Important points for SH1 practical examination

1. Critical skills in measurement, recording measurements and calculations

1.1 Recording measurements

instrument	How are readings taken?	smallest division / decimal place	How should measurement be recorded?	uncertainty due to resolution[$]
mass hanger and slotted mass	value is engraved on instrument	1 g	1 g	1 g
metre rule	read graduated markings on the instrument	0.1 cm	0.1 cm 0.001 m	0.1 cm
protractor		1°	1°	1°
liquid-in-glass thermometers		1 °C	0.5 °C	0.5 °C
measuring cylinder (100 cm^3)		1 cm^3	0.5 cm^3	0.5 cm^3
newton-meter (or spring balance)		0.4 N	0.2 N	0.2 N
vernier callipers	value shown on the digital display	0.01 mm	value on digital display [#]	last decimal place
micrometer screw gauge		0.001 mm	value on digital display [#]	last decimal place
stopwatch		0.01 s	value on digital display [@&]	last decimal place
electronic mass balance		0.01 g	value on digital display	last decimal place

[$] This uncertainty is due to instrumental limit only. Refer to section 1.4 on estimating percentage uncertainty.
[#] You may record values from vernier callipers to the nearest 0.1 mm and micrometer screw gauge to the nearest 0.01 mm.
[@] You may record the stopwatch timing to nearest 0.1 s.
[&] When stopwatch is running continuously while you measure how other quantity changes with time, you may record the timings to nearest 1 s or 0.1 s.

1.2 Expressing calculated values to the correct number of significant figures

How is the value calculated?	How is the calculated value recorded?	Example
Multiplication and/or division and/or reciprocal and/or power of quantities	The s.f. of the final value should follow the least s.f. of the quantities used in the calculation.	**Example 1** The two measured quantities are A = 10.2 and B = 2.3. The calculated quantity C is related to A and B by the formula $C = AB^2$. $C = (10.2)(2.3)^2 = 53.958 = 54$ B has the least s.f. among the values and so C is expressed as 2 s.f. **Example 2** The measured quantity is x = 10.2 cm and $C = \frac{1}{x}$. $C = \frac{1}{10.2} = 0.0980\ \text{cm}^{-1}$ x is 3 s.f., so C is expressed as 3 s.f.
Addition and/or subtraction of quantities	The d.p. of the final value should follow the quantity with the least d.p. of the quantities used in the calculation.	The two measured quantities are X = 10.2 and Y = 2.33. The calculated quantity Z is related to X and Y by the formula $Z = X + Y$. $Z = 10.2 + 2.33 = 12.53 = 12.5$ X has the least d.p. among the values and so Z is expressed to one d.p.
Average of a set of repeated values	The final value should be recorded to the same decimal place (d.p.) as the measured values.	The two repeated timings are 20.23 s and 20.30 s. Average timing $= \frac{20.23+20.30}{2} = 20.265$ s $= 20.27$ s (same d.p. as the measurement)

1.3 Critical skills

<u>Vernier callipers and micrometer screw gauge</u>
- Zero the device by pressing the “zero” button (venier callipers) or the “reset” button.
- Measurement should be repeated at different positions to account for non-uniformity. Calculate the average value.

<u>Electronic mass balance</u>
- Zero the device by pressing the “zero” button.
- If the reading fluctuates, ensure the balance is away from sources of vibration (e.g. fan or shaky surfaces). If fluctuation persists, record the “average” value you can discern from the display.

<u>Stopwatch</u>
The starting and stopping of the stopwatch is subjected to error of judgement and reaction. To ensure reproducibility of results, as a rule of thumb, repetitions depends on the duration of the event.

if the duration is …	you should repeat measurements
more than 15 s	once (i.e. total of <u>two</u> timings)
between 5 s and 15 s	two times (i.e. total of <u>three</u> timings)
less than 5 s	four times (i.e. total of <u>five</u> timings)

Note: Rule of thumb does not apply when the stopwatch is runing continuously while other quantities are measured (e.g. temperature change in a heating experiment over a duration).

Using stopwatch for oscillation experiments

1. Conduct trials, where possible, to determine whether you can vary the number of complete oscillations N to achieve a time duration t of at least 20 s over the range of the independent variable.

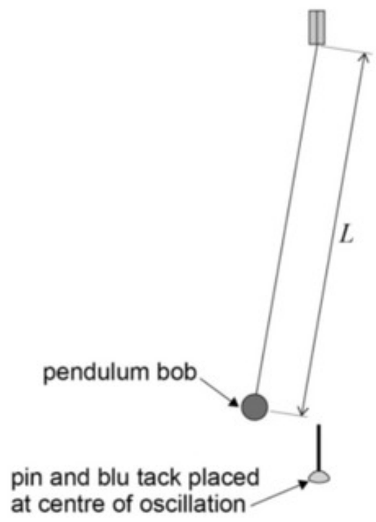
2. For each independent variable setting, repeat the the timing t, based on the rule of thumb, using the same number of oscillations N. The table of values are as follow:

length of pendulum L / cm	number of oscillations N	timing for N oscillation		period T / s
		t_1 / s	t_2 / s	
50.0	15	21.22	21.31	1.418
40.0	17	21.59	21.48	1.267
…	…	…	…	

Note: If the repeated timings differ more than 0.5 s, you should repeat the measurement to eliminate possible mistakes (e.g. miscount oscillations).

3. Ensure the system oscillates **freely** and in the desired plane with very little wobble. This is achieved if the oscillation has small amplitudes.
4. Take care not to miscount oscillations, e.g. say "zero" when starting to time. Use a reference such as a pointer (see the figure on the right) to help you judge when the oscillation passes the equilibrium position.

Note: The speed of the oscillation is fastest through the equilibrium position, so you should time from this point. If you try to time from the maximum displacement, the system is moving slowly and it becomes difficult to judge when it has reached maximum displacement and is about to reverse direction.



5. Only start the stopwatch when the system has completed one or two oscillations. This will help you to start timing at the correct point and the oscillations are steady when the timings are taken.

1.4 Estimating percentage uncertainties

(1) Percentage uncertainty for quantity from a single measurement

- Measure & record based on resolution of the instrument.
- Assess factors (e.g. set-up, use of the apparatus) that could increase the uncertainty.
- Give an estimate of the uncertainty of the measurement.

$$\text{percentage uncertainty} = \frac{\text{estimated uncertainty of measurement}}{\text{measured value}} \times 100\% \text{ (expressed to 2 s.f)}$$

(2) Percentage uncertainty for quantity that is measured at least twice

If a quantity is measured repeatedly (at least twice) and the values are not all equal, then

$$\text{percentage uncertainty} = \frac{\frac{1}{2} \times (\text{max value} - \text{min value})}{\text{average value}} \times 100\% \text{ (expressed to 2 s.f)}$$

(3) Percentage uncertainty for a quantity that is calculated from two or more other quantities

You need to estimate the uncertainty of each of the quantities and apply the rules for combining uncertainties (refer to Topic 1: Measurements).

2. What you need to know about the different questions? (refer to 9748 Specimen Paper 4)

Question 1

Initial measurements *(Refer to (a) and (b))*
You are guided to set up the apparatus and perform some initial measurements.

Marking points:
- ☐ Accuracy of measurements.
- ☐ Measurements are recorded to correct d.p. (refer to section 1.1).
- ☐ Repeated measurements, if required, should be recorded down.
  - Measurement is repeated for stopwatch, vernier callipers and micrometer screw gauge (refer to section 1.3).
  - Measurement should be repeated if it is likely to fluctuate (e.g. PT103 (a)(ii)).

Data collection *(Refer to (c) and (d)(i))*
- This table is **drawn up in advance** of taking readings by converting the given equation into the form of $y = mx + c$. The linearised equation gives you information on the processed data to include in the table.

  Refer to equations given in part (d)(i) of the specimen paper.

	e	=	P	×	$\frac{1}{n}$	+	Q
	y-axis		gradient		x-axis		y-intercept
What you need to measure?	S_1				x		

The table should have the following columns:

x / m	S_1 / m	e / m	n	$1/n$

- All data should be recorded in a **single table**. When constructing the table, the raw data should be in columns on the left of the table and processed data towards the right.

⟵ **measured data** ⟶ ⟵ **processed data** ⟶

independent variable / unit *what you vary*	**measurement 1 / unit** *e.g. t / s*	**measurement 2 / unit** (if applicable)	**calculated value 1 / unit** e.g. t^2 / s^2	**Calculated value 2 / unit**	…	**Other marking points** ☐ headings with variable and units
Marking points ☐ Determine the range of independent variable allowed by the set up. The set of data should cover this range. ☐ Recorded to correct d.p. (Refer to section 1.1). ☐ Repeat measurements should be recorded.			**Marking points** ☐ Express calculated values to correct s.f. (refer to section 1.2). (This point is assessed row–by–row.) ☐ Correct calculation(s).			☐ 6 sets of values for straight line trend (8 sets for curve) ☐ no split table

Presenting data analysed with excel *(Refer (d)(i))*
- Sketch the graph you get in excel with the axes labelled **AND** write down the trendline equation with gradient and y-intercept expressed to 3 s.f.
- State/explain how you use the gradient and y-intercept to obtain the unknown constants (e.g. P and Q *in (d)(i)*).
- You must include the unit for the constants by considering the homogeneity of the given equation.

Question 2

Initial measurements *(Refer to (a))*
You are guided to set up the apparatus and perform some initial measurements.

Marking points:
- ☐ Accuracy of measurements.
- ☐ Measurements are recorded to correct d.p. (refer to section 1.2).
- ☐ Repeated measurements, if required, should be recorded down.

Using excel to analysed the data provided by the examiner *(Refer to (b))*
- You will need to import the data provided into excel.
- Plot the X-Y scatter to see what data you are dealing with. Look for the trend, special features, outliers.
- You will need to manipulate the data to answer questions.
  - Some excel functions (mathematical operations, trigonometry, summation of cells, average of cells, etc). You may refer to the **Excel Reference Guide** loaded in your laptop.
  - Calculate the area under a graph using the sum of trapezium areas.
  - Calculate the gradient at specific point.

Question 3

Measurements
You are guided to set up the apparatus, perform some measurements (refer to (a)(i), (b)(i), (d)(i), (e)(i), (e)(ii)) and estimating percentage uncertainty (refer to 3(a)(ii)).

Marking points:

- □ Accuracy of measurements.
- □ Measurements are recorded to correct d.p. (refer to section 1.2).
- □ Repeated measurements, if required, should be recorded down.
- □ Estimating percentage uncertainty correctly (refer to section 1.4).

Hypothesis testing *(Refer to (e)(iii), (e)(v))*

- Calculate the constant of an equation with data from different parts (e.g. values of k in e(iii) from (e)(i) & (e)(ii)).
- Calculate the percentage difference between values of the constant:

Calculating percentage difference
If k_1 and k_2 are the two values of the constant calculated from the experimental data, the percentage difference is calculated using

$$\text{percentage difference between values of the constant} = \frac{|k_1 - k_2|}{\frac{1}{2}(k_1 + k_2)} \times 100\%$$

- Compare the percentage difference between the values of the constant with a percentage uncertainty that you have calculated in an earlier part(s) and give a clearly phrased conclusion based on this comparison (refer to (e)(v) where you are asked to compare the percentage difference with the percentage uncertainty in (a)(ii)).

Situation	Is relation valid?	Written conclusion
Both values of the constant are **equal**.	Yes	"Since both values of <<constant name>> are equal, the suggested relation is valid."
Percentage difference between values of the constant is **smaller than** or **equal to** the percentage uncertainty.	Yes	"The percentage difference of <<constant name>> is xx% and it is smaller than the percentage uncertainty of yy% for <<quantity name>>. Therefore, the suggested relation is valid." OR "The percentage difference of <<constant name>> is xx% and it is equal to the percentage uncertainty of yy% for <<quantity name>>. Therefore, the suggested relation is valid."
Percentage difference between values of the constant is **greater than** the percentage uncertainty	No	"The percentage difference of <<constant name>> is xx% and it is greater than the percentage uncertainty of yy% for <<quantity name>>. Therefore, the suggested relation is invalid."