

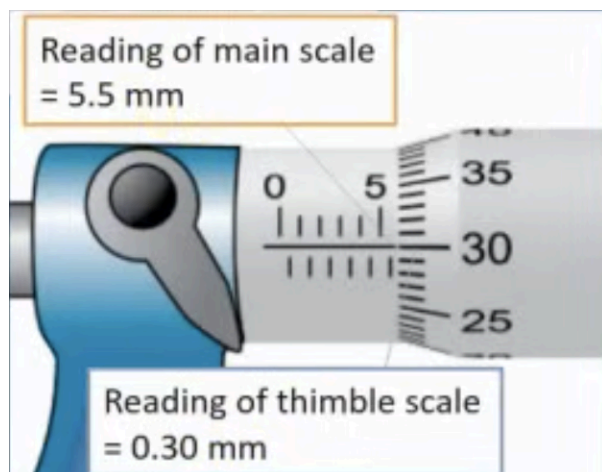
AS Level Physics - Paper 3

PROCEDURE & APPARATUS

Measurement	Accuracy
Length	<ul style="list-style-type: none">- Metre rule: to nearest mm; eg. 2.2cm- Vernier caliper: to nearest 0.1mm; eg. 2.2mm- Micrometer: to nearest 0.01mm; eg. 2.20mm
Angle	To nearest degree / no dp Eg. 27°
Resistance	Whatever is written on fixed resistor Eg. 10Ω
Current	Whatever is shown on digital ammeter Eg. 38.8 mA
Voltage	Whatever is shown on digital voltmeter Eg. 0.082V
Temperature	To nearest 1° or 0.5° ½ smallest division on thermometer Least count will be written on the side of thermometer

Micrometer

- Reading = reading on main scale (linear) + reading on thimble scale (circular)
- Main scale, each division = 1 mm (between top and bottom markings = 0.5mm)
- thimble scale, each division = 0.01 mm



- Final reading = 5.5 + 0.30 = 5.80 mm (to 0.01 mm)

ERRORS & UNCERTAINTIES

1. From repeated readings

$$\text{absolute uncertainty} = \frac{1}{2} \times \text{range of readings} = \frac{\text{max} - \text{min}}{2}$$

$$\% \text{ uncertainty} = \frac{(\frac{1}{2} \times \text{range of readings})}{\text{mean of readings}} \times 100 = \frac{\frac{\text{max} - \text{min}}{2}}{\text{mean}} \times 100$$

Eg. the three readings for θ are $26^\circ, 27^\circ, 28^\circ$

Absolute uncertainty = $(28 - 26) / 2 = \pm 1^\circ$

% uncertainty = $(1/27) \times 100 = 3.70\%$

TABLE

- Sets of readings: If asked to record 6 sets of readings, it must be 6 sets of new readings, excluding the initial.
- Range: Try to use readings that cover the maximum possible range.
- Column headings + units
- Consistency: all raw values to nearest unit (eg. nearest mm)
- Significant figures: all calculated values to the same number of s.f. as OR one more than the s.f. in raw values.

GRAPH

- Axes
 - Use a sensible scale (use scale of 1, 2 or 5 – don't use 3:10 or fractions, etc)
 - Choose a scale that allows plotted points to occupy at least $\frac{1}{2}$ of graph grid in both x and y directions.
 - Label scales with quantity being plotted.
 - Scale markings should be no more than three large squares apart.
- Plotting of points
 - All observations must be plotted on the grid.
 - Diameter of plotted points must be \leq half a small square (no "blobs").
 - Points must be plotted to an accuracy of half a small square.
- Quality
 - Plot all points in the table
 - It must be possible to draw a straight line that is within ± 0.025 units on the y-axis of all points
- Line of best fit
 - There must be an even distribution of points either side of the line along the full length. (at least 5 points)
 - Allow one anomalous point only if clearly indicated (i.e. circled or labelled)
 - There must be at least five points left after the anomalous point is disregarded.
 - Lines must not be kinked or thicker than half a small square.

GRADIENT & Y-INTERCEPT

Gradient

- Hypotenuse of gradient triangle must be greater than $\frac{1}{2}$ the length of drawn line.
- Gradient sign must match graph.
- Method of calculation must be correct. Do not allow $\Delta x / \Delta y$.
- Both read-offs must be accurate to half a small square in both the x and y directions.

Y-intercept

- Correct read-off from a point on the line substituted correctly into $y = mx + c$.
 - Read-off accurate to half a small square in both x and y directions.
- OR
- Intercept read directly from the graph, with read-off at x-axis = 0, accurate to half a small square in the y direction.

1. Justify the number of significant figures used for a value
Justification must be linked to the number of sf in the raw data used to calculate the value.

2. Explain whether your results support the suggested relationship

$$\frac{A-B}{A+B} \times 100$$

(If within 10–15%), results support the suggested relationship because the 2 values can be considered equal within limits of experimental accuracy.

SOURCES OF UNCERTAINTY / LIMITATIONS + IMPROVEMENTS

For every experiment:

Two readings are not enough to draw a valid conclusion.	Take more readings (of raw data) and plot a graph/ take more readings and compare k values.
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When measuring angles

Parallax error affecting the measurement of angle θ .	Photo or still from video to measure θ .
Difficult to know where to measure from for angle θ .	Use a grid behind the (setup) // use markers (on the setup)
Difficult to line up protractor/ horizontal line of protractor not on table	Use a board behind setup with marked angles
Moving hands affect measuring θ / difficult to hold protractor still while measuring	Use another stand for valid purpose (e.g. instead of hand to hold something).

Difficult to measure θ / inaccurate / imprecise because string is thick	Use a thinner string
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When measuring lengths

Parallax error affecting the measurement of d.	Photo or still from video, including scale in frame to measure y.
Moving hands affect measuring d.	Use another stand/ clamped metre rule
Difficult to know where to measure from for d.	Use clamped pointers/ markers
Rule not vertical so difficult to measure d	Method to check that rule is vertical – eg. set squares on bench
difficult to judge centre of object	Measure to top and bottom of object and find the average

When something is being held by hand

Moving hands affect keeping length the same	Use another stand for valid purpose (e.g. instead of hand to hold something).
Difficult to judge the horizontal or vertical.	Method to determine the vertical or horizontal e.g. use a plumb-line/spirit level/set square with detail.

When something is being released

Difficulty in releasing object due to applied force	Use remote-controlled clamp/ electromagnet to release object
Masses/strings collide/hit stand; String wraps around boss/string slips off rod of clamp Trajectory of motion out of alignment/masses not in the right plane.	Method to improve alignment e.g. use longer rod/notched rod/larger diameter on end of rod/place plasticine on the end of the rod/use guide.
Object does not fall vertically/ falls at an angle –light object	Turn off fans/air-conditioning // use wind-shield
Rod falls sideways/ doesn't enter sand vertically –heavy object	Practical method to keep rod vertical; eg. guide for rod
Difficult to start stop-watch and release object at the same time.	Video/record/film with timer/ frame-by-frame.

Difficulty with judging when to stop the stop-watch: e.g. objects arrive separately.	Use a pressure sensor below/position sensor above or below.
Times are small so large error/uncertainty (in t) OR high percentage uncertainty in t.	Use a greater distance to fall through

Experiments with masses

Labelled values of mass may not be accurate	Use balance/ method of weighing mass

Spring-related experiments

Reason for length not remaining constant e.g. loops slip on stand// Movement of spring along rod	Improved method of fixing springs onto stand e.g. use Blu-Tack/tape OR use sandpaper to make stand rough OR use a groove in rod
Difficult to see when coil separation is constant/ separation of coils constant for only a short time	Video with timer/ take video and replay frame by frame

Ball-related experiments

Locating centre of the ball when reading rule	Mark the centre of ball with a marker
Inconsistent bounce	Use a flat surface/ turn off fan

Fast-moving object experiments

Difficult to judge when object is at maximum displacement/ highest point	Position sensor above or below, with data logger OR video camera to play back frame-by-frame
Difficult to see when object strikes the floor	Use pressure sensor to stop timer
Difficult to judge endpoint	Mark distance with lines on a ramp to eliminate parallax
Difficulty in deciding the toppling point	Move in increments

Oscillation experiments

Difficult to measure $n(T)$, because difficult to judge complete oscillation	Use fiducial marker at centre of oscillation Use motion sensor placed under masses
Object doesn't swing freely; friction between pivot and object	Make hole bigger // add bush/bearing
Not swinging in one plane only/ non-uniform oscillation –light object	Turn off fan
Oscillations die out quickly/ heavy damping –light object	Use increased thickness of object
Movement of spring along stand (when oscillating)	Improved method of fixing spring onto rod e.g. use Blu-Tack/tape OR use a groove in rod

Electricity experiments

resistance/ current fluctuating	Clean contacts
Voltmeter scale not sensitive enough	Use digital voltmeter
Wires not straight	Tape wires to ruler/ hang weights off end/ clamp wires to keep them straight

Force experiments

Maximum force reached without warning	Method to record maximum value of force; eg. force sensor with data logger
Weights move	Use tape/ glue to fix weights

Pulley experiments

Masses hit each other	Use larger pulley
Friction at pulley	Lubricate pulley
Uncertain starting position	Use remote-controlled clamp/ electromagnet to release object

Moments experiments

Rule hits bench	Elevate apparatus/ project end of cylinder over bench
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Ruler slips on support	Glue support to block
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Magnetism experiments

Glass may affect magnetic force / effect of surrounding magnetic materials	Use a variety of materials o separate magnets and test if material affects results
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Bench/ramp/surface-related experiments

Some parts of surface rougher than others/ uneven surface/ not flat	Method to ensure same section of board used in each experiment (eg. mark one section)
Board tends to slip/ not stable/ supporting block can topple	Secure board/block/support – clamp the board/ fix supporting block to bench with tape/blu-tack

Heat loss experiments

Heat lost through sides and/or bottom	Reduce heat loss by insulating/ use polystyrene container
temperature change is small/ $\Delta\theta$ values too close	time for longer/ use higher starting temperature/ greater range of surface areas
large (percentage) uncertainty in $\Delta\theta$	use thermometer with greater sensitivity or precision/ use thermometer that can read to 0.1°C
Bulb of thermometer not completely immersed	Use larger volume of water/ thermocouple/ small temperature sensor like probe
Resistor continues to give out heat when switched off/ temperature continues to rise after switching off	Wait until temperature reaches maximum before reading

Water-related experiments

Hard to see water surface due to refraction effect/ meniscus effect	Use coloured liquid
Labels get wet/ ink runs	Use waterproof labels/ ink

Terminal velocity experiments

Object may not have reached terminal velocity	Time constant over 3 markers
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Light dependent experiment

External light affects LDR	Conduct experiment in dark room
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Metre rule

Ruler not vertical	Method to ensure ruler vertical – set squares
Parallax error	Put coloured paper behind (object); Use shadow protection/ extend mark to wood or track/ pointer on rule/ travelling microscope
Difficult to hold rule still	Mount ruler in stand
Difficult to take measurements because ruler moves/ is not vertical	Clamp rule/ ensure rule is vertical using set square on bench
Difficulty in measuring d: viewed through ruler/ parallax error in d	Method to improve measurement of d, eg. travelling microscope
String too wide for markings on rule	Use thinner string
Rules have different thicknesses/lengths so not a fair test	Use rules of similar thicknesses/length

Newton metre

Difficult to pull newton metre parallel to ruler/ bench	Use long string, pulley and weights to ensure force is parallel to ruler
Difficult to judge reading on newton metre when detaches – ruler moves suddenly/ without warning so difficult to read newton meter at instant the ruler starts to move/ force drops to zero immediately after detachment	Use newton metre with 'max hold' facility/ video & playback/freeze frame / system of pulley and weights/ sand to measure F / use force sensor with data logger or computer
Difficult to zero newton metre when used horizontally	Improved method to measure F: use system of pulley and weights/ sand // use force sensor with data logger or computer

Object with unfixed diameter

Difficult to measure diameter because object is flexible/ not circular	Measure diameter of object in 2 directions and average/ use vernier calipers/micrometer screw gauge to measure <u>average diameter</u>
Difficult to form a perfect sphere disc// diameter of sphere/disc varied	Method to make uniforms spheres/discs; eg. moulds

NOTE: If value of quantity measured is very small, write increase the magnitude of quantity of independent variable.

Equipment

Limitations and sources of error	Improvements
Only 2-3 sets of data recorded - not enough to draw a valid conclusion.	Take more readings, and <u>plot graph</u> or calculate ratios of k .
Difficult to check whether a rule is vertical	Hold a set-square on the bench against the rule.
Difficult to check whether a wooden strip is horizontal .	Measure the height of the strip above the bench at both ends and check they are the same.
Difficult to hold a rule or a protractor steady when making a measurement.	Clamp the rule or protractor using a clamp and stand.
Friction at pulley not negligible	Apply oil to lubricate the pulley
Resistance of contacts (electrical equipment)	Clean the contacts to rid rust, dirt etc.

Large % uncertainty to measure small quantity (such as the diameter of a wire or coin thickness.)	Use more precise instrument (e.g. Vernier calipers or a _I micrometer) instead of ruler
Difficult to measure a small change in length (e.g. when stretching a metal wire)	Use a travelling microscope.
Hard to see where moving object passes a marker .	Use sensor to stop timer once marker is passed. Or use an assistant.
Difficult to measure volume of liquid as liquid is clear/transparent .	Add coloured dye to the liquid.

Length

Difficult to time an event because the event is short or there is a large human error in timing	Video the experiment, then play back frame-by-frame and see clock in the video / use light gate
Difficult to release an object without exerting some external force.	Hold the object against a stop (e.g. piece of card) and release.
Difficult to judge the start or end of an oscillation because it moves too fast	Place marker at end or centre of oscillation. Start /stop stopwatch when oscillator passes the marker.
Object movement affected by wind or draught	Turn off fans / air conditioning or make a wind shield.

Timing

For a quantity whose value is TOO small:

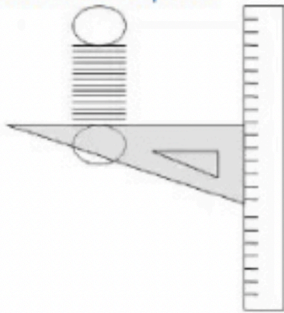
1. (named) quantity's value has a large uncertainty
 - Suggest a way to make this quantity LARGER
2. Measuring instrument not precise enough to measure the required quantity e.g., using a metre ruler to measure the diameter of a coin
 - Use a more precise instrument e.g., vernier callipers

Measuring height/length using a metre ruler:

There are several, choose the best **specific** to the experiment:

1. The set-up of an apparatus can make parallax error very likely
(**Don't write this, this is just to explain:** e.g., you have to bend down to read off the value on the metre ruler, or hold a ruler against a damn oscillating spring)

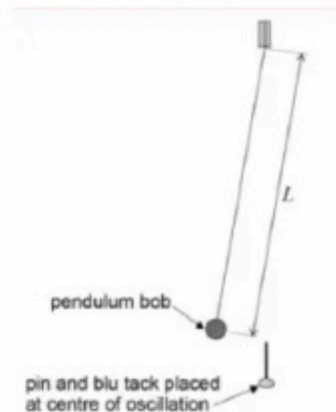
- Hold the rule in a clamp
- Use a set square



2. It's difficult – explain the reason as per the experiment
 - Place a position sensor below/above (idk) (named) object whose height you're measuring
 - Use a graduated (named) object
 - Use a more precise instrument
 - Suggest any other way to better measure/ specific to the experiment

3. Not uniform through out

- Measure along different points of the non-uniform object and calculate the mean value for e.g., diameter/length/thickness/circumference etc.
 - Use a string to determine the length of one turn
4. It was difficult to measure the length of a spring up to the centre of the bob of the pendulum
- Use a micrometre screw gauge to measure the diameter of the bob. Half it to find the length between the top of the bob up till its centre of gravity. Add this value to the measure length of the string.



Oscillations of a spring/pendulum

1. Because the oscillations were too fast, it was difficult to:

- Know the end points of oscillation
- Measure the height of H (H can be anything, just be **specific** to the experiment)
- Measuring the maximum height, because it remains there for a too short time
- Starting and stopping the stop-watch at the exact time object starts to move/judge the start and end of oscillation due to human reaction time/oscillations died too quickly/

- Use a stiffer spring/ heavier mass so oscillations will take longer
- Use a position sensor below the mass with a data-logger to determine maximum/minimum height of oscillation
- Use an electronic timer placed at the centre of the oscillation to measure the time

Position

1. Difficult to maintain (named thing) at a (particular position)/it moves
 - Use a clamp
 - Suggest any other way
2. Affected by wind movement
 - Use a wind shield
3. Difficult to release something without applying an extra force/giving it sideways velocity, which may affect reading
4. Unable to release the object at the same height every single time
 - Use a mechanical hand
 - Use an electromagnet (for e.g., if it's a metallic ball)
 - Release from a higher height/steeper ramp so time measured is greater (it will reduce the percentage error due to human reaction time)
 - Clamp a metre rule vertically and start the bottom of the object exactly at the top of the ruler each time.

5. Moves suddenly, so difficult to take reading at that very instant

6. It was difficult to zero the newton-metre used horizontally

- E.g., if a force metre is involved then use a force sensor and a computer

FOR EVERYTHING SHADED IN A MAROON-OUTLINED GREY BOX:

The following improvement is valid to all:

Use a video camera to record the experiment, (if time involved: with the timer in the background) play the video frame by frame

Random things I did not know how to categorise:

1. Friction at the pulley affects reading
 - Apply oil to lubricate the pulley
2. String on ruler blocks reading
 - Use a thinner thread
3. Spring slides off the rod
 - Use adhesive putty to fix the position of the spring to the rod
4. Difficult to measure the volume of the (named) object
 - Liquid displacement method (seriously)

Electricity

1. Resistance of contacts affects the current readings
 - *Clean the contacts with cloth/sand paper*
2. Difficult to measure the length of the wire as the clips have a width, inside which where they grip the wire is unknown
 - *Use narrower clips*
 - *Solder the contacts onto the wire*
3. Scale not sensitive enough
 - *Use a digital ammeter/voltmeter*
4. Scale only reads to (for example) 0.05 V
 - *Use a voltmeter that reads to 0.01 V*
5. Voltage values are very small
 - *Use a larger current/any other way to make it bigger*
6. The larger area of the crocodile clip makes it difficult to judge a whole turn of a coil
 - *Use a knife edge contact*
7. Temperature (or any other factor) does not stay constant, so resistance changes
 - *Wait for a long time until the temperature remains constant*
 - *Use smaller currents, but a more sensitive voltmeter*
 - *Anything to maintain the factor constant*
8. A lot of electricity practicals involve measuring time, lengths etc. so same limitations and improvements mentioned above the heading 'Electricity'