Edexcel International A Level (IAL) Physics

Your notes

Practical Skills II: Implementation & Measurements

Contents

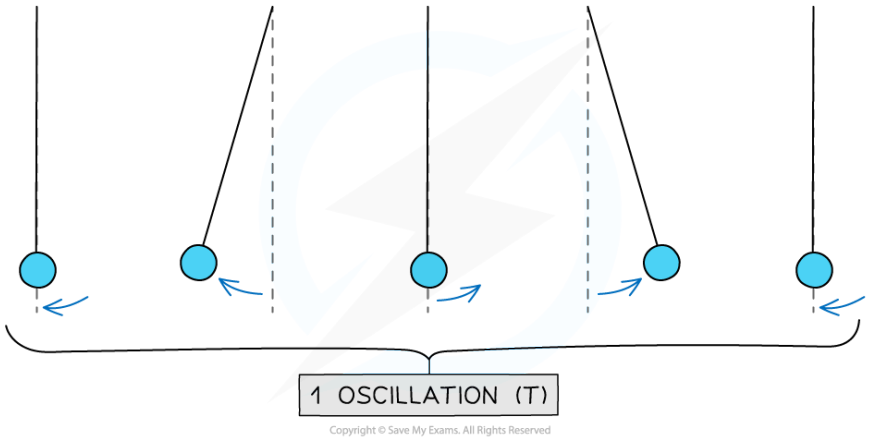
Your notes

Evaluating Experiments

- The **accuracy** of an experiment can be increased by repeating measurements and using mean values
- Methods seeking to reduce **systematic errors** result in increased accuracy
- Sometimes, additional apparatus can be used to improve the experiment, by reducing errors
- Some changes to the method could be:
  - Timing over multiple oscillations
  - Using a fiducial marker

Example: Oscillations

- The time period of oscillations is commonly measured using a stopwatch
  - Reaction time is a common error when measuring time
- Uncertainty in a measurement of periodic time can therefore be reduced by:
  - Measuring many oscillations to calculate the average time for one oscillation
  - Increasing the total time measured for multiple swings
- It would be ideal to measure the time taken for the pendulum to complete 10 (or more) oscillations and **divide** this time by 10 to determine the time period of **one** oscillation



One complete oscillation of a pendulum

Worked Example

A student wants to measure the time period of a vertical mass on a spring system. The time is measured on a stopwatch between when the mass is pulled down till after one complete oscillation.

Discuss how the student could reduce the error in their measured time period.

Answer:

- The student should make sure the amplitude of the oscillations is large so the time period is longer
  - This would reduce the effect of the human reaction time which causes a slight error when using a stopwatch
- The student should measure the time period over 10 oscillations and divide the time by 10 for the time period of one oscillation
  - However, due to damping effects, the amplitude of all the oscillations, and therefore their time periods, will not be the same
  - This effect is reduced if there is a large amplitude for the first oscillations
- The spring must not exceed its elastic limit at any point of the experiment
  - If the spring is stretched too much, it will not go back to its original un-stretched position therefore affecting the oscillations
- The student must make sure the oscillations are all completing vertical
  - This effect will the time period if the mass is pulled down at a slight angle, or pushed one way or another during the experiment

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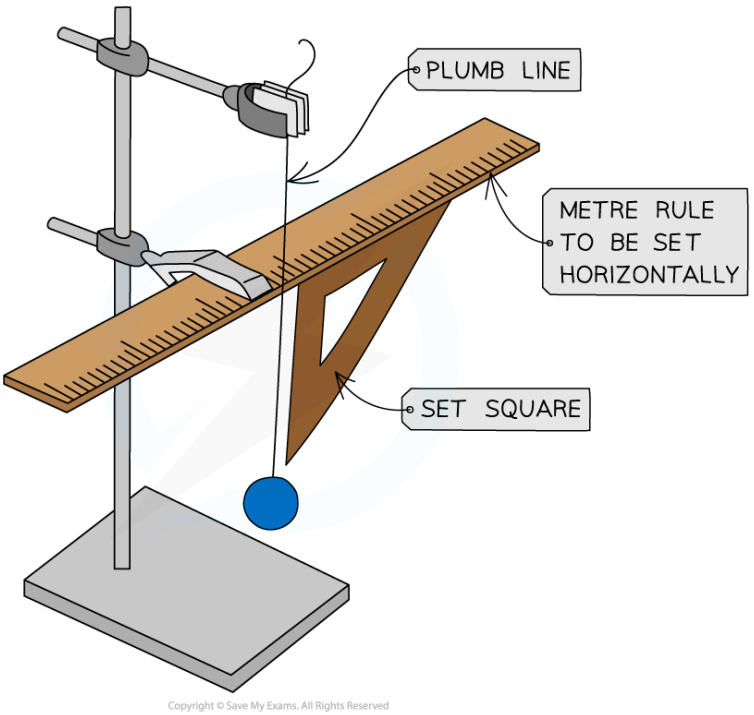
Examples in Further Mechanics

- A set square is a right-angled triangle plane used for drawing lines and determining whether two pieces of apparatus are perpendicular to teach other
- In physics, it is used to determine whether:
  - An object is vertical
  - Two objects are at right angles to each other
  - Two lines are parallel
- A **plumb line** can also be used to determine if a setup is vertically aligned accurately



A plumb line and set square used to make sure the setup is completely vertical

- Another example is using a set square to determine whether a ruler is vertical to aid the measurement of the extension of a spring
  - The right-angle side of a set square is aligned with the ruler and the bottom of the spring
  - This ensures the spring and the ruler are parallel to each other (or in other words, a line joining them both is horizontal)
- If this set up is not correctly checked with a set square, the ruler could be at an angle, thus providing an inaccurate reading of the extension, which can often be very small

Diameter of a Cylinder

- Two set squares can be used to measure the diameter of a cylinder
  - Since a cylinder has a circular cross-section, this is the diameter of its cross-section
- If a ruler is placed directly next to the ends of the cylinder, it is subjective to measure the start and end of the line joining the diameter by eye
- Two set squares are placed on either side of the cylinder
  - These ensure that the ruler and the edges of the cylinder are perpendicular to each other to read the most accurate result

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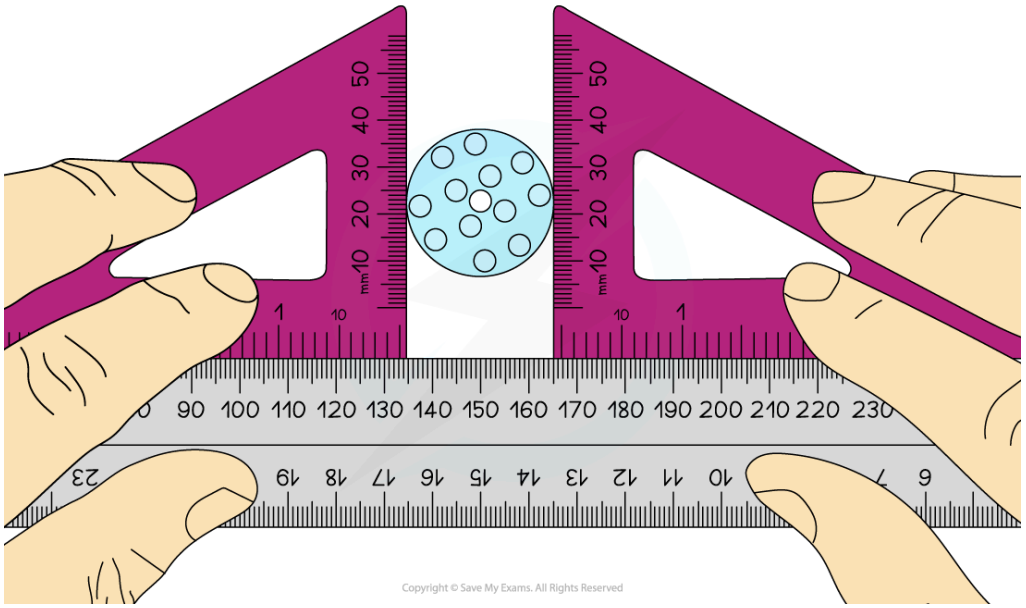

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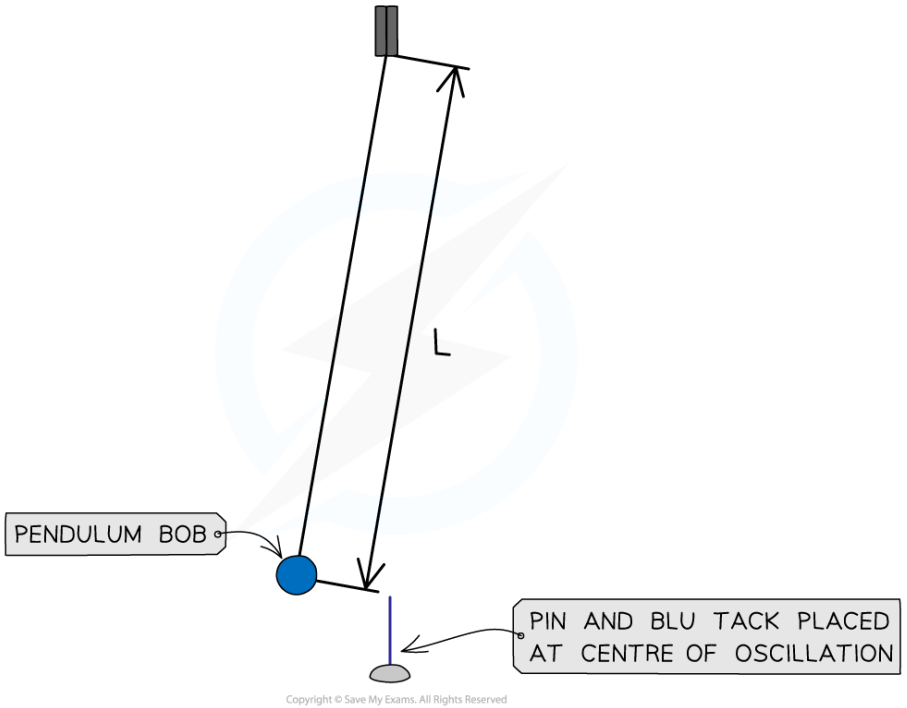
Additional Apparatus

- A **fiducial marker** is a useful tool to act as a clear reference point, such as when measuring the time period of a pendulum using a stopwatch
- This improves the accuracy of a measurement of periodic time by:
  - Making timings by sighting the pendulum as it passes the fiducial marker
  - Sighting the pendulum as it passes the fiducial marker at its highest speed. The pendulum swings fastest at its lowest point and slowest at the top of each swing



A fiducial marker is used to mark the centre of the oscillation of the pendulum

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Number of Readings

- When recording data from an experiment, it is important to take a suitable number of readings
  - **Repeat** readings should also be taken where possible
- An example of a table of results with an appropriate number of readings is:

HEIGHT h/m	TIME t_1/s	TIME t_2/s	TIME t_3/s	AVERAGE TIME t/s
0.10				
0.15				
0.20				
0.25				
0.30				
0.35				

Example Table of Results with a good number of readings

- A good number of repeats is between 3 - 5 times
  - In the diagram, there are 3 repeats of each reading
- Multiple measurements increase precision
  - It also makes your measurements more reliable
- They also increase confidence in the experimental data
  - Making the same measurement multiple times then taking an average decreases the uncertainty in the value
  - The absolute uncertainty in repeat readings is equal to ± **half** the range of readings
- It also checks how reproducible the measurements are, so the results are not just from luck or a fluke
- Results should be recorded to the resolution of the measuring instrument which means there will be a **consistent** number of decimal places for the readings for any one variable
  - They should be recorded to a consistent number of significant figures, which is usually 3, as this is what we can usually confidently plot on a graph

- For example, readings for a micrometer should be to two decimal places (since its resolution is 0.01 mm) whilst for a ruler, only 1 decimal place would be enough when measuring in cm, or 2 decimal places when measuring in metres (since its resolution 0.1 cm / 0.01 m / 1 mm)

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Examiner Tips and Tricks

A common mistake when planning out experiment is not stating exactly how many readings you would take. Just saying 'take readings of the voltage' is not enough. It is better to say 'take 10 readings of the voltage, between a range of 0.5 V to 5 V in steps of 10, each with three repeats and a mean calculated'. Be as descriptive as possible to gain full marks!

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Range of Measurements

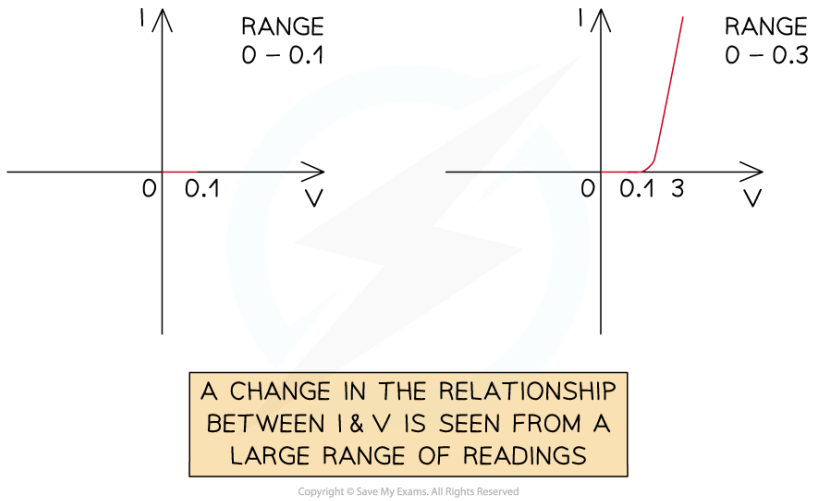
- When recording data from an experiment, it is important to take a good **range** of readings
  - This is between 5 – 10 values, with a step of 1, 2, 5 or a multiple of 10

LENGTH OF WIRE L/m	CURRENT I_1/A	CURRENT I_2/A	CURRENT I_3/A	AVERAGE CURRENT I/A	RESISTANCE R/Ω
0.25					
0.50					
0.75					
1.00					
1.25					
1.50					
1.75					
2.00					

Example table of results with a good range

- In the diagram, there is a good range of 8 values between 0.25 – 2.00 m
- A wide range of readings gives an idea of how well the average represents the data
- When considering the range of readings, think about the limitations of the instrument used to measure the independent variable
- An example of this is the range of the measuring device:
  - A maximum value of the range of 5 m when using a ruler wouldn't be ideal, because a ruler is normally 1 m long. This could become difficult to measure introducing many errors into the readings
  - The smallest division on a ruler is 1 mm, therefore, the smallest reading should be greater than this (e.g. not 0.1 mm)
- Another example is the **limitations** of the apparatus used:
  - When measuring the extension of a spring, a large load is avoided in order for the spring not to extend past its elastic limit
  - Too high voltages and currents could damage the circuit as it heats up, so the highest value in the range required must be well below the limit of any components in the circuit in order for them not to fuse or set on fire
- A range of readings is important to see whether the experiment holds true for all values, or, if there is a different pattern in results after a certain value

- Imagine investing the variation of current and potential difference for a semiconductor diode
  - If a reading of potential difference were only taken up to a value of 0. 5 V, the graph would look like a horizontal line
  - If they were taken up to 3 V, the steep increase in current can be seen by an almost vertical straight line
- Had a larger range not been taken, the full pattern of the current and potential difference in the diode wouldn't have been seen
- In general, the more readings the better, and the wider range the better
  - However, there is only so much time set out to complete the experiment



A wider range of measurements shows a different pattern

Examiner Tips and Tricks

It is important that the difference between each reading in a range is equal (e.g. 1, 2, 3, 4 and **not** 1, 2 , 5, 6) and that the difference between each value is 1, 2, 5 or a multiple of 10 (avoid something like 0.3, 0.6, 0.9)

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Significant Figures

- Significant figures must be used when dealing with **quantitative** data
- Significant figures are the digits in a number that are **reliable and absolutely necessary** to indicate the quantity of that number
- There are some important **rules** to remember for significant figures
  - All non-zero digits are significant
  - Zeros between non-zero digits are significant
    - 4107 (4.s.f.)
    - 29.009 (5.s.f)
  - Zeros that come before all non-zero digits are not significant
    - 0.00079 (2.s.f.)
    - 0.48 (2.s.f.)
  - Zeros after non-zero digits within a number without decimals are not significant
    - 57,000 (2.s.f)
    - 640 (2.s.f)
  - Zeros after non-zero digits within a number with decimals are significant
    - 689.0023 (7.s.f)
- When rounding to a certain number of significant figures:
  - Identify the significant figures within the number using the rules above
  - Count from the first significant figure to the specified number
  - Use the next number as the 'rounder decider'
  - If the decider is 5 or greater, increase the previous value by 1

Worked Example

Write 1.0478 to 3 significant figures

Answer:

Step 1: Identify the number of significant figures

They are all significant figures

Step 2: Count to the specified number (3rd s.f.)

1.0478

Step 3: Round up or down

1.05 (3 s.f)

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Examiner Tips and Tricks

An exam question may sometimes specify how many significant figures the answer should be, make sure you keep an eye out for this, as a mark is often given for that!

Correcting Data in Tables

- Data in tables must also be to the **same** number of significant figures in each column
- An example of data table with consistent significant figures in the data is:

Example Table With Correct Significant Figures

100 slits/mm	h_1/cm	h_2/cm	Average h/cm	Cumulative Total h/cm
n=0 to 1	23.8	24.0	23.9	23.9
n=1 to 2	24.0	25.0	24.5	48.4

- In this table, all the data is to 3 s.f.
  - It is important that data in each **column** must be to the same number of significant figures
- A table of data with **inconsistent** significant figures would look like:

Example Table With Incorrect Significant Figures

f / Hz	l / m
250.0	0.322
320	0.25
348.23	0.2283

512	0.160

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- In the first column, some are to 4 s.f., 3 s.f. and 5 s.f.
  - These should ideally all be to 3 s.f
- In the second column, some are to 2 s.f., 3 s.f. and 4 s.f.
  - These should ideally all be to 3 s.f.
- When considering how many significant figures to put the data in, the resolution of the instrument must be considered
  - A ruler has a resolution of 1 mm
  - This means all measurements in mm with a ruler, should be recorded to 1 s.f as a more precise value cannot be known due to the limitations of the measuring instrument

Worked Example

From the following data set, correct the incorrect values.

f / Hz	*l* / m
250.0	0.322
320	0.25
348.23	0.2283
512	0.160

Answer:

- The correct table of results would look like

f / Hz	*l* / m
250	0.322
320	0.250
348	0.228
512	0.160

Examiner Tips and Tricks

In Edexcel International A-level, questions about tables often say 'criticise these results'. One mark for these types of questions is often simply looking at the consistency of the significant figures in the given table! Although for this question you don't have to go into too much detail, simply 'inconsistent significant figures' can do.

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Correcting Units

- In Physics, a value without its appropriate unit doesn't really mean anything
  - For example, 5 mm or 5 km are **very** different measurements
- Some common units in A-level Physics are:

Common Units Table

Quantity	Unit	Abbreviation
Frequency	hertz	Hz
Force	newton	N
Energy	joule	J
Power	watt	W
Pressure	pascal	Pa
Electric Charge	coulomb	C
Electric Potential Difference	volt	V
Electric Resistance	ohm	Ω
Magnetic Flux Density	tesla	T

- Sometimes practical questions require identifying units that are **incorrect**
- Learning the appropriate unit for each physical quantity in A-level physics is extremely important
- Sometimes the unit can be derived from an equation for that quantity
  - For example, the units of the resistivity ρ can be considered from its equation

$$\rho = \frac{RA}{L}$$

- Where:
  - R = resistance (Ω)
  - A = area (m^2)
  - L = length (m)
- Therefore:

$$[\rho] = \frac{[R][A]}{[L]} = \frac{\Omega m^2}{m} = \Omega m$$

- Common units for measurements are:
  - Length = m
  - Area = m^2
  - Volume = m^3

Worked Example

Correct the following incorrect units:

1. Magnetic Flux Density = 2 Webers
2. Electromotive Force = 7.8 N
3. Capacitance = 0.3 μC
4. Stress = 600 m^2

Answer:

The correct units are:

1. Magnetic Flux Density = 2 T (Tesla)
2. Electromotive Force = 7.8 V (Volts)
3. Capacitance = 0.3 μF (Micro-farads)
4. Stress = 600 Pa (Pascals)

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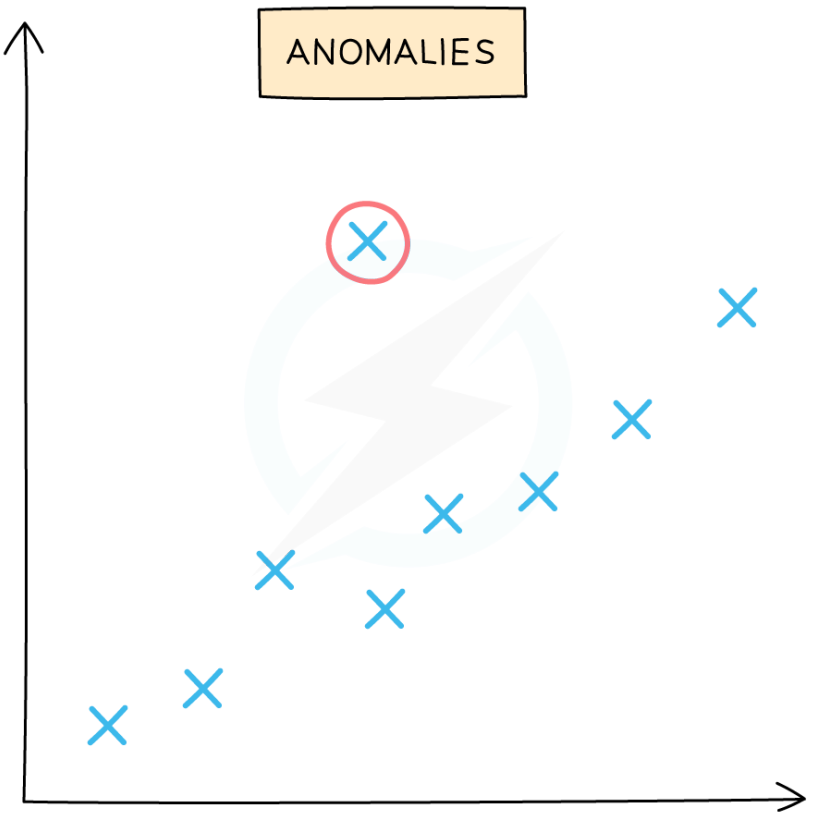
Anomalous Readings

- **Experimental errors** (also known as operator errors or 'one off' errors) will **affect the results** of an experiment and can produce **anomalies**
  - These anomalies should be **identified** during the **evaluation of results** and before drawing conclusions
- Anomalies can be identified by looking for results or data points on a graph that do **not fit** with the trend or with other repeat readings carried out during the experiment
  - These anomalous results will show a larger difference from the mean than the rest of the results (a result is often taken to be anomalous if it differs from the mean result by **more than 10%**)
- The results or 'data' collected from an experiment can be made **more reliable** if the experiment is repeated several times and anomalies are removed
  - This, in turn, allows more **valid** conclusions to be drawn
- Anomalous results are always **inconsistent** with other readings e.g., a point that is not on the line of best fit of a graph



Identifying an anomalous result from a graph

- If an anomaly occurs in the experiment:
  - **Ignore** this value when calculating the mean
  - **Repeat** this measurement

Worked Example

A student achieves a set of repeat readings for the current through a bulb.

2.5 mA	2.8 mA	6.1 mA	2.0 mA	2.3 mA

Calculate the mean current through the bulb.

Answer:

Step 1: Identify the anomalous result

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- The only result that doesn't fit with the rest of the data is 6.1 mA
- This can be ignored when calculating the mean

Step 2: Calculate the mean current

$$\text{Mean current} = \frac{2.5 + 2.8 + 2.0 + 2.3}{4} = 2.4 \text{ mA}$$

Examiner Tips and Tricks

When calculating the mean of some repeat readings for data given in your practical paper, always **ignore** any anomalous readings that are inconsistent when calculating the mean.

Your notes