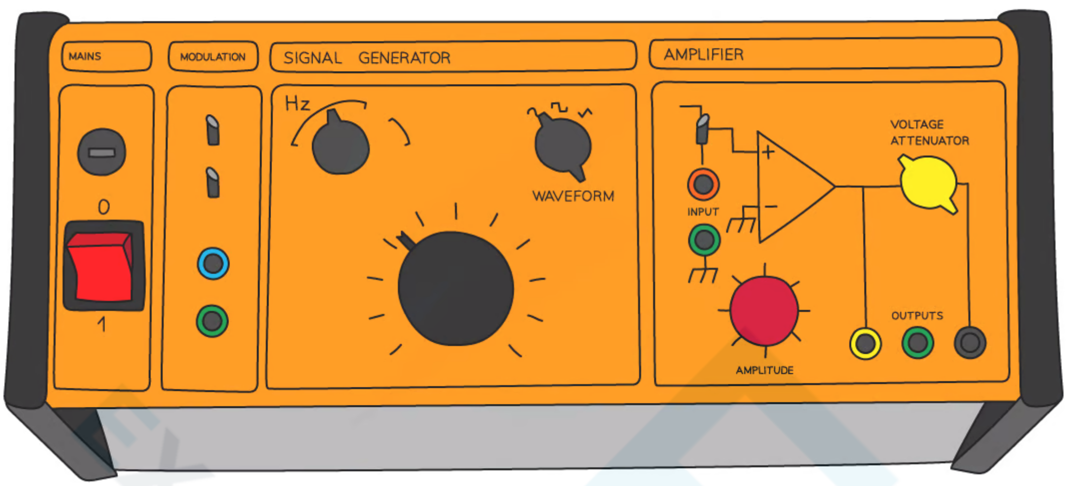
Signal Generators & Oscilloscopes

- Signal generators and oscilloscopes are commonly used in practicals to visualise waves

Signal Generator

- A signal generator is an electronic test instrument used to create repeating or non-repeating waveforms
  - They can be adjusted for different shapes and amplitudes
- These are often used for designing and repairing electronic devices, to check they are working as expected

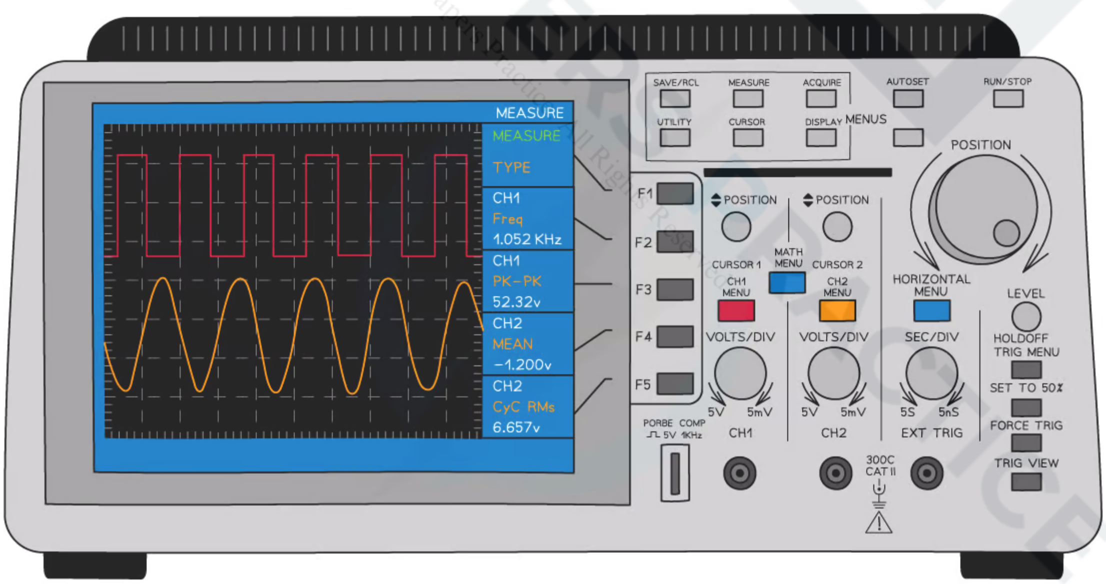
- Signal generators are used to create signals to then show on oscilloscopes



A signal generator can be used to create signals for a CRO

Cathode-Ray Oscilloscope

- A Cathode-Ray Oscilloscope (CRO) is a laboratory instrument used to display, measure and analyse waveforms of electrical circuits
  - It can therefore be used as an a.c and d.c voltmeter



A cathode-ray oscilloscope displays the signal generated by the signal generator

- An **a.c** voltage on an oscilloscope is represented as a **transverse wave**
  - Therefore you can determine its frequency, time period and peak voltage

- A **d.c** voltage on an oscilloscope is represented as a **horizontal line** at the relevant voltage
- The x-axis is the **time** and the y-axis is the **voltage (**or **y-gain)**

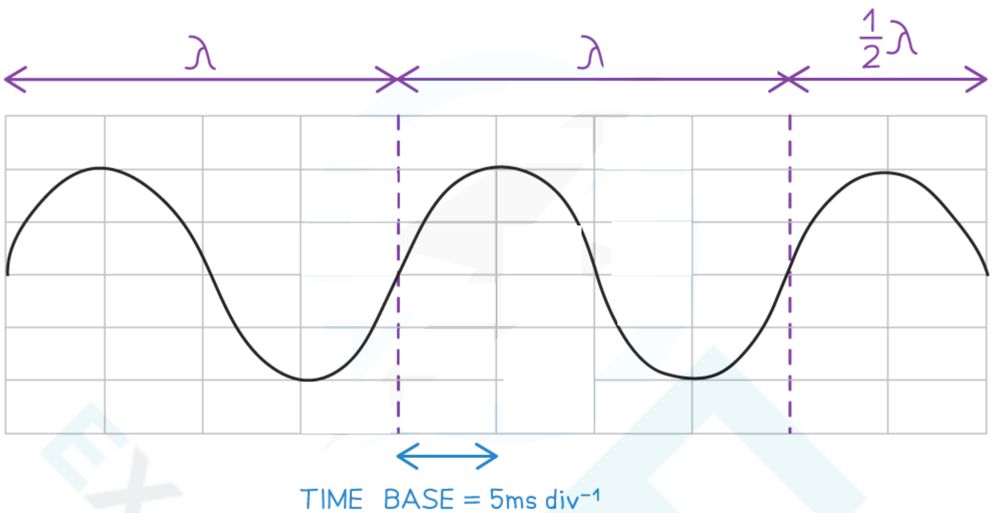


Diagram of Cathode-Ray Oscilloscope display showing wavelength and time-base setting

- The period of the wave can be determined from the **time-base**
  - This is **how many seconds each division represents** measured commonly in **s div^{-1}** or **s cm^{-}**

C.R.O Controls for an A.C waveform

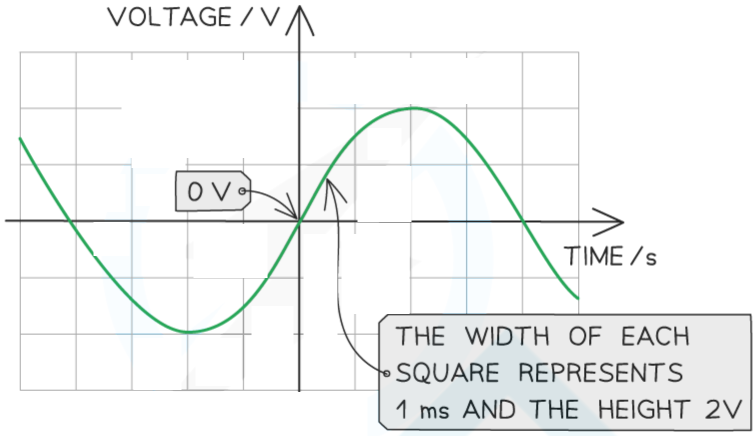
- Time-base
  - When the **time-base** is switched off, only a **vertical line** on the **voltage-gain** axis is seen with its relevant amplitude
  - When the **time-base** is switched on, a wave will appear across the whole screen and the time period can be measured
  - This control has units of time cm^{-1} or **time div^{-1}** and has a range of 100 ms – 1 μs per cm, or division
- Voltage-gain (sensitivity)
  - This controls the vertical deflection, or amplitude, of the wave
  - The **peak voltage** (V_0) is the maximum vertical displacement measured from the time axis
  - The **peak-to-peak voltage** is the vertical displacement between the minimum and maximum values of voltage
  - When the voltage-gain is switched off, only a horizontal line on the time axis will be seen
  - This control has units of volts cm^{-1} or volts div^{-1}

C.R.O Controls for a D.C waveform

- For a d.c waveform, only a horizontal line is displayed at the relevant voltage
  - The time-base settings are irrelevant since there is no time period

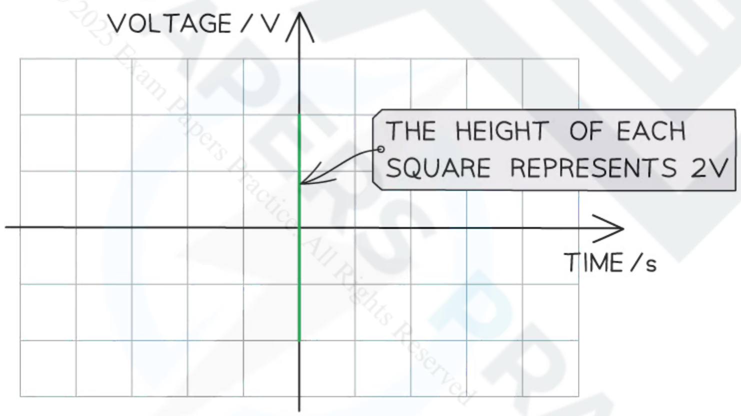
- The voltage-gain setting **is** relevant since this is used to read the value of the d.c voltage

EXAMPLE:
A **SINUSOIDAL ALTERNATING** VOLTAGE SIGNAL



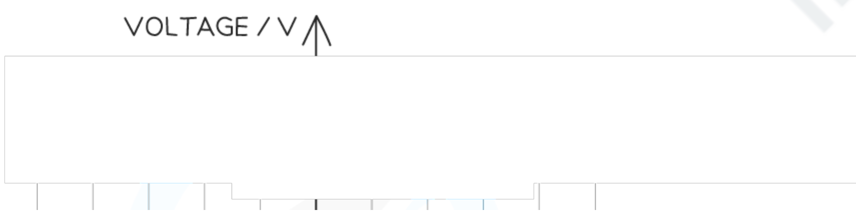
OSCILLOSCOPE SETTINGS:
Y–GAIN = 2V PER DIVISION,
TIME BASE = 1 ms PER DIVISION

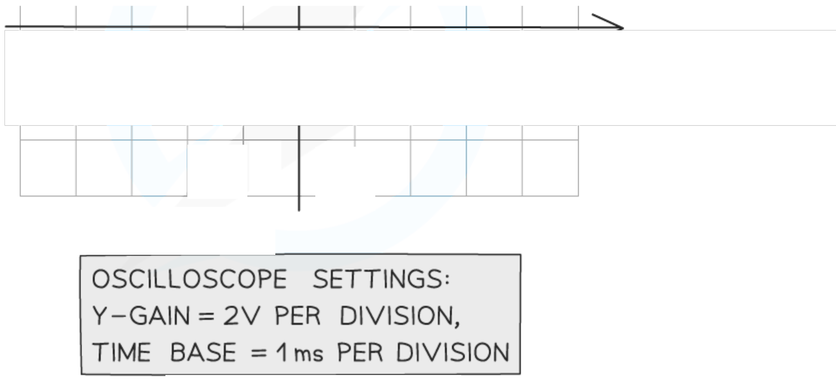
A SINUSOIDAL ALTERNATING VOLTAGE WITH THE **TIME BASE** TURNED **OFF**



OSCILLOSCOPE SETTINGS:
Y–GAIN = 2V PER DIVISION,
TIME BASE TURNED OFF

A **DIRECT CURRENT** SUPPLY

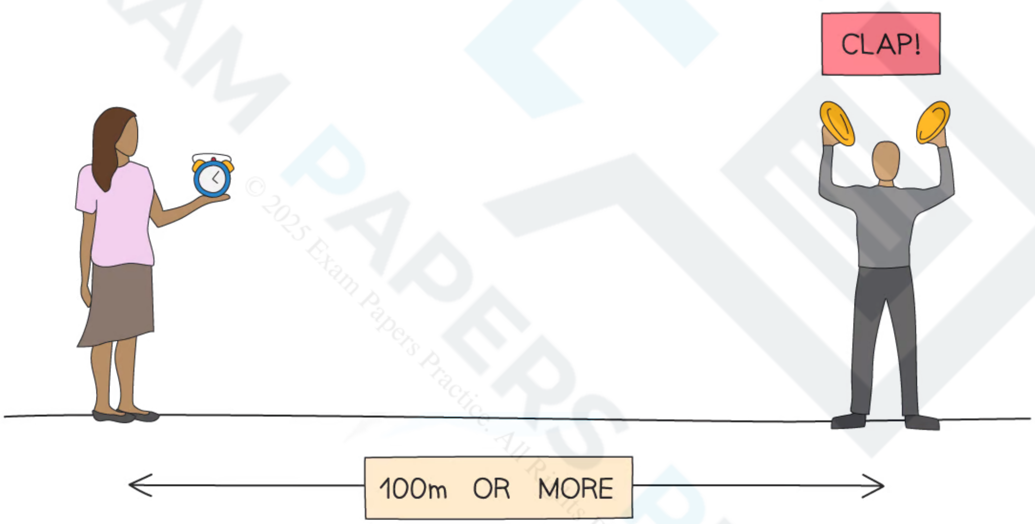




Examples of an alternating and direct voltage on a CRO with and without the time base

Timing

- A stopwatch or light gates are common physics instruments used for measuring time
  - For example, the time taken for a ball to fall a certain distance



A stopwatch is used to measure the time interval between the clap and when the sound is heard

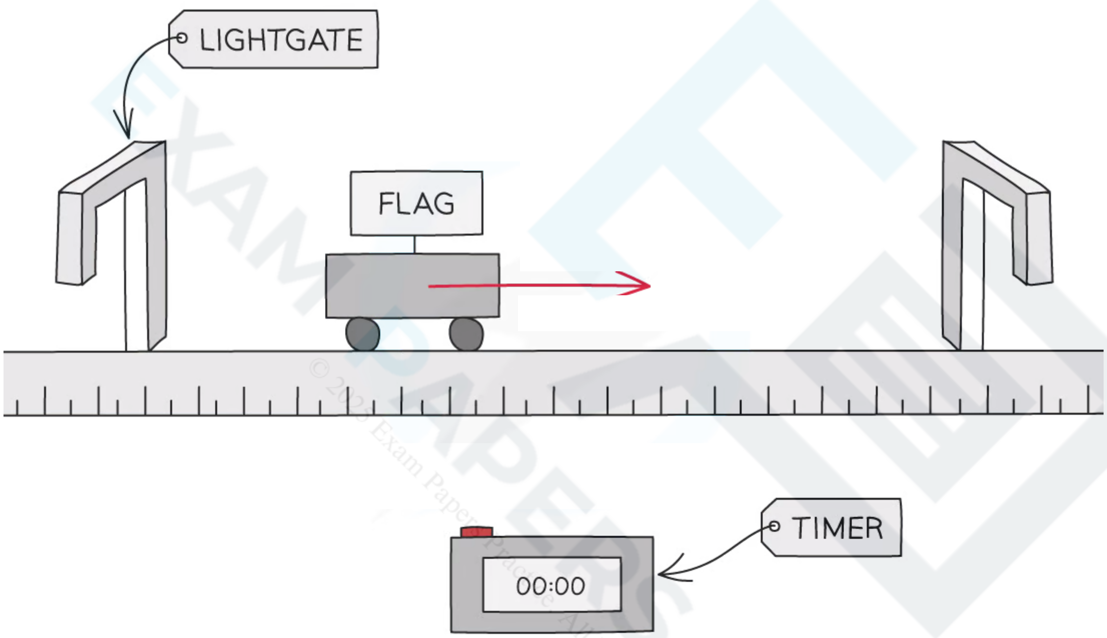
  - The disadvantage of keeping time manually using a stopwatch is there will be a large error in the reading
  - This is caused by:
    - Human reaction time (on average, about 0.25 s)
    - The mechanism of the stopwatch (older stopwatches may have a slight delay)
    - Accidentally pressing the start or stop button too many times
    - Consistently starting the stopwatch too late or too early
  - Therefore, repeat readings are very important for experiments that require timekeeping

Light Gate

- A light gate is a digital switch-type sensor also used in time experiments
  - They consist of an infrared transmitter and receiver between the 'gate'
  - When this signal is obstructed by an object, a timer can either be started or stopped depending on its configuration
- If the distance between two light gates is known, the time interval between an object passes through both gates can then be used to measure its speed using the equation:

speed = distance ÷ time

- This is assuming the object is not accelerating



The first light gate starts a timer, and the second stops the timer when the flag passes between them. This is used to determine the speed of the object

- A light gate is much more **accurate** than a stopwatch, as it removes the errors caused by human reaction time
- They can also be connected to a digital timer or datalogger, which then output the time in which the signals are obstructed for data analysis

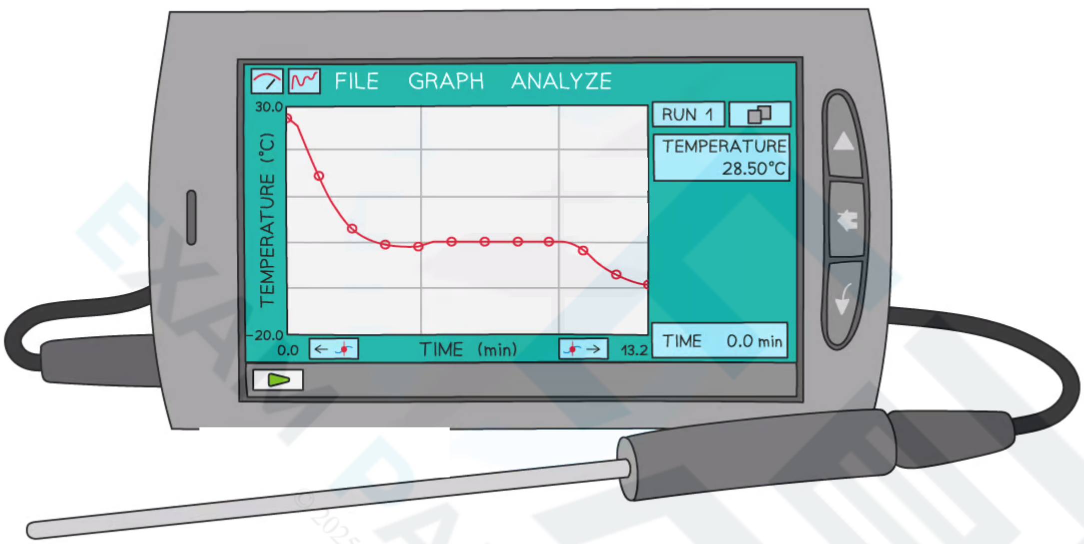
Computer Modelling & Data Loggers

- Computing modelling and data loggers are essential in all scientific experiments for obtaining and analysing reliable results

Data Loggers

- Data loggers are a tool that allows for the **quick and efficient gathering of data**
  - The information contained within a data logger can be inputted into a computer and formatted into a **table**
  - After this is done the computer is able to calculate the **average** and **plot graphs** using the data and calculate gradients, quicker and more accurately than humans

- They are electronic devices that automatically monitor and record environmental parameters over time such as temperature, pressure, voltage or current
  - It contains multiple sensors to receive the information and a computer chip to store it



A data logger measuring and displaying temperature using a probe

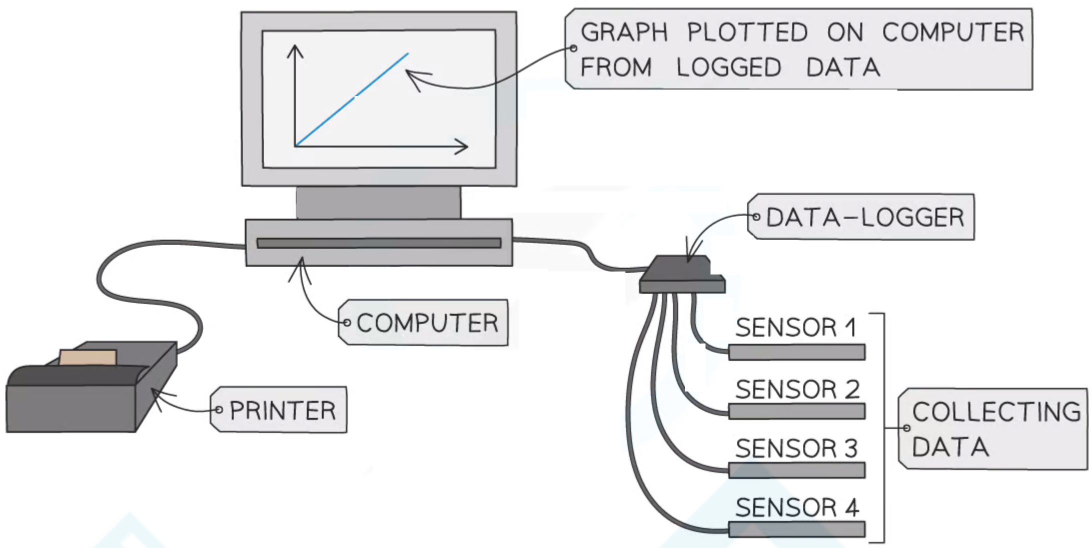
- The benefits of using data loggers and ICT (information and communication technology) include:
  - Readings are taken with **higher** degrees of **accuracy**
  - Reduction of **human error** (eg. human reaction times, subjectiveness)
  - Readings can be taken over a **long period of time** eg. hourly readings of temperature over many days
  - Readings can be taken in a **very short period of time**, which would be too quick for humans to see a difference
  - Reduction in safety risks with **extreme conditions** such as measuring the temperature of boiling water

Computer Modelling

- Computer modelling is commonly done in conjunction with devices such as a **data logger**
  - Modelling is about processing the data collected from a physics experiment into **software** or a **spreadsheet**

- Graphs and charts can be generated from a table of values
  - These can then be exported to a scientific report

- One of the benefits of these computer programs is that **time** can be **sped up to predict the future outcome** of an experiment



Computer modelling uses a computer and sensors to analyse and display data

Exam Tip

You must be familiar with all the different uses of apparatus and techniques. The apparatus to use depends on the measurement you are trying to make. For example, the diameter of a piece of hair is so small (on the order of 0.01 mm) it is best to measure with a micrometer instead of a ruler. However, the length of a piece of string would be better measured with a ruler, since it will be a few centimetres long.

Make sure to practice reading values from a micrometer or vernier scale ready for your practical paper. These can be easy marks when done correctly!

Estimate Physical Quantities

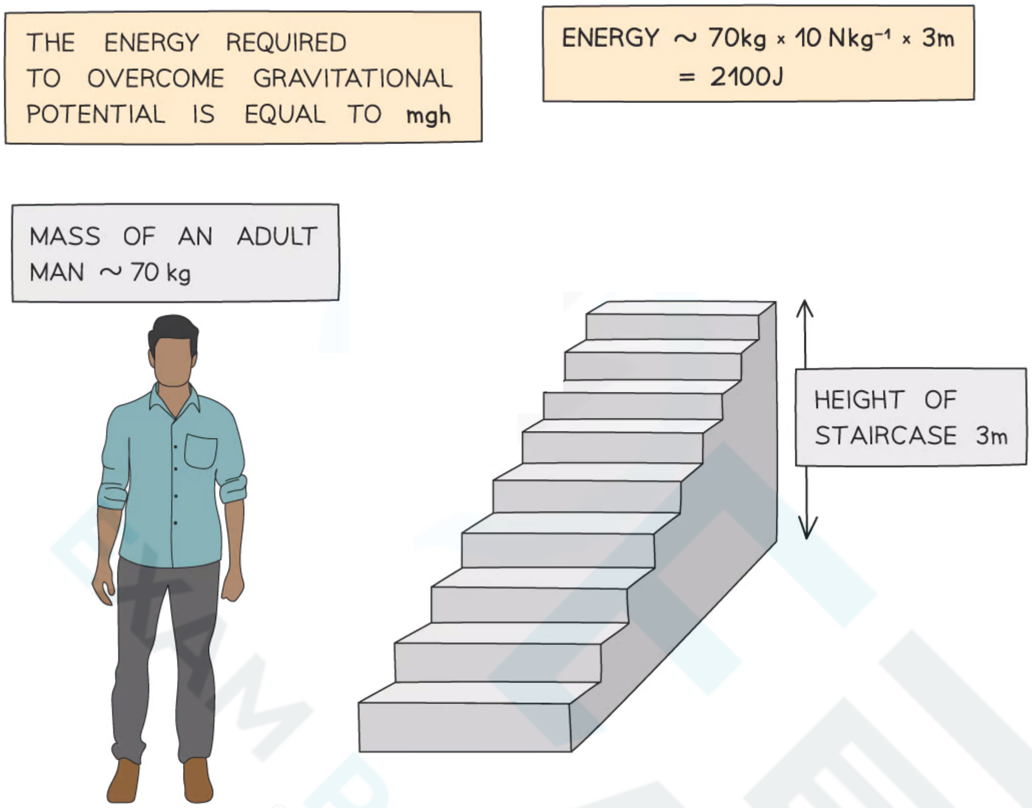
- There are important physical quantities to learn in physics
- They are particularly useful when making estimates
- A few examples of useful quantities to memorise are given in the table below (this is by no means an exhaustive list)

Estimating Physical Quantities Table

QUANTITY	Size
DIAMETER OF AN ATOM	10^{-10} m
WAVELENGTH OF UV LIGTH	10 nm
HEIGHT OF AN ADULT HUMAN	2 m
DISTANCE BETWEEN EARTH AND THE SUN (1AU)	1.5×10^{8} m
MASS OF A HYDROGEN ATON	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 LIGHT BULB	60W
ATMOSPHERIC PRESSURE	1×10^{5} Pa

Worked Example

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



Exam Tip

The mark scheme for calculations involving estimates are normally quite generous and offer a range of values as the final answer. Some common estimates are:

- Mass of an adult = 70 kg
- Gravitational field strength, g = 10 m s^{-2}
- Mass of a car = 1500 kg
- Wavelength of visible light = 400 nm (violet) – 700 nm (red)

Many values are already given in your data booklet that therefore may not be given in the question, so make sure to check there too!

Limitation of Measurements

Types of Error

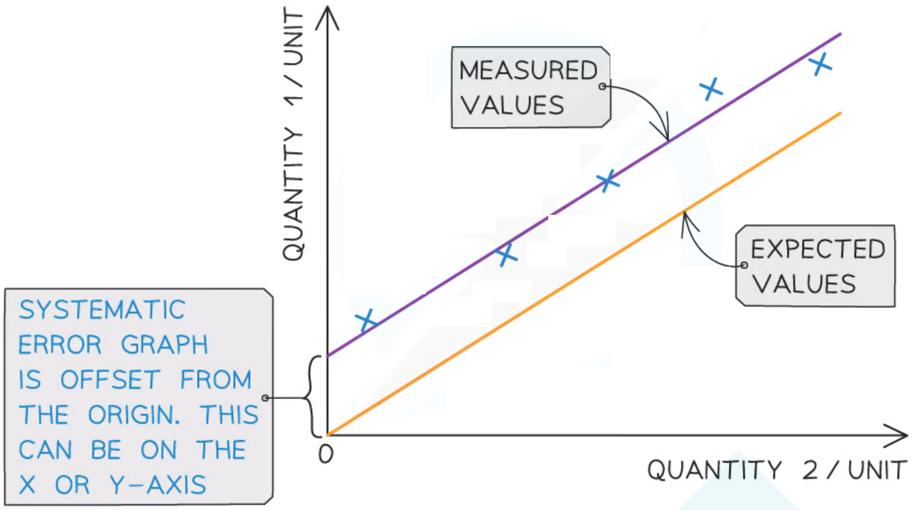
- Measurements of quantities are made with the aim of finding the true value of that quantity
- In reality, it is impossible to obtain the true value of any quantity as there will always be a degree of **uncertainty**
    - This can be seen when you repeat a measurement and you get different results
- An error is the difference between the measurement result and the true value if a true value is thought to exist
    - This is not a mistake in the measurement
    - The error can be due to both systematic and random effects and an error of unknown size is a source of uncertainty.
- Random and systematic errors are two types of measurement errors that lead to uncertainty

Random error

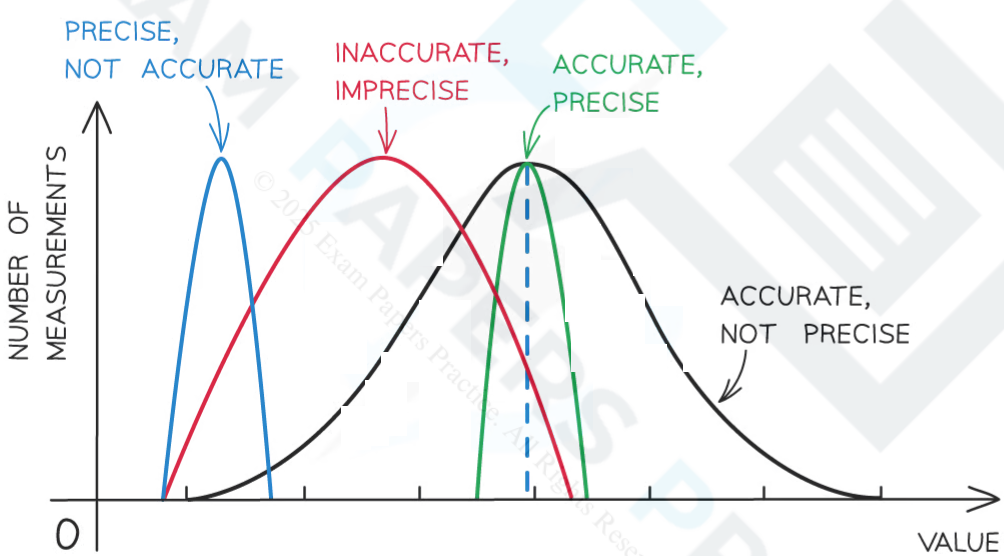
- Random errors cause **unpredictable fluctuations** in an instrument's readings as a result of uncontrollable factors, such as environmental conditions
- This affects the **precision** of the measurements taken**,** causing a wider spread of results about the mean value
- To **reduce** random error:
    - **Repeat** measurements several times and calculate an average from them

Systematic error

- Systematic errors arise from the use of **faulty instruments** or from **flaws** in the **experimental method**
- This type of error is repeated consistently every time the instrument or method are used, which affects the **accuracy** of all readings obtained
- To **reduce** systematic errors:
    - Instruments should be **recalibrated**, or different instruments should be used
    - Corrections or adjustments should be made to the technique



Systematic errors on graphs are shown by the offset of the line from the origin



Representing precision and accuracy on a graph

Zero error

- This is a type of **systematic error** that occurs when an instrument gives a reading when infact the **true reading is zero**
- This introduces a **fixed error** into the readings which must be accounted for when the results are recorded
- Zero error is a type of systematic error since all the values will be displaced by the same amount

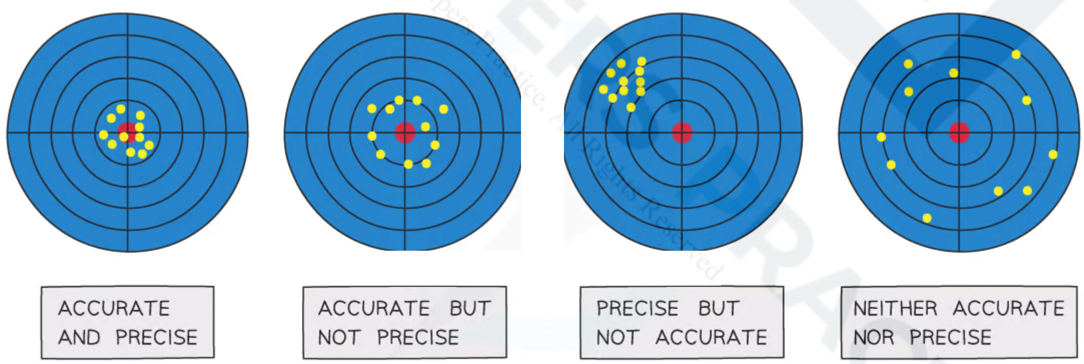
Precision vs Accuracy

Precision

- Precise measurements denote the **closeness** of agreement (consistency) between values obtained by repeated measurement
  - This is influenced only by random effects and can be expressed numerically by measures such as standard deviation.
  - A measurement is precise if the values 'cluster' closely together.
- Precise measurements have very little spread about the mean value, in other words, how close the measured values are to each other
- If a measurement is repeated several times, it can be described as precise when the values are very similar to, or the same as, each other
- The precision of a measurement is reflected in the values recorded - measurements to a greater number of decimal places are said to be more **precise** than those to a whole number

Accuracy

- A measurement is considered accurate if it is close to the true value
- It is a quality denoting the **closeness** of agreement between measurement and true value
  - It cannot be quantified and is influenced by random and systematic errors
- The accuracy can be increased by repeating measurements and finding a mean of the results
- Repeating measurements also helps to identify anomalies that can be omitted from the final results

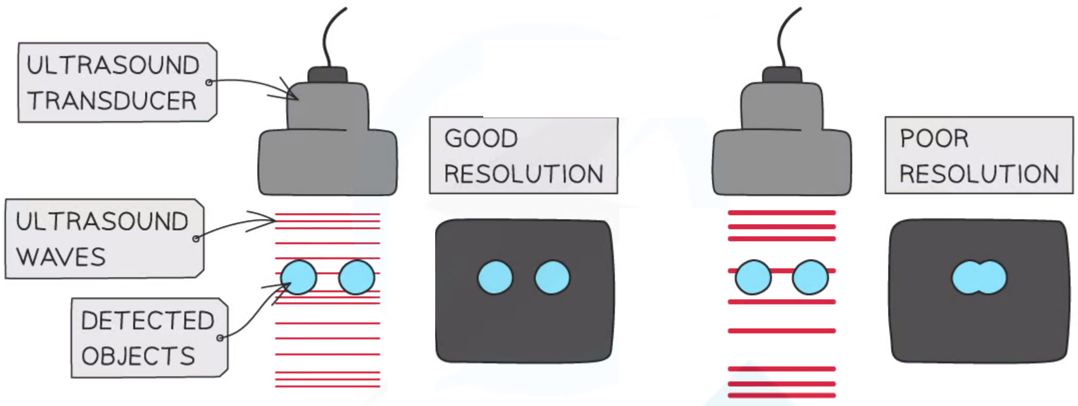


The difference between precise and accurate results

Resolution

- Resolution is the **smallest change** in the quantity being measured
  - It gives a perceptible change in the reading
  - It is also the source of uncertainty in a single reading
- For example, the resolution of a wristwatch is 1 s, whereas the resolution of a digital stop-clock is typically 10 ms (0.01 s)

- In imaging, resolution can also be described as the ability to see two structures as two separate structures rather than as one fuzzy entity



Good resolution and poor resolution in an ultrasound scanner. The good image manages to resolve the two objects into two distinct structures, whereas the poor image shows one fuzzy entity.

Uncertainties

- Uncertainty is an estimate of the difference between a measurement reading and the true value
  - In other words, it is the interval within which the true value can be considered to lie with a given level of **confidence** or **probability**
  - Any measurement will have some uncertainty about the result, this will come from variations in the data obtained and be subject to systematic or random effects
- Uncertainties are **not** the same as errors
  - **Errors** can be thought of as **issues** with equipment or methodology that cause a reading to be different from the true value
  - The **uncertainty** is a range of values around a measurement within which the true value is expected to lie, and is an **estimate**

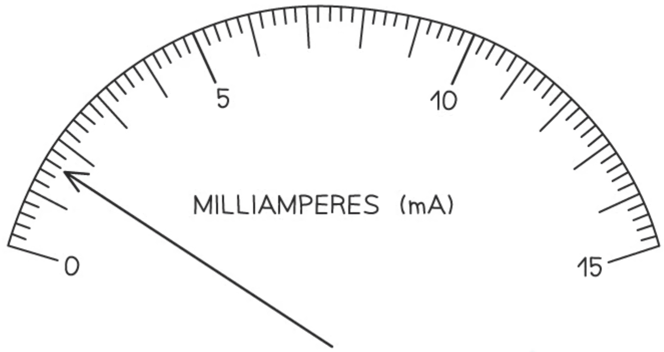
- For example, if the true value of the mass of a box is 950 g, but a systematic error with a balance gives an actual reading of 952 g, the uncertainty is ±2 g
- These uncertainties can be represented in a number of ways:
  - **Absolute Uncertainty:** where uncertainty is given as a fixed quantity
  - **Fractional Uncertainty:** where uncertainty is given as a fraction of the measurement
  - **Percentage Uncertainty:** where uncertainty is given as a percentage of the measurement

- Percentage uncertainty is defined by the equation:

$$\textbf{Percentage uncertainty} = \frac{uncertainty}{measured\ value} \times 100\ \%$$

- To find uncertainties in different situations:
  - **The uncertainty in a reading:** half the smallest division i.e. ± ½ × (resolution)
  - **The uncertainty in a measurement:** at least ±1 smallest division

- **The uncertainty in repeated data:** half the range i.e. ± ½ × (largest – smallest value)
- **The uncertainty in digital readings:** ± the last significant digit unless otherwise quoted



SMALLEST DIVISION = 0.2 mA

READING (I) = 1.6 mA

ABSOLUTE UNCERTAINTY $(\Delta I) = \frac{1}{2} \times 0.2 \text{ mA} = 0.1 \text{ mA}$

$I = 1.6 \pm 0.1 \text{ mA}$

FRACTIONAL UNCERTAINTY $= \frac{\text{UNCERTAINTY}}{\text{VALUE}} = \frac{0.1}{1.6} = \frac{1}{16}$

$I = 1.6 \pm \frac{1}{16} \text{ mA}$

PERCENTAGE UNCERTAINTY $(\%) = \frac{\text{UNCERTAINTY}}{\text{VALUE}} \times 100 = \frac{0.1}{1.6} \times 100 = 6.2\%$

$I = 1.6 \pm 6.2\% \text{ mA}$

How to calculate absolute, fractional and percentage uncertainty

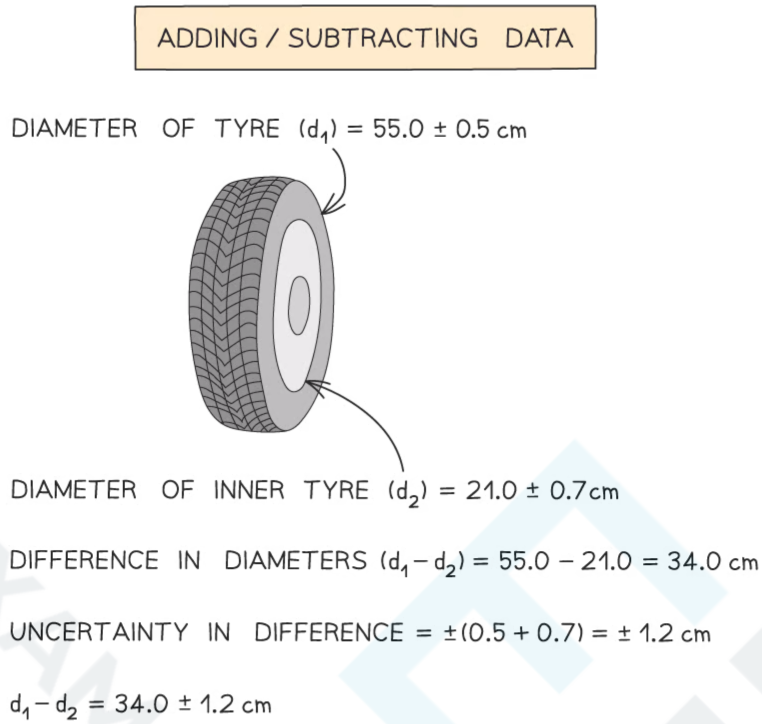
- Always make sure your absolute or percentage uncertainty is to the same number of **significant figures** as the reading

Combining Uncertainties

- When combining uncertainties, the rules are as follows:

Adding / Subtracting Data

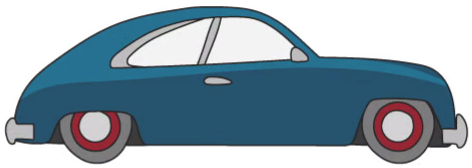
- **Add** together the absolute uncertainties



Multiplying / Dividing Data

- **Add** the percentage or fractional uncertainties

MULTIPLYING / DIVIDING DATA



DISTANCE = 50.0 ± 0.1 m

TIME = 5.00 ± 0.05 s

$$\text{SPEED } (v) = \frac{\text{DISTANCE } (s)}{\text{TIME } (t)}$$

$$V = \frac{50.0}{5.0} = 10.0 \text{ ms}^{-1}$$

$$\frac{\Delta v}{v} = \frac{\Delta s}{s} + \frac{\Delta t}{t} = \frac{0.1}{50.0} + \frac{0.05}{5.00} = 0.002 + 0.01 = 0.012$$

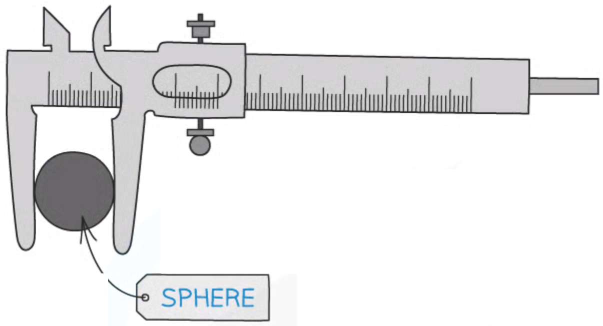
$$\text{ABSOLUTE UNCERTAINTY } (\Delta v) = 10.0 \times 0.012 = \pm 0.12 \text{ ms}^{-1}$$

$$v = 10.0 \pm 0.12 \text{ ms}^{-1}$$

Raising to a Power

- **Multiply** the percentage uncertainty by the power

RAISING TO A POWER



$V = \frac{4}{3}\pi r^3$

$r = 2.50 \pm 0.02$ cm

$V = \frac{4}{3}\pi (2.50)^3 = 65.5 \text{ cm}^3$

$\frac{\Delta V}{V} = 3 \times \frac{\Delta r}{r} = 3 \times \frac{0.02}{2.50} = 0.024$

ABSOLUTELY UNCERTAINTY $(\Delta V) = 65.5 \times 0.024 = 1.57 \text{cm}^3$

PERCENTAGE UNCERTAINTY $(\%\Delta V) = 100 \times 0.024 = 2.4\%$

Worked Example

A student achieves the following results in their experiment for the angular frequency, ω of a rotating ball bearing.

0.154, 0.153, 0.159, 0.147, 0.152

Calculate the percentage uncertainty in the mean value of ω.

Step 1: Calculate the mean value

$$\text{mean } \omega = \frac{0.154 + 0.153 + 0.159 + 0.147 + 0.152}{5} = 0.153 \text{ rad s}^{-1}$$

Step 2: Calculate half the range (this is the uncertainty for multiple readings)

$$\frac{1}{2} \times (0.159 - 0.147) = 0.006 \text{ rad s}^{-1}$$

Step 3: Calculate percentage uncertainty

$$\frac{uncertainty}{measured\ value} \times 100\ \% = \frac{\pm half\ the\ range}{mean} \times 100\ \%$$

$$\frac{0.006}{0.153} \times 100\ \% = 3.92\ \%$$

Exam Tip

It is a very common mistake to confuse precision with accuracy - measurements can be precise but **not** accurate if each measurement reading has the same error. Make sure you learn that **precision** refers to the ability to take multiple readings with an instrument that are close to each other, whereas **accuracy** is the closeness of those measurements to the true value.

Remember:

- Absolute uncertainties have the same units as the quantity
- Percentage uncertainties have **no** units
- The uncertainty in numbers and constants, such as π, is taken to be zero

Scientific Communication

- Scientific communication of the results of an experiment are extremely important
- The ideas must be communicated in an appropriate way using appropriate terminology
  - This involves using terms such as **accuracy**, **validity** and stating the sources of **random** and **systematic** errors
- Scientists have to design an experiment to answer a question or investigate something
- These will involve **dependent** and **independent** variables
  - An independent variable is what is **changed**
  - A dependent variable is what is **measured**
  - The **control variables** are what do **not change**

- For example, in an investigation of the variation of potential difference and current across a light bulb
  - The independent variable is the **potential difference**
  - The dependent variable is the **current**
  - The control variable would be the **temperature** of the apparatus

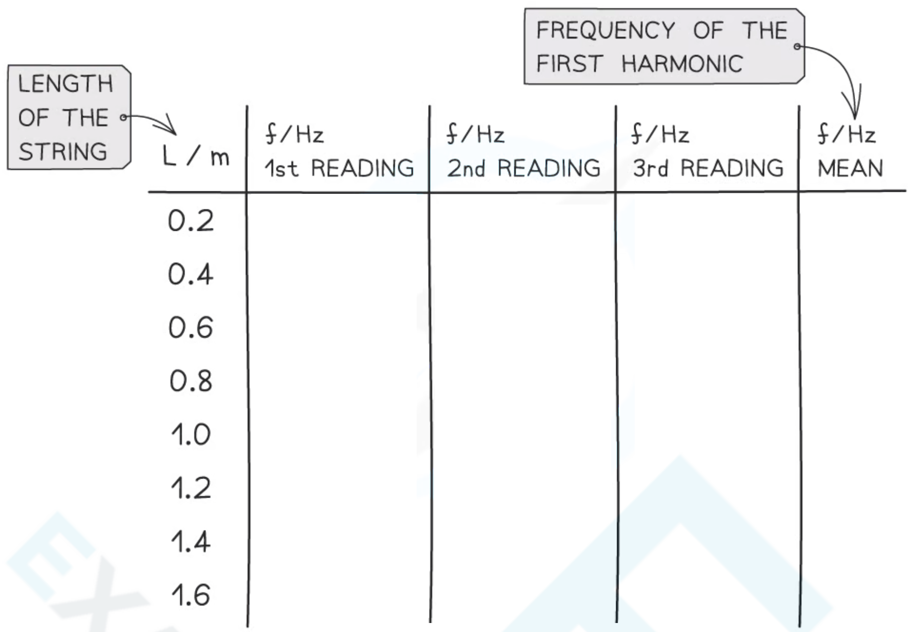
- Data must always be presented in a scientific way
- This may include:
  - Tables
  - Graphs
  - Diagrams

Presenting Data in Tables

- When taking readings, a sensible range should be taken, and the values should all be stated to an appropriate number of significant figures or decimal places
  - This is usually the same number as the resolution of the measuring instrument

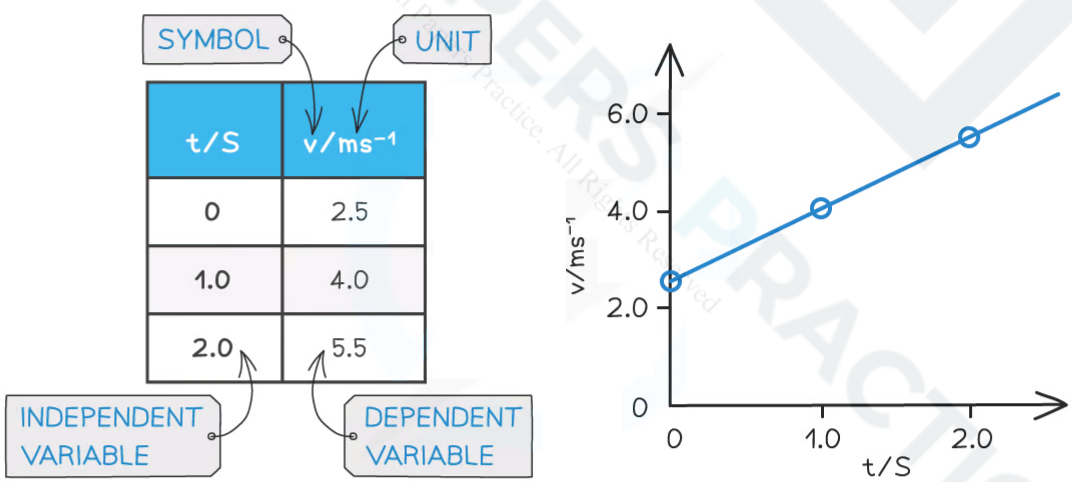
- The columns in any table should have both a **quantity** and a **unit** in their heading
  - When labelling columns, the names of the quantities should be separated from their unit by a forward slash (/)

- For data displayed in a table:
  - The first column should contain the **independent variable**
  - The second column should contain the **dependent variable**
  - If repeat readings of the dependent variable are required, these should be included with a column for the mean value at the end
  - Any columns required for processing data e.g. calculations should come after this



Conventions for presenting data in a table. The length is the independent variable and the frequency is the dependent variable

- In summary, when presenting tables the following must be included:
    - Clear headings, or symbols, for columns
    - Relevant units for measurements
    - Readings listed to the same number of significant figures



An example of a correctly labelled table with corresponding graph

Presenting Data on a Graph

- All readings, including suspected **anomalous results**, should be plotted on a graph so that they can be easily identified
- When taking repeat readings, it is the **mean** value that is plotted

- The way data is presented on a graph depends on what type of data it is

Discrete data

- Only certain values can be taken, normally a whole number e.g. number of students
  - This should be displayed on a **scatter graph** or **bar chart**

Continuous data

- Can take any value on a scale e.g. voltage in a circuit
  - This should be displayed on a **line** or **scatter graph**

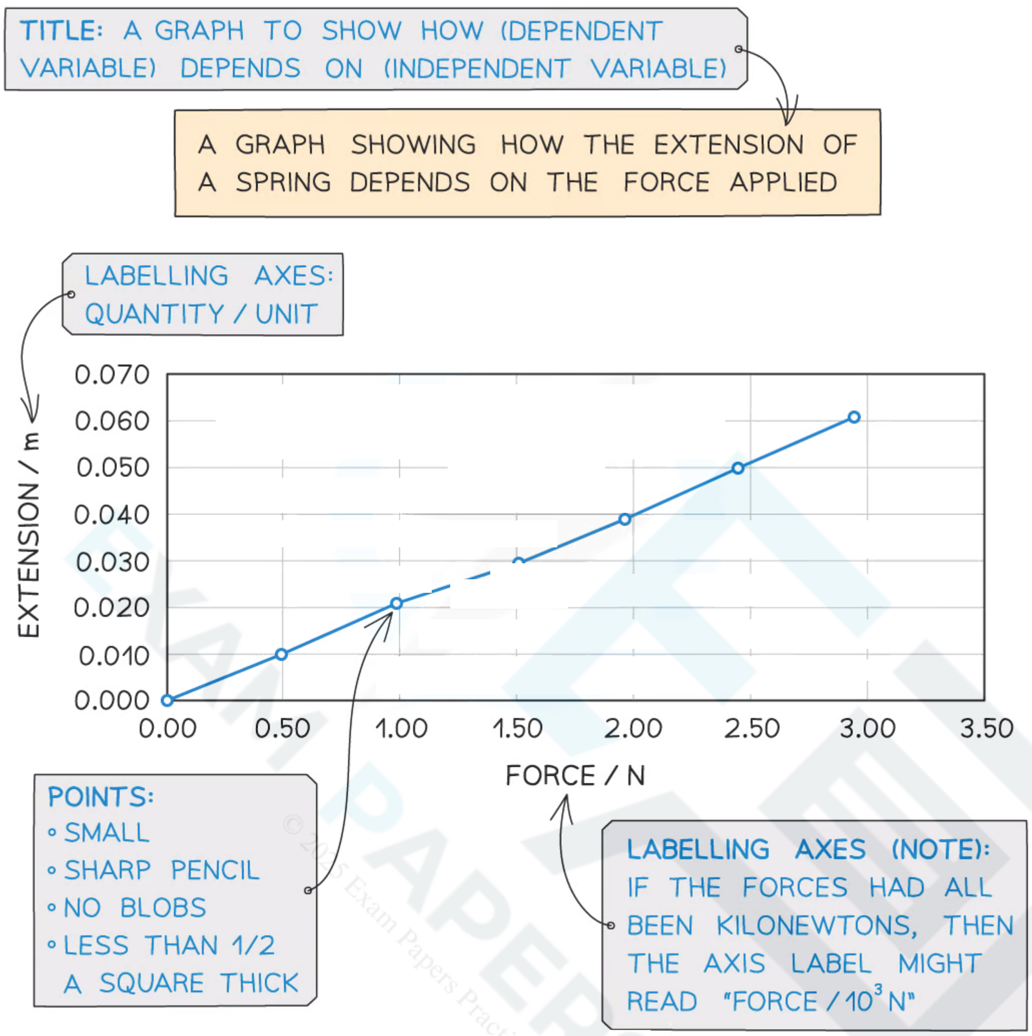
Categorical data

- Values that can be sorted into categories e.g. types of material
  - This should be displayed on a **pie** or **bar chart**

Ordered data

- Data that can be put in ordered categories e.g. low, medium, high
  - This should be displayed on a **bar chart**

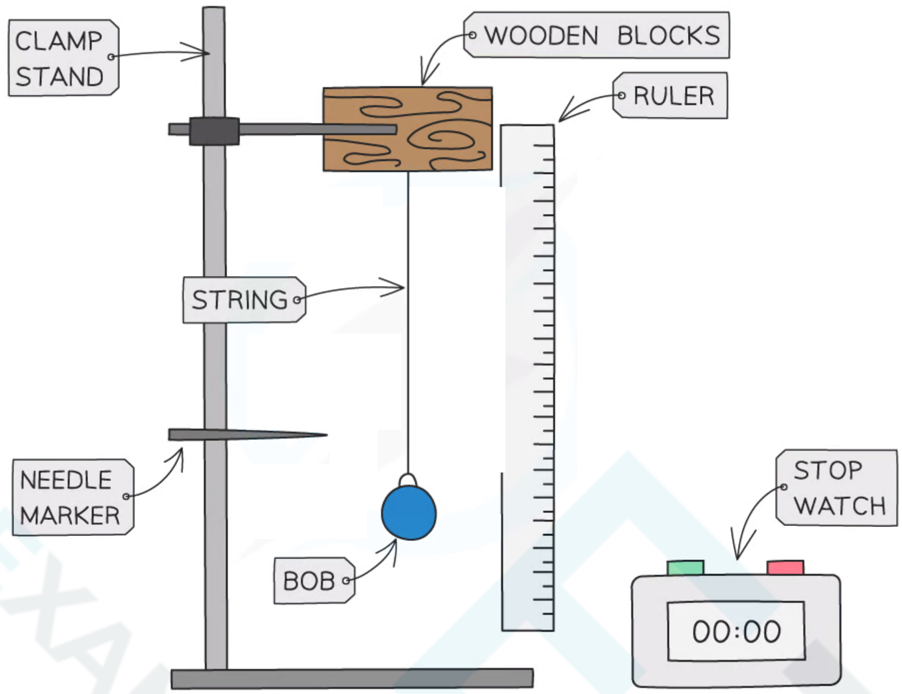
- In summary, when presenting graphs the following must be included:
  - An explanatory title
  - Clearly labeled axes
  - Relevant units for measurements
  - Well plotted points
  - A smooth line or curve of best fit



An example of a correctly labelled and plotted graph

Presenting Diagrams

- When presenting diagrams, such as apparatus set-up, all the relevant parts must be clearly labelled



An appropriately labeled diagram of the set-up of an investigation into simple harmonic motion

Applications of Science

Investigations & Evaluations

- An **application** of science involves using **scientific knowledge** to carry out an **investigation**
  - For example, developing a new type of radiotherapy, which may also include further research based on prior scientific knowledge

- **Evaluating** experimental methods is an important skill for a scientist and is appropriate to meet the expected outcomes of the experiment
- A good way to evaluate an experimental design is by
  - **Repeating** the experiment (using the instructions provided)
  - Determining the **reproducibility** of the experiment i.e. whether or not **similar results** can be achieved
- This process is known as **peer review**

- All applications of science will have **benefits** and **risks**
- For developing a new type of radiotherapy, designed to treat cancer, the benefits are clear that the treatment could potentially save lives
  - However, there are also risks with accidents occurring when using harmful radiation

- All new technologies are therefore always **tested thoroughly**
  - When carrying out practical experiments in A-Level physics, the risks should be reduced as much as possible for everyone's **safety**

- Some safety precautions include:
  - Wearing safety goggles when required
  - Not eating or drinking during experiments
  - Always keeping bags and chairs tucked away under desks to avoid someone tripping over in the classroom
  - Standing up for the duration of the experiment, in case a piece of apparatus falls off and to react quickly
  - No liquids kept around the apparatus, especially if they rely on electricity (e.g. circuits, oscilloscopes etc.)
  - Turning off the power supply in between readings for thin wires so they don't become too hot. This could cause a burn or, affect the results of the experiment from the change in temperature
  - A soft surface underneath anything falling (such as a ball bearing when calculating *g*), to protect surfaces
  - Attaching a clamp stand to the table surface to keep it rigid

Implications of Science

- An **implication** of science is a consequence of the scientific knowledge
- The implications could be:
  - **Commercial** - concerning money e.g. the funding for a scientific experiment
  - **Legal** - concerning law e.g. copyright protection for data collections
  - **Ethical** - concerning moral principles e.g. using animals, humans

- **Social** – concerning society e.g. how the results affect all members of society (children, elderly, disabled etc.)
- For example, when building a new power station, although this will provide an appropriate energy source, the implications could be:
  - **Commercial** – who pays to run and maintain the power station and how much will this cost
  - **Legal** – planning permissions to build the power station which requires a lot of land
  - **Ethical** – is it safe for the wildlife that live in the area
  - **Social** – how will the power station affect the people that live in the surrounding area in both health and economic prospects (e.g. providing more jobs)

YOUR NOTES
⬇

Validating Experimental Results

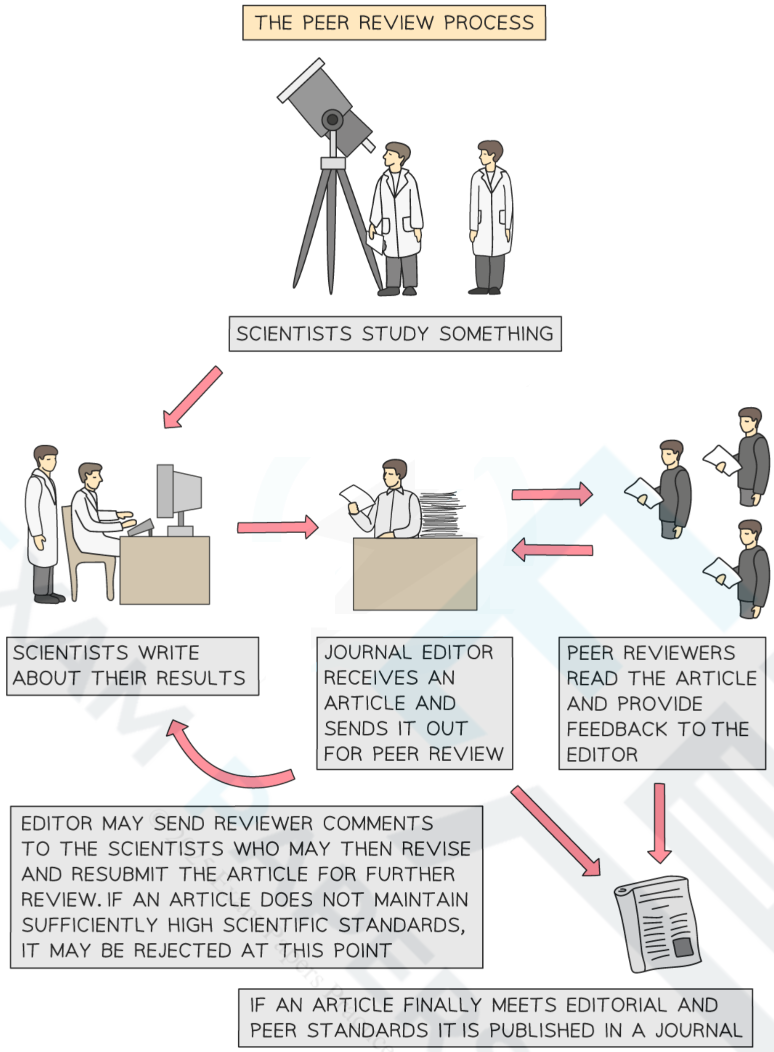
- The scientific community works together to ensure that the knowledge and understanding of scientific concepts are kept as up to date as possible
  - This comes from continuous experimenting based on evolving knowledge and new developments in technology
- For example, one of the early models of the atom was the 'plum pudding model' by JJ Thompson
  - Emerging evidence later found by Ernest Rutherford established that most of the atom was actually empty space
  - This lead to an evolved understanding of what the atom looks like, which is still being investigated to this day
- Scientists **ask questions**, suggest answers (**hypothesise**) then **test** these suggestions
  - This is known as the **scientific process**

The Scientific Process

1. Ask a question about why something happens or how it works e.g. why does light diffract?
2. Suggest an answer by forming a **theory** (a possible explanation of the observation) e.g. light is a wave
   - This could also be in the form of a **model** or a simplified picture of what is physically going on e.g. the spreading out of waves
3. Make a **prediction** or **hypothesis**
   - This is a **testable** statement, based on the theory, about what will happen if it is tested
   - For example, if light is a wave, it is expected to reflect and refract
4. Carry out an **experiment** to test the hypothesis
   - This will provide clear evidence to support the initial prediction
   - For example, investigating the reflection and refraction of light - if the experiment doesn't match the theory, the theory must change

Validating Scientific Knowledge

- A theory is only scientific if it can be tested
- Any pieces of experiment evidence must be **published**
  - This is often in scientific journals and reports (papers)



- The papers are **peer-reviewed** by the scientific community in the same field
  - Other scientists examine the data and results, ensuring that there has been a fair test and the conclusion from the results is reasonable
  - This also ensures that work published in journals is of a good standard
- This process helps **validate scientific knowledge** and ensure **integrity** (trustworthiness)
  - Scientists can be dishonest or **biased**, leading to invalid conclusions from their experiments
  - For example, manipulating the data to fit with their hypothesis
- Peer-review isn't perfect, and often independent scientists test the theory themselves to cross-check the results and make sure the original results weren't just a 'fluke'
- If the evidence then supports a theory, the theory is accepted (for now)
  - If many experiments back this theory with good evidence, and it is not yet deemed incorrect, then the theory is considered a scientific 'fact'
- However, scientific theories are never **indisputable**

- There can be breakthroughs and advances to provide new ways to test the theory which could lead to new evidence and **conflicts**
  - When this happens, the testing happens all over again, the **theory** is **adapted** to the **new evidence** found
  - The best theories are those that scientists are continuously trying to poke holes in and test thoroughly. If the theories survive many different tests, then it is more **trusted**
- The nature of scientific knowledge is therefore continuously changing and evolving

Science Informs Decision Making

- **Society** makes decisions based on **scientific evidence**
  - This is why the evidence must be thoroughly tested and trusted
- Scientific work leads to important **discoveries** that benefit humankind
  - For example, rigorous testing for medication means it is safe for consumption to treat the symptoms of an illness
- These results are used by society to make **decisions** about how people live, eat, drive, work etc.
  - All sections of society use **scientific evidence** to make these decisions
  - This is mostly done by policy makers, politicians and government
- Most individual making these decisions may not be scientists themselves, so they will be trusting the research to base their **opinions** on
  - Other factors can influence decisions about science or the way that it is used

Economic Factors

- The **economy** is based on money and the **cost** of implementing these changes
  - Not only can experiments be very **expensive** to run, but the cost of buying technology for healthcare or transport costs a lot of taxpayer money
- Therefore, when research is expensive, the **government** must **justify** spending money on new equipment,
  - Such as a telescope, instead of other areas of society such as schools or healthcare
- However, the **long term benefits** should also be considered
  - For example, reducing carbon emissions to limit the human contribution to climate change
  - In this case, the current human contribution to climate change will be provided from scientific research, as well as methods to reduce carbon emissions (e.g. solar power)

Social Factors

- Social factors are considered for decisions that affect people's **daily life**
  - This could be how it affects the surrounding area when people live, such as noise pollution
- These factors should take into account all members of society, whether they're young, old, disabled and for all genders
- An example of this is scientific knowledge of a healthy lifestyle informing the choices we make
  - E.g. Cycling to work instead of driving in order to exercise and reduce carbon footprint

Environmental Factors

- Environmental factors are taken into account for any decisions that could affect the environment
  - This is primarily plants and animals within the geography of an area
- An example of this is wind farms

- Although they are **cheap** and **environmentally friendly** (wind is a sustainable energy source) way to generate electricity, the turbines can harm birds and bats
- This means another method of electricity production should be considered, to not cause **harm** to the **environment**

Wind farms can be harmful to wildlife, which may mean they shouldn't be built in certain areas