OCR A Level Physics

Your notes

Handling Data

Contents

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Presenting & Interpreting Results

Your notes

Presenting Observations & Data

- Data can be presented in a variety of ways, such as on graphs, charts, or tables
- Tables are applicable to any experiment yielding data
- Graphs, on the other hand, are a little trickier depending on the type of data collected e.g. quantitative or qualitative
  - Quantitative data uses **numerical values**
  - Qualitative data is **observed** but not measured with a numerical value e.g. colour

Presenting Data in a Table

- 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

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LENGTH OF THE STRING

FREQUENCY OF THE FIRST HARMONIC

L / m	f / Hz 1st READING	f / Hz 2nd READING	f / Hz 3rd READING	f / Hz MEAN
0.2				
0.4				
0.6				
0.8				
1.0				
1.2				
1.4				
1.6				

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

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

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- 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**

Processing, Analysing & Interpreting Experimental Results

- After an experiment has been carried out, sometimes the raw results will need to be processed before they are in a useful or meaningful format
- Sometimes, various calculations will need to be carried out in order to get the data in the form of a straight line
  - This is normally done by comparing the equation to that of a straight line: **y = mx + c**

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Worked Example

A student measures the background radiation count in a laboratory and obtains the following readings:

Count rate/ counts min^{-1}	69	68	70	71	69	72

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The student is trying to verify the inverse square law of gamma radiation on a sample of Radium-226. He collects the following data:

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Distance / cm		10	20	30	40	50	60	70	80	90
Count rate / counts min^{-1}	1	586	202	123	100	89	87	79	78	76
	2	569	193	136	102	94	85	83	77	74
	3	591	199	122	104	90	80	81	79	78

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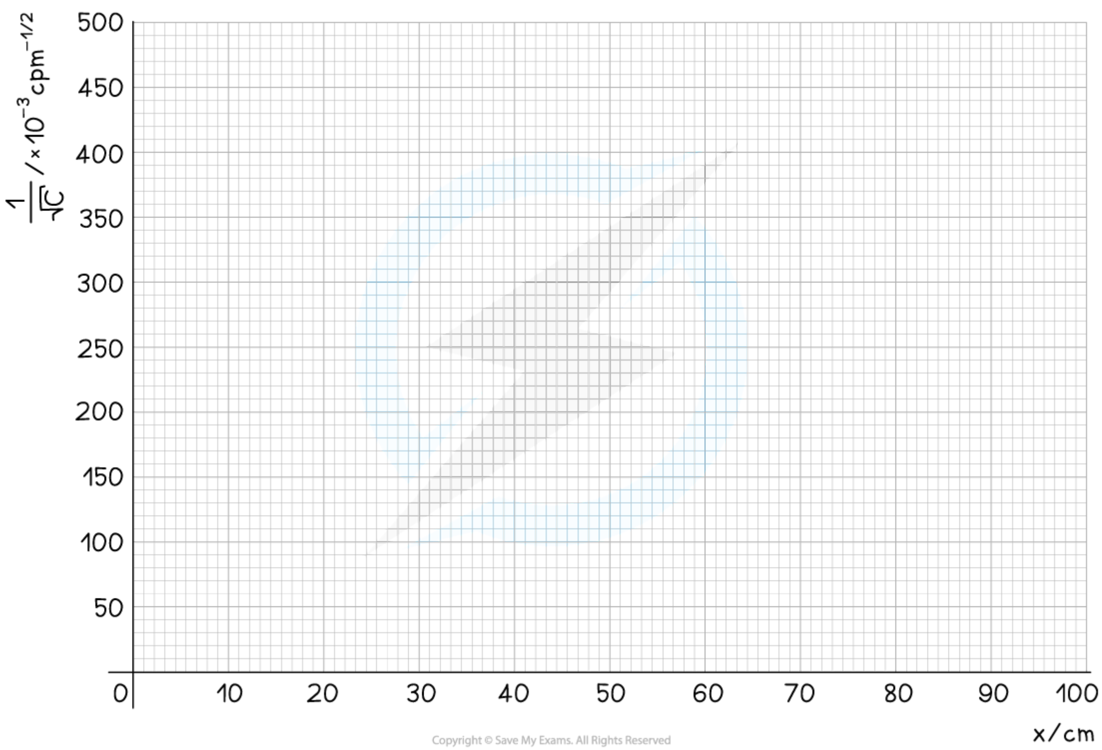
Use this data to determine if the student's data follows an inverse square law.



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Answer:

Step 1: Determine a mean value of background radiation

$$\text{Count rate} = \frac{69 + 68 + 70 + 71 + 69 + 72}{6} = 69.8 = 70$$

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- The background radiation must be subtracted from each count rate reading to determine the corrected count rate, C

Step 2: Compare the inverse square law to the equation of a straight line

- According to the inverse square law, the intensity, *I*, of the γ radiation from a point source depends on the distance, *x*, from the source

$$I \propto \frac{1}{x^2}$$

- Intensity is proportional to the corrected count rate, C, so

$$C \propto \frac{1}{x^2} \rightarrow \frac{1}{C} \propto x^2 \rightarrow \frac{1}{\sqrt{C}} \propto x \rightarrow \frac{1}{\sqrt{C}} = kx$$

- The graph provided is of the form $1/C^{-1/2}$ against *x*
- Comparing this to the equation of a straight line, y = mx
  - $y = 1/C^{-1/2}$ (counts $\text{min}^{-1/2}$)
  - x = x (m)
  - Gradient = constant, k
- If it is a straight line graph through the origin, this shows they are directly proportional, and the inverse square relationship is confirmed

Step 3: Calculate C (corrected average count rate) and $C^{-1/2}$

Distance x / cm	10	20	30	40	50	60	70	80	90
Average count rate / counts min^{-1}	582	198	127	102	91	84	81	78	76
Corrected average count rate C / counts min^{-1}	512	128	57	32	21	14	11	8	6
$\frac{1}{\sqrt{C}}$ / $\text{cpm}^{-1/2}$	0.044	0.088	0.132	0.177	0.218	0.267	0.302	0.354	0.408

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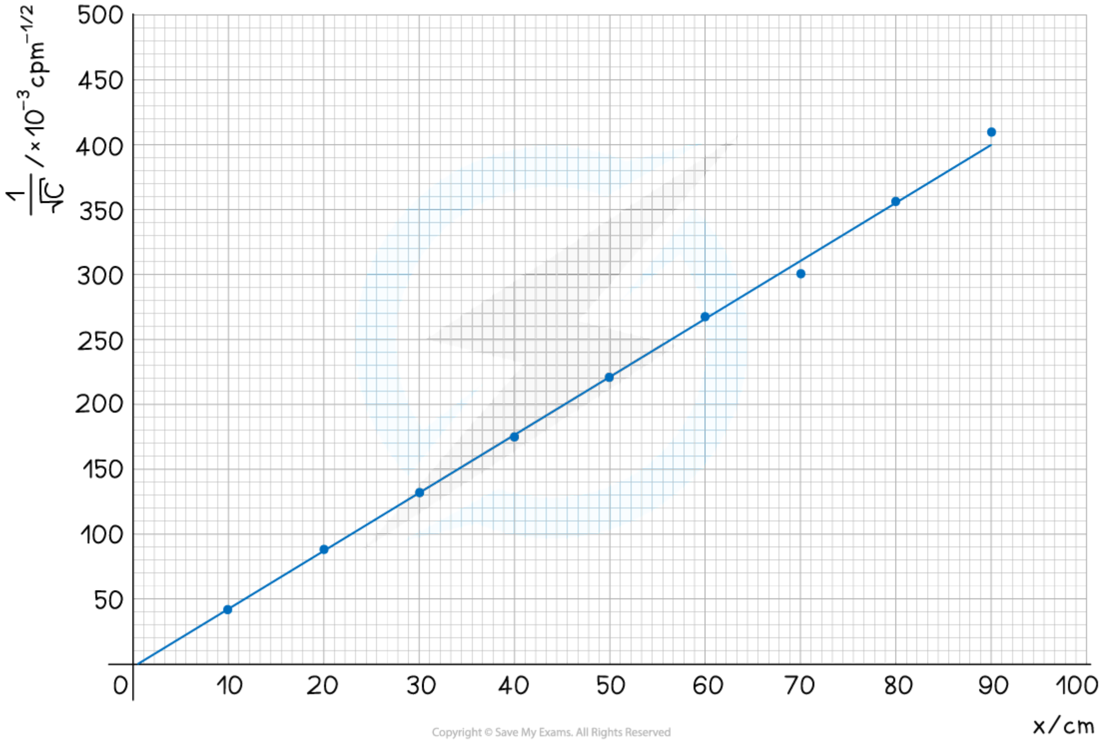
Step 4: Plot a graph of $C^{-1/2}$ against x and draw a line of best fit



- The graph shows $C^{-1/2}$ is directly proportional to x, therefore, the data follows an inverse square law

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Analysing Quantitative Data

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Analysing Quantitative Data

- Maths is very important throughout the whole of physics
- In particular, maths skills are required when dealing with data from experiments
- The mathematical skills required for the analysis of quantitative data include:
  - Using standard form
  - Quoting to an appropriate number of significant figures
  - Calculating mean values
  - Graph skills

Using Standard Form

- Often, physical quantities will be presented in standard form
- This makes it easier to present numbers that are very large or very small without having to repeat many zeros
  - For example, the speed of light in a vacuum equal to 3.00×10^8 m s^{-1}
- It will also be necessary to know the **prefixes** for the numbers of ten

Using Significant Figures

- Calculations must be reported to an appropriate number of significant figures
- Also, all the data in a column should be quoted to the **same** number of significant figures

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✗

Distance / m	Time / s
22.0	
39.5	
60	
81.44	
100	

✓

Distance / m	Time / s
20.0	
40.0	
60.0	
80.0	
100.0	

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It is important that the significant figures are consistent in data

Calculating Mean Values

- When several repeat readings are made, it will be necessary to calculate a mean value
- When calculating the mean value of measurements, it is **acceptable** to increase the number of significant figures by 1

1st reading	2nd reading	3rd reading	4th reading	5th reading	6th reading
54	56	57	54	51	56

$$\text{MEAN} = \frac{\text{SUM OF RESULTS}}{\text{NUMBER OF DATA POINTS}} = \frac{54 + 56 + 57 + 54 + 51 + 56}{6} = 54.7$$

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Graph Skills

- In several experiments during A-Level Physics, the aim is generally to find if there is a relationship between two variables

Your notes

- This can be done by translating information between graphical, numerical, and algebraic forms
  - For example, plotting a graph from data of displacement and time, and calculating the rate of change (instantaneous velocity) from the tangent to the curve at any point
- Graph skills that will be expected during A-Level include:
  - Understanding that if a relationship obeys the equation of a straight-line $y = mx + c$ then the **gradient** and the **y-intercept** will provide values that can be analysed to draw conclusions
  - Finding the **area under a graph**, including estimating the area under graphs that are not linear
  - Using and interpreting **logarithmic** plots
  - Drawing tangents and calculating the gradient of these
  - Calculating the gradient of a straight-line graph
  - Understanding where asymptotes may be required

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Plotting & Interpreting Graphs

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Plotting & Interpreting Graphs

- When plotting graphs, it is important to consider the importance of the following factors:
  - Selecting appropriate scales
  - Labelling axes with quantities and units
  - Carefully plotting the points
  - Measurement of gradients and intercepts

Choice of Scale

- When choosing a scale, it must be big enough to accommodate all the collected values using as much of the graph paper as possible
- At least half of the graph grid should be occupied in both the x and y directions
- Scales should be clearly indicated and have suitable, sensible ranges that are easy to work with
  - For example, scales with multiples of 3 should be avoided
- The scales should increase outwards and upwards from the origin
- Each axis should be labelled with the quantity that is being plotted, along with the correct unit

Labelling the Axes

- Label each axis with the name of the quantity and its unit
  - For example, *F* / N means force measured in Newtons
- The convention is that a forward slash (/) is used to separate the quantity and the unit
- In general:
  - The **independent variable** goes on the x-axis
  - The **dependent variable** goes on the y-axis

Plotting the Points

- Points should be plotted so that they all fit on the graph grid and not outside it
- All values should be plotted, and the points must be precise to within **half a small square**

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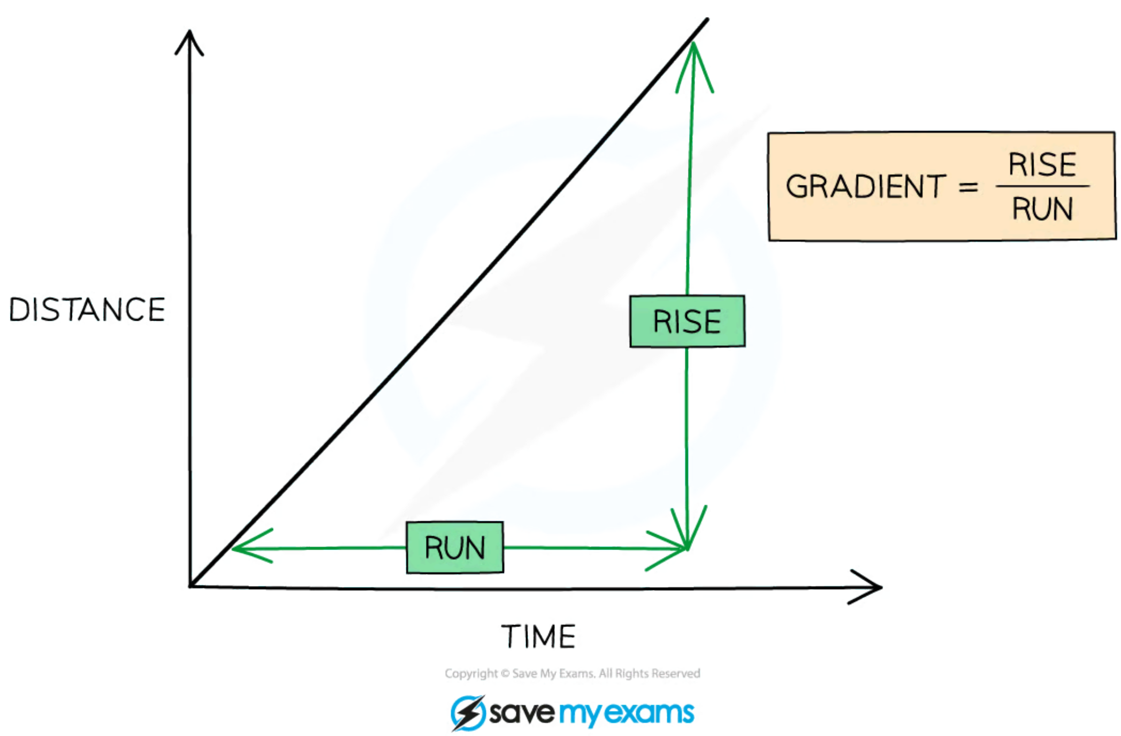
- Points must be clear, and not obscured by the line of best fit, and they need to be plotted with a sharp pencil so that they are thin
- There should be at least six points plotted on the graph, with any major outliers identified

Line or Curve of Best Fit

- There should be equal numbers of points above and below the line of best fit
  - Using a clear plastic ruler will help with this
- Not all lines will pass through the origin and nor should they be forced to
- The line (or curve) of best fit should not be too thick or joined dot-to-dot like a frequency polygon
- Anomalous values that have not been identified during the implementation stage should be ignored if they are obviously incorrect
  - This is because they will have a large effect on the gradient of the line of best fit

Calculating the Gradient

- The gradient can be calculated by dividing the **rise** (change in y) by the **run** (change in x)



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- The calculation needs to be shown, including the correct substitution of identified plotted points from the axes into the equation
- The triangle used to calculate the gradient should be drawn on the graph and it needs to be **as large as possible**
  - Small triangles are **not** acceptable for working out a gradient
- When using the results from a table of values, the triangle that is used to obtain the gradient can utilise points that lie on the line of best fit but not values that lie away from the line

Your notes

Determining the y-intercept

- The y-intercept is the y value obtained where the line crosses the y-axis at x = 0
- Values should be read accurately from the graph, with the scale on the y-axis being interpreted correctly

Worked Example

A student investigates the effect of placing an electric fan in front of a wind turbine. The wind turbine is connected to a voltmeter. When the wind turbine turns, it generates a voltage.The student obtains the following results:

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Blade angle / degree	Voltage / V
0	0.0
10	2.0
20	2.2
30	2.0
40	1.7
50	1.4
60	1.0
70	0.6
80	0.2
90	0.0

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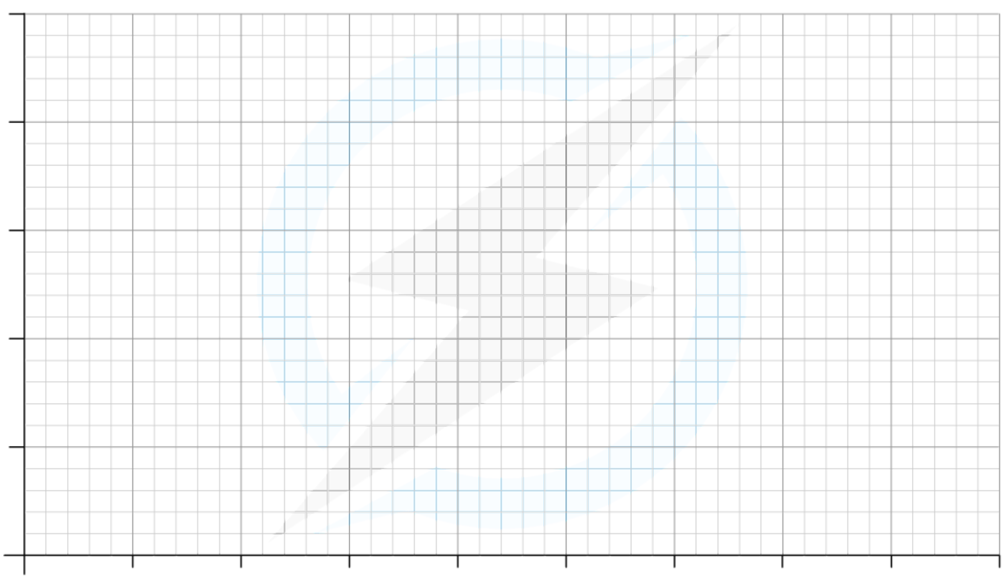
Plot the student's results on the grid and draw a curve of best fit on the graph.



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Answer:

Step 1: Identify the independent and dependent variables

- Independent variable = blade angle / °
- Dependent variable = voltage / V

Step 2: Choose an appropriate scale

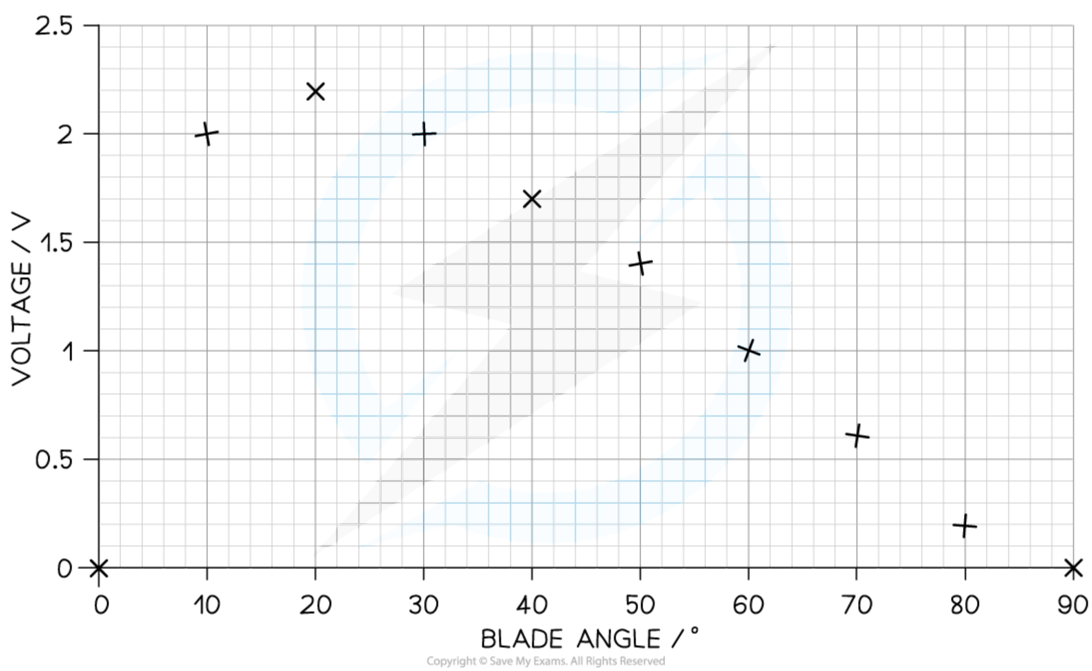
- The range of the blade angle is 0 – 90°
- Ideally, every small square represents 10°
- The range of the voltage is 0 – 2.2 V
- Ideally, each small square represents 0.5 V
- Both axes should occupy at least 50% of the grid

Step 3: Label the axes

- The dependent variable (voltage / V) goes on the y-axis
- The independent variable (blade angle / °) goes on the x-axis
- Both axes should be labelled with a quantity and a unit

Step 4: Plot the points

- Each point should be accurate within half a small square



Step 5: Draw a curve of best fit

- The curve should be smooth with a roughly equal distribution of points on either side of the curve

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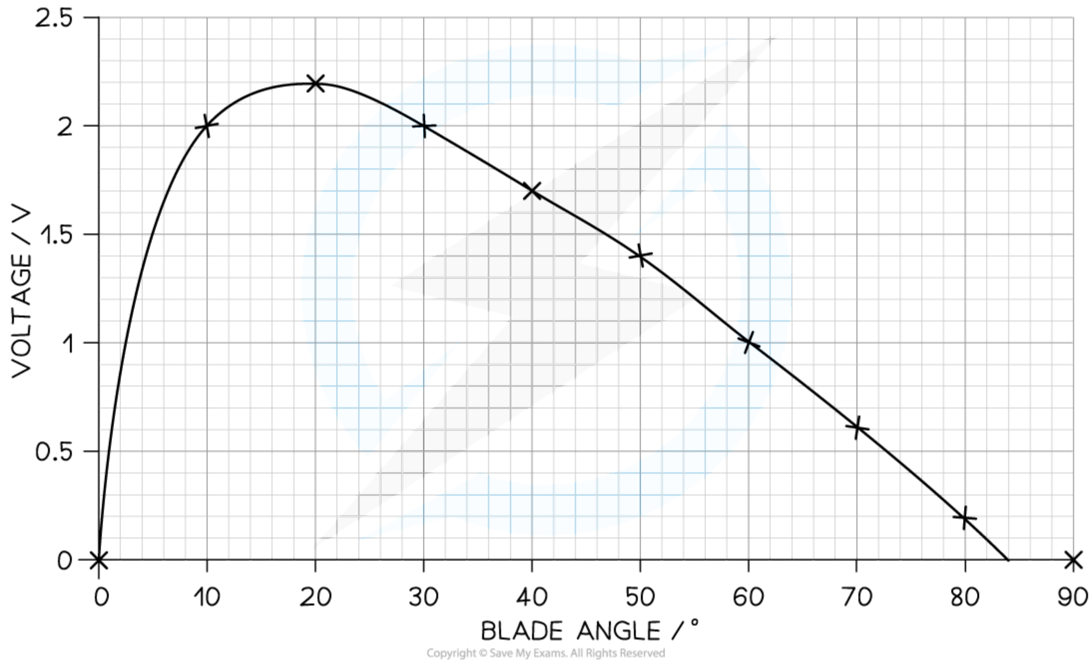
- It must start at (0,0) and peak at (20, 2.2)



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Evaluating Results & Drawing Conclusions

- **Evaluating experimental results** and **drawing conclusions** from them are two very important skills
- Evaluation of **results** is a **different skill** from evaluation of the experimental **procedure** used to obtain those results
- Conclusions can **only be drawn** from the results once they have been **properly evaluated**
  - For example, during the planning of an experiment, potential **limitations** of the experimental procedure should have already been identified
  - Before drawing conclusions, the **impact** that these limitations could theoretically have had (or may actually have had) on the data collected should be evaluated
  - If this evaluation shows these potential impacts to be **negligible,** a **conclusion** can more likely be drawn from the results
  - If it is decided that the limitations could have had a **significant impact** on the data, then it is much harder to draw a conclusion and it should be recognised that any conclusions drawn have a greater chance of being **incorrect**

Identifying Anomalies

- **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 replicates** 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**

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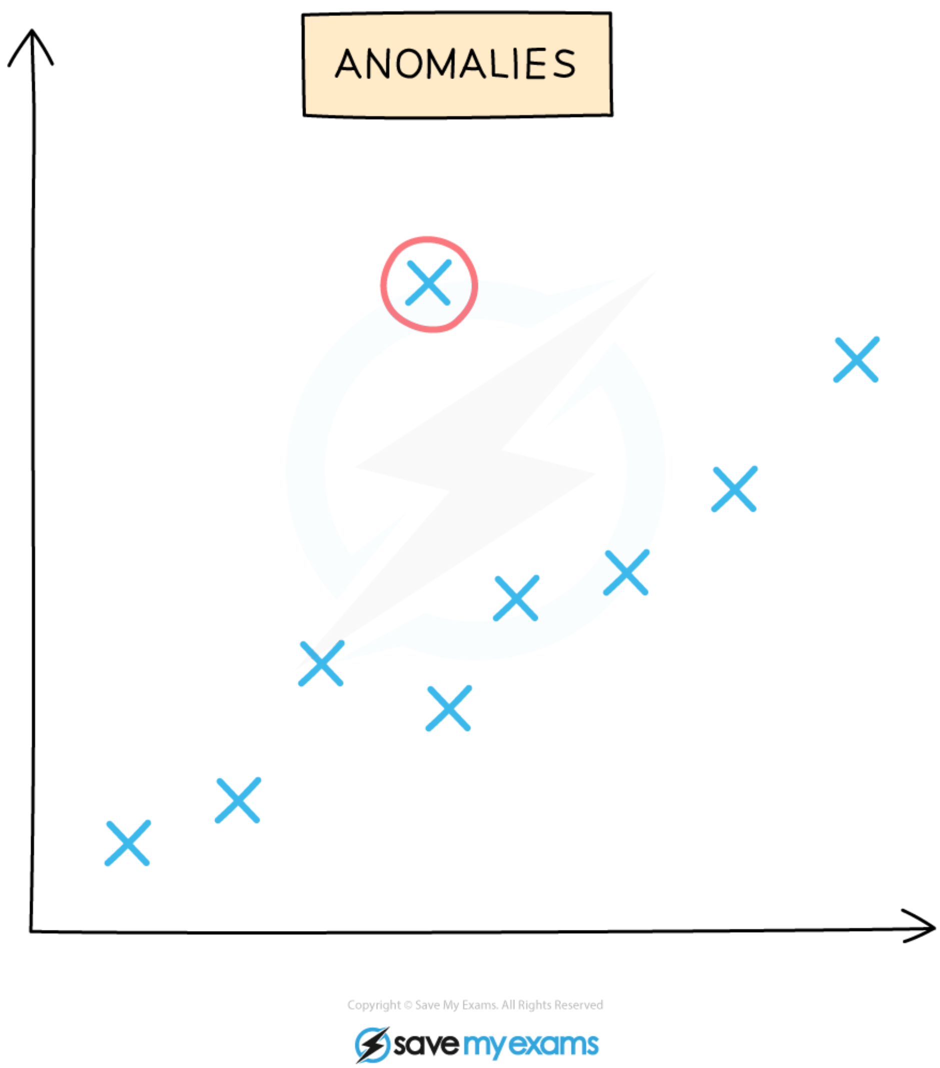

Identifying an anomalous result from a graph

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

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Following Written Instructions

- Scientists always record instructions for their experiments so that they can be repeated
- The instructions should allow an individual to successfully carry out the experiment **without any additional help** or input
- It is very important to **record all required details** within these instructions
- For example:
  - The aims of the investigation
  - The variables investigated
  - The apparatus used
  - The step-by-step method
- Often students struggle to think about the theoretical implications and explanations of the practical at the same time
- It is important to focus on these before and after the practical has been carried out to develop a solid understanding of the purpose of the experiment

Observations & Measurements

- Making observations and recording measurements is a key skill in practical physics

Making Observations

- Observations should be recorded using the appropriate scientific vocabulary and should be precise
- Vague and ambiguous language, such as 'the time wasn't measured very accurately', should be avoided
  - Instead, a more appropriate thing to say would be 'using a stopwatch to measure the oscillation time of the pendulum introduced an error due to the reaction time of the experimenter'

Recording Measurements

- Making measurements using a range of equipment is essential in physics
- When using a digital measuring device eg. top pan balance or ammeter
  - Record all the digits shown

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  - Except in the case of a digital timer, such as a stopwatch, there is no need to record to more than two decimal places
- When using a non-digital device eg. a ruler or a measurement cylinder)
  - Record all the figures that are known
  - Where appropriate, an additional estimated figure may be allowed

Recording Experimental Activities

- Observations and measurements should be routinely recorded in a notebook, file or electronically
  - This enables a physical copy of the completed experiments to be kept
- These records should be made during the laboratory session and are the primary evidence of the outcomes of experiments
- The following will need to be included:
  - A clear explanation of the **measurements** or **observations** taken
  - Analysis of the raw data through **graphs** or **calculations**
  - The **conclusions** drawn from the outcomes of the experiment
  - An **evaluation** of the experiment eg. calculating errors and/or commenting on the limitations of experimental procedures
- The method does not necessarily need to be included unless an investigative approach is taken where the student develops part of the procedure themselves

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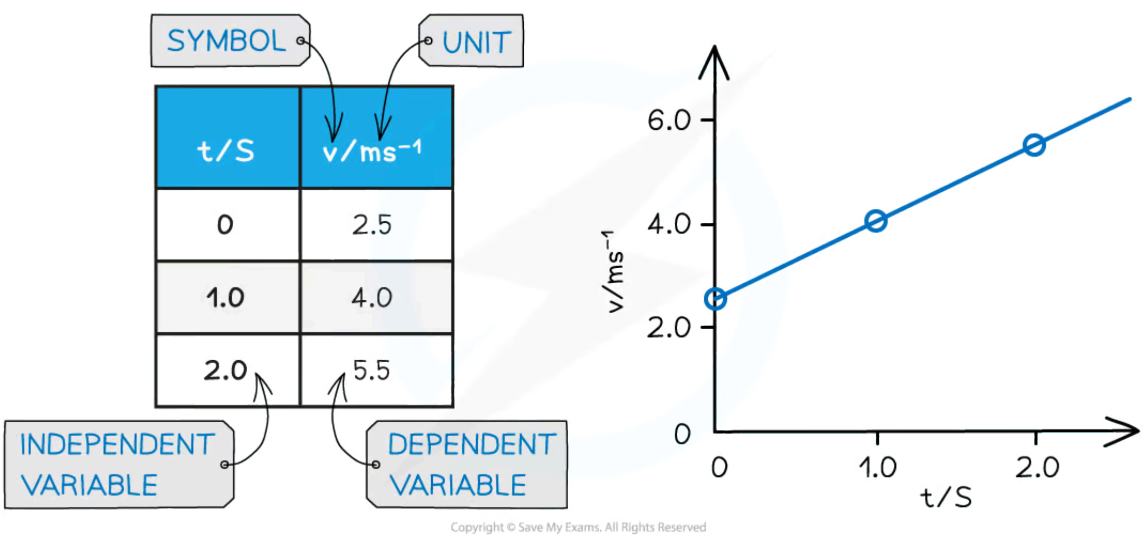
Presenting in a Scientific Way

Presenting in a Scientific Way

- When presenting scientific data, the following may be included:
  - Tables
  - Graphs
  - Diagrams

Presenting Tables

- 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 Graphs

- When presenting graphs, the following must be included:
  - An explanatory title

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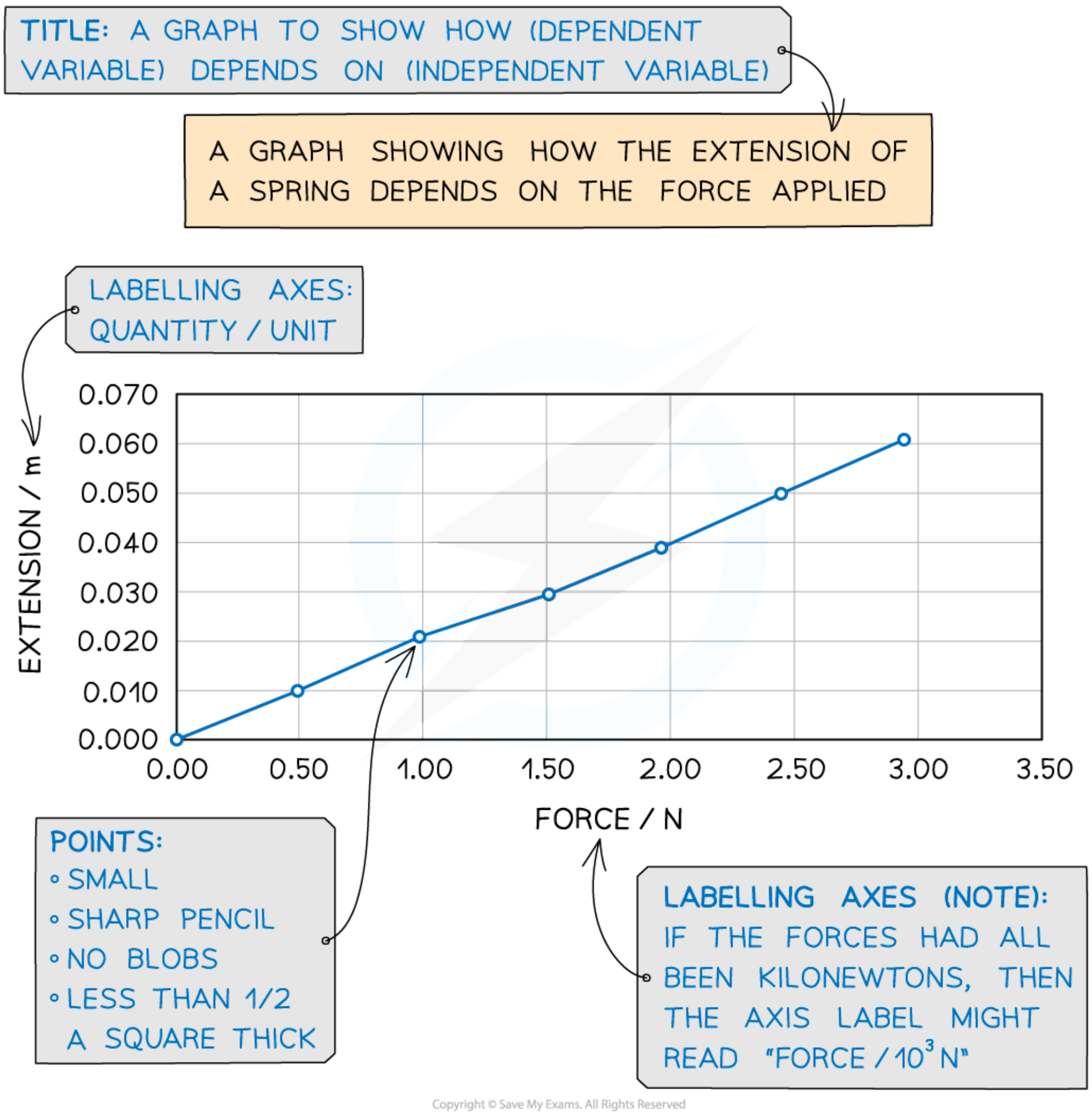
- Clearly labelled axes
- Relevant units for measurements
- Well plotted points
- A smooth line or curve of best fit



An example of a correctly labelled and plotted graph

Presenting Diagrams

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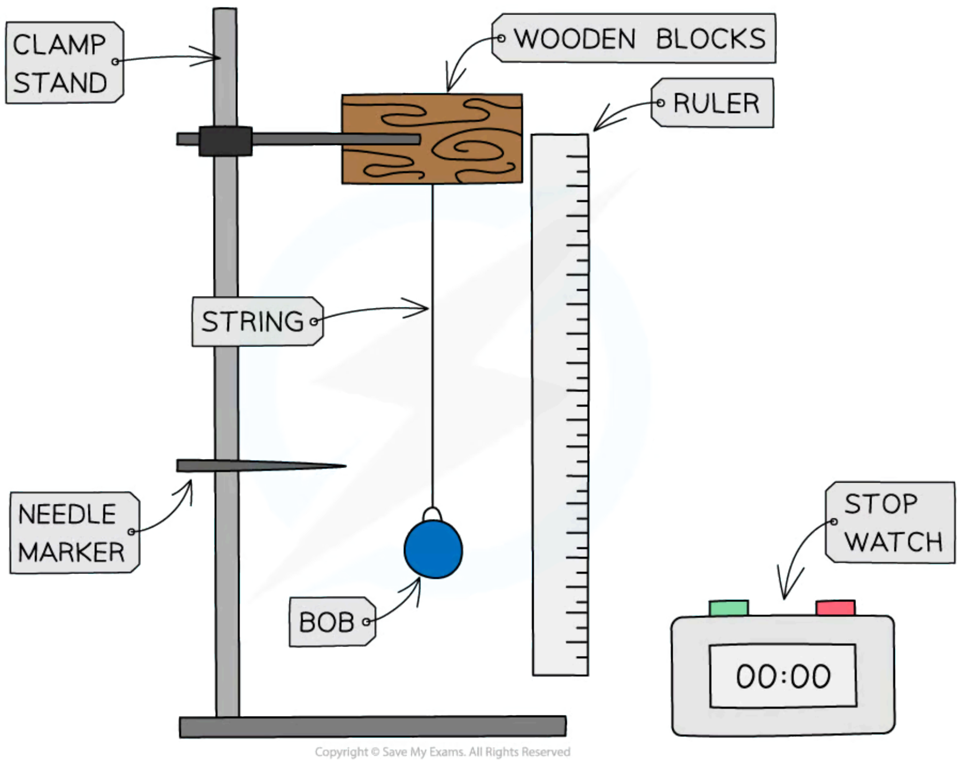
- When presenting diagrams, such as apparatus set-up, all the relevant parts must be clearly labelled



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

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Use of Software & Tools

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Use of Software & Tools

- The use of electronic software and tools is increasingly used in classroom experiments
- These improve accuracy and remove sources of uncertainty such as human error

Spreadsheets

- Graph plotting and data analysis software, such as Microsoft Excel, can be an invaluable tool
- Spreadsheets provide a very effective way of processing data, particularly when the amount of data is large

Data Loggers

- Electronic **data loggers** are more accurate, quick and reliable than manual logging
- They can take multiple readings per second and present the data as a graph or table in real-time

Cameras

- **Cameras** can be used to take photos in experiments that happen too quickly to read a scale
- A camera can be used to take a photo burst as the experiment happens
- The scale can then be read from the photos afterwards
- If the time each photo is taken is known, or if the frame rate is known, then properties such as velocity can be calculated

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Online & Offline Research Skills

- Research is very important in order to gather information about others who have carried out similar experiments
- For example, when carrying out a risk assessment for a practical, the CLEAPSS Student Safety Sheets are an ideal resource
- Suitable sources to use for research include:
  - Books and textbooks
  - Scientific articles and journals
  - Reputable websites

Citing Sources of Information

- A citation is a quotation or reference to an academic text when it is included within a practical report
- The information to be included when citing sources depends on the type of resource

Referencing Books

- The following information is required:
  - Author(s)
  - Book title
  - Chapter and page numbers
  - Edition (if relevant)
  - Date published
  - Publisher
- The general format is:

  Authors (year), *Title*, edition, publisher's location, publisher, pp. xxx–xxx
- **Note**: If the reference is to a single page then 'p.' should be used, if reference is made to several pages then 'pp.' is used
- For example:

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Young, H., Freedman, R. (2004). University Physics with modern physics, 12th ed., Boston, Addison Wesley, p. 125

- For books that have an editor or editors, include (ed.) or (eds) after the names.
- If a book does not have named authors or editors, the reference begins with the title, such as:

CLEAPSS Laboratory Handbook (2001), Uxbridge, CLEAPSS School Science Service

Referencing Articles

- The following information is required:
  - Author(s)
  - Article title
  - Date published
  - Journal
- The general format is:

Authors (year), 'Article title', *Journal title*, vol. no, issue no, pp. xxx–xxx

- For example:

Aad, G, et al (2012), 'Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC' *Physics Letters B* vol 716, no 1, pp 1–29

Referencing Websites

- The following information is required:
  - Author(s)
  - Website title
  - Date written
  - URL
  - Date accessed
- The general format is:

Authors (year), *Title* [online] Last accessed date: URL

- For example:

Dianna Cowern (2014), *Crazy pool vortex* [online] Last accessed 15 June 2021: https://www.youtube.com/watch?v=pnbJEg9r1o8

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Your notes

Precision, Accuracy & Experimental Limitations

Limitations in Experimental Procedures

- Even if the experimental result is close to the true value, there are always potential limitations of experimental methods such as the presence of random errors
- Random errors cannot be completely removed but their effect can be reduced by taking as many **repeats** as possible and using the **average** of the repeats
- There are always opportunities to identify limitations of the procedure, some common examples include:
  - **Parallax error** when reading scales
  - Not using a **fiducial marker** (eg. when measuring the time period of a pendulum using a stopwatch)
  - Not repeating measurements to reduce random errors
  - Not checking for zero errors to reduce systematic errors
  - The equipment not working properly or not checking beforehand with small tests
  - Equipment with poor precision and resolution (eg. a ruler over a micrometer)
  - Difficult to control variables (eg. the temperature of the classroom)
  - Unwanted **heating effects** eg. in circuits

Precision, Accuracy & Error Margins

Precision

- Precision is how close the measured values are to each other
- If a measurement is repeated several times, then they 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

- Accuracy is how close a measured value is to the true value
- The accuracy can be increased by repeating measurements and finding a mean average

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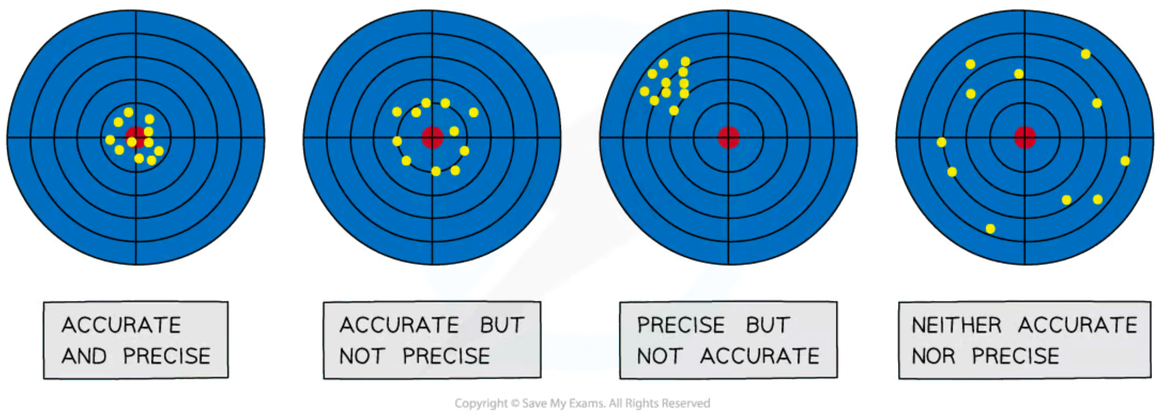

The difference between precise and accurate results

- 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, there will always be a degree of uncertainty
- The uncertainty is an estimate of the difference between a measurement reading and the true value
- Random and systematic errors are two types of measurement errors which 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 used or from flaws in the experimental method
- This type of error is repeated every time the instrument is used or the method is followed, which affects the **accuracy** of all readings obtained
- To **reduce** systematic errors:
  - Instruments should be **recalibrated** or the technique being used should be corrected or adjusted

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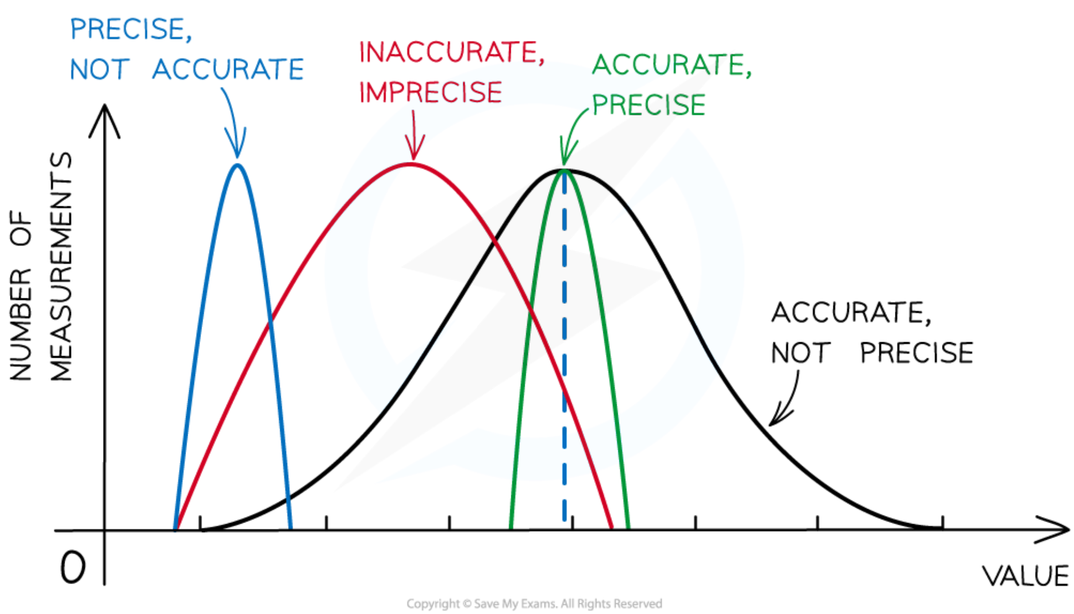

Representing precision and accuracy on a graph

Zero Error

- This is a type of systematic error which occurs when an instrument gives a reading when the **true reading is zero**
- This introduces a fixed error into readings which must be accounted for when the results are recorded

Margin of Error

- Most items of apparatus will have a **margin of error** that can be used in **percentage error** calculations
- This percentage error will then give an idea of the magnitude of any error and therefore how much of an **impact** it may have had on the **results**
- If the percentage error is **too high**, any conclusions drawn may be **rejected** or **further testing may be required** by making improvements to the apparatus used or to the experimental procedure in order to reduce the percentage error

Percentage Uncertainty in Apparatus

- The uncertainty in a measurement is related to the resolution or smallest scale division of the measuring instrument

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- When measuring with analogue instruments, the reading must be rounded up or down to the nearest scale division
  - The uncertainty in the measurement is, therefore, **half the smallest scale division**
- For a **protractor**:
  - Angles are measured to the nearest degree
  - The uncertainty is half a degree, 0.5°
- For a **ruler**:
  - Lengths are measured to the nearest millimetre
  - The uncertainty is half a millimetre, 0.5 mm
- For a **stopwatch**:
  - Time is measured to the nearest 0.01 s
  - However, reaction time is 0.1 – 0.5 s so a degree of precision of 0.1 – 0.5 s is much more reasonable
  - In this case, the uncertainty would be 0.05 – 0.25 s
- The percentage of uncertainty in any single reading taken using the equipment is found using:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{measured value}} \times 100\%$$

- It is important to note that for a particular piece of apparatus, the larger the value measured, the smaller the percentage error
- For example, when measuring the length of a piece of wire there will be a greater percentage error in measuring a length of 7.6 cm than in measuring a length of 38.9 cm using the same ruler

Examiner Tips and Tricks

It is very common for students to confuse precision with accuracy - measurements can be precise but not accurate if each measurement reading has the same error. 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.

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Your notes

Significant Figures

Your notes

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

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Write 1.0478 to 3 significant figures

Answer:

Step 1: Identify the significant figures

They are all significant figures

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

1.0**4**78

Step 3: Round up or down

1.05 (3 s.f)

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!

Your notes

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Your notes

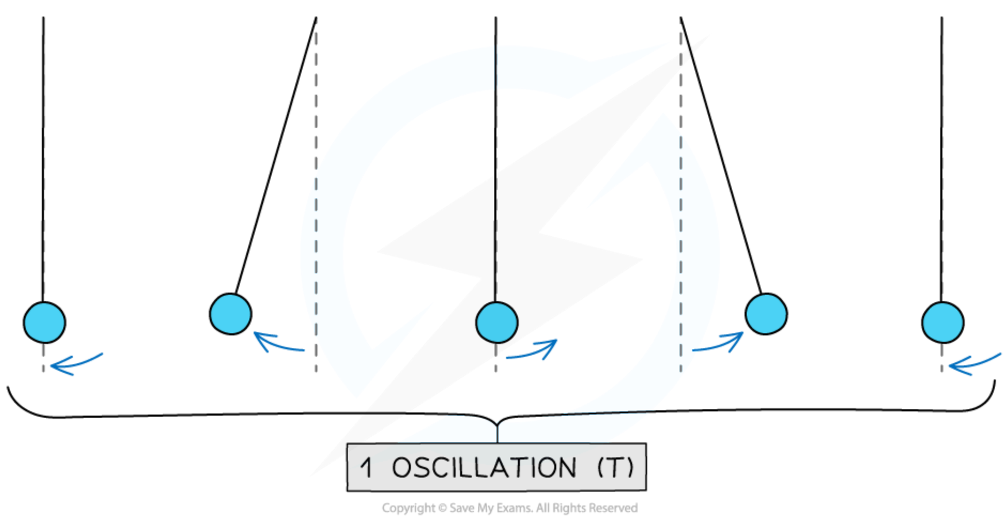
Methods to Increase Accuracy

Methods to Increase Accuracy

- 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
- In order to reduce the uncertainty of results for an experiment some changes may need to be made to the method, such as:
  - Timing over multiple oscillations
  - Using a fiducial marker
  - Using a set square or plumb line

Using Multiple Oscillations

- Uncertainty in a measurement of periodic time can 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

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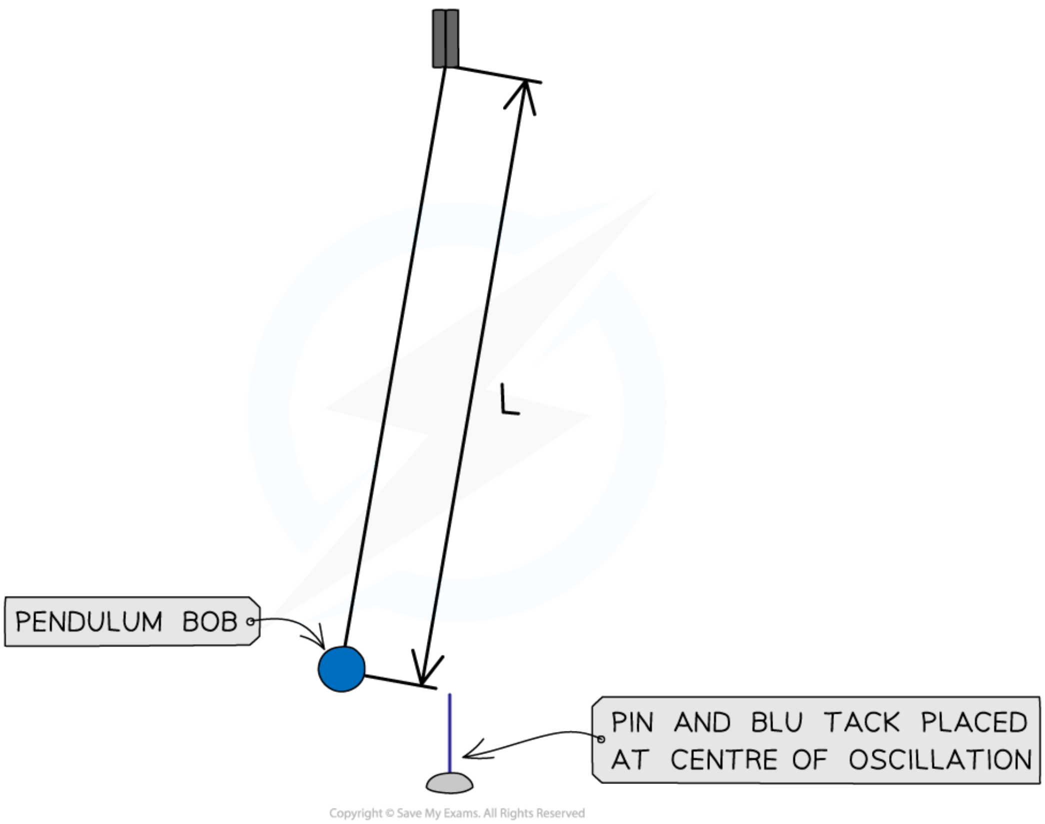
Your notes

Fiducial Marker

- A **fiducial marker** is a useful tool to act as a clear reference point, such as when measuring 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

Set Squares & Plumb Lines

- A **set square** can be used to determine whether:
  - An object is vertical
  - Two objects are at right angles to each other

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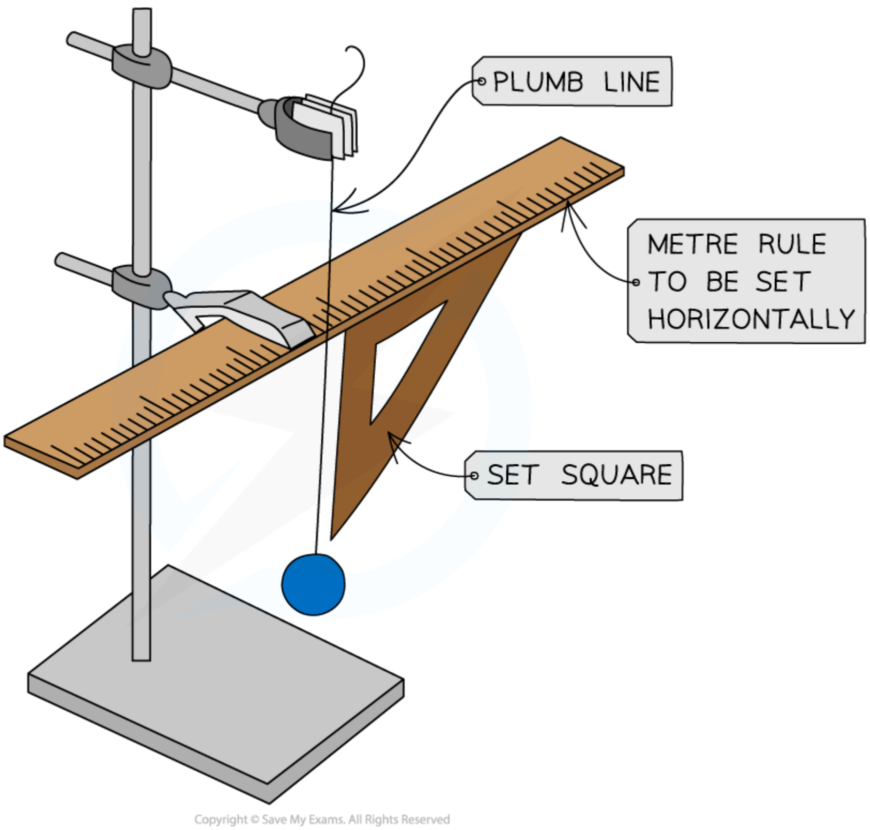
- Two lines are parallel
- A **plumb line** can be also be used to determine if a setup is vertically aligned accurately



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

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