Physics Practical Guide

Name: ______________________________ **CG:** ____________

General Information

Examination

Physics practical skills are tested in Paper 4, a 2 h 30 min paper that makes up 20% of the overall A-Level score in H2 Physics. Total marks of the paper is 55 marks.

In the first 2 × 1 hr, candidates take turns to attempt either 1 long experiment or 2 short experiments. Candidates will then swap work benches to finish the practical components.

In the last 30 min, candidates will attempt a question which tests their ability to plan for an experiment – they will not be allowed to work with any apparatus then.

Experimental skills and investigations

Candidates should be able to:

1. follow a detailed set or sequence of instructions and use techniques, apparatus and materials safely and effectively
2. make, record and present observations and measurements with due regard for precision and accuracy
3. interpret and evaluate observations and experimental data
4. identify a problem, design and plan investigations
5. evaluate methods and techniques, and suggest possible improvements.

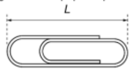
Overview of Question Types

The range of questions include

- **single measurements**: show repeated measurements.
- **setup**: be careful of the relative positioning of equipment.
- **table of measurements**: you'd likely need to check forward for the equation to better guide your lay-out for optimal presentation.
- **equation** relating the measured quantities: check to see if a straight line (linear) graph is expected or a curve.
- **graph**: plot the graph using the guidelines.
- **interpretation of the graph data**: you should never use the raw data points in your table. Rather, you need to read off the best-fit line to an accuracy of half-smallest-square.
- **further questions**: may look further into uncertainties, improvements and meaning behind quantities.

1. Precision of Laboratory Instruments

Example

Measure and record the length L of one paper clip as shown in Fig. 1.1.  **Fig. 1.1** L = ... [1]	Determine the period T of the oscillations. T = ... [2]

The precision of the laboratory equipment contributes to the uncertainty in measurement.

The number of **decimal places for raw data** must be consistent as it will reflect the **precision of the instrument.**

For **digital instruments**, record the full value that is provided on the screen.

For **non-digital instrument** (ruler, thermometer…), record to the precision of the instrument.

A non-exhaustive list of apparatus and their precisions is provided below. For *vast majority* of instruments, precision = smallest division available. There are a few exceptions. It will be to your benefit to understand the principles behind their precision rather than memorise them.

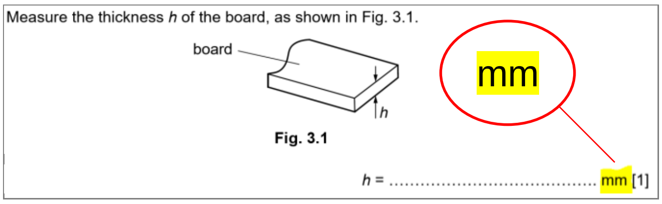
No	Apparatus	Smallest Division	Precision of instrument	Examples of recording
1	Ammeter (0 - 1 A)	0.02 A	0.01 A	0.20 A, 0.21 A
2	Milliammeter (0 - 100 mA)	2 mA	1 mA	20 mA, 21 mA
3	Voltmeter (0 - 5 V)	0.1 V	0.05 V	2.50 V, 2.55 V
4	Digital multimeter (DMM)			Record what is displayed on DMM.
5	Half metre rule or metre rule	0.1 cm	0.1 cm	0.8 cm, 12.1 cm
6	Vernier calipers	0.01 cm	0.01 cm	0.22 cm, 7.51 cm
7	Micrometer	0.01 mm	0.01 mm	0.09 mm, 2.11 mm
8	Protractor	1°	1°	8°, 46°
9	Measuring cylinder (100 cm^3)	1 cm^3	1 cm^3	6 cm^3, 18 cm^3
10	Spring balance (0 - 10 N)	0.1 N	0.1 N	0.4 N, 3.7 N
11	Electronic balance	0.01 g	0.01 g	121.10 g, 121.11 g

No	Apparatus	Smallest Division	Precision of instrument	Examples of recording
12	*Stopwatch (digital)	0.01 s	0.01 s	0.93 s, 28.15 s
13	Thermometer (–10 °C to 110 °C)	1°C	1 °C	7 °C, 24 °C

*When using a stopwatch to time how long a rolling marble takes to roll down a slope, record the timing stopwatch's precision of 0.01 s, do not need to consider human reaction time yet (i.e. give to 0.01 s rather than nearest 0.1 s).

2. Units of Laboratory Instruments

Units are sometimes provided at the end of the space for your answer, ensure that you record your answer according to the correct units.



It is also acceptable to record to the units provided directly by the instrument. Doing so helps to avoid unnecessary conversion errors.

Convert if it is genuinely easier to work with the quantities after conversion, or if the units desired are specified by the question:

For digital multimeters, the unit of the display is given in the range selection:

3. Repeat Measurements (Raw Data)

In most cases, **2 measurements** are sufficient if the measurements are relatively stable and the uncertainty of the measurements are low.

Presentation 1: Show the 2 measurements and the process of calculating average.

Example

$$\text{average } h = \frac{6.0 + 6.1}{2} = 6.05 = 6.1 \text{ cm}$$

Presentation 2: Tables can also be used for clear presentation.

Example

h_1 / cm	h_2 / cm	$\langle h \rangle$ / cm
6.0	6.1	6.1

What is critical,

- each measurement h_1 and h_2 **(raw data)** follows the instrument precision i.e. same d.p..
- the average value $\langle h \rangle$ **(calculated data)** follows the d.p. of the raw data.

Take 3 or more repeat measurements if the uncertainty is high.

For timing using a stopwatch in particular, one should aim for more than 20 s in a single measurement to bring down the percentage uncertainty to less than 1% (considering that human reaction time is 0.2 s).

Example

Let *t* be time taken for 22 oscillations

n	t_1 / s	t_2 / s	$\langle t \rangle$ / s	T / s
22	21.64	21.32	21.48	0.9763

- The addition of column for no. of oscillations n enable us to vary the number of oscillations, so as to ensure that each measurement exceeds 20 s.
- $\langle t \rangle$ refers to average *t*.
- T refers to period of the oscillations.

If the timings involved are less than 15 s, show **3 repeated measurements**.

Example

Let *t* be time taken for a marble to roll down a slope

t_1 / s	t_2 / s	t_3 / s	$\langle t \rangle$ / s
1.22	1.28	1.33	1.28

4. Linearisation of Equations

In practicals, experiments are usually performed to verify certain underlying theoretical equations or to obtain some of the unknown parameters in the theoretical equation.

The first step to start an experiment is to analyse the theoretical equation for the experiment and linearise the equation in a way such that the unknown parameters could be found using the raw data collected.

Even though the space for table of values typically appears *before* the equation, we highly recommend that you linear the equation first before drawing your table.

<u>Example</u>

<table>
<tr><td colspan="2">The period of the oscillation T is given by the equation
$$T = pL^q$$
where L is the length, p and q are constants.

Plot a suitable graph to determine whether the relation is of the form indicated. Hence find the values for p and q.</td></tr>
<tr><td>$T = pL^q$
$\lg(T) = \lg(p) + (q)\lg(L)$

Plot a graph of lg(T / s) against lg(L / cm), this should give a straight line graph of gradient q and
y-intercept lg (p / s cm^{-q})</td><td>Structure:

Plot a graph “y / units” against “x / units” this should give a straight line graph of gradient “qty / units” and y-intercept “qty / units”.</td></tr>
</table>

5. Tables

After linearisation, raw data can then be collected and processed accordingly for the graph to be plotted.

Since a large number of raw data will be collected and processed to establish trends, they must be presented in a table form which can be easily read and understood.

Record all the raw data and processed data collected into a single table as and when they are taken so as to save time. DO NOT split your table into 2 parts!

Steps

1. Draw (in pencil) the table outline that maximises the full available space given in the paper.
2. Identify the $\boxed{\text{“y / units”}}$ and $\boxed{\text{“x / units”}}$ as required from the equation
3. Use first column for the independent variable (don't need repeat).
4. Use next few columns for repeated raw measurements and average of dependent variable(s).
5. Use next few column(s) for processed data required to draw the graph.

Example:

Headings of Table

- Use the standard notation of "quantity / unit". The unit should be written in the index form, i.e. use m s^{-2} and not m/s^2.
- For columns that involve logarithms, the units of the variable must be stated.

Define all new variables using symbols that are not already used.

Let N be the number of oscillations.

Data recorded in vertical

- The range of the independent data must be as wide as the question allows.
- Test for extreme values before starting the experiment.

h / m	N	t_1 / s	t_2 / s	$\langle t \rangle$ / s	T / s	lg(T^2 / s^2)	$h^{1/2}$ / $m^{1/2}$
0.100	20	23.24	23.25	23.25	1.163	0.1308	0.316
0.200	20	25.53	25.47	25.50	1.275	0.2110	0.447
0.300	20	27.62	27.69	27.66	1.383	0.2816	0.548
0.400	20	29.22	29.15	29.19	1.460	0.3284	0.632
0.500	15	23.31	23.52	23.42	1.561	0.3870	0.707
0.600	15	24.14	24.21	24.18	1.612	0.4147	0.775

Independent variable (do not repeat)

dependent variable

Raw Data

- Follow precision of instrument. i.e. data in the same column have the same no. of d.p.

Processed Data

- All intermediate results must be tabulated.
- Follow rules of significant figures/ decimal places.

6. Significant Figures of Calculated Data

The ‘rules of consequential uncertainties’ hold true in the laboratory, but working out the propagation of uncertainties is time consuming.

The <u>rules of significant figures</u> allow a much quicker method to get results that are approximately correct even when values of absolute uncertainty are not available. Follow the rules below when determining the no. of significant figures to use for processed data.

Math Function	Rule-of-thumb	**Examples** Given: B = 34.57 cm, C = 5.6 cm. Express A to an appropriate no. of s.f or d.p.
add or ***subtract*** raw measurements	**follow** (least number of) **d.p.**	$\boldsymbol{A = B + C}$ $= 34.\underline{57} + 5.\underline{6} = 40.\underline{2}$ cm 2 d.p 1 d.p 1 d.p
multiply or ***divide*** raw measurements or ***other function*** (trigo etc)	**follow** (least number of) **s.f.**	$\boldsymbol{A = B \times C}$ $= \underline{34.57} \times \underline{5.6} = 190$ cm^2 4 s.f 2 s.f 2 s.f $\boldsymbol{A = \sin 5.6°} = 0.0\underline{98}$ 2 s.f 2 s.f
multiply or divide ***constants***	**follow** (least number of) **s.f. of raw measurements**	$\boldsymbol{A = 4\pi C^2}$ $= 4\pi \times \underline{5.6}^2 = \underline{390}$ cm^2 Ignore s.f of constants 2 s.f 2 s.f
logarithm of raw measurement	**number of d.p. in result = number of s.f. of raw measurement** *also known as *mantissa* rule	$A = \lg(B\ /\ \text{cm}) = \lg(\underline{34.57}) = 1.\underline{5387}$ 4 s.f 4 d.p. $A = \ln(C\ /\ \text{cm}) = \ln(\underline{5.6}) = 1.\underline{72}$ 2 s.f 2 d.p.

Question: This question follows immediately after separate single measurements of l and H. What rule(s) should be used to determine the s.f of b?

(c) The quantities l and H are related by the equation

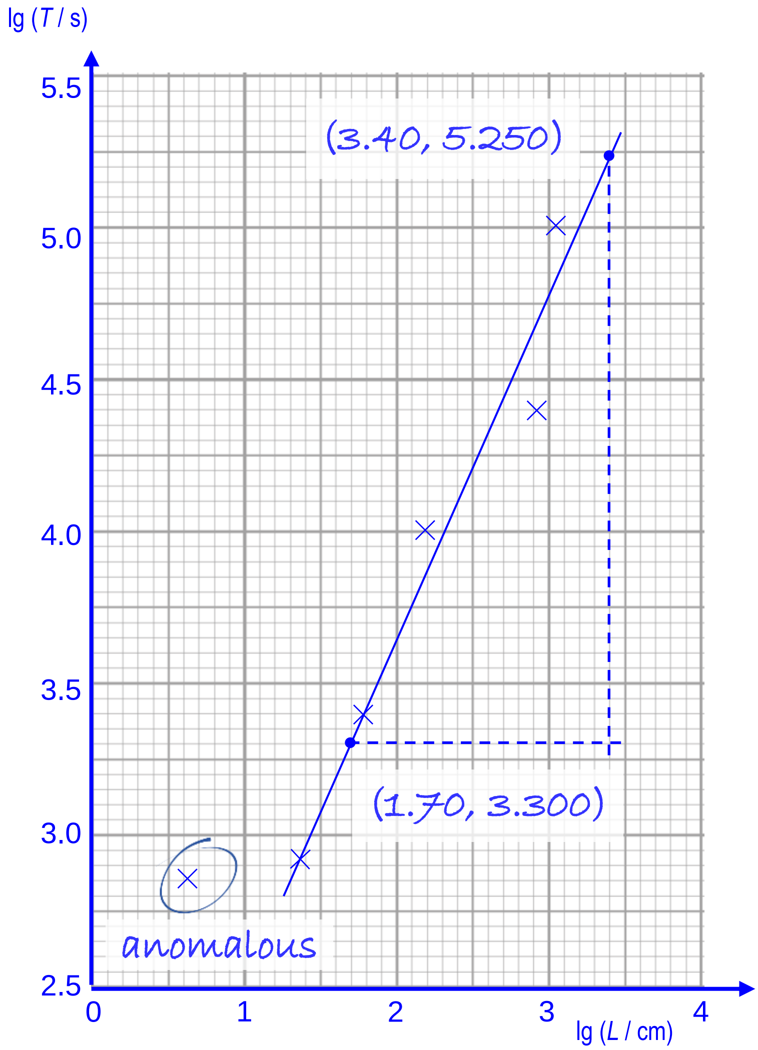
$$b = \sqrt{l(H-l)}$$

where b is a constant.

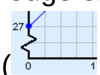
(i) Calculate b.

7. Graph Drawing & Read Offs

A graph is a visual way of understanding the behaviour and quality of data.



Scales and Axes

- Axes labelled with quantity and units (same as table headings)
- Graph need not start from zero (often doesn't!)
- Shift axes to edge of grid so that scale labels are on blank space
- No zig-zags () even if the value doesn't start at zero
- Choose a scale that is in ratios of 1, 2 or 5 only
- Choose a scale that allows your data points to occupy more than half the axis along both *x*- and *y*- axes
  - No data points along edge of grid
  - Try landscape orientation if portrait seems not possible
- Label every 2 cm along both axes

Data points

- Plot all points in table onto graph using crosses (×)
- Work to half-small square accuracy ("snap to nearest half")
- Thin pencil line not thicker than half smallest square
- Circle and label anomalous point clearly (1 at most)

Best fit straight line

- Thin straight continuous line
  - pencil line not thicker than half smallest square
  - invest in clear plastic 30 cm rule and mechanical pencil
- Do not force line through origin even if equation suggest so
  - systematic error may be included by design sometimes
- Balanced line of best fit
  - roughly same number of points above and below best fit line
  - data points roughly equidistant from best fit line
  - do not aim to "pass through as many points possible"
  - ignore effects of any identified anomalous point

Best fit curve

- Do not force a straight line through
- Thin continuous line
- no "hairy" sketching or kinked portions
  - pencil line not thicker than half smallest square
  - invest in flexi-rule and mechanical pencil
- Balanced line of best fit
  - roughly same number of points above and below best fit line
  - data points roughly equidistant from best fit line
  - ignore effects of any identified anomalous point

Read-offs

- Do not use any data-points from table of values as read-offs
- Read-off from best fit line because line represents weighted average across all available data points.
- Mark read-offs differently (suggest small •) and label coordinates clearly
- Read to half-small-square accuracy
  - Every 2 cm "big square" consists 10 divisions, so divide the major interval by 20. Using the example graph above:

    x-axis: nearest $\frac{1}{20} = 0.05$ | *y*-axis: nearest $\frac{0.5}{20} = 0.025$

8. Interpretations from Graph

Question typically asks for values of constants in an equation to be found. To do so, we would have to draw the gradient triangle and use it to find the gradient and y-intercept of the equation most of the times.

Example (using graph from previous sections)

Given $T = pL^q$, find value of *p* and *q.*

$$T = pL^q$$

$$\lg(T) = \lg(p) + (q)\lg(L)$$

Plot a graph of lg(*T* / s) against lg(*L* / cm), this should give a straight line graph of gradient *q* and y-intercept lg (*p* / s cm^{-q})

$$\text{gradient} = \frac{5.250 - 3.300}{3.40 - 1.70}$$

$$q = 1.15$$

← Correct formula for gradient, values copied from the graph to the correct d.p

Substitute (3.40, 5.250) into eqn,

$$5.250 = 1.15(3.40) + \lg(p)$$

← Show correct substitution of values

$$p = 10^{1.35} = 21.9 \text{ s cm}^{-1.15}$$

Notes:

- Gradient triangle should span more than half the best fit line. Show substitution of read-offs.
- Technically the gradient and y-intercept have no units, but the quantities that they represent may have units. When in doubt, just give correct units.
- If the graph has a true origin (*x* = 0 present), one can choose to read off the y-intercept to half smallest square. Else calculate the y-intercept using presentation above.
- It is generally safe to leave answers here to 3 s.f.

9. Further questions that could be asked

9.1 Comment on Anomalous Data Doints

When asked to comment on any anomalous data or results that you may have obtained, use one of the follow templates in your explanation.

If there are no anomalous point:

There are no anomalies.
All points follow the trend of the best fit line.
No points lie significantly far from the best fit line relative to the other points.

If you do have an anomalous point (at most 1):

There is an anomalous point at (,).
It does not follow the trend of the best fit line.
It lies significantly far from the best fit line relative to the other points.

9.2 Estimate Uncertainty in a Particular Measurement

When this is asked, the measurement likely has a large experimental uncertainty. Hence, the estimated uncertainty is usually larger than the precision of the measuring instrument and a range of answers is allowed.

Some common examples of estimated uncertainty are provided below. However, there is a chance that they can vary depending on the actual experiment.

Measurement	**Uncertainty**
Normal timing using stopwatch	human reaction ~0.2 s
Lengths involving moving spheres	radius of sphere
Non-ideal conditions e.g. wobbly/shaky/dangling items	3 × (instrument precision)
3 or more repeated measurements show deviation	$\Delta z \approx \frac{1}{2}(z_{max} - z_{min})$ *(do not use this method if the computed value $\Delta z = 0$, or $\Delta z \leq$ precision of instrument)*

Error-estimation adopts a conservative stance so if given 2 possible ways to reasonably estimate the uncertainty, defer to the larger one.

Example:

t_1 / s	t_2 / s	t_3 / s	$\langle t \rangle$ / s
1.22	1.28	1.33	1.28

Choice 1:
human reaction time so $\Delta t \approx 0.2$ s

Choice 2:

$$\Delta t \approx \frac{1}{2}(t_{max} - t_{min})$$
$$= \frac{1}{2}(t_3 - t_1) = \frac{1}{2}(1.33 - 1.22)$$
$$= 0.055 \text{ s } (2 \text{ s.f.})$$

Both are reasonable methods of estimation. Adopt the more conservative choice

9.3 Calculate Percentage Uncertainty

This type of question usually follows the estimation of an uncertainty. The presentation for the calculation is shown below, and the final answer should be given to 2 s.f.

Example
Percentage uncertainty

$$= \frac{\Delta t}{\langle t \rangle} \times 100\%$$
$$\approx \frac{0.2}{1.28} \times 100\%$$
$$= 16\% \ (2 \text{ s.f.})$$

9.4 Verifying relationships

There are some questions that requires the calculation of constants but only have data for 2 or 3 sets of calculations. Example:

(g) It is suggested that the relationship between F, W, and α is

$$F = \frac{kW}{\tan\alpha}$$

where k is a constant.

(i) Using your data, calculate two values of k,

first value of k = ...

second value of k = ...
[1]

(ii) Explain whether your results support the suggested relationship.

Compare the values using percentage difference, select the smaller constant as denominator (staying true to "conservative stance"):

$$\frac{|k_1 - k_2|}{\text{smaller } k} \times 100\% = \text{percentage difference } (2 \text{ s.f.})$$

The difference needs to be compared to a criteria:

If question has earlier asked for an estimate of percentage uncertainty in a particular quantity	Compare the **percentage difference** from the relationship to the **percentage uncertainty** in the earlier measured quantity. **Example** **Since the percentage difference in *k* (3.2%) is less than the percentage uncertainty in *t* (8.9%), so the relationship is likely valid.** The idea is that a valid relationship: • is best-fit function • balances multiple data points • reduces the effects of random errors So differences in constant of a valid relationship should be better (lesser) than the uncertainty in a single *raw* measurement.
Question did **NOT** ask for an estimate of errors earlier.	Compare it to a sensible percentage (e.g. 10%) of your choice. **Example** **Since the percentage difference in k is less 10%, the relationship is likely valid.**

9.5 Sources of Errors and Suggestions for Improvements

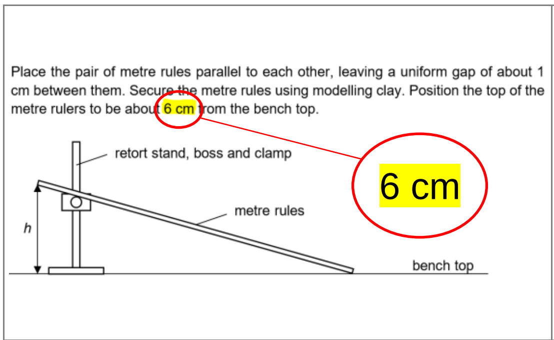
Think through the percentage uncertainty to suggest how to reduce the absolute uncertainty or increase the magnitude of the measurement. $\frac{\Delta z\downarrow}{z\uparrow}$

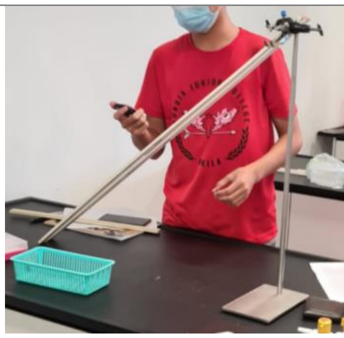
Reducing the absolute uncertainty $\Delta z\downarrow$ usually involves using "better" instruments (such as appropriate sensors connected to a data-logger) or more precise instruments (such as micro-meter over vernier calliper).

For **source of error**:	For **suggestion for improvement**:
• state the difficult faced • state the quantity affected	• address the difficulty faced as stated in the source of error that has been identified.

10. Other Tips For Practical!!

1. Check if the instructions has suggested a value to follow
Read and follow instructions carefully.





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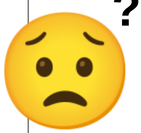
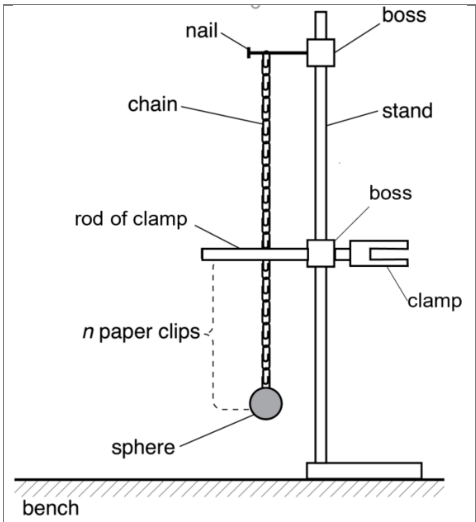


Negative Real - Life Example

2. Setup
Be aware of the different equipment, which part is being used, and the relative placements.

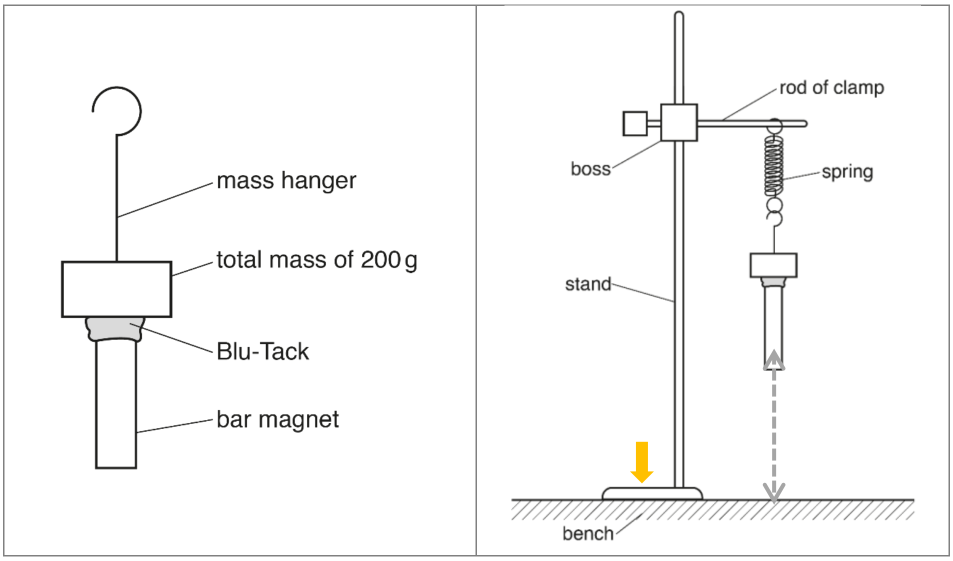
Example: The clamp of a retort stand is not always used, sometimes the setup uses the rod portion.



a "boss" holds 2 rods at right angles:

the rod portion of the clamp:

Example: The bass of the retort stand might be ferromagnetic and should be placed away from a vertically-oscillating magnet.



Ending Notes

This set of notes is intended as a quick guide and the examples and skills is by no means exhaustive, Cambridge examiners are known to vary their question types occasionally. So, the key is to understand the principles well, so that you would be able to use the same set of principles in answering any new question types. Feel free to use the empty spaces to fill up notes and learning points from each practical! All the best!

Annex A: Significant Figures

A In a particular experiment, a student collected the raw data of several quantities and reported them in the following manner:

Mass, M = 2.34 kg
Period, T = 36.52 s
Angle, θ = 45.1°

Complete the following table in accordance to the rules-of-thumb:

quantities	numerical value	units
$5M^2$	$5(2.34)^2 = 27.4\ (3\text{ s.f.})$	kg^2
$\cos^2\theta$	$\cos^2(45.1°) = 0.498\ (3\text{ s.f.})$	(unitless)
$\sqrt{M}$	$\sqrt{2.34} = 1.53\ (3\text{ s.f.})$	$\text{kg}^{0.5}$
$\pi^2 M\cos^2\theta$	$\pi^2(2.34)\ \cos^2(45.1°) = 11.5\ (3\text{ s.f.})$	kg
$\dfrac{T^2}{2}$	$\dfrac{T^2}{2} = \dfrac{36.52^2}{2} = 666.9\ (4\text{ s.f.})$	s^2
$\ln\left(\sqrt{MT}\right)$	$\ln\left(\sqrt{(2.34)(36.52)}\right) = 2.\underline{224}\ (3\text{ d.p.})$	(unitless)

Annex B: Decimal Places and Significant Figures

B Complete the following table in accordance to the rules-of-thumb.
For your own learning, specify which rule you used.

question	working and answer	rule used
103.9 + 2.10 + 0.319	103.9 + 2.10 + 0.319 = 106.3	follow (least) 2 d.p.
5.399 – 5.39	5.399 – 5.39 = 0.01	follow (least) 2 d.p.
2.3×10.0	$2.3 \times 10.0 = 23$	follow (least) 2 s.f.
$6.8907 \div 1.23$	$6.8907 \div 1.23 = 5.66$	follow (least) 3 s.f.
$4.52 \times 6.2 + 5.6372 \times 17.0$	$4.52 \times 6.2 + 5.6372 \times 17.0$ = 28 + 95.8 = 120	follow 2 s.f. + follow 3 s.f. follow (least) 0 d.p.
5.25 *e*	5.25 *e* = 14.3	follow (least) 2 s.f.
$\lg(2.7 \times 10^{-8})$	$\lg(2.7 \times 10^{-8}) = -7.57$	mantissa: input 2 s.f. so output 2 d.p.

[Graph] using coordinates $(-1.58,\ 1.40)$ and $(-0.45,\ 0.22)$:

question	working and answer	rule used
find gradient	$\dfrac{1.40-0.22}{-1.58-(-0.45)} = -1.04$	3 s.f.
find *y*-intercept	gradient $= \dfrac{1.40-c}{-1.58-0}$ $c = -0.250$	3 s.f.

Annex C: Conversions

C Perform the following conversion of quantities to the new units stated.

(a) 110 km h^{-1} to m s^{-1}

$$110\text{ km h}^{-1} = \frac{110\text{ km}}{1\text{ h}} = \frac{110\times10^{3}\text{ m}}{3600\text{ s}}$$
$$= 30.6\text{ m s}^{-1}$$

(b) 61.5 kg m^{-3} to g cm^{-3}

$$61.5\text{ kg m}^{-3} = \frac{61.5\text{ kg}}{1\text{ m}^{3}} = \frac{61.5\text{ kg}}{(1\text{ m})^{3}}$$
$$= \frac{61.5\times10^{3}\text{ g}}{(100\text{ cm})^{3}}$$
$$= 6.15\times10^{-2}\text{ g cm}^{-3}$$

(c) 13.0 m s^{-1} to km h^{-1}

$$13.0\text{ m s}^{-1} = \frac{13.0\text{ m}}{1\text{ s}}$$
$$= \frac{13.0\times10^{-3}\text{ km}}{\frac{1}{3600}\text{ h}}$$
$$= 46.8\text{ km h}^{-1}$$

(d) 1.5 g cm^{-3} to kg m^{-3}

$$1.5\text{ g cm}^{-3} = \frac{1.5\text{ g}}{1\text{ cm}^{3}} = \frac{1.5\text{ g}}{(1\text{ cm})^{3}}$$
$$= \frac{1.5\times10^{-3}\text{ kg}}{(10^{-2}\text{ m})^{3}} = \frac{1.5\times10^{-3}\text{ kg}}{10^{-6}\text{ m}}$$
$$= 1.5\times10^{3}\text{ kg m}^{-3}$$

(e) 7030 g cm^{-2} K^{-1} to kg m^{-2} K^{-1}

$$7030\text{ g cm}^{-2}\text{ K}^{-1} = \frac{(7030\times10^{-3})\text{kg}}{(1\text{ cm})^{2}\text{ K}}$$
$$= \frac{7030\times10^{-3}\text{ kg}}{(10^{-2}\text{ m})^{2}\times1\text{ K}}$$
$$= 7.03\times10^{4}\text{ kg m}^{-2}\text{ K}^{-1}$$

Annex D: Linearisation

D Write down the statement that describes how to plot a straight line graph and its features:

(a) Suggest which quantities to plot, given that T / s and h / m are related by:

$$T = n\sqrt{h} + k$$

Plot of T / s against $\sqrt{h}$ / $m^{\frac{1}{2}}$ should give a straight line graph

with gradient n / s $m^{-0.5}$ and y-intercept k / s.

(b) Suggest which quantities to plot, given that d / cm and P / N are related by

$$d = \frac{PL^3}{3EI}$$

Plot of d / cm against P / N should give a straight-line graph

with gradient $\frac{L^3}{3EI}$ / cm N^{-1} and no y-intercept.

(c) Suggest which quantities to plot, given that P / kg m^2 s^{-3} and T / K are related by:

$$P = A\varepsilon\sigma T^4$$

Plot of P / kg m^2 s^{-3} against T^4 / K^4 should give a straight line graph

with gradient $A\varepsilon\sigma$ / kg m^2 s^{-3} K^{-4} and no y-intercept.

(d) Suggest which quantities to plot, given that P / kg m^2 s^{-3} and T / K are related by

$$P = A\varepsilon\sigma T^4$$

Plot of lg (P / kg m^2 s^{-3}) against lg (T / K) should give a straight line graph

with gradient 4 and y-intercept lg ($A\varepsilon\sigma$ / kg m^2 $s^{-3}K^{-4}$).