PURE PHYSICS PRACTICAL NOTES

1. Reading and recording of raw data

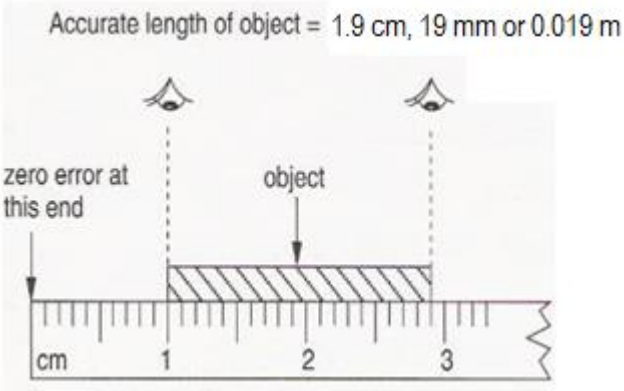
Precision of instruments

The table below summarizes the precision of each instrument used in experiments.

No	Apparatus	Smallest division	Correct precision	Example of recording	Remarks
1	Ammeter (0 – 1 A)	0.02 A	0.01 A	0.24 A 0.31 A	These instruments' readings are recorded to half the smallest division.
2	Ammeter (0 – 1 A)	0.02 A	0.01 A	0.25 A 0.20 A	
3	Voltmeter (0 – 3 V)	0.1 V	0.05 V	0.65 V 1.30 V	
4	Voltmeter (0 – 5 V)	0.1 V	0.05 V	2.15 V 2.20 V	
5	Laboratory thermometer (-10 to 110 °C)	1 °C	0.5 °C	37.5 °C 91.0 °C	
6	Half – metre rule	0.1 cm	0.1 cm	12.0 cm 12.1 cm	These instruments' readings are recorded to the smallest division.
7	Metre rule	0.1 cm	0.1 cm	88.3 cm	
8	Protractor	1 °	1 °	36 ° 45 °	
9	Measuring cylinder (100 ml)	1 ml	1 ml or cm^3	75 ml or cm^3	
10	Spring balance (0 – 1 N)	0.01 N	0.01 N	0.76 N 0.70 N	
11	Spring balance (0 – 10 N)	0.1 N	0.1 N	3.7 N 3.6 N	
12	Stop watch (digital)	0.01 s	0.01 s	36.54 s 20.72 s	Reading to 2 d p unless otherwise stated.
13	Digital Micrometer screw gauge	0.01 mm	0.01 mm	2.00 mm 2.11 mm	
14	Digital calipers	0.01 cm	0.01 cm	7.22 cm 7.89 cm	
15	Electronic mass balance	0.01 g	0.01 g	121.00 g 2.45 g	

The method to obtain readings in some of the common instruments is discussed below.

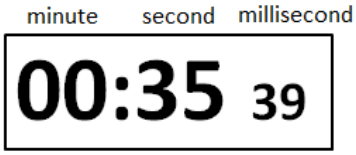
1. Metre rule



- Read to the smallest division.
- Take note of the decimal place (d.p.)

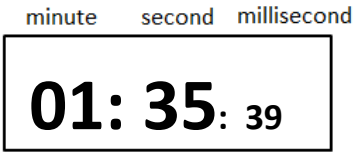
cm	1 d.p. (1.9 cm)
mm	whole number (19 mm)
m	3 d.p. (0.019 m)

2. Stop watch



Note: Do not record timing as “3539” or “35 $_{39}$”

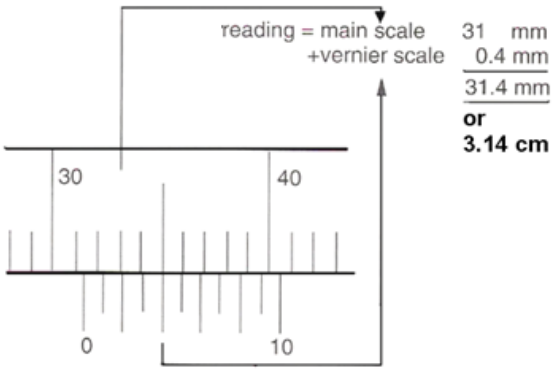
- Read to 2 d.p. unless otherwise stated (The time interval can be very short for some experiments and thus the question will specify to record timings to nearest second).
- Record as 35.39 s



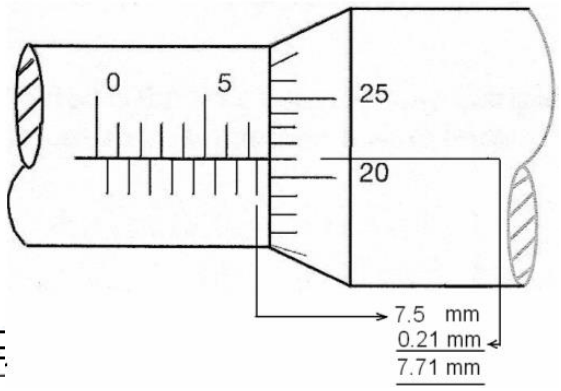
- Read to 2 d.p.
- Record as 1 min 35.39 s which is equivalent to 60 + 35.39 s = 95.39 s

3. Electronic mass balance
   - Reset the machine first (Press the “tare” button).
   - Once reading is stable, record reading accordingly in grams.

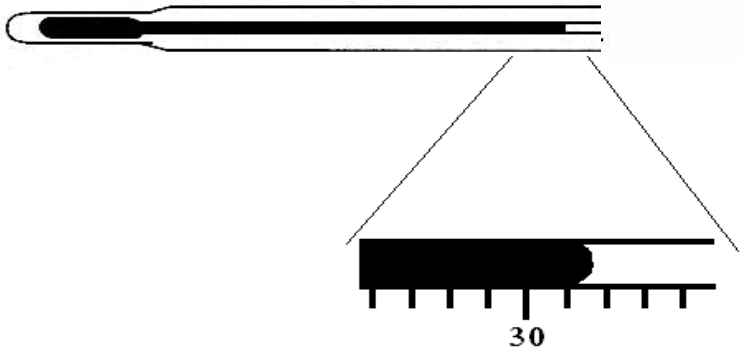
4. Vernier calipers
   - 2 d.p. (in cm) or 1 d.p (in mm)



5. Micrometer
   - 2 d.p. (in mm)

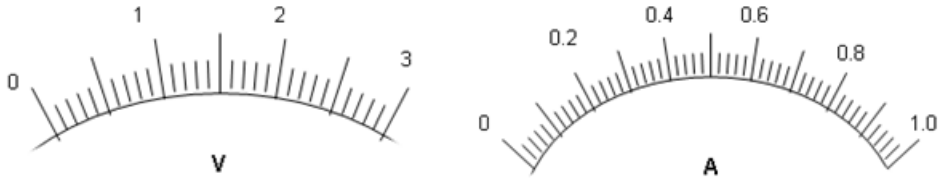


6. Thermometers (Laboratory)

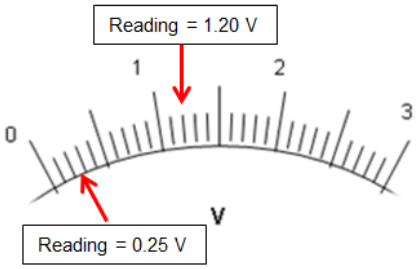


- Read to half the smallest division. i.e. the last digit: 0 ˚C or 5 ˚C
- Record the above as 31.5 ˚C

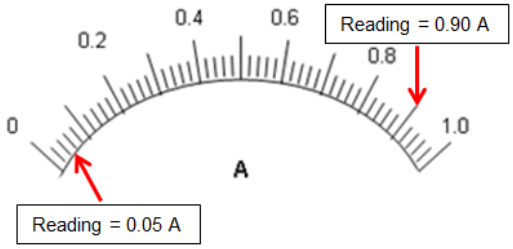
7. Voltmeters & ammeters



- Read up to half the smallest division for both.



2 d.p. Last digit: 0 or 5



2 d.p. Last digit: 0 to 9.

General precautions for experiments

The tables below describe precautions that are taken in the various type of experiments. These precautions should be followed and will help improve the accuracy of the readings obtained.

Mechanics

	Precautions
Measurements of width, diameter, angles. etc	• The eye must be placed vertically above the scale when reading the ruler/protractor/etc. to avoid parrallax error. • Take reading over a few points and find the average value.
Period of oscillation	• Make sure that pendulum is swinging in a plane so that correct timing of oscillation can be taken. • Allow a few oscillations to take place before starting the stopwatch. • Take the lowest point of oscillation as the reference point to start timing. • Fans must be switched off so that the time taken is not affected by draught. • Take 2 sets of readings per interval for 20 oscillations, find the average and divide by 20.
Volume of irregular solid	• Make sure there are no air bubbles in the liquid when taking readings. • Make sure solid is dry before lowering into liquid. • Ensure no liquid spillage or splashes when lowering the solid.
Determining C.G of plane lamina	• Ensure plumb line (a string with a bob), is hanged freely with the plane lamina at three locations. • After obtaining the intersection from two traced lines, use the third traced line to confirm the C.G.
Principle of moments	• Always measure the distance from pivot to centre of gravity of mass of object to obtain the perpendicular distance.

Heat

Precautions
• The eye must be placed in line with the top of the meniscus of the mercury thread in the thermometer to avoid parallax error. • Switch off the fan so as to minimise heat loss to surrounding. • Stir the liquid in the beaker/boiling tube/test tube quickly to ensure even distribution of heat. • If lagging (insulation) is used, make sure it is adequte to reduce heat loss to surrounding. • If transferring a hot liquid from one container to another is required, transfer the liquid quickly so as to minimise heat loss to surrounding.

Light

	Precautions
Experiments involving pins	• Pins must be placed vertically so that image can be located accurately. • The eye must be placed vertically above the scale when reading the ruler/protractor/etc. to avoid parallax error. • Make sure pins are reasonably far apart (at least 5 cm apart). • Close one eye when aligning pins and do not tilt head when looking at pins. • Check back using the refractive index of glass. (n of glass usually about 1.5; although could range from 1.48 to 1.96)
Experiments involving lenses	• The eye must be placed vertically above the scale when reading the ruler to avoid parallax error. • The illuminated object, lens and screen must be placed in line so that image can be obtained accurately. • In order to obtain a sharp image, the lens must be placed upright and parallel to the screen. The distance between lens and screen is the approximated focal length. • The torch light must be switched off when not in use so as to conserve the e.m.f of the batteries.

Electricity

Precautions
• The eye must be placed vertically above the scale when reading the ruler/ammeter/voltmeter etc. to avoid parallax error. • All connections must be tightened so as not to increase the resistance in the circuit and readings taken. • Ensure positive terminal of meter is connected to positive terminal of batteries. • The zero error in meters must be corrected so as to avoid errors in meter readings. • Make sure that there in no 'kink' in the bare resistance wires (usually in potentiometer) as this would reduce the accuracy in the measurement of the length of wire. • The circuit must be switched off when not in use so that heat is not produced in the resistance wire (resistance of wire may vary because of difference in temperature) and also to conserve the e.m.f of the batteries. • When using the jockey, do not press it tightly on the wire as this will alter the thickness of the wire and hence changes its resistance. • The jockey must be held vertically on the wire so that point of contact with wire is small and reading taken will be accurate.

2. Tabulation of data

The presentation of experimental data is a crucial part of the practical exam. The section below describes the guidelines in data tabulation.

Number of readings

- Take note of the number of readings required.
- "Take four more readings…" implies there are **FIVE** readings to take all together.
- If not stated, take at least **FIVE** sets of readings.
- For **straight** line graph, plot at least **FIVE** points
- For **curve** graph, plot at least **EIGHT** points

Range of readings

- Take a range as wide as possible.
- Equal intervals are preferred but not a must.
- E.g. "Six readings between 30º to 70º" → take readings at 30º, 40º, 50º, 60º, 65º, 70º

Filling in the table

Consider the data tabulated for an experiment on period of oscillation.

L / m	**t_1 / s**	**t_2 / s**	**t_{ave} / s**	**T / s**	**T^2 /s^2**
0.295	40.21	41.32	40.77	2.038	4.154
0.450	37.58	38.22	37.90	1.895	3.591
0.600	35.05	35.03	35.04	1.752	3.070
0.750	31.37	31.21	31.29	1.565	2.448
0.900	27.10	27.21	27.16	1.358	1.843

- No units, only values. (Units found only at headings)
- Readings in the first column are recorded in either an ascending or descending order.
- Readings in the same column must have the same d.p. (depends on the instrument)
  - E.g. Under column for length **L**, all readings must be in 3 d.p.
  - Under time measured **t_1, t_2**, all readings in 2 d.p.
  - Thus **t_{ave}** also in 2 d.p.
- For readings that involves calculation from a raw data, follow the significant figures of the raw data.
  - E.g. Period **T** is calculated by dividing **t_{ave}** with 20.
  - Since **t_{ave}** is in 4 sig. fig., **T** is also in 4 sig. fig.
  - Similarly, **T^2** is calculated from **T**.

- Since **T** is in 4 sig. fig, $\mathbf{T^2}$ is also in 4 sig. fig.

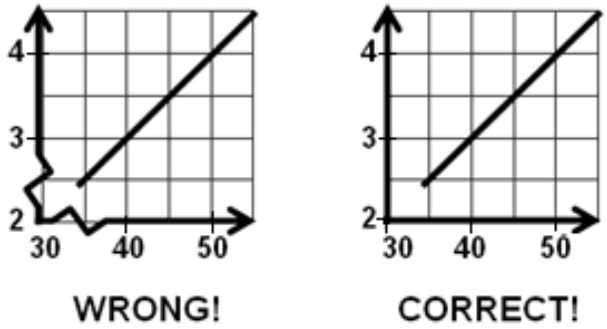
3. Graph plotting

Graph plotting is usually performed after the tabulation of data. The accuracy of the graph is important because its gradient and intercepts are subsequently used in calculations. In this section, the guidelines of plotting are listed.

General guidelines

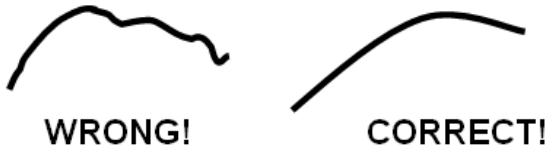
Terms used:
1 square (sq) is 2 cm by 2 cm.
1 grid is the smallest square of graph paper.

1. Use a sharp pencil to plot graph.
2. Label both axes with variable/unit. (e.g. T^2/s^2 and L/m)
3. Axis markings on at least every 2 sq.
4. *"Plot a graph of T^2/s^2 against L/m"* means T^2/s^2 is the vertical axis and L/m is the horizontal axis.
5. Select an appropriate scale. (e.g. 1 sq to 2 units)
   Other acceptable scale 1 sq to 1, 5, 10, 20 or 50 units.
   Avoid 1 sq to 3 units or 7 units
6. Scale should allow the length of first to last data point to occupy more than half of graph paper in both directions. (At least 6 sqs for vertical, 5 sqs for horizontal.)
7. Need not start from origin if question does not require. Label the starting values at the intersection of the axis and do not use zig zag to cut the axis.

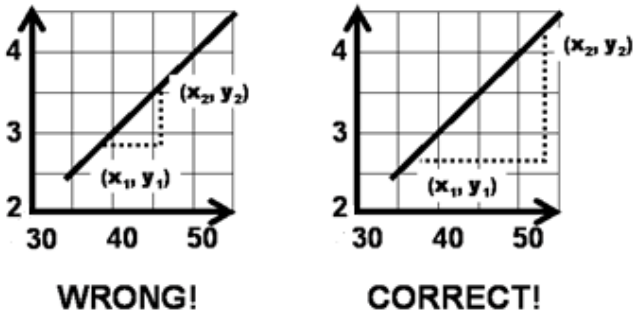


8. Use an "X" to represent data points. Big crosses will be penalized.
9. Points plotted must be accurate to half the smallest grid.
10. Draw best-fit straight line graphs with approximately equal number of points on both top and below the line.
11. For stray points, adjust the best fit line to include the reading. If it is not possible, retake the reading for that point if time permits. If there is not enough time, ignore stray point by circling it and labelling it "anomalous point".

12. Draw smooth curves (e.g. cooling curves).
Do not connect individual points.



13. Gradient triangle's hypotenuse must be longer than half length of graph.



14. Readings interpreted from the graph (e.g. y-intercept value) should be read to accuracy better than half of the square grid.
E.g. From the graph, when y = 3.5, the x value is 4.5.

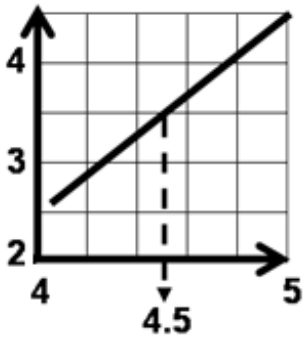
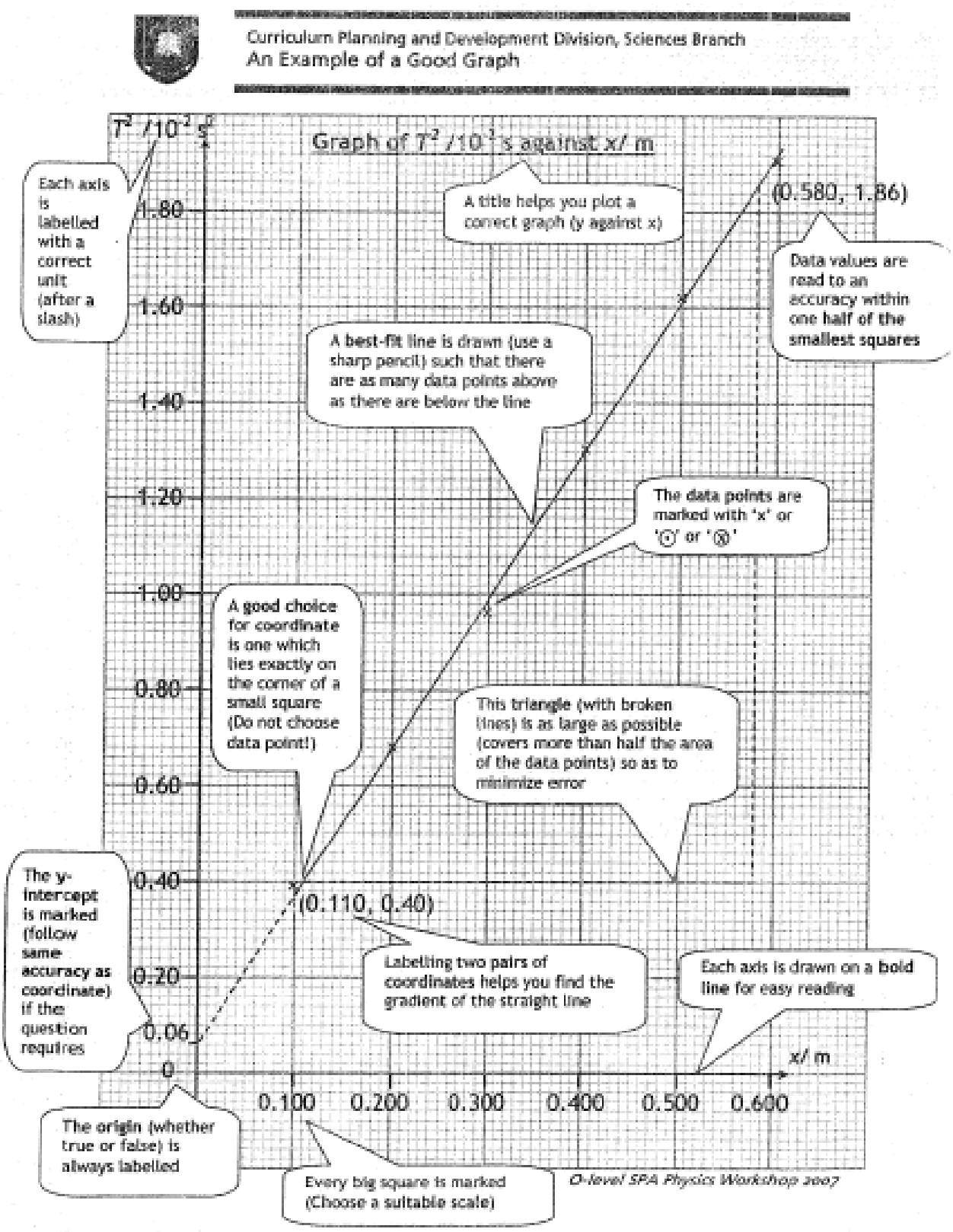
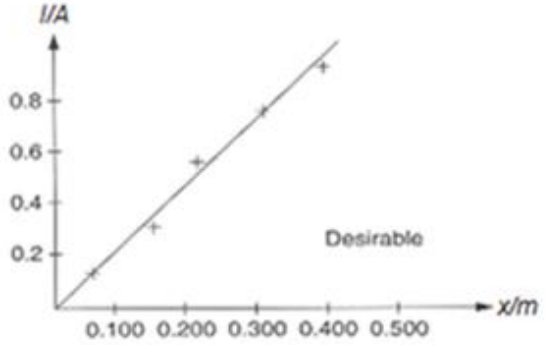


Diagram of a good graph

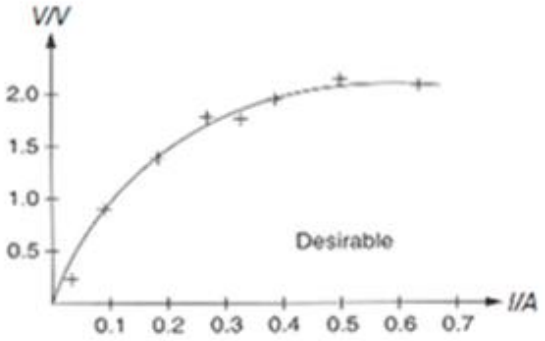


Examples of desirable and undesirable graphs

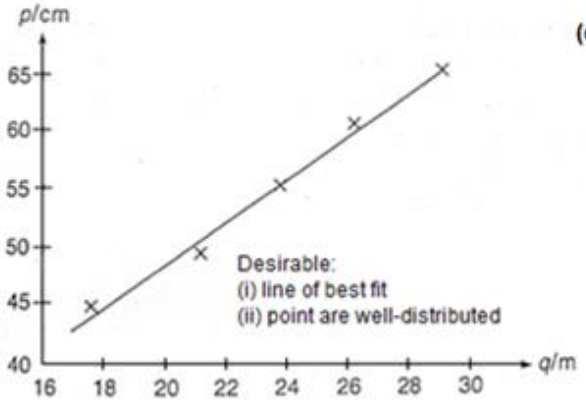
(a)



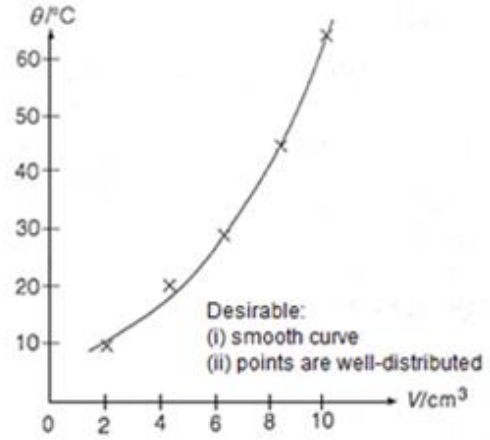
(b)



(c)



(d)



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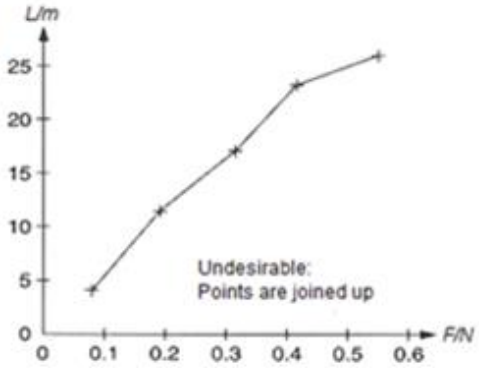

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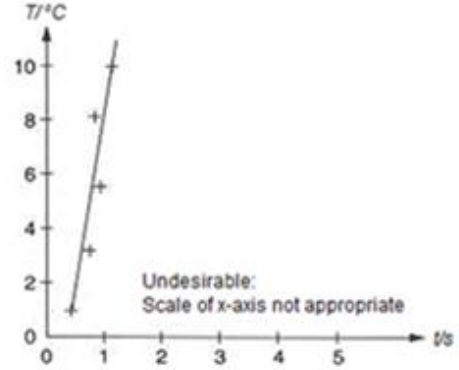

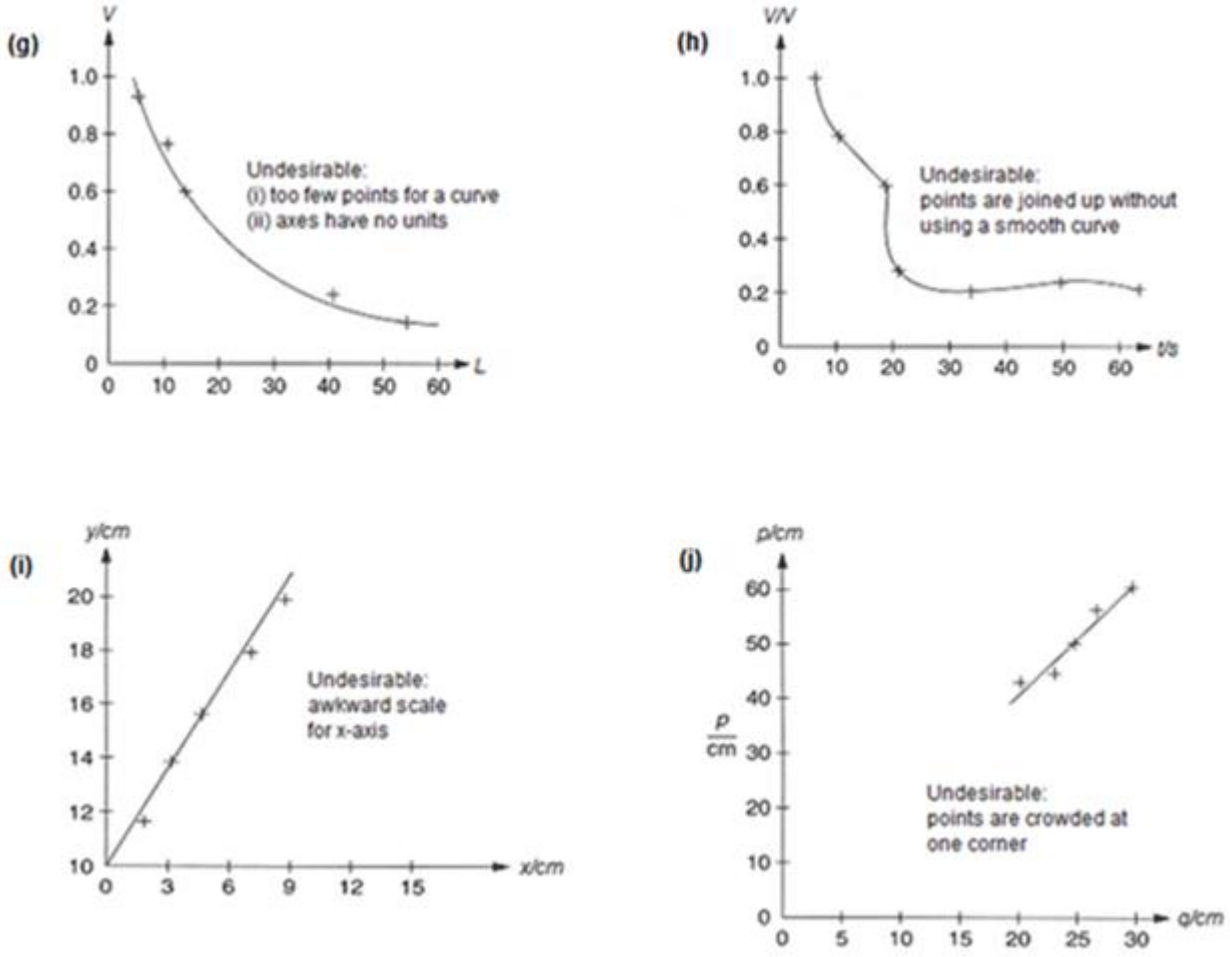

4. Sources of errors

Key sources of errors of the experiment are often asked at the end of the practical exam. The required answer is open-ended and requires much thinking and thus, can be difficult to answer. In some questions, suggestions to improvement the experiments are required too.

How to answer the question?

Key sources of errors in an experiment are errors that can affect the result of the experiment. They lead to significant errors in the results and are usually inherent to the experiment due to the procedure and the apparatus used in the experiment. Errors that can be either corrected with better practical skills or gives a consistent error throughout the whole experiment will **not** likely be accepted as key sources of error. Some examples of common incorrect answers are parallax error, random error and zero error of apparatus.

To have a structured answer, the following questions can be used as a guide.

- What is the source of error?
- How does the error affect the results of the experiment?

Some key sources of errors are listed below. The list of examples are not exhaustive and should be used as guidelines to answering questions since the actual answer varies with the task given.

Mechanics

- The time taken for the oscillation is too short, causing inaccuracy in the timing due to human reaction time to be significant.
- The release of the spring is not consistent, leading to inaccurate measurement of timing …….
- The string used is slightly extendable, causing the measurement of the length of the string …… to be inaccurate.
- Shifting of the card / plumbline when marking points along the edge, hence affecting the accuracy of …….
- String attached to the plumbline is thick which prevents the exact position of the marks to be determined along the edge, hence affecting the accuracy of ……
- The metre rule is not exactly horizontal which causes the mass to slide, hence affecting the reading of ……
- The metre rule cannot be exactly balanced on the knife edge which affects the reading of distance ……
- The clamp of the retort stand does not allow small changes in height to be adjusted which affects the accuracy of ……
- The timing and the measurement of …… cannot be recorded simultaneously which affects the accuracy of ……
- As the spring stretches, it may not be possible to find the same reference points to measure, causing inconsistency in the measurement of ……
- The metre rule cannot be held close to …… / steadily from …… which causes the length measurement to be estimated.

Heat

- Mass of substance added is not equal to the mass of substance recorded hence affecting the accuracy of ……
- There is heat loss to / gain from the surroundings hence leading to inaccurate value of ……
- Inconsistent amount of stirring of the solution leading to inaccurate value of …….
- Difficulty in reading the temperature and time readings simultaneously leads to inaccurate values of ……

Light (Reflection and refraction)

- The bevelled edges of the glass block does not allow it to be placed back to its original position, leading to inconsistency of reading ……
- The mirror shifts easily despite checks which affects the accuracy of angle ……
- The holes made by the pins are large which affects the accuracy of the lines drawn, hence affecting the reading of ……

Light (Converging lens)

- The lens is not fixed tightly on the lens holder, allowing the lens to shift slightly and not be perpendicular to the surface while adjusting to form a sharp image, causing reading …… to be inaccurate.
- The lens holder is positioned at a distance away from the metre rule which causes the measurement of …… to be estimated.
- Inconsistent judging of the sharpness of the image leading to inaccurate readings of ……
- Shifting of metre rule / screen when taking measurements, hence leading to inaccuracy in readings of ……

Electricity

- The wire have kinks/bends which causes the measurement of the length of wire …… to be inaccurate.
- The temperature of the wire may increases which caused the resistance of the wire to increase, hence affecting the accuracy of ……
- The point of contact between the jockey and the wire is not consistent which affects the accuracy of ……
- The thickness of the wire is not uniform which affects the resistance of the wire, hence affecting the consistency of readings ……

5. Planning

Planning question tests on the skills in identifying the variables in an investigation and presenting a procedure in a coherent manner. Typically, marks are awarded for the points listed below and can be used as a checklist when answering the question.

Marking point
• identifying independent variable, dependent variable and control variables (give at least 2)
• describing precautions to obtain accurate and reliable readings
• describing how the dependent variable is measured
• describing how the independent variable is varied to obtain a set of data for graph plotting
• describing the graph plotted for the investigation (either to verify relationship or to obtain unknown constants)
<u>Depending on question</u> • stating how unknown constants can be determined using the graph (e.g. calculating gradient, determining y-intercept, calculating reciprocal of gradient etc) • stating how the relationship between the variables (e.g. proportional, linearly-related, non-linearly related, independent) can be shown using the graph (may be asked to provide a sketch of the graph)

How to answer the question?

When writing the procedure, the independent, dependent and control variables (give at least two) should be clearly stated and the steps should be written in concise sentences and numbered accordingly. Listed below are some pointers on answering the planning question.

1. Always begin by identifying the variables. To identify the independent and dependent variables, match the equation given to Y = mX + C where Y is the dependent variable and X is the independent variable. The equation given in the question needs to be rearranged in some cases.

Example: Investigate the relationship between magnification *m* and image distance *v*. $m = \frac{1}{f} v - 1.$ Analysis: From the equation given, magnification m is the dependent variable, image distance v is the independent variable, 1/f is the gradient of the graph and – 1 is the y-intercept.

   To identify the control variables, focus on factors that can affect the measurements directly. Be specific when stating the control variables

Example: × type of lens ✓ focal length of lens

2. To state precautions that are relevant, focus on how the dependent variable is obtained.

Example: To obtain accurate values of magnification *m*, the image and object distance must be accurate. Relevant precautions would be steps to ensure these distances are accurate such as ensuring the lens holder are parallel to the metre rule when measuring the distances.

3. To describe how the dependent variable is obtained and independent variable is varied, you may modify the instructions given in the parts of the question that was carried out before the planning question. Be specific in describing how the dependent variable is obtained by stating <u>which steps are repeated</u>, <u>the change in the independent variable</u> and the <u>number of times to repeat</u>.

Example: Repeat <u>steps 3 to 8</u> with <u>different distances between cross-wire and lens</u> to obtain <u>five further values</u> of magnification *m*.

4. To identify the graph plotted, the dependent variable will be always be the y-axis and the independent variable will be the x-axis. The answer should be a short statement.

Example: Plot a graph of magnification *m* against image distance *v*.

5. To use the graph for the investigation, read the question carefully for the requirements. Do not lump the steps together.

Example: × Calculate the gradient of the graph and flip the gradient to obtain f. ✓ Calculate the gradient of the graph. Calculate the reciprocal of the gradient to obtain f.