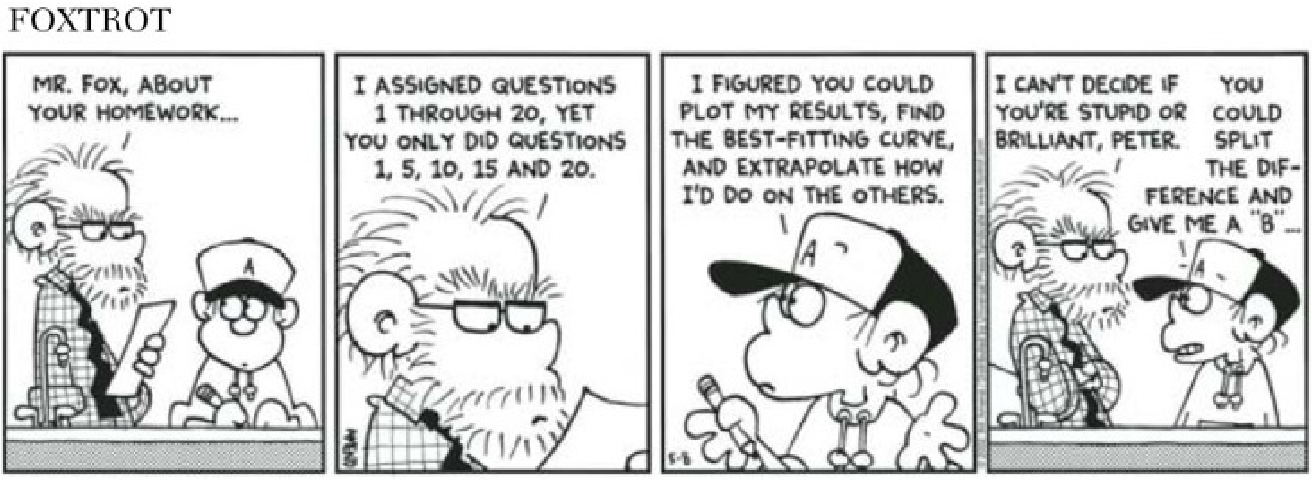
Name: ______________________________ (      )

Class: 3 - ________

# Catholic High School
## 2022 Level 3
## Physics Practical




**NOTES**

| No. | Contents | Pg |
|---|---|---|
| I | Singapore-Cambridge General Certificate of Education Ordinary Level (2018) (Syllabus 6091 - Physics) | 1 |
| II | Introduction to Physics Practical Experiments | 6 |
| III | Physics Practical Experiment Skills | 7 |
| IV | Physics Practical Experiment Notes | 8 |
| V | Physics Sample Graph Plotting | 23 |

## (I) Singapore-Cambridge General Certificate of Education Ordinary Level (2018) (Syllabus 6091 - Physics)

## SCHEME OF ASSESSMENT

**Candidates are required to enter for Papers 1, 2 and 3.**

| Paper | Type of Paper | Duration | Marks | Weighting |
|---|---|---|---|---|
| 1 | Multiple Choice | 1 h | 40 | 30 % |
| 2 | Structured and Free Response | 1 h 45 min | 80 | 50 % |
| 3 | Practical | 1 h 50 min | 40 | 20 % |

**Theory papers**

**Paper 1** (1 h, 40 marks)
This paper will consist of 40 compulsory multiple choice items of the direct choice type.

**Paper 2** (1 h 45 min, 80 marks)
This paper will consist of 2 sections.

Section A will carry 50 marks and will consist of a variable number of compulsory structured questions.

Section B will carry 30 marks and will consist of three questions. The first two questions are compulsory questions, one of which will be a data-based question requiring candidates to interpret, evaluate or solve problems using a stem of information. This question will carry 8–12 marks. The last question will be presented in an either/or form and will carry 10 marks.

**Practical assessment**

**Paper 3** (1 h 50 min, 40 marks)

This paper will consist of 2 sections.

Section A will carry 20 marks and will consist of 1–2 compulsory practical experiment questions with a total duration of 55 min.

Section B will carry 20 marks and will consist of one compulsory 55 min practical experiment question.

One or more of the questions may incorporate assessment of Planning (P) and require candidates to apply and integrate knowledge and understanding from different sections of the syllabus. The assessment of PDO and ACE may include questions on data-analysis which do not require practical equipment and apparatus.

Candidates would be allocated a specified time for access to apparatus and materials of specific questions

Candidates are not allowed to refer to notebooks, textbooks or any other information during the assessment.

# PRACTICAL ASSESSMENT

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of Science should include a component relating to practical work and experimental skills.

This assessment is provided in Paper 3 as a formal practical test and is outlined in the Scheme of Assessment.

**Paper 3**
This paper is designed to assess a candidate's competence in those practical skills which can realistically be assessed within the context of a formal test of limited duration.

Candidates will be assessed in the following skill areas:

(a) Planning (P)

Candidates should be able to

- identify key variables for a given question/problem
- outline an experimental procedure to investigate the question/problem
- describe how the data should be used in order to reach a conclusion
- identify the risks of the experiment and state precautions that should be taken to keep risks to a minimum

(b) Manipulation, measurement and observation (MMO)

Candidates should be able to

- set up apparatus correctly by following written instructions or diagrams
- use common laboratory apparatus and techniques to collect data and make observations
- describe and explain how apparatus and techniques are used correctly
- make and record accurate observations with good details and measurements to an appropriate degree of precision
- make appropriate decisions about measurements or observations

(c) Presentation of data and observations (PDO)

Candidates should be able to

- present all information in an appropriate form
- manipulate measurements effectively for analysis
- present all quantitative data to an appropriate number of decimal places/significant figures

(d) Analysis, conclusions and evaluation (ACE)

Candidates should be able to

- analyse and interpret data or observations appropriately in relation to the task
- draw conclusion(s) from the interpretation of experimental data or observations and underlying principles
- make predictions based on their data and conclusions
- identify significant sources of errors and explain how they affect the results
- state and explain how significant errors may be overcome or reduced, as appropriate, including how experimental procedures may be improved.

One, or more, of the questions may incorporate some assessment of skill area P, set in the context of the syllabus content, requiring candidates to apply and integrate knowledge and understanding from different sections of the syllabus. It may also require the treatment of given experimental data in drawing relevant conclusion and analysis of proposed plan.

The assessment of skill areas MMO, PDO and ACE will be set mainly in the context of the syllabus content. The assessment of PDO and ACE may include questions on data-analysis which do not require practical equipment and apparatus.

Candidates are not allowed to refer to notebooks, textbooks or any other information during the assessment.

Candidates should be able to make measurements or determinations of physical quantities such as mass, length, area, volume, time, current and potential difference. Candidates should be aware of the need to take simple precautions for safety and/or accuracy. Candidates will be required to follow the instructions given in the question paper and answer on the question paper itself.

Candidates may be asked to carry out exercises based on:
1. measurements of length, time interval, temperature, volume, mass and weight using appropriate instruments
2. determination of the density of a liquid, or of a regularly or irregularly shaped solid which sinks in water
3. determination of the value of the acceleration of free fall
4. investigation of the effects of balanced and unbalanced forces
5. the principle of moments
6. determination of the position of the centre of gravity of a plane lamina
7. investigation of the factors affecting thermal energy transfer
8. determination of heat capacities of materials and latent heat of substances
9. the law of reflection
10. determination of the position and characteristics of an optical image formed by a plane mirror or a thin converging lens
11. the refraction of light through glass blocks
12. the principle of total internal reflection
13. the focal length of lenses
14. determination of the speed, wavelength and frequency of waves
15. measurements of current and voltage by using appropriate ammeters and voltmeters
16. determination of the resistance of a circuit element using appropriate instruments
17. investigation of the magnetic effect of current in a conductor
18. investigation of the effects of electromagnetic induction

This is not intended to be an exhaustive list. Candidates are expected to be familiar with the use of data-loggers. Assessment of skill area P may include the appropriate use of data-loggers.

Responsibility for safety matters rests with Centres.

Reference may be made to the techniques used in these experiments in the theory papers but no detailed description of the experimental procedures will be required.

Within the Scheme of Assessment, the practical paper constitutes 20% of the O-Level Physics examination. It is therefore recommended that the schemes of work include learning opportunities that apportion a commensurate amount of time for the development and acquisition of practical skills.

**Apparatus List**
This list below gives guidance to Centres concerning the apparatus and items that are expected to be generally available for examination purposes. The list is not intended to be exhaustive.

The apparatus and materials requirement for Paper 3 will vary from year to year. Centres will be notified in advance of the details of the apparatus and materials required for each practical examination.

It is intended that candidates should have 55 minutes with the apparatus for each section of the paper. Please note the requirement to provide a seating plan of the examination, as indicated on the instructions. It is essential that candidates are warned of these arrangements in advance. Spare sets of apparatus must be available to allow for breakages and malfunctions.

Unless otherwise stated, the rate of allocation is “per candidate”.

| Electrical | Mechanics and General Items |
|---|---|
| Ammeter (analogue): f.s.d 1 A | Pendulum bob |
| Voltmeter (analogue): f.s.d 3 V | Stand, boss and clamp: × 2<br>(Rod length: 60 cm) |
| Cells: 2 x 1.5 V with holder, 2 V | |
| Lamp and holder: 2.5 V, 0.3 A | Pivot |
| Rheostat: Max resistance: 22 Ω, Rating: at least 3.3 A | Pulley |
| Resistors, various | Newton-meter: 1 N, 2.5 N |
| Switch | Rule with millimeter scale<br>(1 × 1 m, 1 × 0.5 m, 1 × 300 mm) |
| Jockey | |
| Leads and crocodile clips | Vernier calipers (1 per 4–6 candidates) |
| Wire: constantan 28 s.w.g. or metric equivalents | Micrometer screw gauge (1 per 4–6 candidates) |
| Wire: nichrome 28, 32 s.w.g. or metric equivalents | |
| Magnets: 2 × bar magnets | Stopwatch (reading to 0.1 s or better) |
| Compass: 1 × small | Balance to 0.01 g (1 per 8–12 candidates) |
| | Plasticine |
| | Blu-Tack |
| **Heat** | Springs |
| Long stem thermometer: –10 °C to 110 °C at 1 °C | Optical pin |
| Beaker: 500 $cm^3$, 2 × 250 $cm^3$ | Slotted masses: 1 × 5 g; 1 × 10 g; 2 × 20 g;<br>4 × 50 g; 1 × 50 g hanger |
| Boiling tube, 150 mm × 25 mm | |
| Measuring cylinder: 50 $cm^3$, 100 $cm^3$ | Slotted masses: 4 × 100 g; 1 × 100 g hanger |
| Plastic or polystyrene cup 200 $cm^3$ | Burette |
| Means to heat water safely to boiling | Rubber tubing |
| Heating mat | Cork |
| Stirrer | Dropper |
| | String/thread/twine |
| **Light** | Scissors |
| Glass block (120 mm × 60 mm × 20 mm) | Adhesive tape |
| Microscope slides | Card (assorted sizes) |
| Mirror, plane (100 mm × 50 mm) | Wood (assorted sizes, for various uses, e.g. support) |
| Lens, converging f = 15 cm | |
| Lens holder | Wooden board |
| Screen (10 cm wide, 15 cm high) | Sand and tray |
| Torch | Bricks: 2 × (approx. 22 cm × 10 cm × 7 cm) |
| Protractor | |
| Pin board (23 cm × 30 cm) | |
| Pins | |
| Tracing paper | |

## General marking points

*Taking readings*

During the course of their preparation for this paper, candidates should be taught to observe the following points of good practice, which are often featured in the mark scheme. A measuring instrument should be used to its full precision. Thermometers are often marked with intervals of 1 °C. It is appropriate to record a reading which coincides exactly with a mark as, for example, 22.0 °C, rather than as a bald 22 °C. Interpolation between scale divisions should be to better than one half of a division. For example, consider a thermometer with scale divisions of 1 °C. A reading of 22.3 °C might best be recorded as 22.5 °C, since '0.3' is nearer '0.5' than '0'. That is, where a reading lies between two scale marks, an attempt should be made to interpolate between those two marks, rather than simply rounding to the nearest mark. The length of an object measured on a rule with a centimetre and millimetre scale should be recorded as 12.0 cm rather than a bald 12 cm, if the ends of the object coincide exactly with the 0 and 12 cm marks. A measurement or calculated quantity must be accompanied by a correct unit, where appropriate.

*Recording readings*

A table of results should include, in the heading of each column, the name or symbol of the measured or calculated quantity, together with the appropriate unit. Solidus notation is expected. Each reading should be repeated, if possible, and recorded. The number of significant figures given for calculated quantities should be the same as the least number of significant figures in the raw data used. A ratio should be calculated as a decimal number, to two or three significant figures.

*Drawing graphs*

A graph should be drawn with a sharp pencil. The axes should be labelled with quantity and unit. The scales for the axes should allow the majority of the graph paper to be used in both directions and be based on sensible ratios, e.g. 2 cm on the graph paper representing 1 or 2 or 5 units of the variable (or 10, 20 or 50, etc.). Each data point should be plotted to an accuracy better than one half of one of the smallest squares on the grid. Points should be indicated by a small cross or a fine dot with a circle drawn around it. Large 'dots' are penalised. Where a straight line is required to be drawn through the data points, Examiners expect to see an equal number of points either side of the line over its entire length. That is, points should not be seen to lie all above the line at one end, and all below the line at the other end. The gradient of a straight line should be taken by using a triangle with a hypotenuse that extends over at least half the length of the candidate's line. Data values should be read from the line to an accuracy better than one half of one of the smallest squares on the grid. The same accuracy should be used in reading off an intercept. Calculation of the gradient should be to two or three significant figures.

## (II) Introduction to Physics Practical Experiments

**Basic safety procedures**

It may appear to some people that doing Physics practical experiments is less dangerous than doing Chemistry or Biology experiments. This is a serious misconception. Doing any experiment in the laboratory can be dangerous if we do not follow some basic safety procedures. Below are some basic safety procedures that we should be aware of.

**Before you begin**

1. Make sure that your workbench is not full of unnecessary things (such as school bags, files, clothes and books).
2. Read all the instructions and check that the apparatus provided on the table match those in your worksheets before you do anything.
3. Look out for any possible dangerous procedures.

**While you are doing the experiment**

1. Follow the directions in the worksheet closely. Do not do anything you are not instructed to do without your teacher's permission.
2. Do not fool around and endanger yourself or the people around you.
3. Wear or use protective devices that are provided for you. These include goggles, gloves and safety tongs.
4. Never leave heating apparatus unattended. Turn off Bunsen burners and gas when you have to leave your workbench for a while or when you have finished your experiments.
5. If you have broken any glassware (eg. beakers, test tubes and thermometers) or spilt anything, inform your teacher immediately. You may have to help in cleaning up.
6. Be aware of where the fire extinguishers are located in the laboratory.

**After you have finished the experiment**

1. Clean up your workbench.
2. Do not dispose of materials in the sink unless you are instructed to do so.
3. Wash your hands thoroughly.

The above are only some of the safety procedures that you should take to avoid accidents. It is not possible to list all the safety procedures. The best preventive measure to take is to always be careful and be alert. Take care of yourself and your neighbours.

## (III) Physics Practical Experiment Skills

**For practical experiments, always bring**

1. A blue or black pen
2. A sharpened pencil (with sharpener) or mechanical pencil (with spare pencil lead)
3. A 30.0 cm clear plastic ruler (do not assume that the lab will provide a ruler)
4. Flexible curve
5. Calculator
6. Eraser

**During practical experiments, you will develop the following experimental skills:**

1.
2. Carry out techniques, use apparatus, and handle measuring devices and materials effectively and safely based on instructions.
3. Make and record observations, measurements and estimates with due regard to precision, accuracy and units.
4. Interpret, evaluate and report observations and experimental data.
5. Evaluate methods and suggest possible improvements.
6. Plan an experiment by identifying key variables, outlining experimental procedures with appropriate instruments, explaining how to process the data and identifying any risks and associated precautions to minimise them.

**Display of data**

1. Take at least <u>5 sets of readings for straight lines</u> (or at least <u>7 sets of readings for curves</u>).
2. Plan all your readings so that they are uniformly spread out within the given limits.
3. All raw data under the same column must be recorded to the same number of decimal places (based on the precision of the measuring instrument).
4. When determining the average value of a set of raw data, it should be recorded to the same precision (i.e. same number of decimal places) as the raw data taken.

   <u>E.g.</u>: Average of 2.36, 2.41 and 2.38 = (2.36 + 2.41 + 2.38) ÷ 3
   = 2.383
   = 2.38 (2 d.p.)

**Precision of readings** (for information only)

| **Instruments** | **Precision** |
|---|---|
| Metre rule | 0.1 cm |
| Vernier Calipers | 0.01 cm |
| Micrometer Screw Gauge | 0.01 mm |
| Measuring Cylinder (100 $cm^3$) | 0.5 $cm^3$ |
| Protractor | 1° |
| Digital Stopwatch | 0.1 s |
| Thermometer | 0.5 °C (or 1 °C, depending on instrument used) |
| Spring Balance | 0.05 N |
| Digital Balance | 0.1 g (or 0.01 g, depending on instrument used) |
| Standard Masses | 1 g |
| Ammeter (0 - 1A) | 0.01 A |
| Milliammeter (0 - 100 mA) | 1 mA |
| Voltmeter (0 - 3 V) | 0.05 V |
| Resistor | 1 Ω |
| Electronic Balance | 0.1 g or 0.01 g (depending on instrument) |

## (IV) Physics Practical Experiment Notes

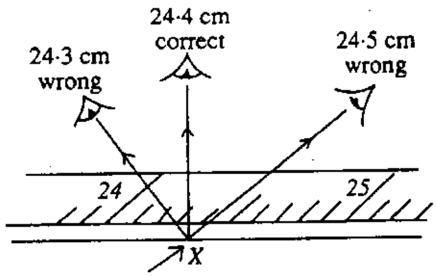
Physics practical experiments are concerned with measurements. Measurements are only useful if they are correctly taken, recorded, processed and analysed. Do take note of the following points when taking measurements:

**1. Parallax error**

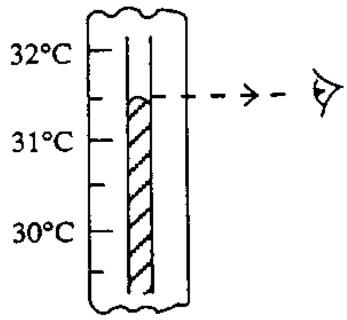
An important skill in Physics practical experiments is reading a scale correctly. Parallax error which arises from the incorrect positioning of the eye results in incorrect scale readings. To avoid such an error, the following precautions should be kept in mind when using the various instruments:

**(a) Metre rule**

The eye must always be placed vertically above the point X (the reading to be taken) on the scale.

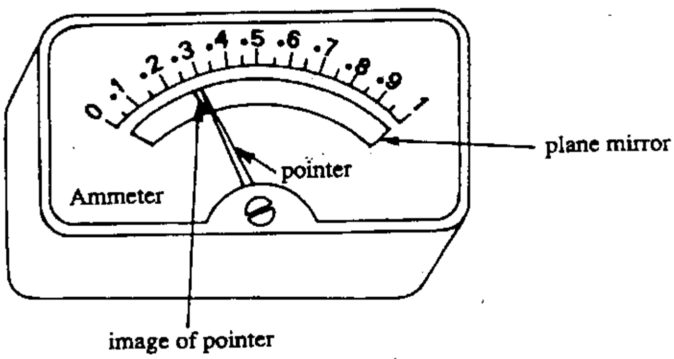



**Thermometer**



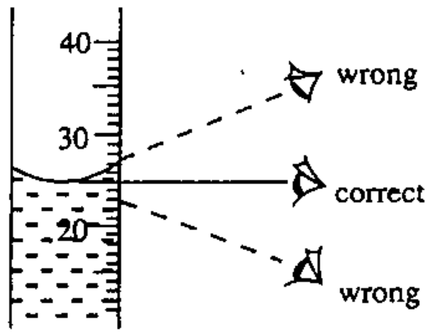

**(c) Ammeter**

Move your head above the ammeter until the pointer covers its image in the mirror .




**(d) Measuring cylinder**

For liquids other than mercury, read off the meniscus at eye level as shown.



**2. Use of measuring instruments**

**(a) Metre rule**
Metre rules are graduated in millimetres (mm). Readings taken with a metre rule are recorded in centimetres to one decimal place, e.g. 20.5 cm or 40.2 cm.

**(b) Vernier calipers**
Vernier calipers are used to measure lengths in centimetres precise to two decimal places, i.e. 0.01 cm.

Refer to Chapter 1 notes to learn how to read vernier calipers.

**(c) Micrometer screw gauge**
The micrometer screw gauge is an instrument for measuring the diameters of wires and thin rods in millimetres precise to two decimal places, i.e. 0.01 mm.

Refer to Chapter 1 notes to learn how to read micrometer screw gauge.

**3. Precision of readings**
To quote say 34.12 °C for the temperature of a sample of liquid, you are actually telling others that in your measurement, you are certain of all the digits but the last. This precision cannot be obtained with the ordinary thermometer used in the school laboratory.

Never quote more decimal places for the readings or final answer than what the instrument can provide.

**4. Addition and subtraction**
When two or more values are added or subtracted, the result will have the **<u>same number of decimal places (d.p.) as the given values</u>**.

<u>E.g.</u>:
21.22 cm + 12.66 cm = <u>33.88 cm</u> (2 d.p.)

[<u>For information only</u>: At A-level Physics, when adding or subtracting two or more values, the number of decimal places of the result will follow the given value which has the *least number of decimal places (d.p.)*. However, such calculations (involving values with different d.p.) never occur at O-level Physics.]

**5. Significant figures**
To determine the number of significant figures in a number, apply the following rules:

**1. The following figures in a number are significant**:

(a) **All non-zero figures**.

E.g.: 7.12 has 3 significant figures.

(b) **All zeros between non-zero digits.**

E.g.: 2003 has 4 significant figures.

(c) **All zeros after a non-zero digit in a decimal**.

E.g.: 22.300 has 5 significant figures.

2. **The following figures in a number are *NOT* significant**:

(a) **All zeros before a non-zero digit in a decimal**

E.g.: 0.000325 has 3 significant figures.

(b) **All zeros at the end of a number may or may not be significant. It depends on how the estimation is made.**

E.g.: 4962 (when corrected to 2 s.f.) = 5000, where the first zero is significant while the last two zeros are not significant.

6. **Multiplication and division**
When multiplying or dividing numbers with different number of significant figures, the number of significant figures of the result will be **rounded off to least significant figures (s.f.)**.

E.g.:
11.70 cm × 1.40 cm = 16.38 = 16.4 cm² (3 s.f.)

7. **Average**
To check or to improve the accuracy of your measurements, you can take several readings and then find the average of these readings.

E.g.:
Length of wire, *l*:

| $l_1$ / cm | $l_2$ / cm | $l_3$ / cm | $l_4$ / cm | $l_5$ / cm | $l_{av}$ / cm |
|---|---|---|---|---|---|
| 12.6 | 12.4 | 12.7 | 12.5 | 12.4 | 12.5 |

Average length, $l_{av}$ $= \frac{12.6 + 12.4 + 12.7 + 12.5 + 12.4}{5} = \frac{62.6}{5} = 12.52$
$= 12.5$ cm (1 d.p.)

It is important to note that the number of decimal places of the average is the same as each of the readings.

- Special case:
If the average of an answer is zero when it follows the number of decimal places of the readings, we round off the answer to 3 s.f.

E.g.:
Mass of a grain of rice, *m*:

| Total mass of 50 grains, $m_{50}$ / g | $m_{av}$ / g |
|---|---|
| 1.0 | 0.0200 |

Average mass, $m_{av}$ = 1.0 ÷ 50
= 0.02 g → *if rounded off to 1 d.p., the answer is 0.0 g.*
= 0.0200 g (3 s.f.) → *instead of 1.d.p.*

Note: It is encouraged to take repeated measurements of the same quantity with the same instrument as it increases the reliability of readings. This is because repeated measurements may not produce the same readings. Repeated readings are typically required for experiments involving measurement of time.

8. **Direct proportion**

If a quantity *y* varies directly as another quantity *x*, this relation can be written as:

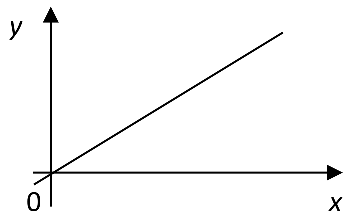
$y \propto x$

or: $y = kx$, or $k = \frac{y}{x}$, where *k* is a constant

For different values of *x* and *y*, $y_1 = kx_1$ and $y_2 = kx_2$

so, $\frac{y_1}{y_2} = \frac{x_1}{x_2}$

To show that *y* is directly proportional to *x*, plot a graph of *y* against *x*.



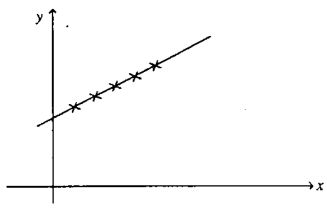

If the graph is a <u>straight line passing through the origin (0,0)</u>, then <u>***y* is directly proportional to *x***</u>.

OR: <u>*y* is linearly related to *x* AND passes through the origin</u>.

9. **Linear relationship**

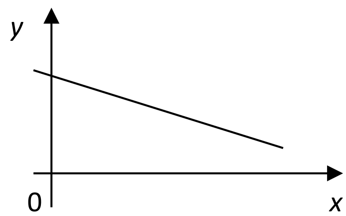
If the relation between two quantities *x* and *y* is linear, then the two quantities can be related by a first degree equation of the form $y = mx + c$, where *m* and *c* are constants. This is an equation of a straight line.

To show that *y* is linearly related to *x*, plot a graph of *y* against *x*.




If the graph is a <u>straight line</u>, then <u>***y* is linearly related to *x***</u>.

<u>Relationships of straight line graphs with negative gradients</u>:
<u>*y* is linearly related to *x*, with a negative gradient</u>.




10. **Table of values**

In an experiment, values calculated from readings must be recorded in a table. The first row of the table is the heading for each column and includes both the quantity being measured and the unit in which the measurement is made. The unit should be written in solidus (backslash) notation e.g. x / cm.

Readings taken from an experiment must be <u>widely spread</u> within a possible range, and are to be entered into the leftmost columns of the table first. This is then followed by the values calculated from these readings. The readings and calculated values should not contain units as they are already listed in the heading.

E.g.: In a simple pendulum experiment, the length *L* of the thread was adjusted from 20 cm to 100 cm. The time *t* for 20 oscillations was measured, and the period *T* and $T^2$ were calculated. The data are tabulated as with headings as follows:

| $L$ / cm | $t_1$ / s | $t_2$ / s | $t_{av}$ / s | $T$ / s | $T^2$ / $s^2$ |
|---|---|---|---|---|---|
| 100.0 | 35.3 | 35.8 | 35.6 | 1.78 | 3.16 |

**11. Units**

It is important to indicate appropriate units for all physical quantities, e.g. a length *L* in mm should be written as "*L* / mm".

The gradient of a graph of *y* / mm against *x* / mm has no unit.

For the graph of (*u* + *v*) / cm against *uv* / cm², the gradient therefore has a unit of $\frac{\text{cm}}{\text{cm}^2}$ = $\text{cm}^{-1}$.

**12. Graphs**

A graph allows us to see how a physical quantity varies with another. It also shows how well an experiment was conducted and provides a more accurate way of averaging a set of readings taken in an experiment. To plot a graph, you must take note of the following points:

**(a) Axes**

- Clearly labelled, numbered and with units (where appropriate).
- The labelling of the axes must be the same as the heading in the table of results, e.g. *y* / cm, *θ* / ºC, *m* / *g*, etc.
- 'To plot *y* against *x*' means *y* is the vertical axis and *x* is the horizontal axis.

**(b) Scales**

- There is no need to start either the y-axis and x-axis from zero unless you are asked to do so.
- Use scale ratios of 1:1, 1:2, 1:5 and 1:10. Avoid scale ratios like 1:3, 1:6, 5: 6 or other awkward scales.
- Scales must be chosen so that the graph plotted is as large as possible (in any case, it must be ≥ 50 % of the graph paper).
- When the needs of maximum use of paper space and suitable scales cannot be met at the same time, suitable scales should take priority.
- When choosing scales, you should see whether extrapolation is needed. For example, if you are asked to find y when x = 0, then the x-axis must start from zero.

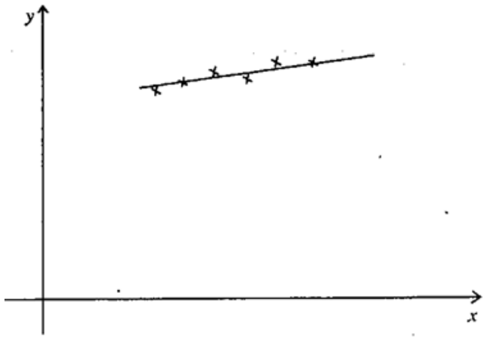
**(c) Best-fit line (curved or straight)**

Because of errors (human, equipment or both), points do not always fall neatly on a line. Instead, they would scatter about a line (best-fit) so that the number of points on one side of the line is about the same as that on the other side, and the points are as close as possible to the line.

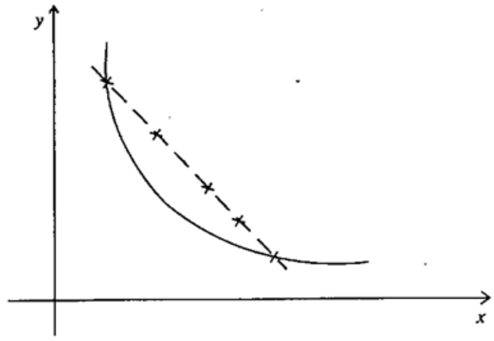
A best-fit line should have an equal number of points on either side of the line over its entire length (or at most differ by one). A good line usually does not have points that are seen to lie all above the line at one end, and all below the line at the other end.

In plotting a graph, use a sharp HB pencil (or a mechanical pencil), a 30-cm plastic transparent ruler and an flexible curve for getting a best-fit line. Use a small cross for a point plotted. Your graph should be a smooth continuous curve or a single fine straight line. Draw your line based on the plotted points rather than one which you think would give you a better result based on theory.

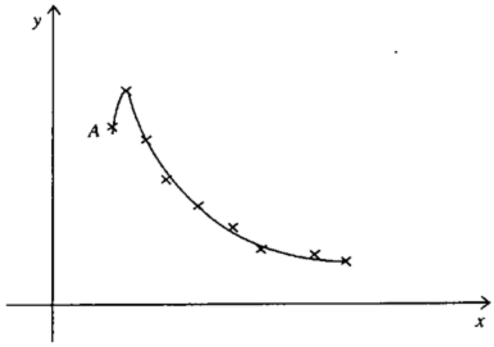
- <u>Some examples of incorrectly plotted graphs</u>:



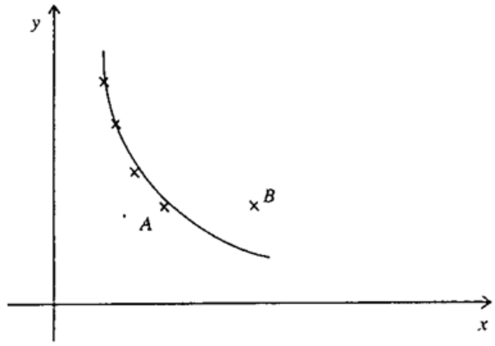

Small portion of paper space is used – due to poor choice of scales.



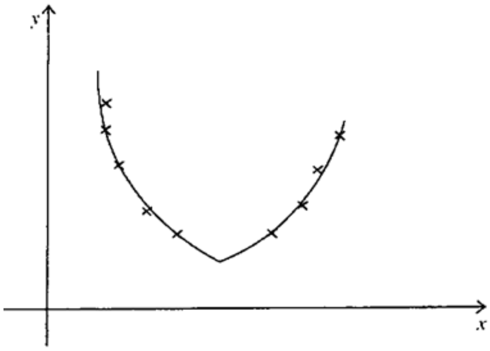

You may be told that your result is a curve, but your measurements do not show it is so.
You should check the plotting of points or repeat a few measurements.



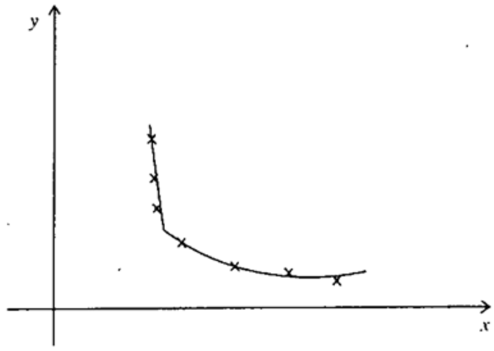

Check the point *A.*



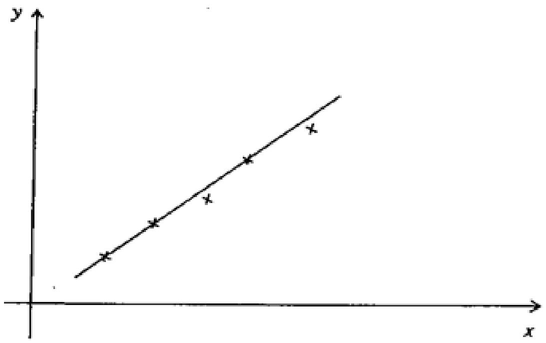

The space between *A* and *B* is too large for *B* to be included safely.
Check the point *B* or get a point between *A* & *B*.



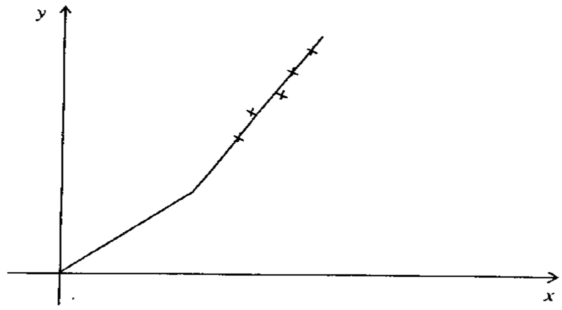

Curve with sharp turning point.
Curves should turn smoothly.



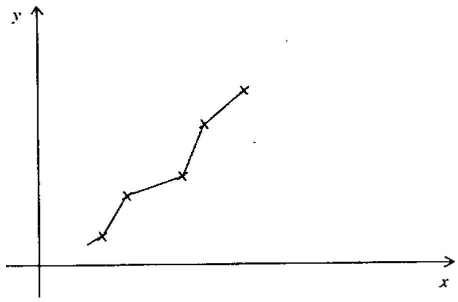

A line and a curve combined (no such graphs in Physics).




Too many stray points are on the same side. There should be approximately the same number of points on both sides of the graph, such that the graph is 'balanced'.




This straight line is forced to pass through the origin. Not all graphs need to pass through the origin (even if the theoretical relationship is direct proportion).



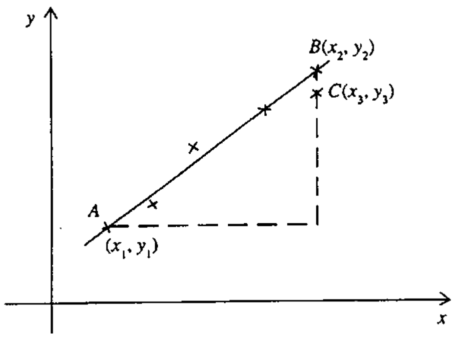

Points joined by short straight lines. There are no such 'centipede' graphs in Physics!

**(d) Gradient**

The gradient, *m* of a line *AB* is defined as: $m = \frac{\text{Change in } y,\ \Delta y}{\text{Change in } x,\ \Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$

1. To determine the gradient, you should choose two widely separated points on the graph so that $\Delta y$ and $\Delta x$ are large (ie. at least 50% of the range of *x* and *y* values on the graph).
2. To calculate $\Delta y$ and $\Delta x$, it is important **not** to use the values from your table, even if all the points lie exactly on the line. Rather, you should read the coordinates of the points ($x_1$, $y_1$) and ($x_2$, $y_2$) as accurately as possible from the graph. This is because the line of best fit represents the average of all measurements.

<u>E.g.</u>:
In the given figure, use co-ordinates of the points A and B (but not C).




3. You are expected to show, with clear workings, how Δ*y* and Δ*x* are obtained and how the gradient is calculated.

<u>E.g.</u>:

Gradient of graph $= \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{5.25 - 1.40}{8.0 - 0.7}$

$= \frac{3.85}{7.3}$

$= 0.527$

$= 0.53$ cm $s^{-1}$ (2 s.f.)

[Note: the unit of this calculated gradient is 'cm $s^{-1}$', as the graph was a 'graph of distance / cm (y-axis) against time / s (x-axis)'.]

**13. Precautions and sources of error**

- Precautions are taken in practical experiments to maximise accuracy of readings. They should be factual, constructive and clear.
- Give a reason to support why you chose this precaution, i.e. **<u>Precaution = Action + Reason</u>.**
- Statements like 'avoid parallax error' , 'connect circuit properly', 'make sure that readings are taken correctly' etc. are vague and so should be avoided or explained clearly.

**(a) General precautions for MECHANICS experiments**

**(i) Pendulum experiments**

I. The time for the first few swings should not be taken (ACTION). Start timing only when the oscillations are steady (REASON).

**(ii) Avoiding parallax error** (REASON)

To avoid parallax error (ACTIONS listed as follows):

I. View the scale reading at eye level when using a measuring cylinder, burette or ruler standing upright.
II. Place eye directly above the scale reading on the ruler in the case of a ruler lying on the bench.
III. Align the pointer with its image before taking readings for a voltmeter and/or ammeter (ACTION).
IV. Place the eye in line with the top of the meniscus of the mercury thread in the thermometer (ACTION).

**(iii) Checking for horizontal and vertical alignments**

I. Horizontal alignment (REASON): Use a spirit level, set-square or half-metre rule to measure both ends from the top of the bench (ACTION).

II. Vertical alignment (REASON): Use a plumbline or compare with reference to a vertical structure, such as a pillar (ACTION).

**(iv) Experiments with springs**

I. Oscillate spring with small amplitude (ACTION) to prevent it from oscillating out of plane (REASON).

II. Load the spring gently (ACTION) to prevent sudden and large deformation of the spring (REASON).

**(b) General precautions for LIGHT experiments**

**(i) Experiments involving pins and glass blocks**

I. When using 2 optical pins to locate the path of a light ray, place both pinsas far apart as possible (ACTION) to align them more accurately along the light ray (REASON).

***Tips involving lenses**

I. There will be times when the exact distance of an image formed on the screen is uncertain (REASON). For such cases, it is best to take the average distance of the 'sharp image' (ACTION).

II. The approximate focal length of a lens can be checked (REASON) using a distant, faraway object focused on a white screen (ACTION).

**(c) General precautions for THERMAL experiments**

**(i) Experiments using calorimeters**

I. The calorimeter should be:

- covered with a lid (ACTION) to prevent thermal energy loss through convection and evaporation (REASON).
- lagged with a jacket (ACTION) to prevent thermal energy loss through the sides (REASON).
- stirred continuously (ACTION) (with a stirrer, in the absence of which the thermometer may be used but with added caution so that the bulb does not touch the sides of the calorimeter or it may break) to ensure uniform temperature throughout the liquid (REASON).

II. When transferring a hot liquid from one container to another, do so quickly (ACTION) to minimise thermal energy loss to the surroundings (REASON).

III. When the water in the beaker is boiling, the thermometer should not be left with its bulb touching the bottom of the beaker (ACTION) so as to measure the actual temperature of the water accurately (REASON).

**(d) General precautions for ELECTRICITY experiments**

I. Ensure that there is no 'kink' in the bare resistance wires (ACTION) as this would reduce the accuracy in the measurement of the length of the wires (REASON).

II. The circuit should not be turned on for too long (ACTION) as this would produce a heating effect in the resistance wire which would affect the accuracy of e measurements of currents and/or potential differences (REASON).

III. Always check for zero errors in the measuring meters and make the necessary corrections in the readings (ACTION) to ensure accuracy of readings of current and/or potential differences (REASON).

IV. When taking readings from ammeter (or voltmeter), eye must be placed above the ammeter (or voltmeter) until the pointer covers its own image in the mirror (ACTION) to avoid parallax error (REASON).

**14. Sources of errors**

**(a) Classifications of error**

- There are generally 2 types of errors:
  I. **Random errors** are statistical fluctuations (in either direction) in the measured data due to the limitations in precision of the measurement device. Random errors usually result from the experimenter's inability to take the same measurements in exactly the same way to get exactly the same number.
  II. **Systematic errors** are reproducible inaccuracies that are consistently in the same direction. Systematic errors are often due to a problem which persists throughout the entire experiment.

| Error | Example | How to minimize it |
|---|---|---|
| **Random Error** | You measure the mass of a ring three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g | Take more data. It can be evaluated through statistical analysis and reduced by averaging over a large number of observations. |
| **Systematic Error** | The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all of your length measurements were too small.) | Systematic errors are difficult to detect and cannot be analyzed statistically, because all the data are erroneous in the same direction (either too high or too low). |

- In identifying sources of errors, highlight those which are usually unique for a particular experiment and cannot be prevented or rectified. Some guiding questions that can be used to determine sources of errors are:
  - Which experimental procedures were difficult to carry out?
  - Which measurements were difficult to observe and record accurately?
  - Other than the measured variables, what other factors could have affected the results?
- **In general, errors like wind, parallax errors, zero errors, human errors, instrument errors (e.g. markings on ruler are worn out) are preventable/ rectifiable and should not be identified as key sources of errors.**

**(b) How the accuracy of the readings are affected (by sources of error)**

- For most practical experiments, you are expected to explain how the source of error affects the accuracy of the readings. It is not acceptable to just state that 'the readings are affected' or 'inaccurate'.
- You are expected to state:
  I. which reading(s) are affected, and
  II. how the reading(s) are affected (if this can be interpreted from the experiment).
  E.g.: 'angle $\theta$ will be
  - ***larger*** than its true value' or,
  - ***smaller*** than its true value' or,
  - ***smaller or larger*** than its true value'.

  → depending on how the source of error can affect the reading(s).

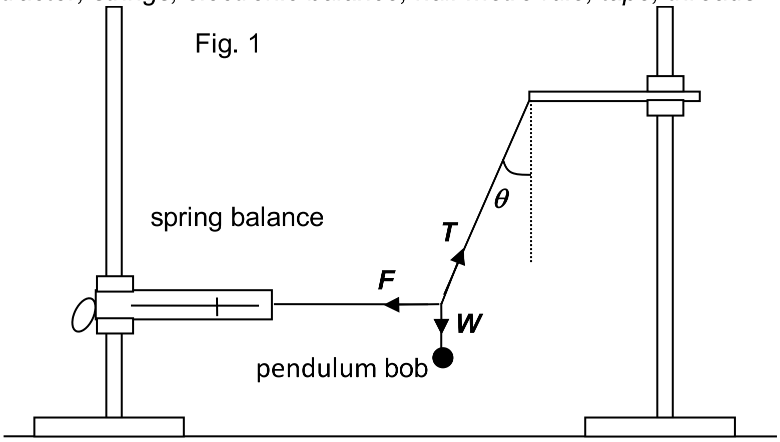
**(c) Example on source of error**

***Mechanics Experiment: To investigate forces in 2-D***

*In this experiment, you are to investigate the relationship between the forces shown in the figure below and compare your results with vector diagrams.*

*Apparatus: Retort stands with boss and clamp, pendulum bob, spring balance (0 – 1 N), protractor, strings, electronic balance, half metre rule, tape, threads*

Fig. 1




*In Fig. 1, T is the tension in the string, $\theta$ is the angle the string makes with the vertical, F is the force measured by the spring balance and W is the weight of the pendulum bob.*

*It is given that F is directly proportional to W, given by the formula F = W tan $\theta$.*

1. *Set up the experiment as shown in Fig. 1 with angle $\theta$ = 30º.*
2. *Measure and record the force on the spring balance, F, and the angle $\theta$. Calculate and record tan $\theta$.*
3. *Repeat Step 2 for further values of $\theta$.*
4. *Plot a graph of F against tan $\theta$ to determine the values of the gradient and the y-intercept. Hence, verify the relationship between F and tan $\theta$.*
5. *From your graph, determine the weight, $W_1$, of the pendulum bob.*
6. *Using an electronic balance, measure and record the mass of the pendulum bob. Hence, calculate and record its weight $W_2$.*
7. *Comment on the values of $W_1$ and $W_2$ obtained from Steps 5 and 6.*
8. *Using a set of values of F and W, draw a vector diagram to determine a value of T graphically. Compare with the calculated result for the corresponding value of $\theta$ from the formula F = W tan $\theta$.*
9. *Identify any key sources of error and explain how they affect the accuracy of the readings.*

- **Suggested sources of error and how they affect the accuracy of the readings**

  I. The spring balance may not be exactly horizontal.
  This may cause F and T to be ***larger or smaller than their true values***.

  II. It is difficult to measure $\theta$ correctly from the protractor, as the threads will move when the protractor comes into contact with them.
  This may cause $\theta$ to be ***larger or smaller than its true value***.

  III. The spring balance and protractor might not lie on the same plane.
  This may cause F and T to be ***larger or smaller than their true values***.

## 15. Planning

For this section, students are expected to be able to manipulate an existing equation from a previous part of the question to the equation provided in the planning question.

Based on the equation given in the planning question, students should be able to

**(a) Identify key variables for a given problem/question.**

There are three kinds of variables to be identified as described below:

1. Independent variable (IV): a variable with values that are selected or changed by the investigator (this is the variable that is drawn on the x-axis).
2. Dependent variable (DV): a variable that is being measured for each change in the IV (this is the variable that is drawn on the y-axis).
3. Control variable(s) (CV): a variable(s) which could affect the IV and/or DV and has to be kept constant to ensure accuracy of experimental results.

**(b) Outline an investigative procedure to investigate the problem/question**

The description of the procedures should be brief but concise. It includes describing how the IV is varied and measured, and how the DV is measured. Highlight the experimental instruments used to vary and measure the IV, and measure the DV respectively.

After that, highlight the number of data points to be taken, and specify that the data points should be of a wide range. A good template (if the IV and DV have a linear relationship) to be used is as follows:

"Take 5 sets of values, with a wide range of x."

**(c) Describe how the data should be used in order to reach a conclusion.**

A description of the graph to be plotted should be provided. Students may also be expected to sketch the shape of the graph obtained, with the axes labelled accordingly and the y-intercept drawn correctly (ie. positive or negative, and to include value if possible).

In some other instances, students may have to identify which part of the equation represents the y-intercept or gradient.

**(d) Identify the sources of error of the experiment and state precautions that should be taken to keep errors to a minimum.**

A description of the key sources of errors and precautions to be taken may be required.

**(e) Example of Planning Question**
**O-Level Specimen Paper – Paper 3 (Practical)**
**(Syllabus 6091 - Physics)**

2

**Section A**

1 *In this experiment, you will investigate the extension of a spring in a simple model of a suspension bridge.*

You have been provided with

- a spring,
- a stand, labelled A with boss and clamp,
- a mass labelled M,
- a 30 cm rule,
- a set square,
- a metre rule with holes at the 10.0 cm and 90.0 cm marks,
- a second stand labelled B, with a boss and clamp to hold the pivot,
- a pivot,
- a loop of string,
- an S-hook.

**(a)** Measure and record the unstretched length *L* of the coiled part of the spring, as shown in Fig. 1.1.

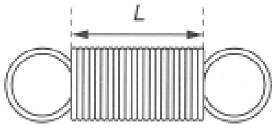



**Fig. 1.1**

*L* = .......................................................... [1]

**(b)** You are to set up the apparatus as shown in Fig. 1.2.

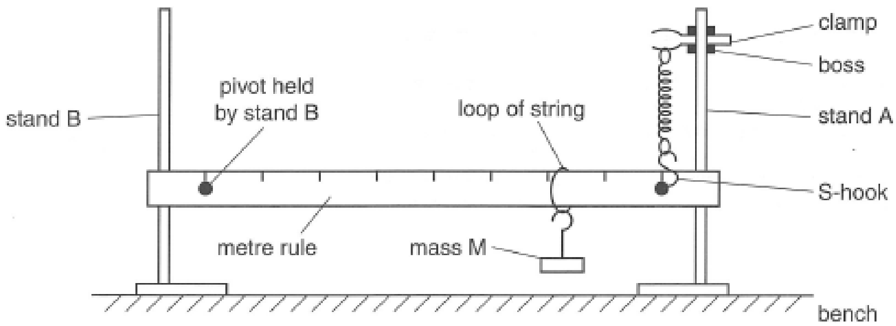



**Fig. 1.2**

- Suspend the metre rule at the 10 cm mark, using the pivot held in stand B.
- Use the loop of string to suspend mass M from the metre rule at the 70 cm mark.
- Pass the S-hook through the hole in the metre rule at the 90 cm mark.
- Attach the S-hook to the spring and use stand A to support the metre rule.
- Adjust the height of the boss on stand A so that the metre rule is horizontal.

**(i)** Measure and record the new length $L_1$ of the coiled part of the spring and determine the extension $e$ of the spring using the equation

$$e = L_1 - L.$$

$L_1$ = ..................................................................

$e$ = ..................................................................

[1]

**(ii)** The upward force $T$ exerted by the spring is given the equation

$$T = ke$$

where $k$ is the spring constant of the spring and $e$ is the extension of the spring.

Given that $k$ is 0.25 N / cm, calculate $T$.

$T$ = .............................................................. [1]

**c)** When the metre rule is horizontal, the principle of moments gives the equation

$$W_R y + W x = T z$$

where

- $W_R$ is the weight of the metre rule,
- $W$ is the weight of mass M,
- $x$ is the distance between the pivot and loop of string,
- $y$ is the distance between the pivot and the centre of mass of the metre rule,
- $z$ is the distance between the pivot and the S-hook.

**(i)** With the metre rule horizontal, record the values of $x$, $y$ and $z$.

$x$ = ..................................................................

$y$ = ..................................................................

$z$ = ..................................................................

[1]

**(ii)** Using your value for $T$ from **(b)(ii)** and your values in **(c)(i)**, calculate a value for $W_R$. Assume that the centre of mass of the metre rule is at its centre and $W$ = 1.96 N.

$W_R$ = .............................................................. [1]

(d) Plan

The equation in (c) may be written in the form

$$T = \frac{Wx}{z} + \frac{W_R y}{z}.$$

Using the same apparatus as in Fig. 1.2, plan an experiment to investigate this relationship.

Your plan should include

- a list of the quantities that remain constant,
- a description of how you would perform the experiment,
- a statement of the graph that you would plot to test the relationship,
- an explanation of how $W_R$ would be found from the graph.

**Suggested solution:**

$$T = \frac{W}{z}(x) + \frac{W_R y}{z}$$

Notice that this equation is derived from the one in **(c)**.

$$\Rightarrow y = mx + c$$

where:
$y$ = $T$ (upward force exerted by spring)
$x$ = $x$ (distance between pivot and loop of string)
gradient, $m = \frac{W}{z}$
$y$-intercept, $c = \frac{W_R y}{z}$

**List of quantities that remain constant [1]**

1. $W$ (weight of mass M)
2. $y$ (distance between pivot and centre of mass of metre rule)
3. $z$ (distance between pivot and S-hook)

**Description of how to perform the experiment [2]**

State brief, concise steps

- How to vary and measure $x$-axis variable:
  Shift the mass along the ruler and adjusting the position of the height of the boss on stand A so that the metre rule is horizontal.
  Record the value of $x$ by reading off the metre rule.
- Measure $y$-axis variable:
  Record the corresponding value of $L_1$, and find the extension of the spring, $e$, by subtracting $L$ from $L_1$.
  Find the corresponding value of $T$ using $T = ke$, where k is the spring constant (= 0.25 N/cm).
- Take 5 sets of values (for straight lines), with a wide range of $x$.

**Statement of the graph plotted to test relationship [1]**

Plot $T$ ($y$-axis) against $x$ ($x$-axis).

**Explanation of how $W_R$ would be found from graph [1]**

$$y\text{-intercept} = \frac{W_R y}{z} \Rightarrow W_R = \frac{(y\text{-intercept})(z)}{y}$$