Edexcel International A Level (IAL) Physics

Your notes

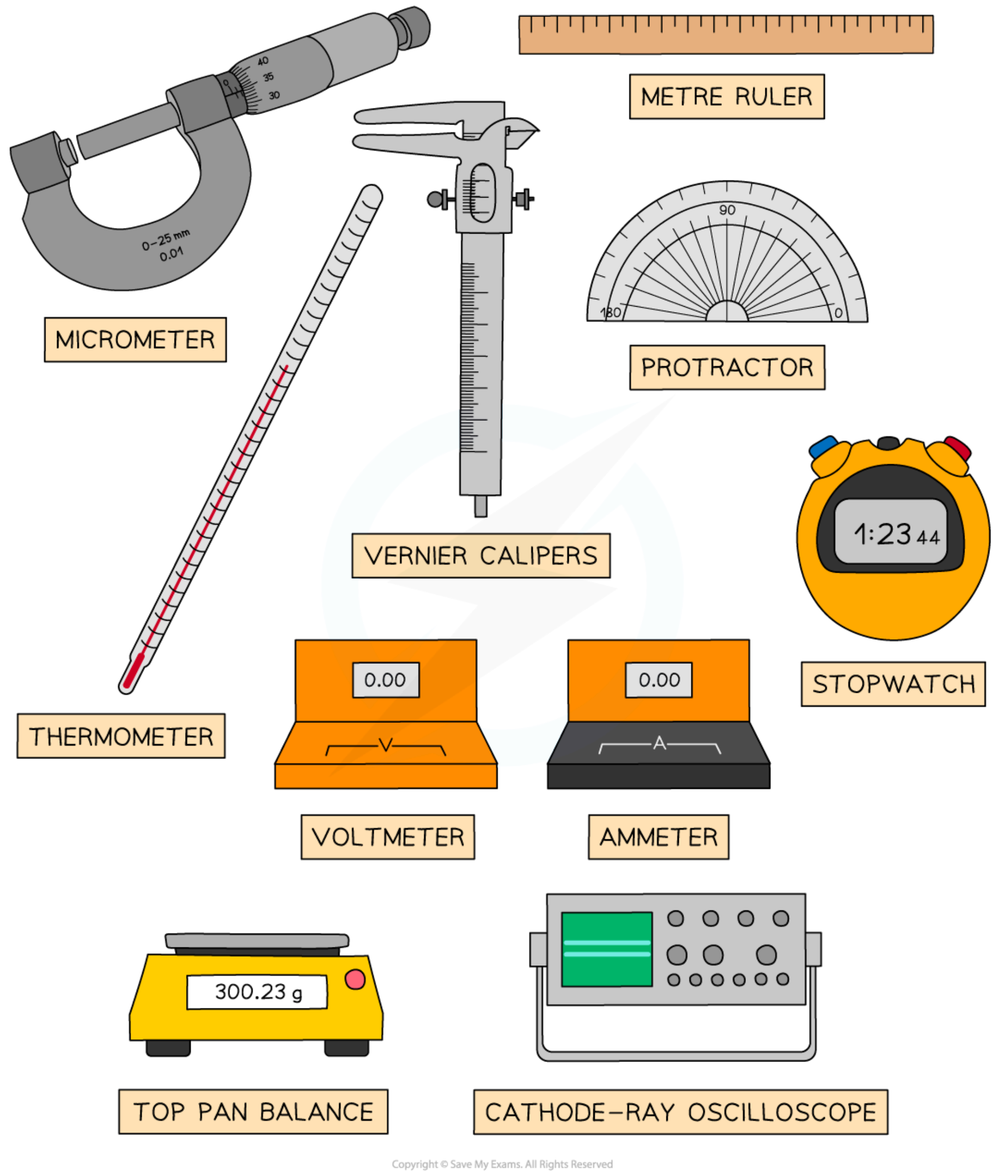
Practical Skills I: Planning

Contents

Identifying Apparatus

- When planning an experiment, the first step is to identify the apparatus required
  - Each experiment will have its own unique set of apparatus
- The apparatus is the equipment needed to carry out the experiment
  - This includes both what you are measuring and how you are measuring it
- Common apparatus include:
  - Metre rulers - to measure distance and length
  - Balances - to measure mass
  - Protractors - to measure angles
  - Stopwatches - to measure time
  - Ammeters - to measure current
  - Voltmeters - to measure potential difference
- More complicated instruments such as the micrometer screw gauge and Vernier calipers can be used to more accurately measure length

Your notes



Examples of apparatus used in scientific experiments

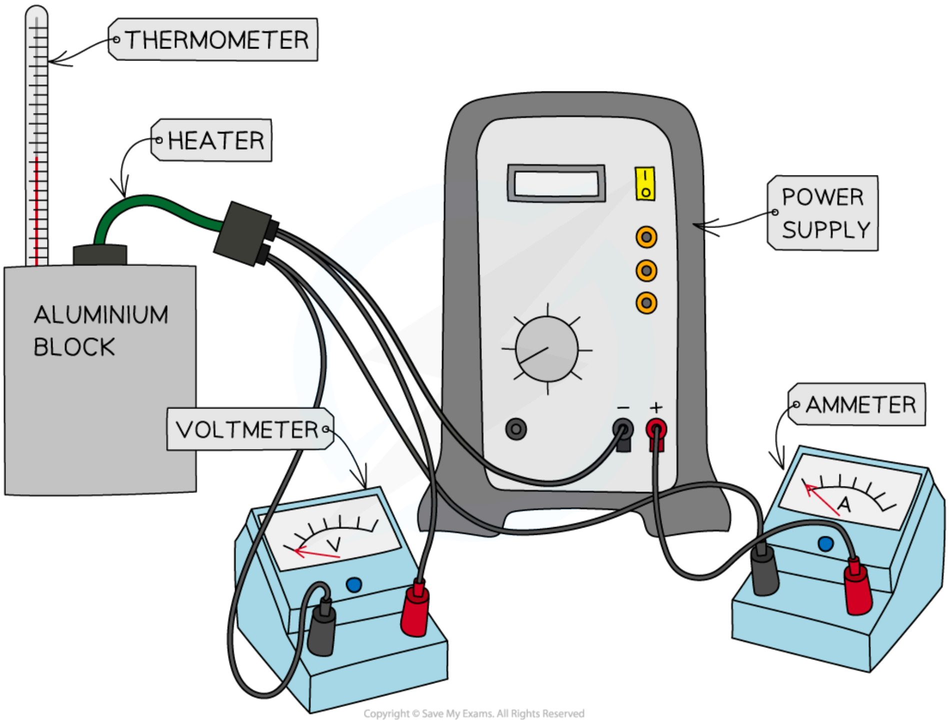
- The apparatus required depends on what you are trying to measure
- A few examples are shown in the table below

Apparatus Table

Quantity	Apparatus
Length	Metre ruler, Micrometer, Vernier caliper
Mass	Top-pan balance

Angle	Protractor
Time	Stopwatch
Temperature	Thermometer
Potential difference	Voltmeter
Current	Ammeter
Frequency	Oscilloscope

- An example of apparatus for measuring the specific heat capacity of an aluminium block is shown below:



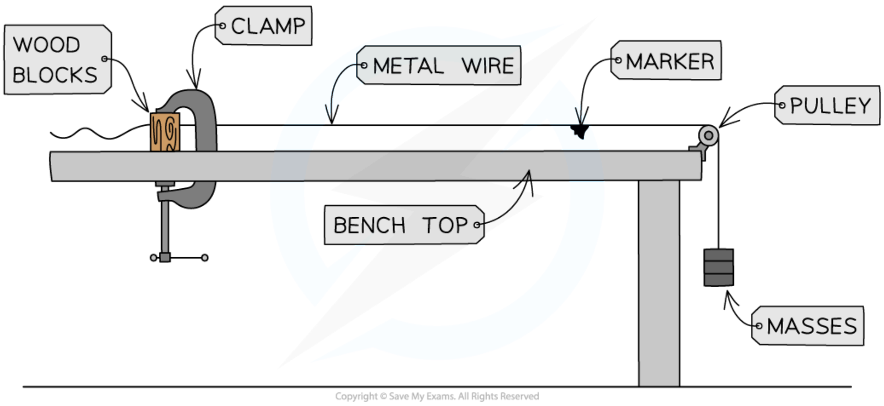
Apparatus needed to measure specific heat capacity

- This includes:
  - A block of the substance (preferably 1kg in mass) or in the case of a fluid, a beaker containing a known mass of the fluid
  - A thermometer
  - An appropriate heater (e.g. an immersion heater)
  - A power source

- A joule meter or a voltmeter, ammeter and stop-clock (I will assume we have the latter)
- Wires and connectors

Worked Example

The diagram below shows one possible method for determining the Young modulus of a metal in the form of a wire.



Describe how you can use this apparatus to determine the Young modulus of the metal. The sections below should be helpful when writing your answers.

- The measurements to be taken.
- The equipment used to take the measurements.
- How you would determine Young modulus from your measurements.

Answer:

Step 1: State the necessary measurements to be taken

- The **diameter** of the wire
- The **initial length** of the wire
- The **extension** of the wire (final length – initial length)
- The **mass** of the hanging masses or the **weight** applied to the wire

Step 2: State and explain which equipment would be the most suitable

- For measuring the diameter of the wire:
  - A **micrometer screw gauge** or **vernier callipers**
  - Micrometer would be best as this has the highest resolution when measuring small areas
- For measuring the original length / extension of the wire:
  - A **metre ruler** or a **tape measure**
  - The wire has a moderate length which cannot be measured using a vernier scale
- For measuring extension:

Your notes

- **Travelling microscope**
- These are designed for measuring small changes in length
- For measuring the mass:
  - **Scales** or a **top-pan balance**
  - A top-pan balance would be best as this has the higher resolution
  - $W = mg$ equation can be used to calculate weight
- For measuring the weight directly:
  - A **newton-meter**
  - This is useful if 'known' weights are used and to check if the quoted masses are accurate

Step 3: Explain how Young's modulus can be determined from these measurements

- Young modulus is equal to the **gradient** of a stress-strain graph (in the linear region)
- Stress is equal to:

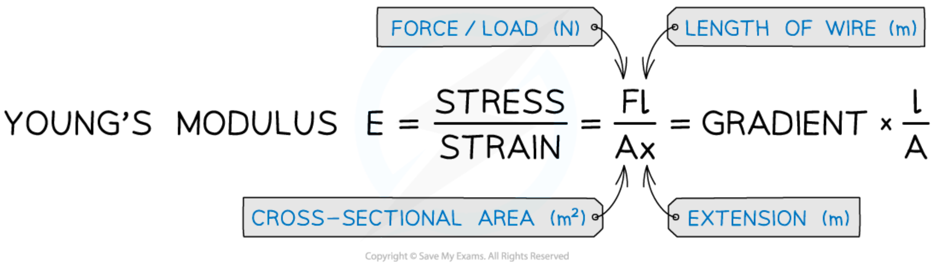
$$\text{Tensile stress} = \frac{F}{A}$$

- Strain is equal to:

$$\text{Tensile strain} = \frac{\Delta L}{L}$$

Where:

- F = weight (N)
- A = cross-sectional area of wire (m^2)
- ΔL = extension (m)
- L = original length (m)
- Young's modulus for this metal is then calculated using the following equation:



Examiner Tips and Tricks

When listing the apparatus for an experiment, make sure you've referred to every last piece of equipment, even the small parts such as wires and power supplies

Range & Resolution of Instruments

- All instruments have a **range** and **resolution**
  - The range is the **highest** and **lowest** value an instrument can measure
  - The resolution is the **smallest increment** an instrument can measure
- Examples of resolutions for instruments are:

Experimental Instrument	Typical Resolution	Typical Range
Metre ruler	1 mm	0 – 1 m
Vernier Calipers	0.1 mm	0 – 300 mm
Micrometer Screw Gauge	0.01 mm	0 – 25 mm
Top-pan Balance	0.01 g	0 – 1 kg
Protractor	1°	0 – 180°
Stopwatch	0.01 s	0 – 9 hours 59 mins 59.99 seconds
Thermometer	1 °C	-10 °C – 110 °C
Voltmeter	1 mV – 0.1 V	0 – 1000 V
Ammeter	1 mA – 0.1 A	0 – 10 A
Oscilloscope	1 Hz	0 – 200 MHz

- These are just examples of ranges and resolutions for these devices
  - For example, some multimeters may have a bigger or smaller range depending on their model
- The resolution of an instrument gives its absolute uncertainty for a digital device
  - For an analogue device, such as a thermometer, ruler or pan balance, the uncertainty is ± **half** the resolution
  - This is because when reading between the millimetre scale the measurement will be rounded up or down by eye from the midpoint at 0.5 mm

Your notes

Worked Example

Two digital thermometers display a reading in °C.

Thermometer 1: 80.13 °C

Thermometer 2: 42.0 °C

Which thermometer has the better resolution?

Answer:

- The resolution is given by the smallest increment that the thermometer can read
  - For thermometer 1 this is 0.01 °C
  - For thermometer 2 this is 0.1 °C
- Therefore, thermometer 1 has the better resolution

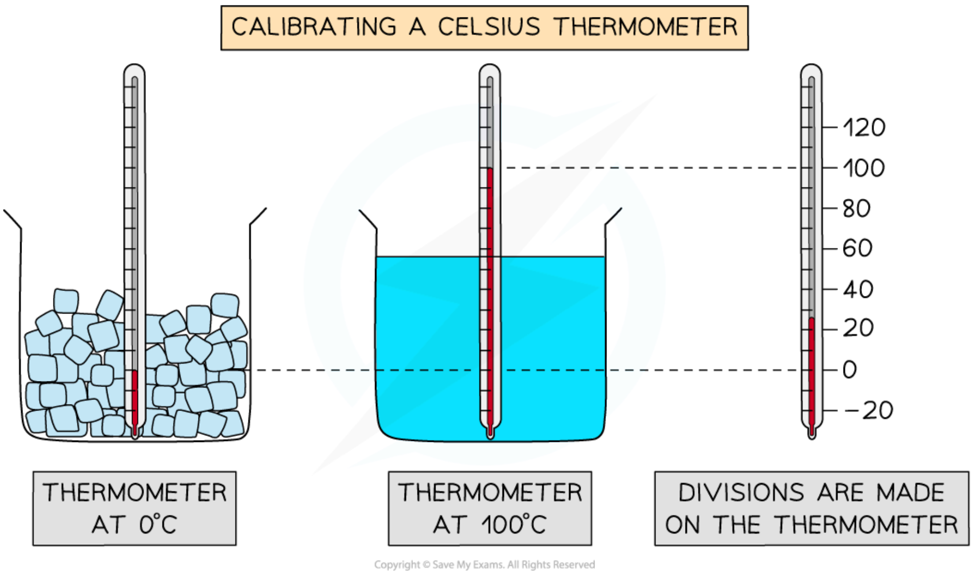
Examiner Tips and Tricks

Exam questions can refer to different instrument with various ranges and resolutions, for example, ammeters with resolution of 0.2 mA instead. Always use the information given in the question, and look carefully at the scales given. Never just assume the resolution of a piece of instrument given in an exam question.

Your notes

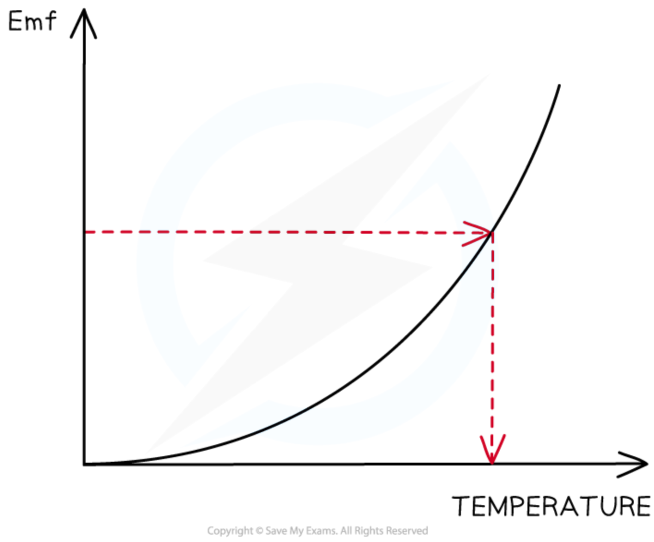
Calibrating Instruments

- Calibration is a comparison between a **known** measurement and the measurement you achieve using the instrument
- This checks the accuracy of the instrument, especially for higher readings
- An example is checking whether a meter (e.g., voltmeter, micrometer, ammeter) reads **zero** before measurements are made
  - This helps avoid zero error
- To calibrate a thermometer means to put the correct mark of readings at the correct place so that other temperatures can be deduced from these marks
  - An uncalibrated thermometer may not read 0 °C for the freezing point of water, or 100 °C for its boiling point, but we know these values to be accurate



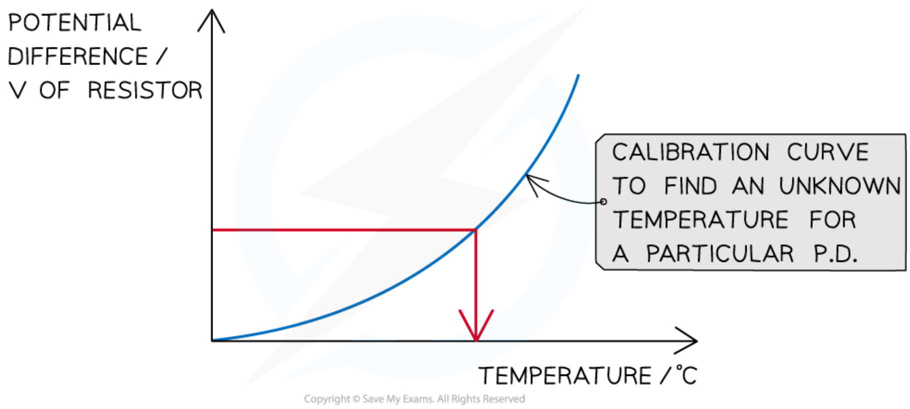
Calibration Curves

- Calibration curves are used to convert measurements made on one measurement scale to another measurement scale
- These are useful in experiments when the instruments used have outputs which are not proportional to the value they are measuring
  - e.g. e.m.f and temperature (thermocouple) or resistance against temperature (thermistor)
- For example, the calibration curve for a thermocouple, in which the e.m.f varies with temperature, is shown below:



A curve of voltage against temperature can be used as a temperature sensor

- The calibration curve for a thermistor looks like:



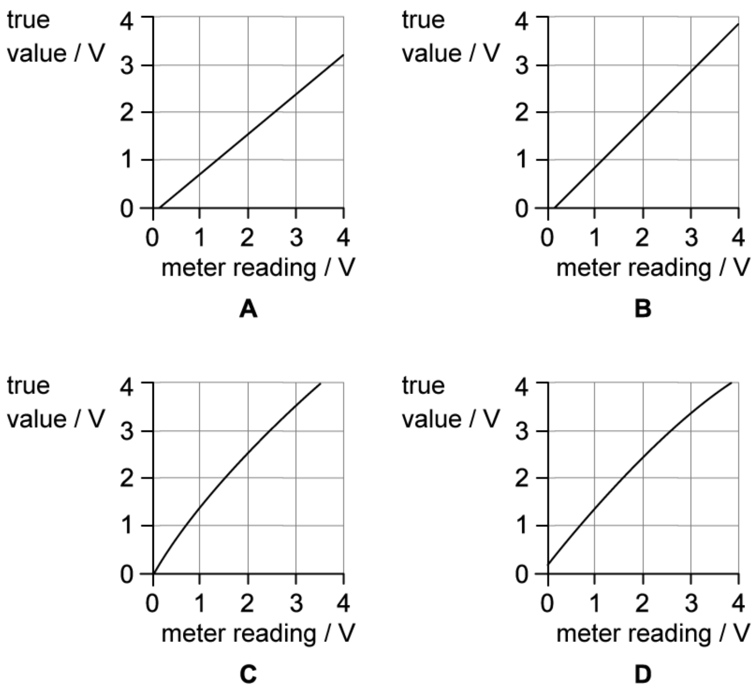
Thermistor calibration curve

- The accuracy of all measuring devices degrades over time. This is typically caused by normal wear and tear
  - Calibration improves the accuracy of the measuring device

Worked Example

A voltmeter gives readings that are larger than the true values and has a systematic error that varies with voltage. Which graph shows the calibration curve for the voltmeter?

Your notes



Answer: A

- The voltmeter has a systematic error as the reading it gives is always greater than the true value
- If the true value is zero, the voltmeter would give a value greater than zero
- Therefore, the curve doesn't pass through the origin (0,0) as this would indicate that the reading is the same as the true value, and not greater - this rule out graph **C**
- So, when the true value is zero, the meter would give a reading greater than zero. This is either graph **A** or **B**
- The systematic error varies with voltage
    - So, the amount by which the meter reading is greater than the true value changes
- Therefore, graph **A** is correct, because the difference between the meter reading and the true value increases with voltage

Examiner Tips and Tricks

You will be expected to use a calibration curve for the Core Practical 12: Calibrate a thermistor in a potential divider circuit as a thermostat

Your notes

Your notes

Measuring Variables

- When measuring a variable in an experiment, it is important to use the most appropriate instrument and measuring technique to achieve the most accurate value for that measurement
- A list of the common apparatus and their purpose is shown in the table below:

Apparatus and Their Purpose Table

Experimental Instrument	Purpose	Example
Metre ruler	To measure the length of an object of a length between 1 cm - 1 m	Length of a wire
Vernier Calipers	To measure short lengths between 0.1 mm - 1 cm	Extension of a wire
Micrometer Screw Gauge	To measure very short lengths between 0.01 mm – 0.1 mm	Diameter of a wire
Top-pan Balance	To measure the mass of an object	Weight of a block
Protractor	To measure angles	Measuring angle of refraction of a beam of light
Stopwatch	To measure time	Time taken for an oscillation
Thermometer	To measure temperature	Temperature increase for specific heat capacity of a material
Voltmeter	To measure potential difference	Potential difference across a bulb
Ammeter	To measure current	Current through a bulb
Oscilloscope	To display waves and measure their frequencies	Frequency of a signal
Laser	To provide a monochromatic, coherent source of light	Investing the interference of light

- The key factor associated with choosing the appropriate instrument is its resolution
  - If the resolution of an instrument is too big, then it won't be able to measure small measurements

Your notes

Examiner Tips and Tricks

When planning experiments, make sure to really think about which instrument you need to measure the **length** of something. A rough rule could be:

- Length will be between a few cm – 1 cm, use a ruler
- Length will be between 0.1 mm – few cm, use a vernier caliper
- Length will be between 0.01 mm – 0.1 mm, use a micrometer

Control Variables & Fair Tests

- In an experiment, a variable is any factor that could change or be changed
- There are different types of variables within an experiment
  - The **independent variable**: the only variable that should be changed throughout an experiment
  - The **controlled variables**: any other variables that may affect the results of the experiment that need to be controlled or monitored
  - The **dependent variable**: the variable that is measured to determine the outcome of an experiment (the results)
- It is essential that any variable that may affect the outcome of an experiment is controlled in order for the results to be **valid** and to have a **fair test**
  - A fair test is one in which **only** the independent variable has been allowed to affect the dependent variable
- Preliminary research and preliminary studies can be used to identify variables within an experiment and to determine ways of controlling these variables effectively
  - The science surrounding the issue / problem being investigated is likely to contain information about different factors or variables that may exist
- A common control variable in circuits (unless using a thermistor) is **temperature**
  - The temperature of a wire or electrical component increases as current goes through for a long period of time (think of a laptop charger)
  - Therefore, to keep temperature (the control variable) constant, it is common to disconnect components from the power supply to cool down between readings

Identifying Control Variables: An Example – Science Surrounding Ideal Gases

- There are several experiments that can be carried out to investigate the properties of ideal gases
- Factors that can be **changed** include:
  - Temperature
  - Pressure
  - Volume
  - Number of moles of gas
- The **key** point with ideal gas experiments is to ensure that **only one** of these variables is **changed** during a particular experiment

- This is known as the **independent** variable
- All other variables must be **controlled** (they must stay the **same**)
  - These are known as the **control** variables
- When investigating **Charles' law**:
  - The temperature varies (**independent** variable)
  - The volume is measured (**dependent** variable)
  - The pressure and number of moles must be kept the same (**control** variables)
- When investigating **Boyle's law**
  - The pressure varies (**independent** variable)
  - The volume is measured (**dependent** variable)
  - The temperature and number of moles must be kept the same (**control** variables)
- If these control variables are not kept constant, they could **affect the results** of the experiment
  - This would make the results **unreliable**

Worked Example

A student carries out an experiment to measure how the rate of cooling of a beaker depends on its initial temperature.

List the control variables in this experiment.

Answer:

The control variables are:

- Using the same beaker (this implies the same size and material)
- Volume of water
- Position in the room
- Surrounding temperature

Examiner Tips and Tricks

When answering practical questions, try and use scientific terms where possible. For example, avoid saying 'amount' of water and instead say 'volume', as this is technically the variable that you can measure in a beaker.

Your notes

Repeat Readings

Repeat Readings

- Experiments commonly require repeat readings
- This improves the accuracy of a measurement, that is dependent on the quality of the measuring instruments used to determine it, as well as the skill of the scientists involved
- Repeat readings also means the data is considered reliable
  - The spread of the readings should be as small as possible to be precise
  - This ensures the measurements are not just by luck or random
- Repeat readings also allows you to identify any anomalous results
  - This is a result that doesn't fit in with the pattern of readings
- It is appropriate to have repeat readings where possible in an experiment, and to leave sufficient space in data tables to accommodate these
  - The average value of that variable should always be found from the repeat readings to use in further calculations

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					

A table of results with space for repeat readings

- It may not be best to repeat readings every time for all experiments
- This should be decided on how easy it is to take the readings in the first place
  - For example, electrical components heat up from current after a while which could affect the results
  - Therefore, for each reading the components should be disconnected from the power supply to cool down

    - When they are reconnected again, the whole experiment needs to be repeated to get the repeat reading. This could take too long, especially for a wide range for the independent variable
- There could also be difficulty getting repeat readings for a time dependent variable
    - This is because time will pass between the readings
    - For example, if you want to measure a dependent variable at certain time of day (e.g., between 6am-7am), the whole experiment will have to be repeated the following day, and the next and so on, which may not be in the scope of the time allowed for the experiment

Your notes

Worked Example

A student is asked to determine the power of another student who runs up some stairs.

Comment on whether repeat readings are appropriate in this case.

Answer:

- The student may become tired so their speed could change as they lose energy
- The experiment will have to be repeated after rest, after their heart rate gets back to a regular level
- The height of the stairs should be measured before each reading to check whether it stays the same
- There could be difficulty of starting and stopping the stopwatch to measure the time because of reaction time

Examiner Tips and Tricks

When asked to discuss repeat readings, think about how easy it would be to take those repeat readings (commonly between 3–5 times). If it is just connecting up a circuit, or letting a pendulum oscillate, this could be quite simple. If there are possible changes that could happen to the apparatus or environment of the experiment between taking these repeat readings, then taking repeats straight away would not make it a fair test, therefore it could be best not to do so.

Remember that you will always need to take a wide range of readings (between 5–10) and experiments will have to be completed in a certain amount of time. If each reading takes 1 minute, and you are taking 10 readings, if these are all repeated 3 times this could make the experiment 30 minutes long, compared to 10 minutes!

Health & Safety

- All experiments must be carried out safely to protect the scientists from injury and the equipment from damage
- There are some common health and safety precautions in practicals
- When working with masses, wires or springs:
    - Wear safety goggles when required (e.g., when using wires, in case it snaps)
    - A support stand should be weighted or clamped to prevent it falling over (commonly with a G clamp)
    - Do not overload springs with masses so they stretch past their elastic limit or break when oscillating
    - Provide a soft surface, such as a cushion, underneath anything falling (such as a ball bearing when calculating g), to protect surfaces
- When using electrical circuits:
    - Don't have liquids kept around the apparatus, as these could spill and cause a fire
    - Turn off the power supply in between readings so the components, especially thin wires, don't become too hot. This could cause a burn or affect the results of the experiment from the change in temperature affecting resistance
    - Do not exceed the voltage rating for all the appliances in the circuit
- General lab health and safety practice includes:
    - Always keeping bags and chairs tucked away under desks to avoid someone tripping over in the classroom
    - Stand up for the duration of the experiment, in case something goes wrong with a piece of apparatus and need to react quickly
    - Don't eat and drink when conducting experiments
    - Wear comfortable clothing and a lab coat when necessary
    - Long hair to be tied back
    - Spills can cause slips, mop this up
    - Do not leave an experiment, or piece of apparatus, unsupervised (especially Bunsen burners)
    - Let hot glass cool down, or wear gloves when handling (e.g., for investigating specific heat capacity)
    - Let a supervisor know about any spills or problems with equipment as soon as possible

Your notes

Examiner Tips and Tricks

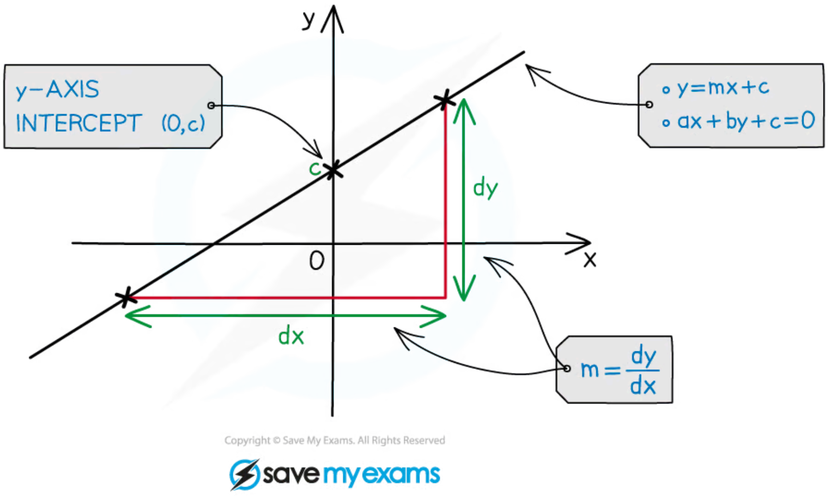
The common way a question on health and safety is asked in the Edexcel International exam papers is 'comment on safety' and will often be 1 mark.

In your answer, think about how the issue should be dealt with to gain the mark. For example, it may not be enough to just state that 'wires can become too hot', you should also explain how to address this, e.g. by turning off the power supply between readings to allow wires to cool down. Or, there could be spills whilst using a liquid, so you must remember to clean this up immediately to prevent anyone from getting injured or damaging equipment.

Your notes

Data Collection

- 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**



A straight life graph showing the y-intercept and gradient, m

- The mathematical skills required for the analysis of quantitative data include:
    - Using standard form
    - Quoting an appropriate number of significant figures
    - Calculating mean values

Using Standard Form

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

Prefixes Table

Prefix	Abbreviation	Power of ten
Giga–	G	10^9
Mega–	M	10^6
Kilo–	k	10^3
Centi–	c	10^{-2}
Milli–	m	10^{-3}
Micro–	μ	10^{-6}
Nano–	n	10^{-9}

Your notes

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

✗

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	

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

Your notes

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

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

Graph Skills

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

Worked Example

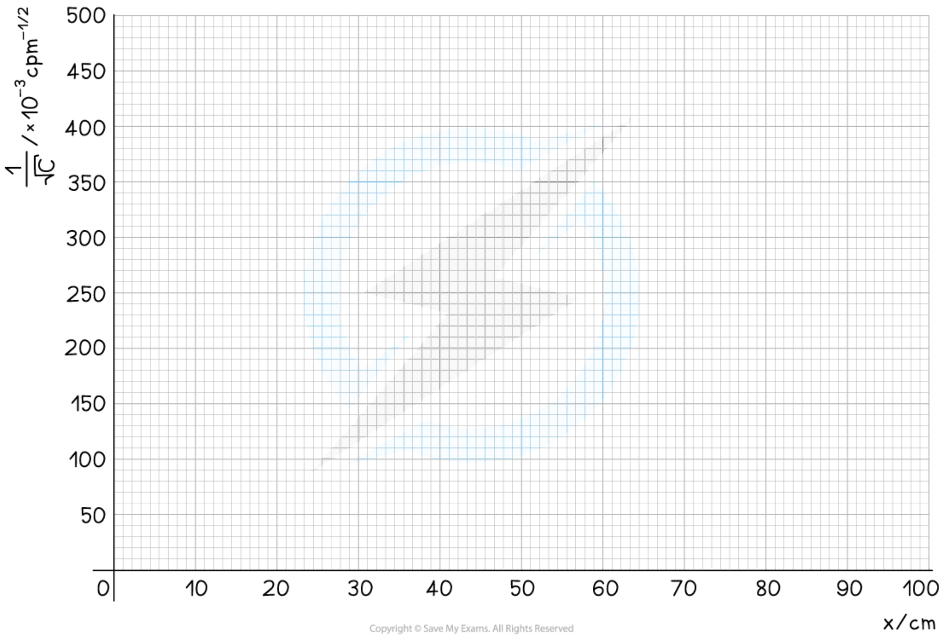
A student measures the background radiation count in a laboratory and obtains the following readings:

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

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

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

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



Answer:

Step 1: Determine a mean value of background radiation

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

- 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

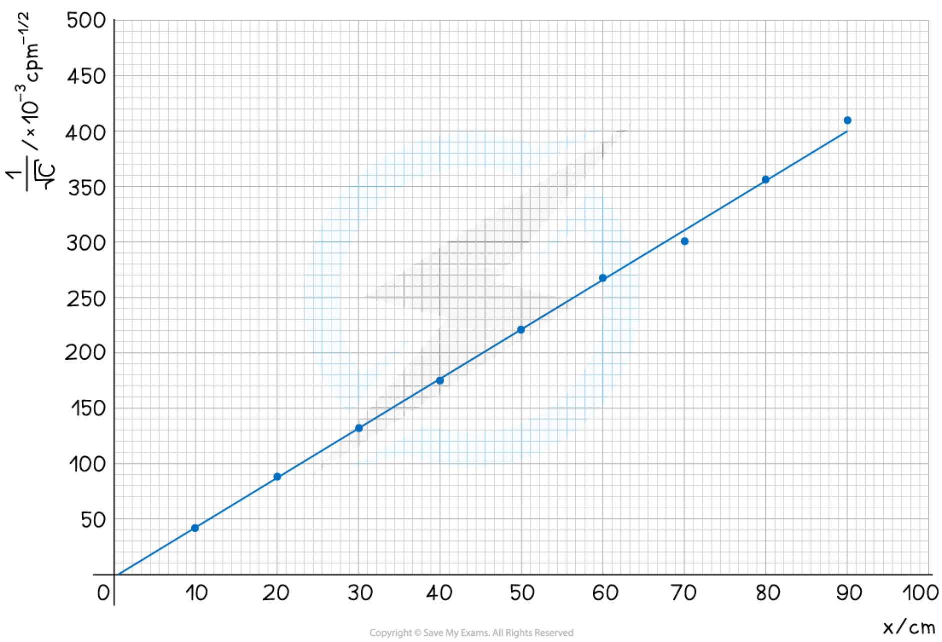
$$C \propto \frac{1}{x^2} \rightarrow \frac{1}{C} \propto x^2 \rightarrow \frac{1}{\sqrt{C}} \propto x \rightarrow \frac{1}{\sqrt{C}} = kx$$

- 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 $min^{-1/2}$)
  - 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
$\frac{1}{\sqrt{C}}$ / $cpm^{-1/2}$	0.044	0.088	0.132	0.177	0.218	0.267	0.302	0.354	0.408

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



Your notes

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

Your notes

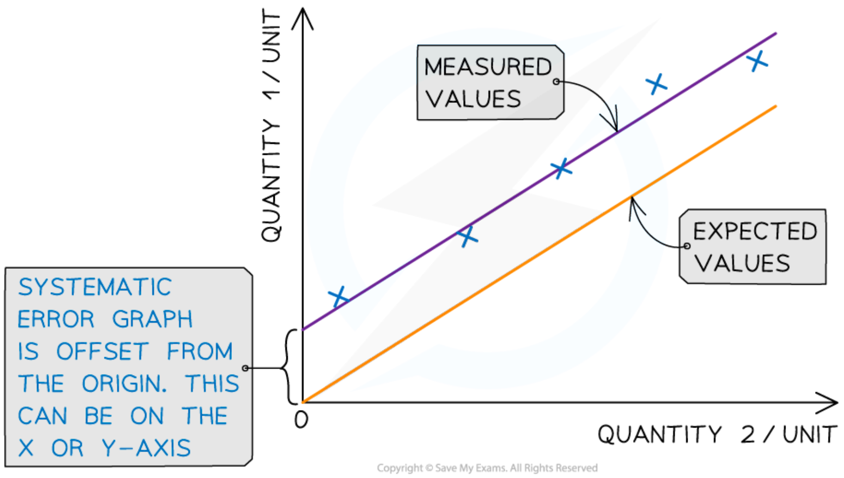
Predicting Uncertainty & Systematic Errors

Predicting Uncertainties

- The 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 variation in the data obtained and be subject to systematic or random effects
- 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 often get different results
- Uncertainties are **not** the same as errors
- 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.
    - They 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
- The most common ways to reduce uncertainties are:
    - Take repeat readings (about 3 – 5) and calculate the mean of a value
    - For a wire, measure the diameter in different places, to make sure it's fully uniform
    - Use the appropriate piece of apparatus for the measurement e.g., do not use a ruler for a very small distance of a few mm, a micrometer or vernier scale would be better for this

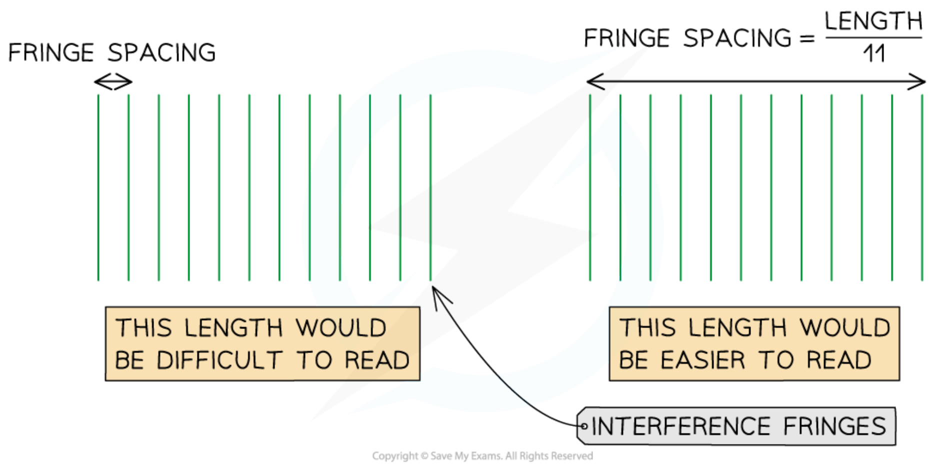
Systematic errors

- 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 is used or the method is followed, which affects the **accuracy** of all readings obtained
- Systematic errors can clearly be seen on graphs
  - If the line of best fit of a straight-line graph is expected to go through the origin (0,0) but the results collected actually pass through the *y* or *x* axis instead, then all the points are offset by the same amount
  - The amount they are offset by is the amount of systematic errors



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

- To **reduce** systematic errors:
  - Instruments should be **recalibrated**, or different instruments should be used
  - Corrections or adjustments should be made to the technique
- An example of a systematic error is a zero error
- A common method for measuring small distances, such as the fringe spacing on an interference pattern, is measuring a larger distance (multiple fringe spacings) and **divide** by the number of fringe spacings
  - A fringe spacing is a very small measurement and it is often difficult to see the middle of each bright fringe (the maxima can be broad)
- The same can be done for oscillations
  - Measuring the time for 10 oscillations, then dividing by 10 is more accurate than just timing 1 oscillation



Measuring the distance between multiple fringes reduces the uncertainty in the fringe spacing

Examiner Tips and Tricks

Extremely small or large measurements tend to have the largest uncertainties. When evaluating an experiment, think of which measurements are the most subjective, as these will provide the largest uncertainties e.g. trying to distinguish between two lines of a diffraction pattern when it is blurry or, the instrument used that has the worst resolution

Wider Implications

- An **implication** of physics is a consequence of 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 around the area when the power station is built
  - **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)
- 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 that could cause injury or death to the doctors or the patient
- All new technologies are therefore always tested thoroughly
- 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
  - E.g. rigorous testing for medication means we trust that medication is safe consumption to treat symptoms of an illness
- The results are used by society to make decisions about the way we live, what we eat, what we drive, how we work etc.
- All sections of society use scientific evidence to make these decisions
  - This is mostly done by policy makers, politicians and government

- Most individuals 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 around money and the cost of implementing changes based on scientific conclusions
- Not only can experiments be very expensive to run, but the cost of buying technology based on science to provide 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 another area of society such as schools or the healthcare system
- However, the long-term benefits should also be taken into account
  - 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 where 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 footprints

Environmental Factors

- Environmental factors are taken into account for any decisions that could affect the environment
  - This is primarily nature such as plants and animals and the geography of the 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

Your notes