ACHS A-level Physics Year 11 to 12

Name ....

TASK 1

Read and reduce pages 3-16, produce 1-2 A4 sides. Include key terms, sketch graphs and defined equations. You may then want to attempt task 2. This applies some of these skills to one of the required practical's you will complete next year.

Physics required practical's (1-6 AS), (1-12 A-level) You may want to look into these in preparation for next year. You will only complete practical's 1-6 in year 12.

Required practical activities	
1	Investigation into the variation of the frequency of stationary waves on a string with length, tension and mass per unit length of the string
2	Investigation of interference effects to include the Young's slit experiment and interference by a diffraction grating
3	Determination of g by a free-fall method
4	Determination of the Young modulus by a simple method
5	Determination of resistivity of a wire using a micrometer, ammeter and voltmeter
6	Investigation of the emf and internal resistance of electric cells and batteries by measuring the variation of the terminal pd of the cell with current in it
7	Investigation into simple harmonic motion using a mass-spring system and a simple pendulum
8	Investigation of Boyle's (constant temperature) law and Charles's (constant pressure) law for a gas
9	Investigation of the charge and discharge of capacitors. Analysis techniques should include log-linear plotting leading to a determination of the time constant RC
10	Investigate how the force on a wire varies with flux density, current and length of wire using a top pan balance
11	Investigate, using a search coil and oscilloscope, the effect on magnetic flux linkage of varying the angle between a search coil and magnetic field direction
12	Investigation of the inverse-square law for gamma radiation

A.
Uncertainties

Sources of uncertainties

You should know that every measurement has some inherent uncertainty.

The important question to ask is whether an experimenter can be confident that the true value lies in the range that is predicted by the uncertainty that is quoted. Good experimental design will attempt to reduce the uncertainty in the outcome of an experiment. The experimenter will design experiments and procedures that produce the least uncertainty and to provide a realistic uncertainty for the outcome.

In assessing uncertainty, there are a number of issues that have to be considered. These include

- the resolution of the instrument used
- the manufacturer's tolerance on instruments
- the judgments that are made by the experimenter
- the procedures adopted (eg repeated readings)
- the size of increments available (eg the size of drops from a pipette).

Numerical questions will look at a number of these factors. Often, the resolution will be the guiding factor in assessing a numerical uncertainty. There may be further questions that would require candidate to evaluate arrangements and procedures. Students could be asked how particular procedures would affect uncertainties and how they could be reduced by different apparatus design or procedure

A combination of the above factors means that there can be no hard and fast rules about the actual uncertainty in a measurement. What we can assess from an instrument's resolution is the **minimum** possible uncertainty. Only the experimenter can assess the other factors based on the arrangement and use of the apparatus and a rigorous experimenter would draw attention to these factors and take them into account.

Readings and measurements

It is useful, when discussing uncertainties, to separate measurements into two forms:

Readings
the values found from a single judgement when using a piece of equipment

Measurements
the values taken as the difference between the judgements of two values.

Examples:

When using a thermometer, a student only needs to make one judgement (the height of the liquid). This is a reading. It can be assumed that the zero value has been correctly set.

For protractors and rulers, both the starting point and the end point of the measurement must be judged, leading to two uncertainties.

The following list is not exhaustive, and the way that the instrument is used will determine whether the student is taking a reading or a measurement.

Reading (one judgement only)	Measurement (two judgements required)
thermometer	ruler
top pan balance	vernier calliper
measuring cylinder	micrometer
digital voltmeter	protractor
Geiger counter	stop watch
pressure gauge	analogue meter

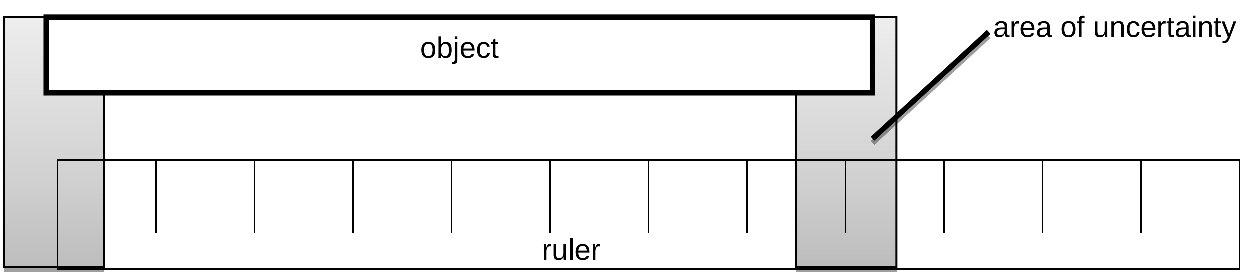
The uncertainty in a **reading** when using a particular instrument is **no smaller** than plus or minus half of the smallest division or greater. For example, a temperature measured with a thermometer is likely to have an uncertainty of ±0.5 °C if the graduations are 1 °C apart.

You should be aware that readings are often written with the uncertainty. An example of this would be to write a voltage as (2.40 ± 0.01) V. It is usual for the uncertainty quoted to be the same number of significant figures as the value. Unless there are good reasons otherwise (eg an advanced statistical analysis), students at this level should quote the uncertainty in a measurement to the same number of decimal places as the value.

Measurement example: length

When measuring length, **two** uncertainties must be included: the uncertainty of the placement of the zero of the ruler and the uncertainty of the point the measurement is taken from.

As both ends of the ruler have a ±0.5 scale division uncertainty, the measurement will have an uncertainty of ±1 division.



For most rulers, this will mean that the uncertainty in a measurement of length will be ±1 mm.

This "initial value uncertainty" will apply to any instrument where the user can set the zero (incorrectly), but would not apply to equipment such as balances or thermometers where the zero is set at the point of manufacture.

In summary

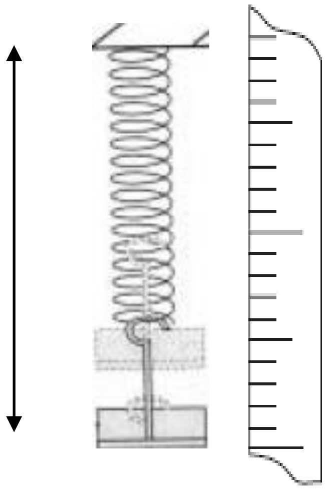
• The uncertainty of a reading (one judgement) is at least ±0.5 of the smallest scale reading.
• The uncertainty of a measurement (two judgements) is at least ±1 of the smallest scale reading.

The way measurements are taken can also affect the uncertainty.

Measurement example: the extension of a spring

Measuring the extension of a spring using a metre ruler can be achieved in two ways.

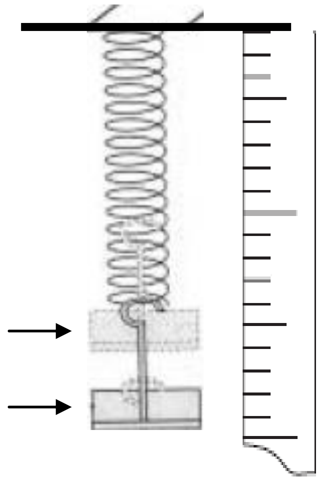
1. Measuring the total length unloaded and then loaded.



Four readings must be taken for this: The start and end point of the unloaded spring's length and the start and end point of the loaded spring's length.

The minimum uncertainty in each measured length is ±1 mm using a meter ruler with 1 mm divisions (the actual uncertainty is likely to be larger due to parallax in this instance). The extension would be the difference between the two readings so the minimum uncertainty would be ±2 mm.

2. Fixing one end and taking a scale reading of the lower end.



Two readings must be taken for this: the end point of the unloaded spring's length and the end point of the loaded spring's length. The start point is assumed to have zero uncertainty as it is fixed.

The minimum uncertainty in each reading would be ±0.5 mm, so the minimum extension uncertainty would be ± 1 mm.

Even with other practical uncertainties this second approach would be better.

Realistically, the uncertainty would be larger than this and an uncertainty in each reading of 1 mm or would be more sensible. This depends on factors such as how close the ruler can be mounted to the point as at which the reading is to be taken.

Other factors

There are some occasions where the resolution of the instrument is not the limiting factor in the uncertainty in a measurement.

Best practice is to write down the full reading and then to write to fewer significant figures when the uncertainty has been estimated.

Examples:

A stopwatch has a resolution of hundredths of a second, but the uncertainty in the measurement is more likely to be due to the reaction time of the experimenter. Here, the student should write the full reading on the stopwatch (eg 12.20 s), carry the significant figures through for all repeats, and reduce this to a more appropriate number of significant figures after an averaging process later.

If a student measures the length of a piece of wire, it is very difficult to hold the wire completely straight against the ruler. The uncertainty in the measurement is likely to be higher than the ±1 mm uncertainty of the ruler. Depending on the number of "kinks" in the wire, the uncertainty could be reasonably judged to be nearer ± 2 or 3 mm.

The uncertainty of the reading from digital voltmeters and ammeters depends on the electronics and is strictly not the last figure in the readout. Manufacturers usually quote the percentage uncertainties for the different ranges. Unless otherwise stated it may be assumed that ±0.5 in the least significant digit is to be the uncertainty in the measurement. This would generally be rounded up to ±1 of the least significant digit when quoting the value and the uncertainty together. For example (5.21 ±0.01) V. If the reading fluctuates, then it may be necessary to take a number of readings and do a mean and range calculation.

Uncertainties in given values

The value of the charge on an electron is given in the data sheet as 1.60×10^{-19} C.

In all such cases assume the uncertainty to be ±1 in the last significant digit. In this case the uncertainty $\pm 0.01 \times 10^{-19}$ C. The uncertainty may be lower than this but without knowing the details of the experiment and procedure that lead to this value there is no evidence to assume otherwise.

Example: If the number of lines per m is quoted as 3.5×10^{3} (as in Physics specimen AS P2 Q1.1) then it is usual to assume that the uncertainty is ±1 in the last significant figure, $\pm 0.1 \times 10^{3}$ since there is no indication of the uncertainties in the measurements from which that figure came.

Multiple instances of measurements

Some methods of measuring involve the use of multiple instances in order to reduce the uncertainty. For example measuring the thickness of several sheets of paper together rather than one sheet, or timing several swings of a pendulum. The uncertainty of each measurement will be the uncertainty of the whole measurement divided by the number of sheets or swings. This method works because the percentage uncertainty on the time for a single swing is the same as the percentage uncertainty for the time taken for multiple swings.

For example:

Time taken for a pendulum to swing 10 times: (5.1 ± 0.1) s
Mean time taken for one swing: (0.51 ± 0.01) s

Repeated measurements

Repeating a measurement is a method for reducing the uncertainty.

With many readings one can also identify those that are exceptional (that are far away from a significant number of other measurements). Sometimes it will be appropriate to remove outliers from measurements before calculating a mean. On other occasions, particularly in Biology, outliers are important to include. For example, it is important to know that a particular drug produces side effects in one person in a thousand.

If measurements are repeated, the uncertainty can be calculated by finding half the range of the measured values.

For example:

Repeat	1	2	3	4
Distance/m	1.23	1.32	1.27	1.22

1.32 – 1.22 = 0.10 therefore
Mean distance: (1.26 ± 0.05) m

Percentage uncertainties

The percentage uncertainty in a measurement can be calculated using:

$$percentage\ uncertainty = \frac{uncertainty}{value}\ x\ 100\%$$

The percentage uncertainty in a repeated measurement can also be calculated using:

$$percentage\ uncertainty = \frac{uncertainty}{mean\ value}\ x\ 100\%$$

Further examples:

Example 1. Some values for diameter of a wire

Repeat	1	2	3	4
diameter/mm	0.35	0.37	0.36	0.34

The exact values for the mean is 0.355 mm and for the uncertainty is 0.015 mm

This could be quoted as such or recorded as 0.36 ±0.02 mm given that there is a wide range and only 4 readings. Given the simplistic nature of the analysis then giving the percentage uncertainty as 5% or 6% would be acceptable.

Example 2. Different values for the diameter of a wire

Repeat	1	2	3
diameter/mm	0.35	0.36	0.35

The mean here is 0.3533 mm with uncertainty of 0.0033 mm

The percentage uncertainty is 0.93% so may be quoted as 1% but really it would be better to obtain further data.

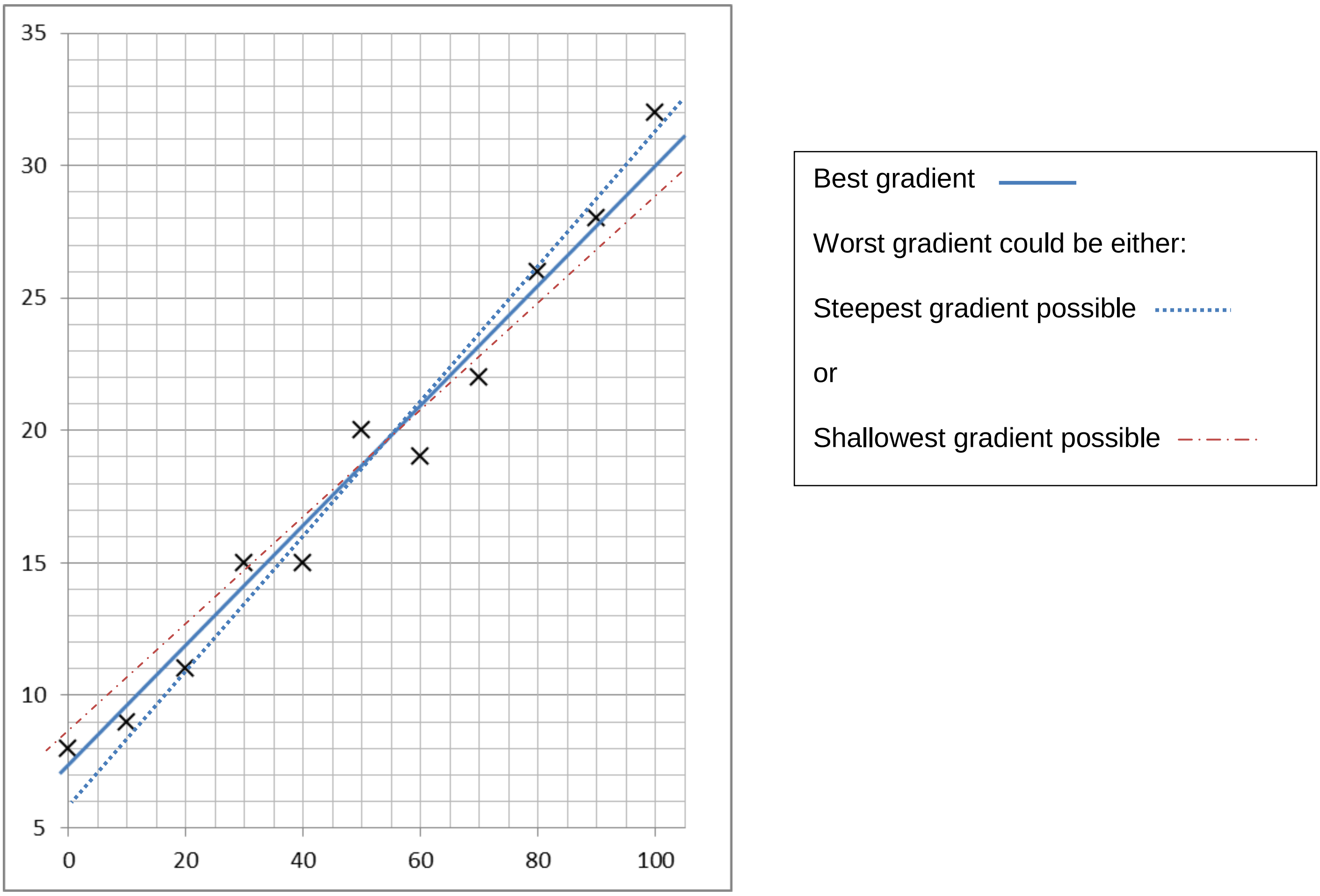
Uncertainties from gradients

To find the uncertainty in a gradient, two lines should be drawn on the graph. One should be the "best" line of best fit. The second line should be the steepest or shallowest gradient line of best fit possible from the data. The gradient of each line should then be found.

The uncertainty in the gradient is found by:

$$\text{percentage uncertainty} = \frac{|\text{best gradient} - \text{worst gradient}|}{\text{best gradient}} \times 100\%$$

Note the $|$modulus bars$|$ meaning that this percentage will always be positive.



In the same way, the percentage uncertainty in the y-intercept can be found:

$$\text{percentage uncertainty} = \frac{|\text{best } y \text{ intercept - worst } y \text{ intercept}|}{\text{best } y \text{ intercept}} \times 100\%$$

Error bars in Physics

There are a number of ways to draw error bars. Students are not expected to have a formal understanding of confidence limits in Physics (unlike in Biology). The following simple method of plotting error bars would therefore be acceptable.

- Plot the data point at the mean value
- Calculate the range of the data, ignoring any anomalies
- Add error bars with lengths equal to half the range on either side of the data point

Combining uncertainties

Percentage uncertainties should be combined using the following rules:

Combination	Operation	Example
Adding or subtracting values $a = b + c$	Add the absolute uncertainties $\Delta a = \Delta b + \Delta c$	Object distance, *u* = (5.0 ± 0.1) cm Image distance, *v* = (7.2 ± 0.1) cm Difference (*v* – *u*) = (2.2 ± 0.2) cm
Multiplying values $a = b \times c$	Add the percentage uncertainties $\varepsilon a = \varepsilon b + \varepsilon c$	Voltage = (15.20 ± 0.1) V Current = (0.51 ± 0.01) A Percentage uncertainty in voltage = 0.7% Percentage uncertainty in current = 1.96% Power = Voltage x current = 7.75 W Percentage uncertainty in power = 2.66% Absolute uncertainty in power = ± 0.21 W
Dividing values $a = \frac{b}{c}$	Add the percentage uncertainties $\varepsilon a = \varepsilon b + \varepsilon c$	Mass of object = (30.2 ± 0.1) g Volume of object = (18.0 ± 0.5) cm^3 Percentage uncertainty in mass of object = 0.3 % Percentage uncertainty in volume = 2.8% Density = $\frac{30.2}{18.0}$ = 1.68 gcm^{-3} Percentage uncertainty in density = 3.1% Absolute uncertainty in density = ± 0.05 g cm^{-3}
Power rules $a = b^c$	Multiply the percentage uncertainty by the power $\varepsilon a = c \times \varepsilon b$	Radius of circle = (6.0 ± 0.1) cm Percentage uncertainty in radius = 1.6% Area of circle = πr^2 = 113.1 cm^2 Percentage uncertainty in area = 3.2% Absolute uncertainty = ± 3.6 cm^2 (Note – the uncertainty in π is taken to be zero)

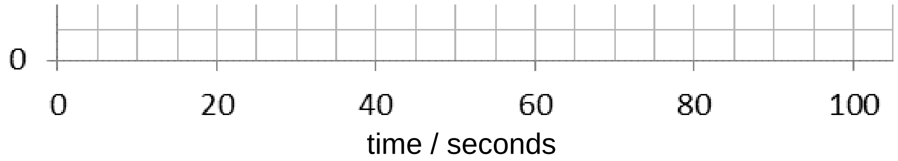
Note:
Absolute uncertainties (denoted by Δ) have the same units as the quantity.
Percentage uncertainties (denoted by ε) have no units.
Uncertainties in trigonometric and logarithmic functions will not be tested in A-level exams.

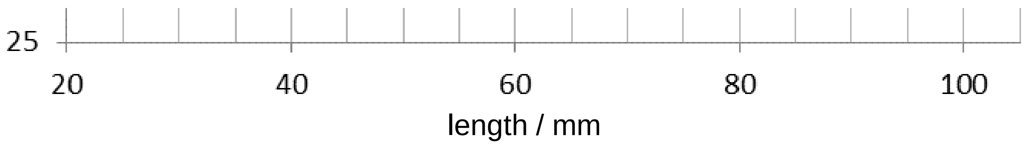
B. Graphing

Graphing skills can be assessed both in written papers for the A-level grade and by the teacher during the assessment of the endorsement. Students should recognise that the type of graph that they draw should be based on an understanding of the data they are using and the intended analysis of the data. The rules below are guidelines which will vary according to the specific circumstances.

Labelling axes

Axes should always be labelled with the quantity being measured and the units. These should be separated with a forward slash mark:





Axes should not be labelled with the units on each scale marking.

Data points

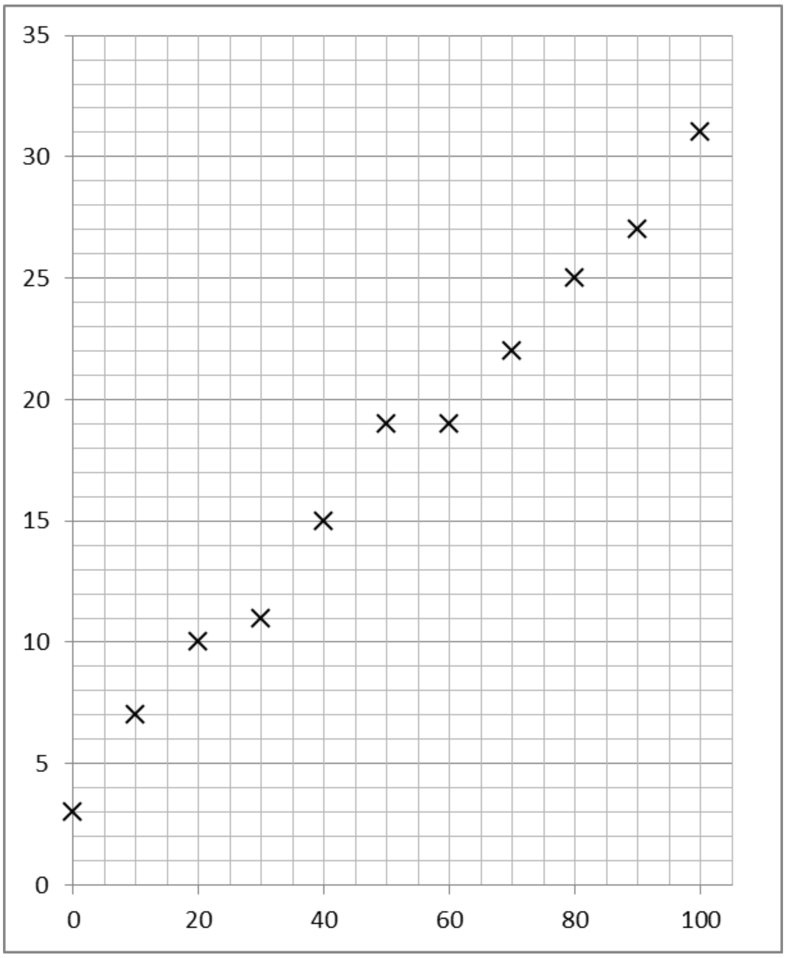
Data points should be marked with a cross. Both × and + marks are acceptable, but care should be taken that data points can be seen against the grid.

Error bars can take the place of data points where appropriate.

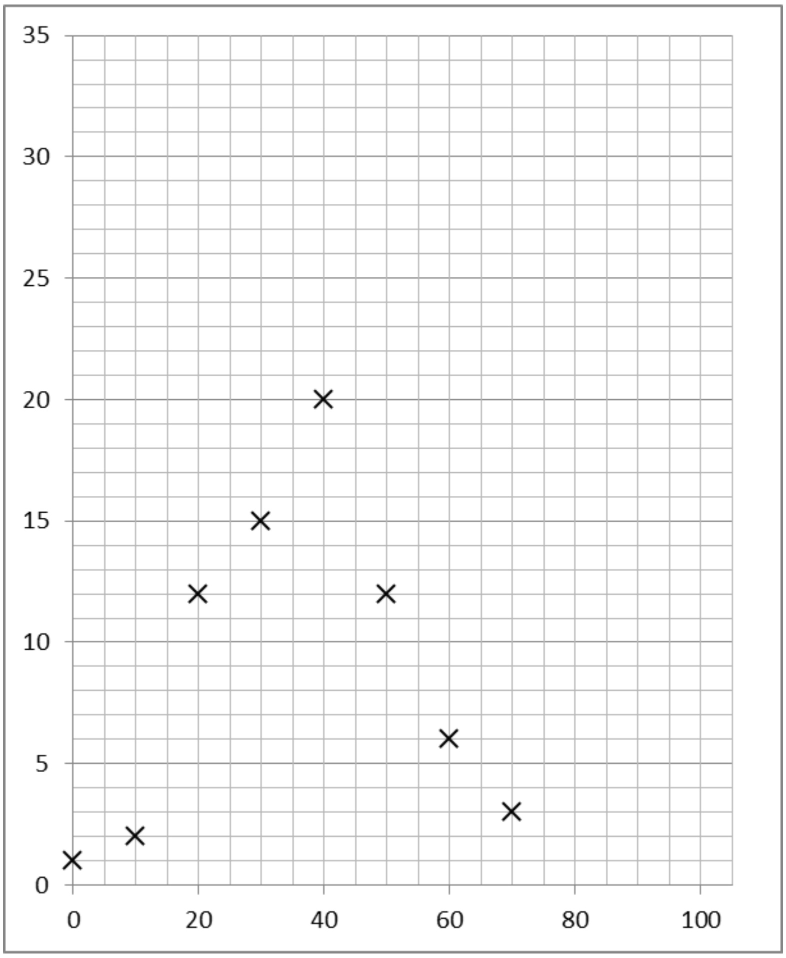
Scales and origins

Students should attempt to spread the data points on a graph as far as possible without resorting to scales that are difficult to deal with. Students should consider:

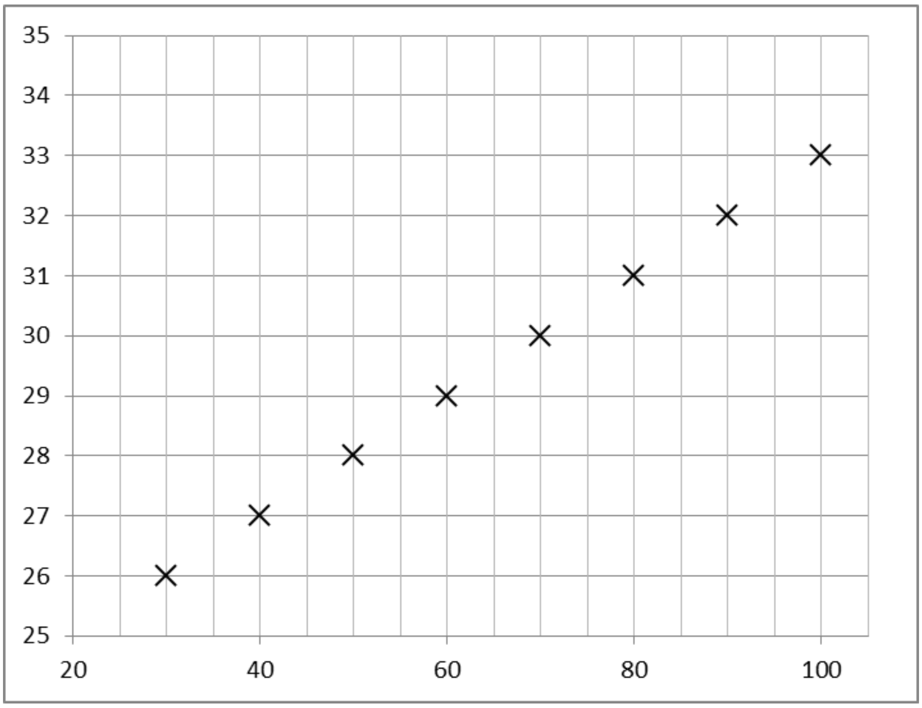
- the maximum and minimum values of each variable
- the size of the graph paper
- whether 0.0 should be included as a data point
- whether they will be attempting to calculate the equation of a line, therefore needing the y intercept (Physics only)
- how to draw the axes without using difficult scale markings (eg multiples of 3, 7, 11 etc)
- In exams, the plots should cover **at least half** of the grid supplied for the graph.



This graph has well-spaced marking points and the data fills the paper.
Each point is marked with a cross (so points can be seen even when a line of best fit is drawn).



This graph is on the limit of acceptability. The points do not quite fill the page, but to spread them further would result in the use of awkward scales.



At first glance, this graph is well drawn and has spread the data out sensibly.
However, if the graph were to later be used to calculate the equation of the line, the lack of a y-intercept could cause problems. Increasing the axes to ensure all points are spread out but the y-intercept is also included is a skill that requires practice and may take a couple of attempts.

Lines of best fit

Lines of best fit should be drawn when appropriate. Students should consider the following when deciding where to draw a line of best fit:

- Are the data likely to have an underlying equation that it is following (for example, a relationship governed by a physical law)? This will help decide if the line should be straight or curved.
- Are there any anomalous results?
- Are there uncertainties in the measurements? The line of best fit should fall within error bars if drawn.

There is no definitive way of determining where a line of best fit should be drawn. A good rule of thumb is to make sure that there are as many points on one side of the line as the other. Often the line should pass through, or very close to, the majority of plotted points. Graphing programs can sometimes help, but tend to use algorithms that make assumptions about the data that may not be appropriate.

Lines of best fit should be continuous and drawn with a thin pencil that does not obscure the points below and does not add uncertainty to the measurement of gradient of the line.

Not all lines of best fit go through the origin. Students should ask themselves whether a 0 in the independent variable is likely to produce a 0 in the dependent variable. This can provide an extra and more certain point through which a line must pass. A line of best fit that is expected to pass through (0,0), but does not, would imply some systematic error in the experiment. This would be a good source of discussion in an evaluation.

Dealing with anomalous results

At GCSE, students are often taught to automatically ignore anomalous results. At A-level students should think carefully about what could have caused the unexpected result. For example, if a different experimenter carried out the experiment. Similarly, if a different solution was used or a different measuring device. Alternatively, the student should ask if the conditions the experiment took place under had changed (for example at a different temperature). Finally, whether the anomalous result was the result of an accident or experimental error. In the case where the reason for an anomalous result occurring can be identified, the result should be ignored. In presenting results graphically, anomalous points should be plotted but ignored when the line of best fit is being decided.

Anomalous results should also be ignored where results are expected to be the same.

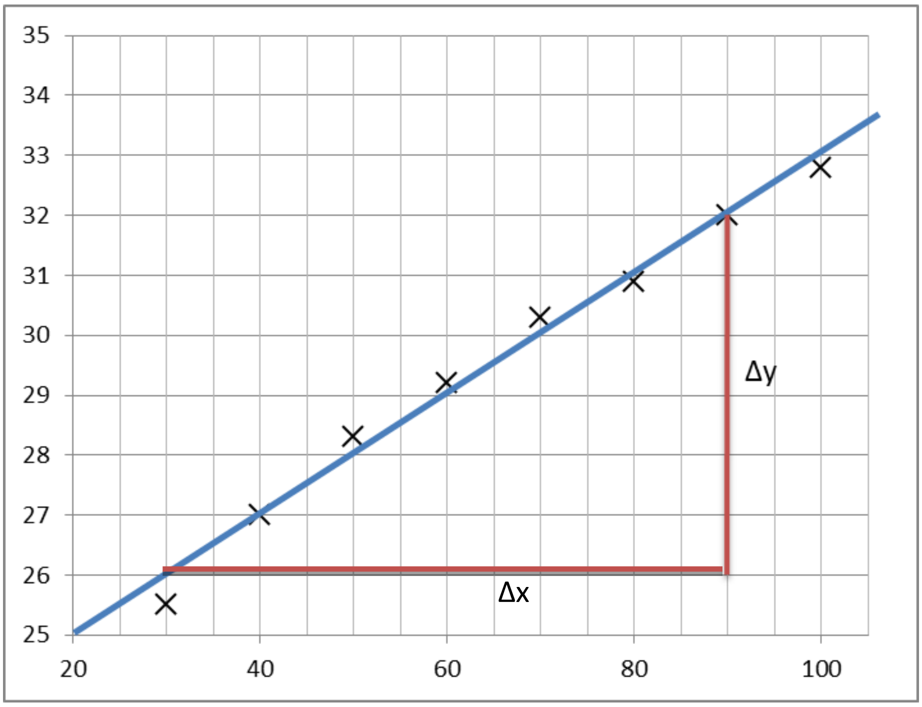
Where there is no obvious error and no expectation that results should be the same, anomalous results should be included. This will reduce the possibility that a key point is being overlooked.

Please note: when recording results it is important that all data are included. Anomalous results should only be ignored at the data analysis stage.

It is best practice whenever an anomalous result is identified for the experiment to be repeated. This highlights the need to tabulate and even graph results as an experiment is carried out.

Measuring gradients

When finding the gradient of a line of best fit, students should show their working by drawing a triangle on the line. The hypotenuse of the triangle should be at least half as big as the line of best fit.



The line of best fit here has an equal number of points on both sides. It is not too wide so points can be seen under it.
The gradient triangle has been drawn so the hypotenuse includes more than half of the line.
In addition, it starts and ends on points where the line of best fit crosses grid lines so the points can be read easily (this is not always possible).

$$gradient = \frac{\Delta y}{\Delta x}$$

Use of mirrors

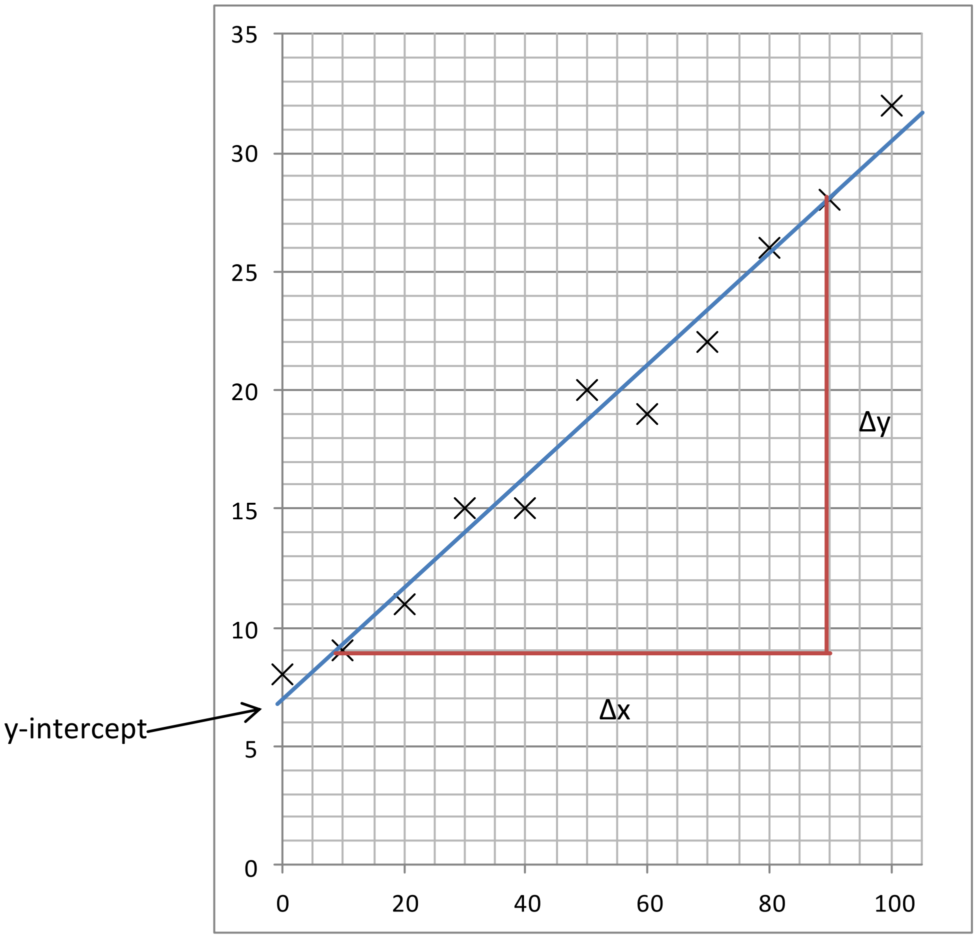
It is possible to use mirrors in class to draw lines of best fit. However, mirrors are **not** allowed to be used in exams.

The equation of a straight line

You should be able to translate graphical data into the equation of a straight line.

$$y = mx + c$$

Where y is the dependent variable, m is the gradient, x is the independent variable and c is the y-intercept.



$\Delta y = 28 - 9 = 19$

$\Delta x = 90 - 10 = 80$

gradient = 19 / 80 = 0.24 (2 sf)

y-intercept = 7.0

equation of line:

$y = 0.24\,x + 7.0$

More complex relationships – This section will not be covered until year 13.
You <u>may</u> still want to add this to task 1.

Graphs can be used to analyse more complex relationships by rearranging the equation into a form similar to y=mx+c.

Example one

When water is displaced by an amount l in a U tube, the time period, T, varies with the following relationship:

$$\mathrm{T} = 2\pi\sqrt{\frac{l}{2\mathrm{g}}}$$

This could be used to find g, the acceleration due to gravity.

- Take measurements of T and l.
- Rearrange the equation to become linear:

$$T^2 = 4\pi^2\frac{l}{2g}$$

- Calculate T^2 for each value of l.
- By re-writing the equation as:

$$T^2 = \frac{4\pi^2}{2g}l$$

  it becomes clear that a graph of T^2 against l will be linear with a gradient of $\frac{4\pi^2}{2g}$.
- Calculate the gradient (m) by drawing a triangle on the graph.
- Find g by rearranging the equation $m = \frac{4\pi^2}{2g}$ into $g = \frac{4\pi^2}{2}m = 2\pi^2 m$

Example two: testing power laws

A relationship is known to be of the form $y = A x^n$, but the power n is unknown.

Measurements of y and x are taken.

Taking logs of both sides of the equation gives:

$$\log(y) = n(\log(x)) + \log(A)$$

A graph is plotted with log(y) against log(x).

The gradient of this graph will be n.
The y intercept will be log(A).

Example three

The equation that relates the pd, *V*, across a capacitor, *C*, as it discharges through a resistor, *R*, over a period of time, *t*, is:

$$V = V_0 e^{-\frac{t}{RC}}$$

Where V_0 = pd across capacitor at *t* = 0

Taking natural logs, this can be rearranged into

$$\ln V = -\frac{t}{RC} + lnV_0$$

So a graph of $\ln V$ against t should be a straight line,

with a gradient of $-\frac{1}{RC}$

and a y-intercept of lnV_0.

C. Glossary of terms.

(This section is not part of task 1. However you do need to be aware of these terms so why not have a look)

The following subject specific vocabulary provides definitions of key terms used in AQA's AS and A-level Biology, Chemistry and Physics specifications.

Accuracy

A measurement result is considered accurate if it is judged to be close to the true value.

Calibration

Marking a scale on a measuring instrument.

This involves establishing the relationship between indications of a measuring instrument and standard or reference quantity values, which must be applied.

For example, placing a thermometer in melting ice to see whether it reads 0 °C, in order to check if it has been calibrated correctly.

Data

Information, either qualitative or quantitative, that have been collected.

Errors

See also uncertainties.

measurement error

The difference between a measured value and the true value.

anomalies

These are values in a set of results which are judged not to be part of the variation caused by random uncertainty.

random error

These cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next.

Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by making more measurements and calculating a new mean.

systematic error

These cause readings to differ from the true value by a consistent amount each time a measurement is made.

Sources of systematic error can include the environment, methods of observation or instruments used.

Systematic errors cannot be dealt with by simple repeats. If a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

zero error

Any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, eg the needle on an ammeter failing to return to zero when no current flows.

A zero error may result in a systematic uncertainty.

Evidence

Data that have been shown to be valid.

Fair test

A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis

A proposal intended to explain certain facts or observations.

Interval

The quantity between readings eg a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

Precision

Precise measurements are ones in which there is very little spread about the mean value.

Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction

A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Range

The maximum and minimum values of the independent or dependent variables;

For example a range of distances may be quoted as either:

'From 10cm to 50 cm' or

'From 50 cm to 10 cm'

Repeatable

A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results.

Reproducible

A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

Resolution

This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.

Sketch graph

A line graph, not necessarily on a grid, that shows the general shape of the relationship between two variables. It will not have any points plotted and although the axes should be labelled they may not be scaled.

True value

This is the value that would be obtained in an ideal measurement.

Uncertainty

The interval within which the true value can be expected to lie, with a given level of confidence or probability eg “the temperature is 20 °C ± 2 °C, at a level of confidence of 95%”.

Validity

Suitability of the investigative procedure to answer the question being asked. For example, an investigation to find out if the rate of a chemical reaction depended upon the concentration of one of the reactants would not be a valid procedure if the temperature of the reactants was not controlled.

Valid conclusion

A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Variables

These are physical, chemical or biological quantities or characteristics.

categoric variables

Categoric variables have values that are labels eg names of plants or types of material or reading at week 1, reading at week 2 etc.

continuous variables

Continuous variables can have values (called a quantity) that can be given a magnitude either by counting (as in the case of the number of shrimp) or by measurement (eg light intensity, flow rate etc).

control variables

A control variable is one which may, in addition to the independent variable, affect the outcome of the investigation and therefore has to be kept constant or at least monitored.

dependent variables

The dependent variable is the variable of which the value is measured for each and every change in the independent variable.

independent variables

The independent variable is the variable for which values are changed or selected by the investigator.

nominal variables

A nominal variable is a type of categoric variable where there is no ordering of categories (eg red flowers, pink flowers, blue flowers).

Task 2 :RESISTIVITY

This is an exercise for you to practice data handling and analysis skills. You <u>may</u> want to complete this to test your understanding of task 1. DON'T PANIC! This is tough stuff. Have a go, see how you do. You can have an extra mark for telling me the cover of the fictional book that 'DON'T PANIC' is printed on. Good luck, see you in September ☺

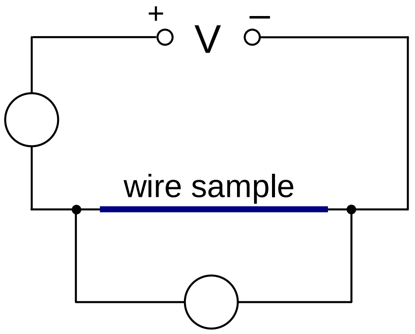
Electrical ***resistivity***, ρ, is a property of a material. It is defined as being equal to the resistance of a sample of material of length 1 m and cross-sectional area 1 m^2.
For a wire of length l, cross-sectional area A and material of resistivity ρ, the resistance R is given by

$$R = \frac{\rho L}{A}$$

Resistivity, ρ, has units Ωm.

The results table (over the page) shows measurements carried out on seven different thicknesses of the same material wire.
The diameter of each wire was measured at three different places along the wire to a precision of ± 0.01 mm (columns 2 to 4).
The diameter was measured using a ……………………..……………..…. .

The following electrical circuit was used to measure the current, I, through each wire and the p.d., V, across it.



Crocodile clips were connected to the wire and their positions adjusted until the measured distance between them was L = 0.900 m.

A …………………………… was used to measure the distance.
Each reading was accurate to ± 1 mm.

Calculate the uncertainty (error) in length L ……………..

Calculate the percentage uncertainty in length L ……………

Calculate the mean value for d for 32 swg wire and write it in the table.

Work out the uncertainty in this mean value for d.

……………………….……………………………...

Work out the percentage uncertainty in this mean value.
…………………………………………….

If you were to improve the precision of the data, which would you try to improve first - the measurement of L or of d? Give a reason.

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1	2	3	4	5	6	7	8	9	10
swg	d_1/mm	d_2/mm	d_3/mm	d/mm		$\frac{1/A}{mm^{-2}}$			
20	0.93	0.88	0.92	0.91	0.65	1.5	1.00	1.30	
24	0.54	0.55	0.58	0.56			2.00	0.97	
28	0.38	0.39	0.37	0.38	0.11	8.8	2.00	0.45	
32	0.28	0.25	0.29				5.00	0.64	
34	0.24	0.22	0.32	0.23	0.042	24	5.00	0.43	
36	0.20	0.16	0.20	0.19	0.028	35	10.00	0.56	
38	0.17	0.14	0.15	0.15	0.018	57	10.00	0.38	

Circle the one d measurement which looks to be anomalous.

The scientists ignored this anomalous value when calculating the mean. What could they have done that would have been better?

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Column 6 is the cross-sectional area of the wire, A.
Column 8 is the p.d., column 9 is the current and column 10 is the resistance.
Label the headings for these columns [quantity names or symbols; units].

Complete all the missing data in the table. State all values to the correct number of sig. figs.

Rearrange the equation for R, ρ, L, A to show what graph you should plot to test the relationship between R and A. State what the gradient and intercept of the graph should be.

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Plot the graph and determine the gradient. Show full data for your gradient calculation.

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Calculate the resistivity of the wire.

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How does your graph show that R is proportional to 1/A?

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………………………………………………………………………………….………………………
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The values for current and voltage in the table are recorded with the correct number of sig. figs.

What is the precision of the ammeter? …………………

What is the precision of the voltmeter? …………………

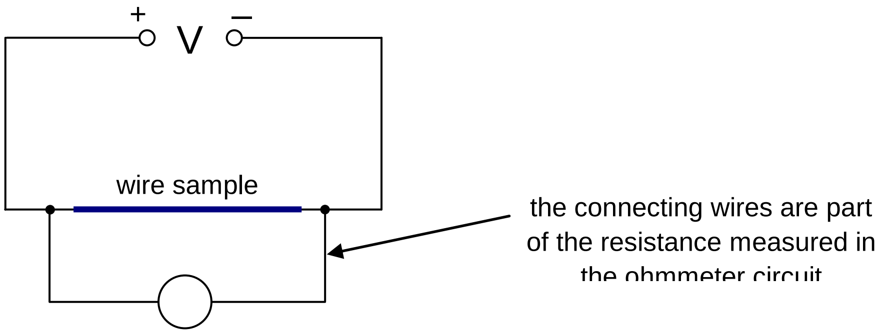
For the 32 swg wire, calculate the % uncertainty in V, in I and in R.

V …………………………..   I …………………………..   R …………………………

On page 1 you worked out the % uncertainty in d for the 32 swg wire.
What are the % uncertainties in the values of A and 1/A for this wire?

A …………………………..   1/A …………………………..

In a different investigation, some students measured the resistance R for different lengths L of
32 swg wire.
The resistance was measured using a multimeter as an ohmmeter.



An ohmmeter measures the total amount of resistance in the circuit it is connected to. This includes the connecting wires as well as the wire sample. So, all the ohmmeter readings are in error in the same way.
What do we call this type of error? ……………………………………….

What should the students do to remove this error?
……………………………………………………..

……………………………………………………………………….………………………………
………….

Use the resistivity equation to show that a graph of R against L should be a straight line, and state what the gradient and intercept should be. Explain how you would use this graph to find ρ.

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Skills checklist

Work out the uncertainty in a quantity that is the difference of two measured values.

Calculate: percentage uncertainty = $\pm \dfrac{\text{uncertainty}}{\text{value}} \times 100\%$

Find the uncertainty in a mean value by considering the range of measured values:

$$\text{uncertainty} = \pm \frac{\text{measurement range}}{2}$$

Combine the % uncertainties for quantities that are multiplied or divided or squared.

Compare the precision of two different values by comparing their % uncertainties.

Calculate a mean value and state it to the correct number of sig. figs.

Calculate cross-sectional area when given the diameter.
Calculate resistance from current and p.d., giving your answer to the correct sig.figs.

Identify anomalous values and state what action to take.

Use correct table headings and graph labels, in the format $\dfrac{\text{quantity}}{\text{units}}$.

Rearrange an equation to the form y = mx + c and identify what quantities to plot to produce a graph which should be a straight line.
Be able to state what the gradient and y-intercept of the graph should be.
Know how a graph shows that $y \propto x$.

Know that at least 7 data points are needed for a valid graph.

Choose good graph scales so that

- the range of points cover at least half the available space in each direction
- the scale is simple i.e. a multiple of 1, 2 or 5 (possibly 4, but this can be hard to use)

Plot data points within ± 1 mm.
Draw a best fit straight line, with a fairly even scatter of points either side of the line.
Know that even if the theory suggests that the intercept should be zero, not to force the best fit to go through zero.

Calculate the graph gradient:

- large triangle using at least half the graph paper in each direction
- Δ values clearly calculated as the difference of two values read from the graph line
- gradient calculated as $\dfrac{\Delta y}{\Delta x}$ [instead of 'y' and 'x' it's better to use the actual plotted quantity symbols]
- state the gradient to correct sig. figs. [usually 3 sig. figs. at most].
- state the units of the gradient, found from $\dfrac{\text{y axis units}}{\text{x axis units}}$.

Use your gradient value, along with other values, to find a significant quantity (ρ in this work).

Know that using a multimeter as an ohmmeter brings in a systematic error, and what steps to take to correct this error.