CAMBRIDGE OL PHYSICS
PAPER-6 REVIEW
MAY/JUNE 2019/1
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What is paper-6 exam about?

You may be asked questions on the following experimental contexts:

1. **General Physics**
    - Measurement of physical quantities
    - Springs & Balances
    - Timing, Motion or Oscillation
2. **Thermal Physics**
    - Cooling and heating
3. **Electricity and Magnetism**
    - Electric circuit of a resistor
    - Electric circuit of a potential divider
4. **Wave properties**
    - Optic equipment such as mirrors, prisms or lenses
5. **Procedure using a simple apparatus, in situation where the method may not be familiar to you**

What are the skills needed to tackle the exam?

1. **Skills regarding handling the experiment**
    - **How to measure the length/thickness/diameter using the suitable tool?**
        - Measuring length
        - Measuring the thickness of thin object
        - Measuring the diameter of a cylinder or a sphere
        - Measuring the diameter of ball bearings
        - Measuring circumference of a cylindrical-shaped object (cup, test tube...)
        - How to check that the ruler is vertical to the bench?
        - How to check that the ruler is horizontal to the bench?
    - **How to measure the volume?**
        - Liquids
        - Regular solids
        - Irregular solids
            - Measuring cylinder
            - Displacement can
    - **How to measure the mass?**
    - **How to measure the time?**
    - **How to read results on Ammeter and Voltmeter?**
    - **What are the electricity symbols?**

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2. **Skills regarding handling the data**
    - **Calculation skills**
        - Significant Figures and rounding
        - Calculating the average according to SF
        - Experimental accuracy limit (within & beyond)
    - **Graphing skills**
        - How to best represent and plot the data?
        - How to make line fitting?
        - How to calculate the gradient/slope (triangle method)?
        - How to describe the relation represented by the graph?
            - Linear
            - Direct
            - Inverse
            - Graph with x/y reciprocals of inverse relation (Direct)
    - **Tabulating data skills (making a table)**

3. **Experiments (next items will be studied for each experiment individually)**
    - Aim of the experiment
    - Apparatus
    - The procedure of the experiment
    - Precautions to be taken into consideration
        - Accuracy precautions
        - Safety precautions
    - Difficulties and how to overcome them?
    - Possible causes of error (inaccuracy)
    - Conditions kept constant for fair comparison OR to repeat the experiment
    - Common questions

1. Skills regarding handling the experiment

A. How to measure the length?

a) Measuring the length of an object:

I. <u>The ruler (up to 30 cm)</u>

- Accuracy: 0.1 cm = 1mm
- The ruler should be placed as close to the object as possible.
- The eye must be directly above the mark on the scale or the thickness of the ruler causes parallax error.

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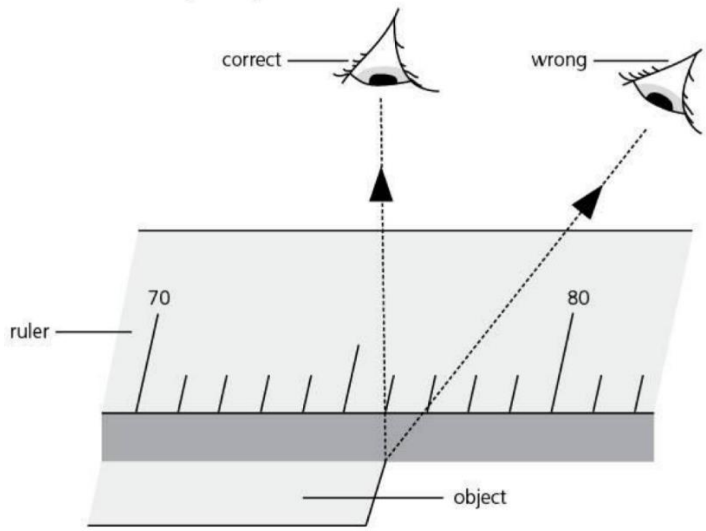
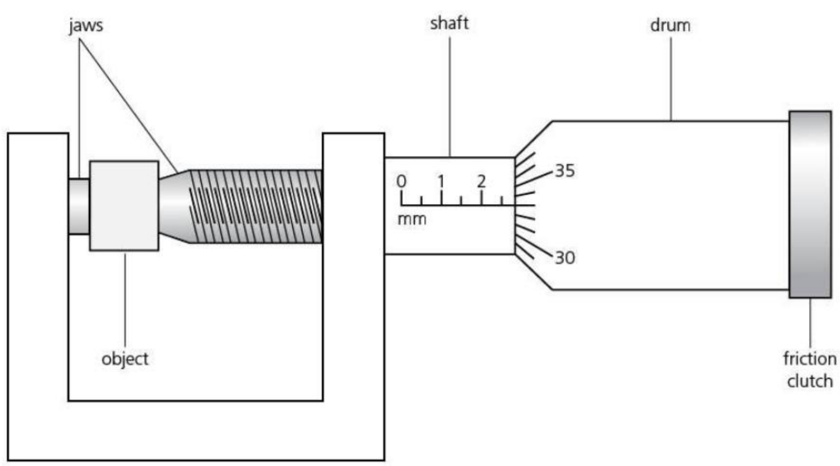


- When measuring extensions (of springs, for example), it is best to record the actual scale readings for the stretched and relaxed lengths, and then work out the extension afterwards.

II. **<u>The micrometre screw gauge (up to 2 cm)</u>**

- Accuracy: 0.01 mm = 0.001 cm
- Can be used to measure small objects in the millimetre range.
- One revolution on the drum (50 divisions) = one division on the shaft (0.5mm) i.e. one drum division = 0.5/50 = 0.01 mm (accuracy).
- The total reading = shaft scale reading + drum scale reading $\times$(accuracy)
- A friction clutch ensures that the jaws always exert the same force on an object and over-tightening does not occur.
- Before making measurement, check to ensure that the reading is zero when the jaws are closed, otherwise a zero error must be allowed for where a reading is taken**.**



The object length = 2.5mm on the shaft scale + 33 division on the drum scale = 2.5mm + (33 $\times$0.01mm) = 2.5mm + 0.33mm = 2.83 mm

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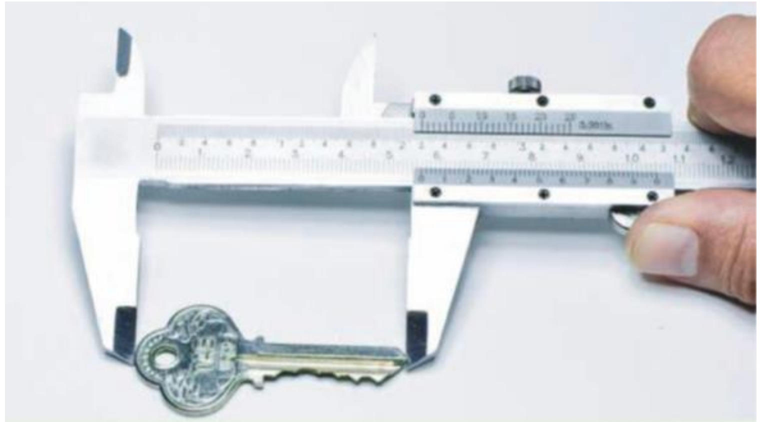
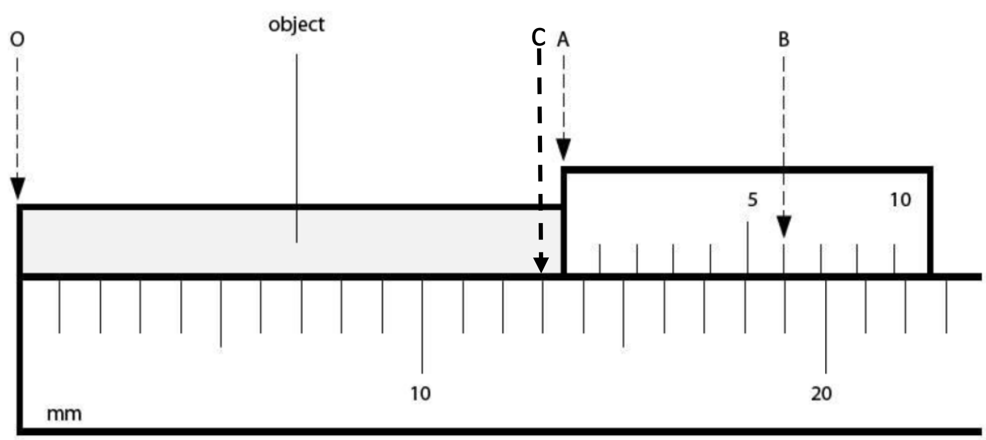
III. Vernier scale (up to 15 cm):



- Accuracy: 0.1 mm = 0.01 cm
- Has two scales, the mm scale and Vernier scale (9.0 mm divided into 10 divisions 10.0 equal divisions). One Vernier division = 0.9 mm.
- The correct reading = the reading on the mm scale at coincidence – the number of marks on Vernier scale at coincidence $\times 0.9$ mm OR The correct reading = The reading on mm scale at the end of the object + the number of marks on Vernier scale$\times$0.1 mm.

The object length = OB – (6×0.9 mm) =19 mm - 5.4 mm = 13.6 mm OR
The object length = OC + (6×0.1mm) = 13 mm + 0.6 mm = 13.6 mm



IV. The meter rule (up to 1 m)

Accuracy: 1 mm = 0.1 cm

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V. **The measuring tape (distances more than 1 m)**

Accuracy: 1 cm

Notes:

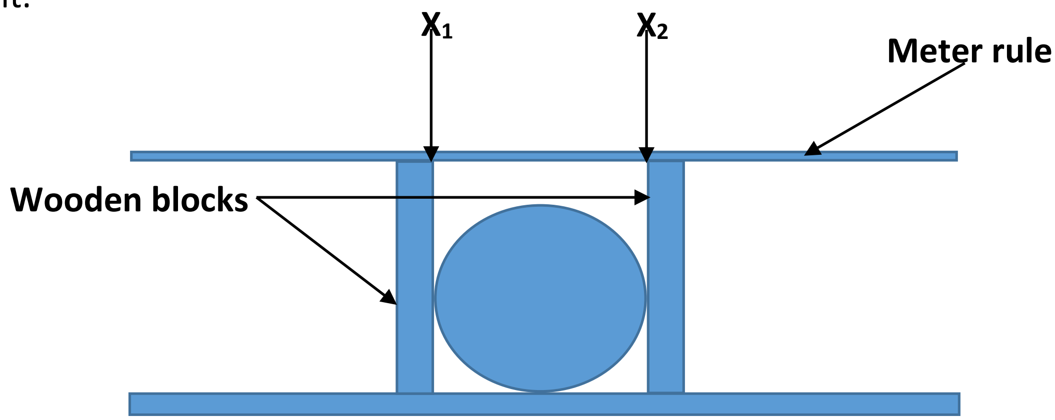
- each reading should be repeated several times to get an acceptable average.
- Some readings should be excluded if their values are very far from the other readings (abnormal readings).

b) **Measuring thickness of a thin object:**

Multiples can be measured and the divided to find an average value. For example, to obtain the average thickness of one page of a book, measure the thickness of 20 pages and divide your result by 20.

c) **Measuring the diameter of a cylinder or a sphere:**

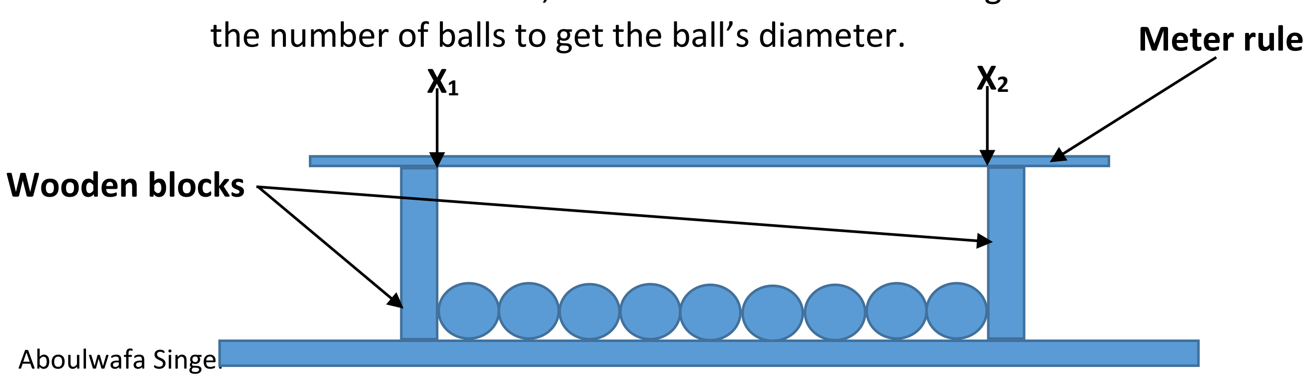
To measure the diameter of a sphere or a cylinder, place it between two vertical blocks and take the difference between the two readings at the edges of it.



Diameter = $X_2 - X_1$

d) **Measuring Diameter of ball bearings:**

To measure the diameter of ball bearings collect them together in a row between two vertical blocks, measure the total length and then divide by the number of balls to get the ball's diameter.



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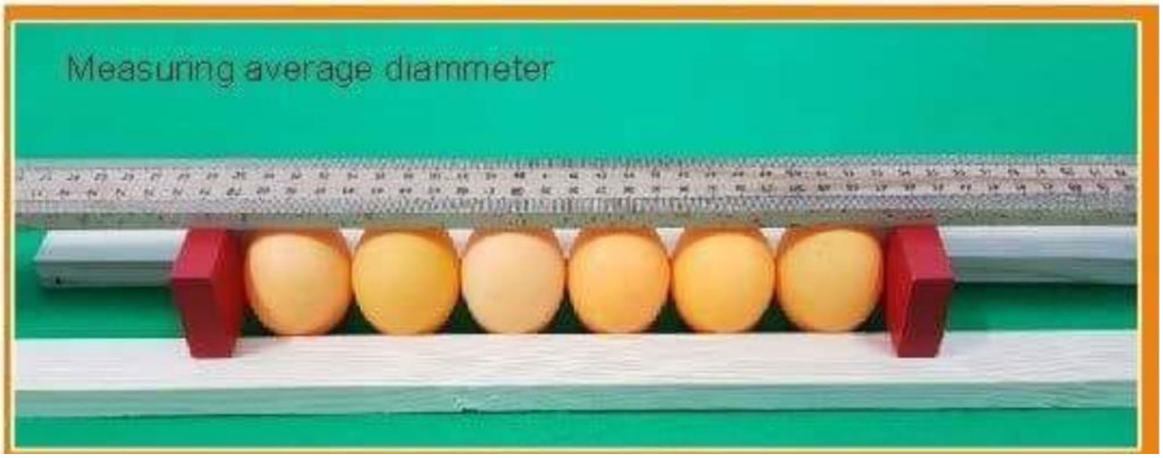
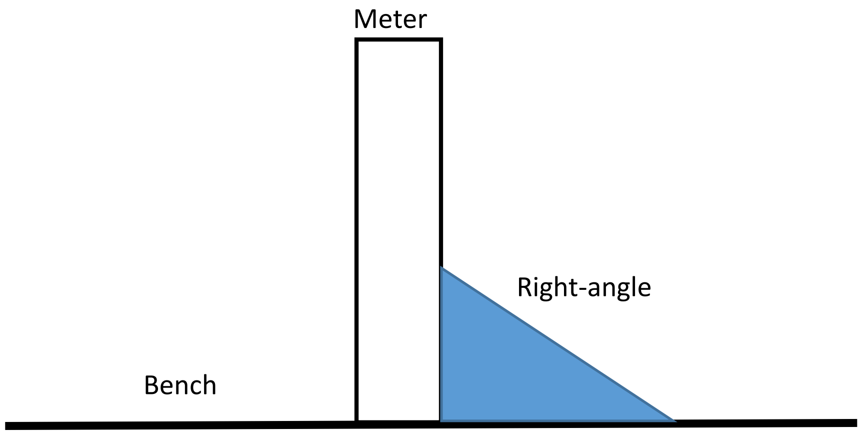
Diameter = $(X_2 - X_1)/N$



e) How to check that the ruler is vertical to the bench?

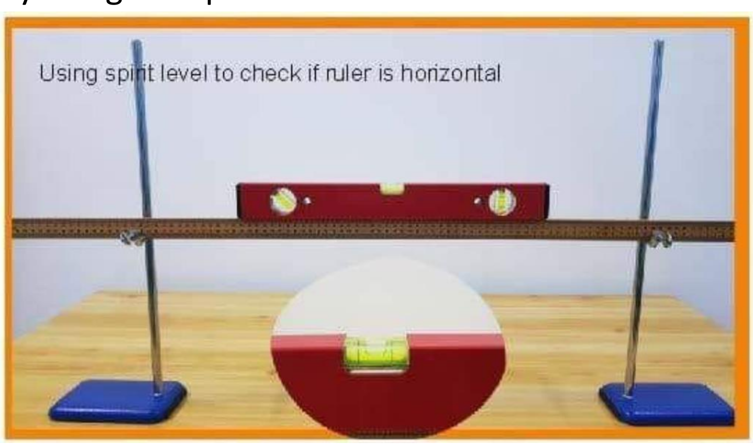
- By using set square method: put the set square (right-angle triangle) so that one side of the angle is parallel to the bench, while the other side of the right angle is parallel to the meter rule.



- By protractor

f) How to check that the ruler is horizontal to the bench?

- By using the spirit level



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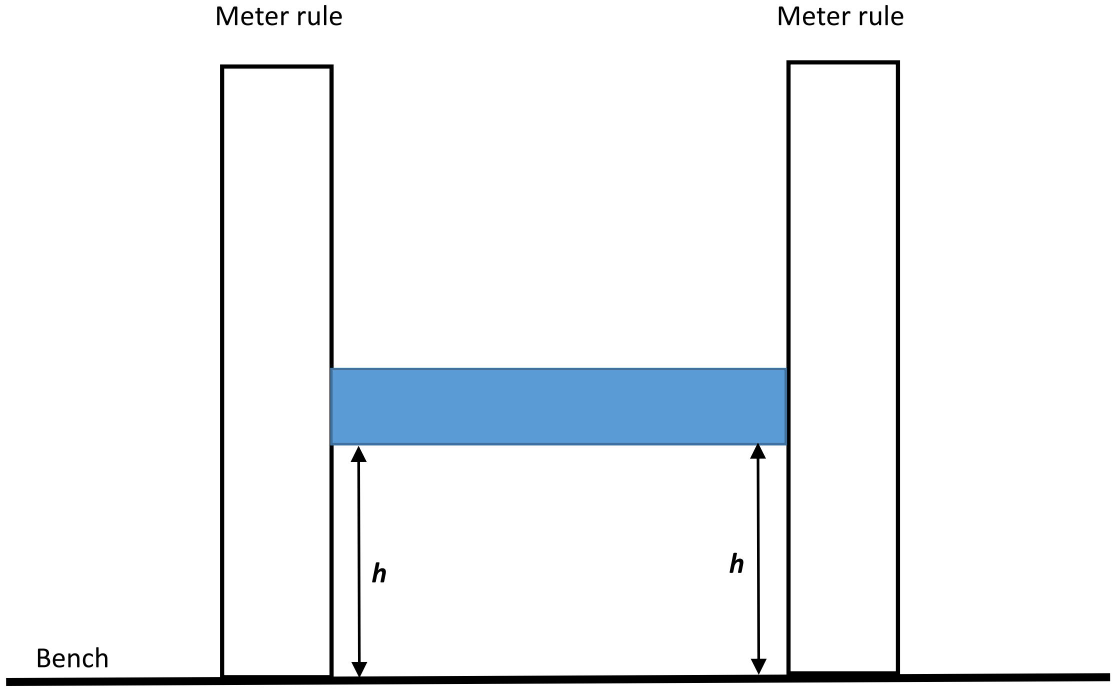
- By measuring the height of the meter rule above the bench (*h*) from both sides (must be equal).



B. How to measure a circumference of a cylindrical-shaped object (cup, test tube…)?

To measure a circumference of a cylindrical-shaped object, wind a string 10 times around it then unwind it, measure the length of the string and divide by 10. The string should be thin, tangent and without spacing between turns.

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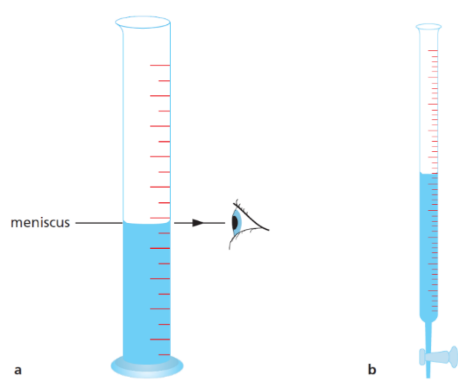
- **Reasons for inaccuracy:**
  - Using thick string
  - The marks are thick
  - Leaving space between turns
  - Winding turns at angles
  - Stretching of the string
- **Precautions:**
  - Use thin string
  - Thin marks
  - Tangent turns without spacing
  - Take more number of turns
  - Make sure that the string isn't stretched

Note: Dividers could be used if there is a difficulty using the measuring tool directly or when the distance is not easy-to-access. The divider is kept fixed and then measured by the rule.

C. How to measure the volume?

1) <u>Volume of liquids</u>

- The volume of relatively large volumes is measured using measuring cylinder (a). Small volumes are measured using a pipette or a burette (b).
- The unit of volume is ml. $1ml = 1cm^3$, $1l = 1dm^3$ and $1m^3 = 10^6m^3$.
- The following precautions should be taken into consideration:
  - The measuring cylinder must be vertical by setting on a horizontal bench.
  - The eyes should be perpendicular to the scale to avoid parallax
  - The reading should be taken at the *bottom* of the meniscus of the liquid surface unless for *mercury*, it should be taken at the *top* of the meniscus.



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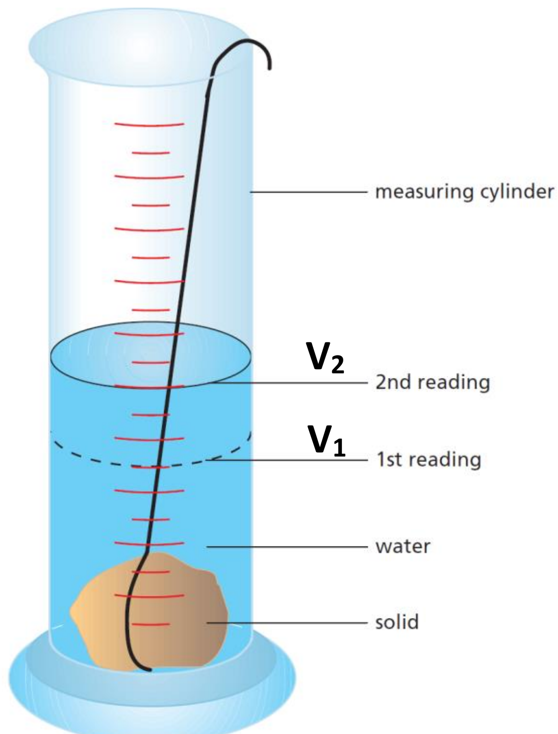
2) **<u>Volume of regular solids:</u>**

- Volume of a rectangular block = Length × width × Height
- Volume of a sphere of radius R = $\frac{4}{3}\pi R^3$
- Volume of a cylinder of radius R and height H= $\pi R^2 H$

3) **<u>Volume of irregular solids:</u>**

- **By using *measuring cylinder (Accuracy 1cm^3)*:**
  - Fill the measuring cylinder with some water with a volume V_1.
  - Insert the solid gently in the cylinder and make sure it is totally immersed.
  - Measure the volume of the solid and the water V_2.
  - The volume of the solid is $V_2 - V_1$.



- **By using *displacement can and measuring cylinder:***
  When the solid is large to be inserted in the cylinder.
  - Fill the displacement can to its full capacity.
  - Insert the solid gently in the displacement can and collect the volume of water that floods from the can in an empty measuring cylinder.
  - Take the volume reading in the measuring cylinder which is the volume of the solid.

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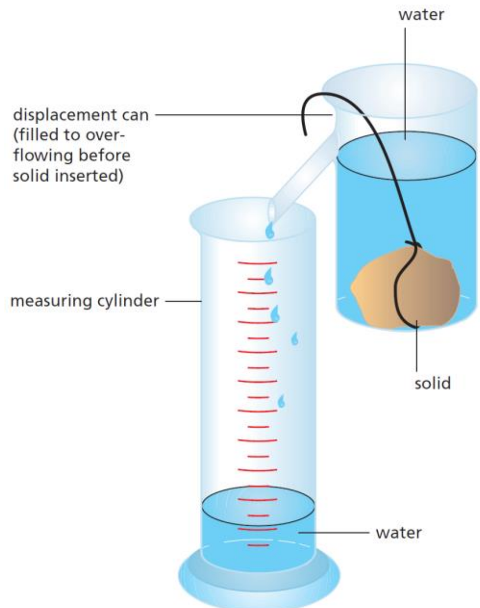
- **Note:** in both methods, if the solid traps air inside it so that some volume of air cannot be occupied by the liquid, the measured volume is greater than the real volume of the solid.



D. How to use measure the mass?

1. Mass can be measured by a digital top-pan balance, which gives a direct reading of mass placed on the pan.
2. The unit of mass is kg = 1000 g
3. The mass of a very light object like a pin is determined by finding the mass of large number of these objects and then divided by the number of object to get the average mass of a single object.
4. Note:
   - The balance should be clean, horizontal and reads zero before applying a mass on it.
   - A digital top-pan balance is ***accurate*** to the size of the smallest mass which can be measured on the scale setting you are using, probably 1 g or 0.1 g.

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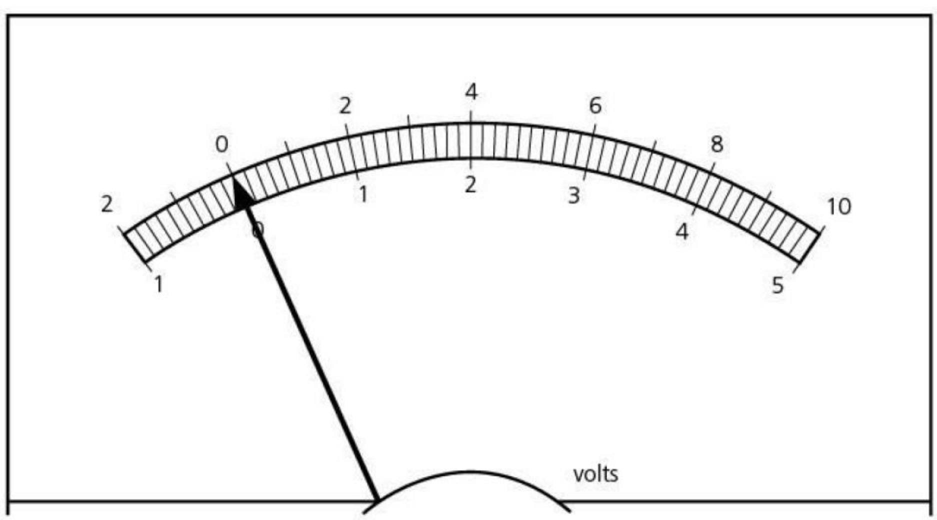
E. How to measure the time?

- Long times (hours) are measured using a clock or a watch.
- Shorter times (up to one hour) are measured using a stopwatch. It should be reset to zero before pressing start: otherwise a correction should be performed.
- Very short times (up to s sec) are measured using electronic /digital timer

F. How to read results on Ammeter and Voltmeter?

- An *ammeter* measures electric current
- The unit of current is ampere (A)
- An ammeter should be placed *in series* with the device in which the current is to be measured.
- A *voltmeter* measures potential difference (p.d.).
- The unit of potential difference is the volt (V).
- A voltmeter should be placed *in parallel* with the device across which the p.d. is to be measured.
- There are two types of Ammeters/Voltmeters, *analogue* and *digital.*



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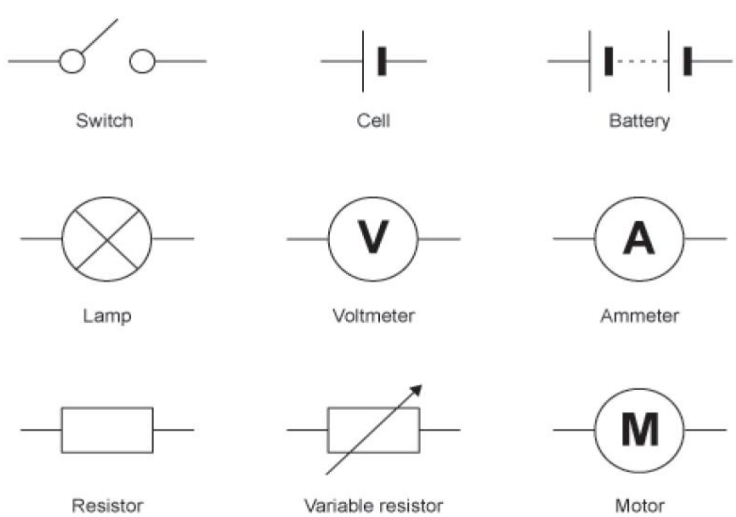
- If the analogue meter is used, the accuracy = 1 division value.
- The division value = difference between two successive numbers on the scale/number of divisions between them.
- For the upper scale in figure the division value= (2-0)/10= 0.2 V= the accuracy.
- For the lower scale in figure the division value= (1-0)/10= 0.1 V= the accuracy.
- As with rulers, the eye should be immediately above the pointer when taking a reading to avoid introducing parallax errors; if there is a mirror behind the pointer, the needle and its image should coincide when you take a reading.
- Check that the meter reads zero when there is no current; adjust the screw at the base of the pointer until it reads zero.
- Digital meters allow different ranges to be selected and the display gives measurement in whatever units have been chosen.
- The reading will be ***accurate to the last figure on the display,*** so for small currents and voltages it will be more accurate to use the mA or mV setting.

- **<u>Tips for using meters in electrical circuits:</u>**
  - Construct circuits with the power switched off or battery disconnected and the meter last.
  - Check that meters are connected with the correct polarity and are set to their ***lower sensitivity*** initially.
  - Set the power supply output to zero before you switch it on.

G. What are the electricity symbols?



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2. Skills regarding handling the data

A. Calculation skills:

a) Significant Figures and rounding

Note: Always show answers to 2 or 3 significant figures. Double check all calculations at the end of the test and check that you have given the correct unit.

- When doing calculations, your answer should have the same number of significant figures as the measurements used in the calculation. For example, if your calculator gives an answer of 1.23578, this should be given as 1.2 if the measurements on which you based your calculations have two significant figures and 1.24 if your measurements have three significant figures.
- **Example: if you measure lengths in mm, then:**
  - When you use a rule, no SF is allowed to the right of the decimal point as the accuracy is only 1mm. 15.7 mm should be written as 16.0 mm.
  - When you use a Vernier scale, only 1 SF is allowed to the right point as the accuracy is only 0.1 mm. 15.73 mm should be written as 15.7mm.
  - When you use a micrometre, only 2 SFs are allowed to the right of the decimal point as the accuracy is only 0.01 mm. 15.73 mm should be written as 15.73 mm and 15.77mm is rounded to 15.80 mm.
- If values of different numbers of SFs are used to calculate a quantity, quote your answer to the smallest number of SFs.
- If a number is expressed in standard notations, the number of significant figures is the number of digits before the power of 10; for example, 6.24×10^2 has three significant figures.
- In deciding the least SF, you look at the following figure; if that is less than 5. You round down (1.23 becomes 1.2) but if it is 5 or above, you round up (1.235 becomes 1.24).

b) Calculating the average according to SFs:

- Sum the values for a quantity you have measured and divide the sum by the number of values to obtain the average.
- For example if you measure the length of a pendulum as 81.5 cm and 81.6 cm, then:

$$\text{The average value} = \frac{(81.5+81.6)}{2}\ \text{cm}$$

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$$= \frac{(163.1)}{2} \text{ cm}$$

= 81.55 cm

= 81.6 cm

The value has been given to 3 SFs because that was the accuracy of the individual measurements on which the calculation was based.

c) Experimental accuracy limit (below & beyond)

- Subtract the smaller number from the greater number.
- Divide the result by the greater number
- Multiply the result by 100 to obtain the percentage error.
- If the percentage is below 10%, then the results are ***equal within the experimental accuracy.***
- If the percentage is beyond 10%. Then the results are ***not equal within the experimental accuracy.***
- Example: An experiment is performed to determine the focal length of a lens by two different methods.

f_1 = 16.0 cm f_2 = 15.5 cm

$$\% = \left(\frac{\text{the greater value} - \text{the smaller value}}{\text{the greater value}}\right) \times 100$$

$$\% = \left(\frac{16.0 - 15.5}{16.0}\right) \times 100 = 3\%$$

  - The results are equal within the experimental accuracy as the percentage (3%) is less than 10% (below the experimental accuracy limit).

B. Graphing skills

a) How to best represent and plot the data?

- You will need about ***6 points taken over as large a range as possible*** to plot a graph.
- Choose scales that make it easy to plot the points and use ***as much of the graph paper as possible (at least half of X axis and half of Y axis unless more)*** **but don't use an awkward scale to force the graph to take up all the grid.** If your range of values is for example 89 to 170, you don't need to start at zero, start at 80.
- Make sure you ***label each axis of graph with the name and unit*** of the quantity being plotted e.g. Resistance / Ω (Don't write Resistance (Ω), use the forward slash "/").

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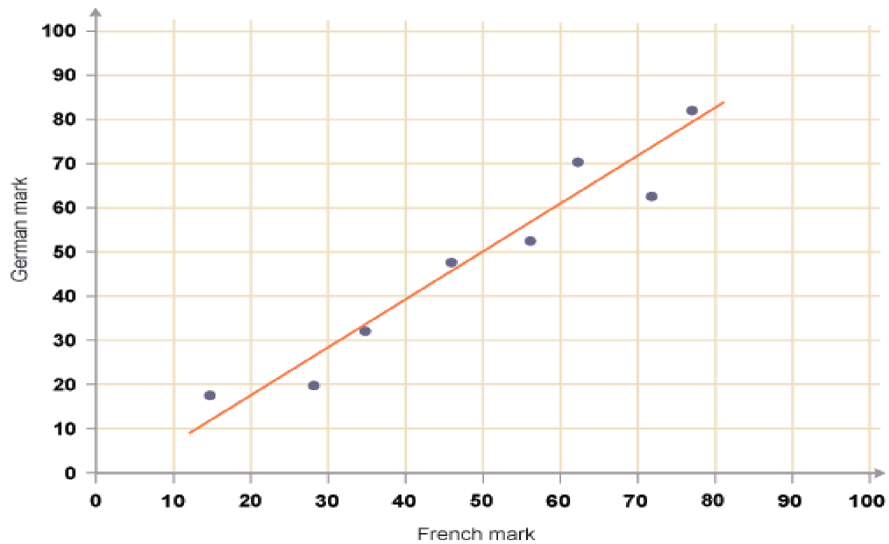
- Plot all points to within ½ small square (examiner checks this very carefully).
- Mark the data points clearly with a ***dot in a circle or a cross with a sharp pencil.***
- Join up your points with a ***single, continuous, sharp and smooth line or curve***.

b) How to make a line fitting?



- In practice, points plotted on a graph from actual measurements may not lie exactly on a straight line due to experimental error.
- The best straight line is then drawn through them such that they are equally distributed about it; this automatically averages the results.
- Do not force the line through the origin unless the graph should go through the origin (for example this is fine in the case of someone starting a stopwatch at a start line if you are plotting time against displacement).
- If possible, repeat any anomalous measurement/calculation to check that they have been recorded and/or calculated properly or try to identify the reason for the anomaly.

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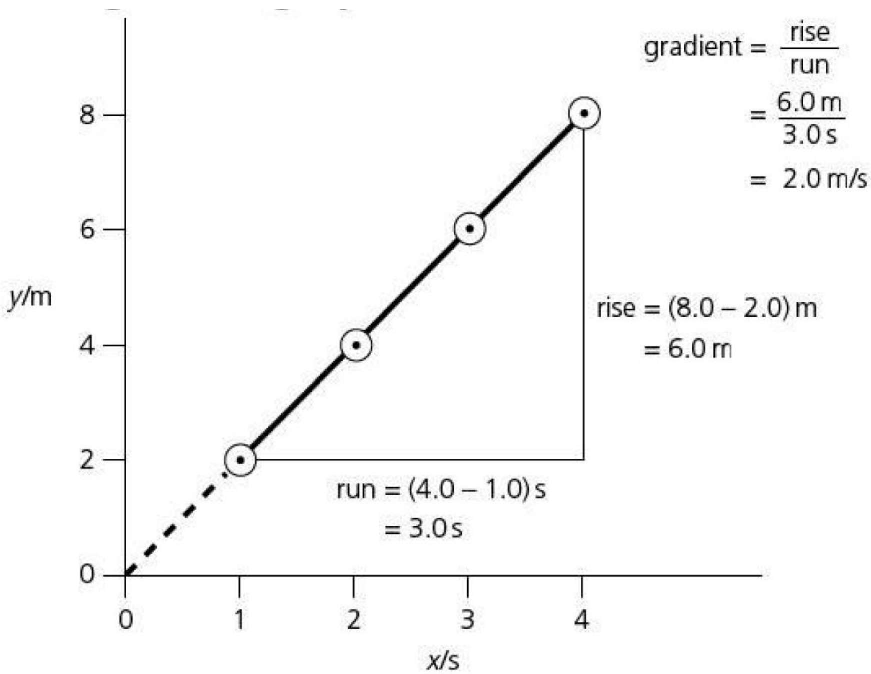
c) How to calculate the gradient/slope (triangle method)?



x/s	y/m
1.0	2.0
2.0	4.0
3.0	6.0
4.0	8.0

- The slope or gradient of a straight-line graph can be determined by the triangle method.
- Use as long length of line as possible to determine the gradient from the ratio of the vertical (rise) to the horizontal (run) of the triangle chosen.
- It is best practice to draw the triangle in your exam paper with a thin line.
- $$\text{Gradient} = \frac{rise}{run}$$
  $$= \frac{6}{3}\ m/s$$
  $$= 2\ m/s$$
- Show your working out – put numbers into (y2 – y1) / (x2 – x1)

d) How to describe the relation represented by the graph?

I. Linear:

- The straight line equation is:

  Y = mx + c

  where, m is the slope/gradient and c is constant. The constant c represents the intersect point with the Y axis (at X = 0).
- X and Y are called to have a linear dependence relation.

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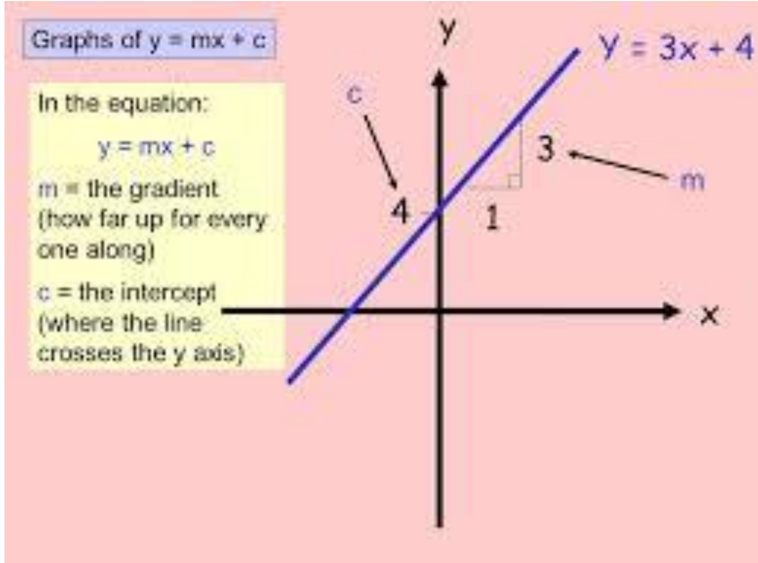


II. **Direct proportionality:**

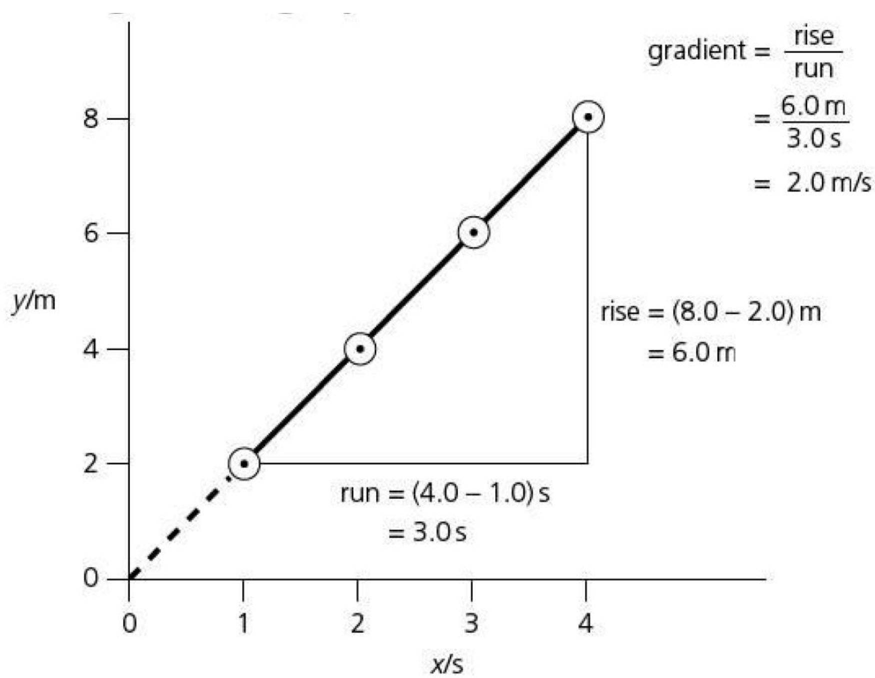
- If the constant in the linear equation becomes zero as a special case, then the linear equation becomes:

$$Y = mX$$

In this case, the line intersects at X = 0 and Y = 0 (the origin) and the relation is said to be ***DIRECT*****.**

- Each *DIRECT* equation is *LINEAR* but not each *LINEAR* equation is *DIRECT*.
- The main sign of the *DIRECT* equation is that:

$$\frac{Y}{X} = m \text{ is always constant all over the graph.}$$



x/s	y/m
1.0	2.0
2.0	4.0
3.0	6.0
4.0	8.0

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- **For this graph, $\frac{Y}{X} = 2$ for all the points on the graph.**

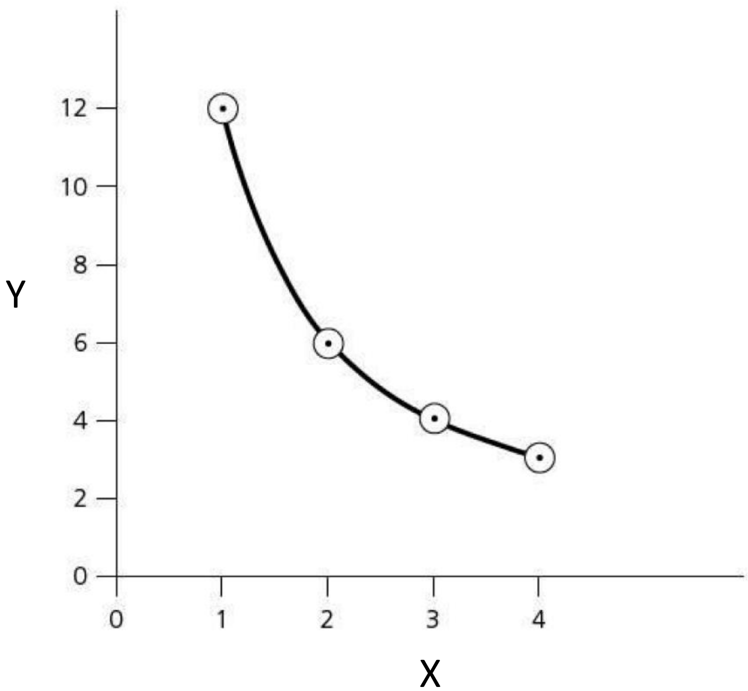
(Y∝X)

III. Inverse proportionality:

- If the relation between X and Y is:

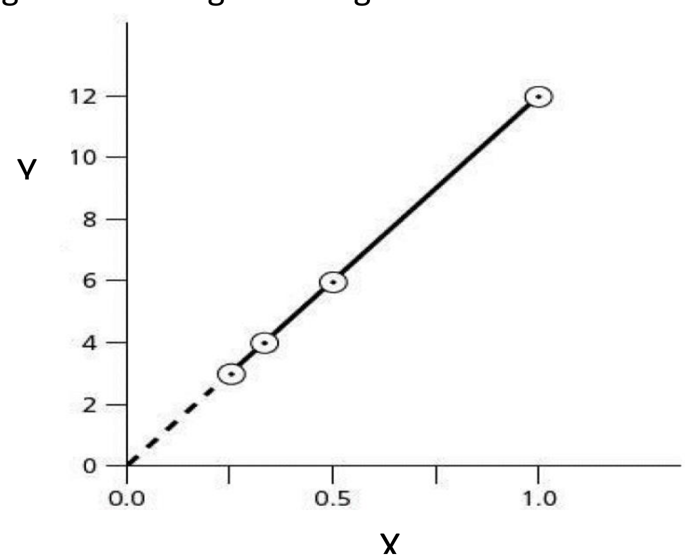
$$Y = \frac{m}{X}$$ **, then $YX = m$ is always constant.**

- The continuous line in this case is a curve.



X	Y	1/X
1.0	12	1.00
2.0	6	0.50
3.0	4	0.33
4.0	3	0.25

- For the graph above, $YX = 12$ for all the X and Y values. It represents an *INVERSE* proportionality relationship.
- If, however, 1/X is plotted against Y (or X is plotted against 1/Y) then a straight line through the origin is obtained.



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- In this case 1/X is proportional to Y and there is an inverse proportionality between X and Y:

$$\frac{1}{X} \propto Y \qquad \text{OR} \qquad \frac{1}{Y} \propto X$$

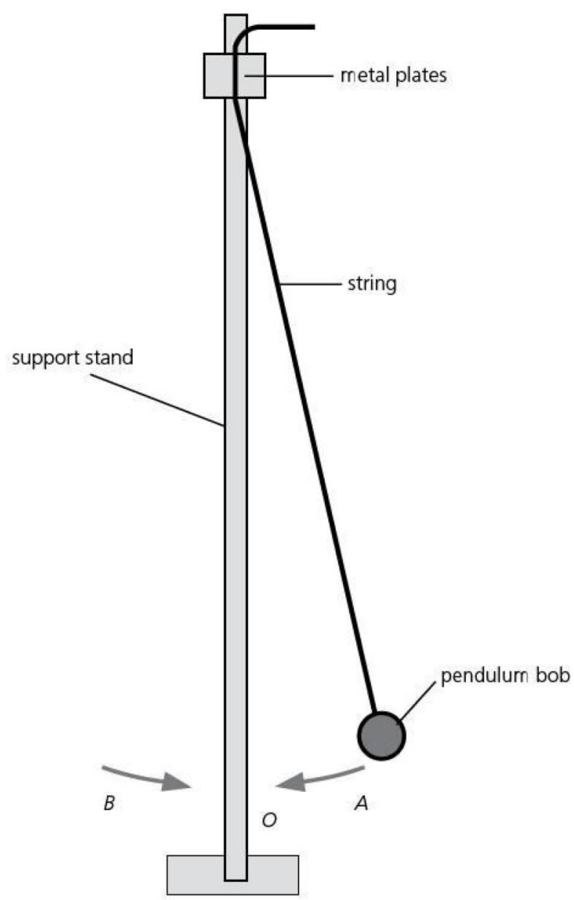
e) Table skills:

- Numerical values should be given to the number of significant figures appropriate to the measuring device.
- Column headings in tables of readings must be headed with the quantity and unit as in these examples: I/A, or t/s, or y/m.
- Any ***calculated quantity*** should have the ***least number of SFs*** of the quantities that were involved in the calculation (or at most one more).
- If an ***average*** is calculated, it should be written to the least number of ***decimal places*** of the averaged numbers.

Experiments:

1. General Physics:

1.1 Simple pendulum



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Aim	To investigate the effect of length and mass on the period of a simple pendulum.
Apparatus	Support stand-String-2 metal pendulum bobs of different mass-metre rule-scales.
Procedure	1. Measure the length of the pendulum from the point of support to the centre of the bob; repeat measurements and calculate the average. 2. Measure the time taken for the bob to make ten small angle oscillations; Repeat the measurement and calculate the average time. 3. Work out the period, *T,* of the pendulum –this is the time needed for one oscillation. 4. Measure the mass of the pendulum bob. 5. Repeat steps 1 to 4 using a longer pendulum length. 6. Repeat steps 2 to 4 using a heavier pendulum bob and the same pendulum length as was used in step 5.
Precautions to improve accuracy or to give more reliable results	▪ No air currents in the place. ▪ Take the time of number of swings then divide the time measured by the number of swings to get *T.* ▪ Repeat and take the average. ▪ Look perpendicular to ruler while measuring the height. ▪ Use the set-square as a horizontal reference. ▪ Metre rule should be close to pendulum. ▪ Measure the length from the centre of the mass of the bob
Conditions kept constant to fair comparison or to repeat the experiment	▪ Same stopwatch. ▪ Release the bob from the same height (same amplitude). ▪ Same number of swings. ▪ Same shape of bob. ▪ Same size of bob.
Common questions	▪ **Explain why measuring time of 20 swings (oscillations) rather than 1 swing is more accurate** ➢ To reduce the effect of reaction time ➢ To reduce error ➢ Time of one swing is too small to be measured ▪ **Why measuring the time of 200 oscillations isn't suitable?** ➢ Pendulum may stop ➢ Student may lose counting ▪ **Suggest a practical reason why the result obtained from experiment is different?** ➢ Student didn't react quickly when the pendulum started. ➢ Difficulty to measure the length from the centre of bob.

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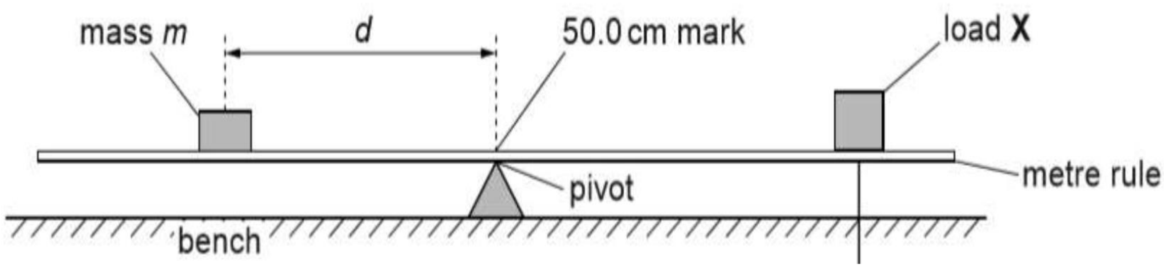
	▪ **Suggest improvement to the experiment** ➢ Repeat and take average ➢ Use different lengths ➢ Use fiducial mark ➢ Draw a graph for the results to find the anomalous results.

1.2 Balancing a beam:



Aim	To measure the moment about a pivot and to show that there is no net moment on a body in equilibrium.
Theory	The moment of a force is a measure of its turning effect and is given by: Moment of a force = $F \times d$ Where F is the turning force acting on a body and d is the perpendicular distance of the line of action of the force from fulcrum. For a body in equilibrium, the law of moments states that the sum of the anticlockwise moments about any point equals the sum of clockwise moments about the same point.
Apparatus	As shown in figure
Procedure	Set up the apparatus as shown in the figure,
Difficulties and how to overcome them	**Balancing the ruler above the pivot:** ▪ Repeat several times until it balances **The mass slips over the ruler:** ▪ Stick the mass with the ruler **The centre of mass of the cylinder may not above the correct mark (X):** ▪ Measure the diameter of the cylinder d. ▪ Calculate the radius $r = d/2$ ▪ Adjust the cylinder above the correct mark (X) so that one side of the cylinder at mark (X-r) and the other at mark (X+r).

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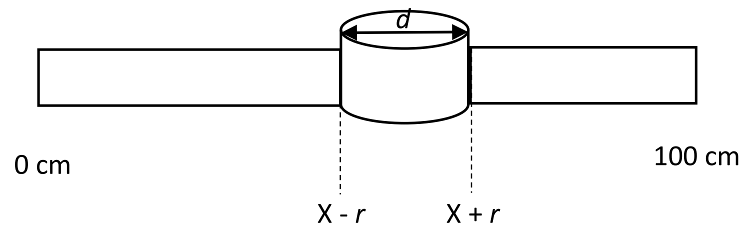
<table>
<tr><td></td><td>

$r = d/2$



</td></tr>
<tr><td>Precautions to improve accuracy or to give more reliable results</td><td>

- Repeat and take the average
- Look perpendicular at the scale of the ruler while taking the readings to avoid parallax error.
- The range of masses

</td></tr>
<tr><td>Common questions</td><td>

What is the mass of the ruler?

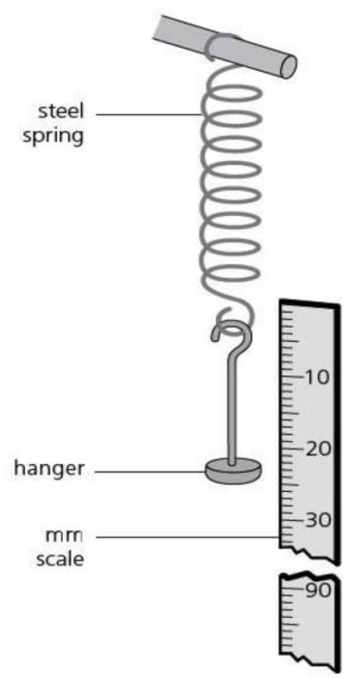
- From 100 to 200 g

Where is the position of the centre of the mass?

- It is the point at which the meter rule balanced above the pivot

</td></tr>
</table>

1.3 Spring Experiment (Hook's law):



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Aim	To investigate Hook's law for a spring.
Theory	Hook's law states that: $F = kx$ Where F is the stretching force, x is the extension of the spring and k is the spring constant. The law should hold if the spring is not permanently stretched
Apparatus	-retort stand (clamp stand)-spring-hanger with 100 g weights-ruler-adhesive/sticky tape.
Procedure	Set up the apparatus as shown in the figure. 1. Fix the ruler vertically next to the spring so that it can be used as a scale. 2. Record the position of the bottom of the unweighted spring on the scale, l_s, and repeat your measurement. 3. Measure the length of the hanger, l_o. 4. Hang an unweighted (100 g) hanger on the spring and record the scale position of the bottom of the hanger 5. Add a 100 g mass to the hanger and again record the scale position of the bottom of the hanger. 6. Repeat step 5 with 200g, 300g and 500 g masses on the hanger. 7. Plot a graph of the stretching force along the x-axis against the extension along the y-axis. 8. Calculate the gradient of the graph.
Difficulties and how to overcome them	▪ The clamp retort stand might topple. To overcome: use small loads. ▪ Spring might overstretch/spring too weak To overcome: use loads that don't overstretch spring
Possible causes of inaccuracy	▪ Spring extension is not uniform with load ▪ Spring exceeds the limit of proportionality
Precautions of safety	▪ Take care with masses and think the hanging masses would fall if the spring snapped. ▪ Wear eye protection
Precautions to improve accuracy or to give more reliable results	▪ Look perpendicular to the scale of the ruler while taking the readings to avoid parallax error ▪ Wait until the spring stops vibrating ▪ Always measure from the same point of spring ▪ Ensure the ruler is vertical/use horizontal aid ▪ Bench surface must be horizontal ▪ At least 5 loads for each spring if producing a graph ▪ **Improve the accuracy by:**

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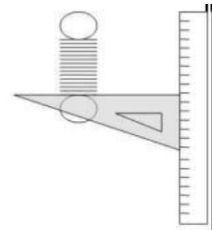
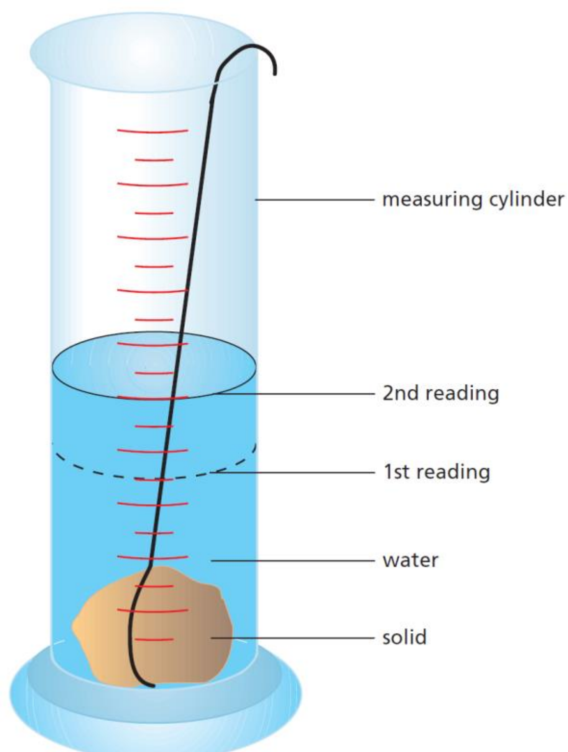
	➢ Clamping the metre ruler in place and then using the set square to make the length/extension measurement  ➢ Use the set square to make sure that the clamped ruler is vertical in relation to the bench ➢ Set the clamped ruler at 0 cm when no masses are added and ,so read the extension directly.
Conditions kept constant to fair comparison between springs of different materials	▪ Same spring diameter ▪ Same spring thickness ▪ Same range of loads ▪ Same length of spring/hanger ▪ Same number of coils ▪ Same coil spacing

1.4 Density (Displacement Method)



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Aim	To measure the density of a solid
Theory	By definition, the density of a substance is given by: Density = mass/volume For a regular-shaped solid the volume can be found by measuring its dimensions and the mass is determined by weighing. For an irregularly-shaped solid, the volume is found by immersion in a liquid.
Apparatus	As shown in figure.
Procedure	▪ Measure the mass of the solid material *m* on a top-pan balance ▪ Fill the measuring cylinder with a known volume of water V_1 ▪ Shack the solid material very well. ▪ Immerse the solid in the cylinder. ▪ Measure the new volume V_2 ▪ Calculate the solid volume as: ▪ $V = V_2 - V_1$ ▪ Calculate the density as: Density = m/V
Precautions to improve accuracy or to give more reliable results	▪ Shack the solid material/rock ▪ Thin string/wire should be used ▪ Look perpendicular to the scale of the cylinder ▪ Look from the meniscus ▪ Put the solid material/rock gently
Possible causes of errors/inaccuracy	▪ Parallax error ▪ Student did not look from the meniscus of the liquid ▪ Splashes during immersing the solid material/rock ▪ Air bubbles may found in the solid material/rock ▪ String/wire used may be thick ▪ Cylinder may not be sensitive

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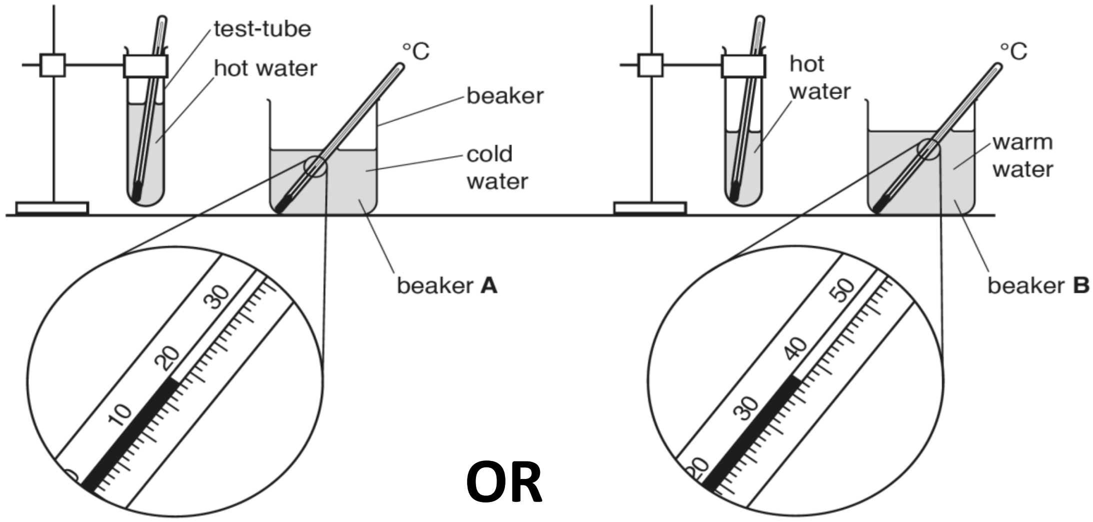
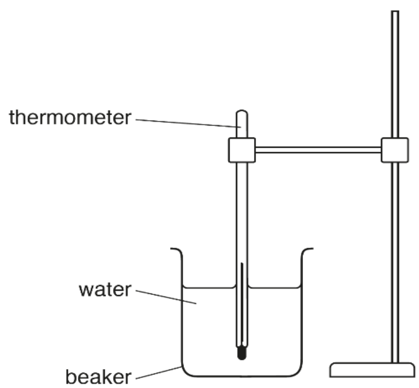
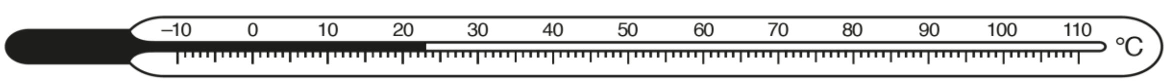
2.1 Cooling rate experiment:



OR





Aim	To study how the surrounding temperature affects the rate at which water/liquid cools
Theory	▪ A hot body loses its heat energy gradually to the surroundings. The experiment is done by measuring the temperature (using a thermometer) at equal time intervals (using a stopwatch). ▪ The temperature decreases until the body reaches the room temperature. ▪ The rate of cooling (rate of heat lost by radiation) of a body depends on: ➢ The difference in temperature between the body and surroundings

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	➢ The exposed surface area of the body. The greater the area the greater the chance of the body to emit heat. ➢ The nature of the radiating surface (dull black is a good radiator while shiny or white surface is a poor radiator).
Apparatus	-heater-thermometer (or 2)- beaker(or 2)- stopwatch.
Procedure	▪ ***The details of procedure may differ from an experiment to another (this is the general procedure).*** ▪ Place heater into the beaker and turn it on to raise the temperature of water to……… ▪ Stir the contents of the water and place thermometer into the beaker. ▪ Note the starting temperature and turn on the stopwatch. ▪ Take readings of the thermometer and stopwatch at regular intervals. ▪ Tabulate and plot a graph to conclude your experiment.
Precautions of safety	▪ Take care when dealing with beakers of hot water. ▪ Set the hot water in a safe position where they will not be accidently knocked over. ▪ Handle with caution to avoid burns
Precautions to improve accuracy or to give more accurate/reliable results	▪ Stir before reading ▪ Keep the thermometer at same level ▪ Set eye to as perpendicular to the scale ▪ Wait until reading stops rising (at start) ▪ Position clock so the thermometer and clock can be seen easily.
Possible causes of errors/inaccuracy and how to overcome	▪ Heat loses due to surrounds ➢ Lag container with insulator ➢ Cover container with lid ➢ Initial temperature near to room temperature
Conditions kept constant to fair comparison or to repeat the experiment	▪ Measure water into test-tube / beaker ***to ensure the same volume/amount being used each time as cooling rates are different at different volumes.*** ▪ Use the **same starting temperatures** in tubes ***because cooling rates are different at different temperatures*** ▪ Ensure all water in tube below level of water in beaker ***to ensure that all water in tube has the same surrounding temperature.*** ▪ Use insulation / lid on beaker ***to keep water in beaker at (more) constant temperature***

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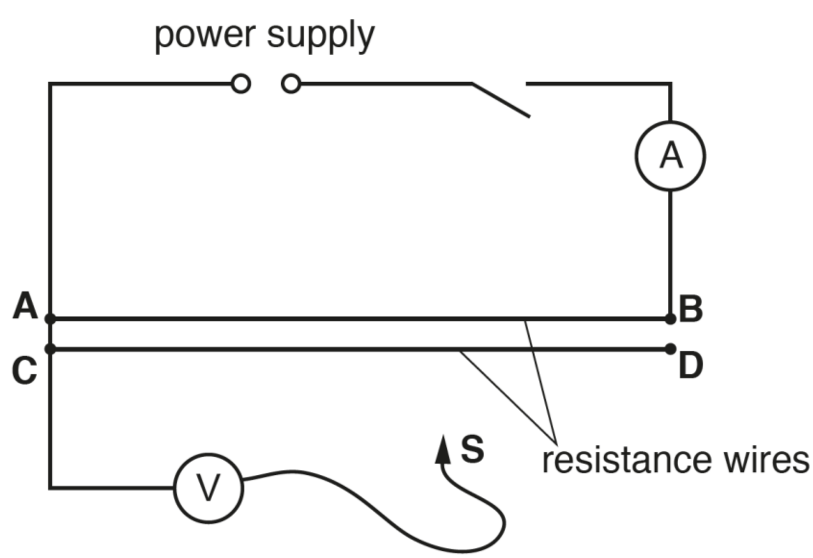
	▪ Same beaker. ▪ Same thermometer ****Explanation is written in italic bold (needed in some questions).***
Common questions	▪ **Explain why the rate of cooling decrease by time/ Why the initial rate of cooling is greater than the final rate of cooling?** Because the liquid temperature becomes near the room temperature **Justification:** ➢ If you have two tables in the question, and you need to justify the statement, calculate the difference in temperature in a given time interval in each table then compare between the results within the limit of experimental accuracy. ▪ **Examples of insulators:** ➢ Glass, Wool, Cotton, Plastic, Rubber.

3.1 Electricity experiment:



Aim	To measure the resistance of a wire and/or to investigate its dependence on the length of the wire.
Theory	The resistance *R* of a wire is given by: *R= V/I* *Where* V *is the p.d.* across the wire and *I* is the current flowing through it.

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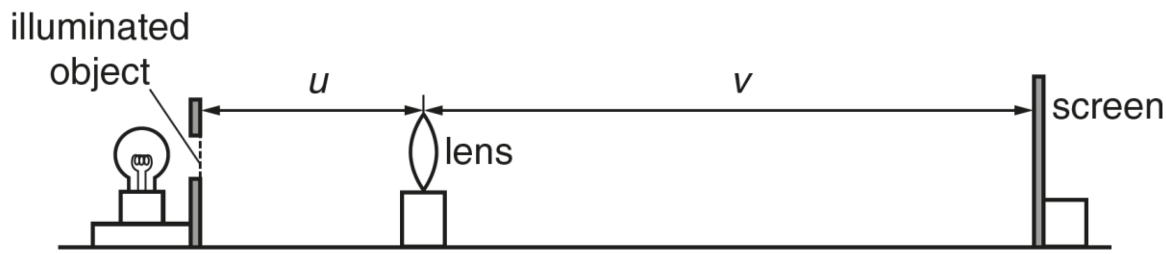
Apparatus	-Battery-switch-wire or more- Ammeter-Voltmeter-meter rule- mounting clamps- 0-25 Ω rheostat (depending on the experiment)
Procedure	
Precautions of safety	The wire may become hot when current flows in it
Precautions to improve accuracy or to give more reliable results	▪ **To overcome the heat effect in the wire:** ➢ Use a battery of lower electromotive force. ➢ Switch on and off between readings. ➢ Add a lamp to lower the current ➢ **Sometimes** (not in all times)-depending on the given diagram- you can increase resistance of resistor. ▪ **To improve accuracy and give reliable results:** ➢ Look perpendicular while taking the readings. ➢ Tap on both the ammeter and voltmeter to check that the pointer is free to move (avoid sticking). ➢ Take several readings and then take overall average. ➢ Always check the connections are clean. ➢ Check the ammeter/voltmeter for zero-error ➢ Initially choose the highest range for the ammeter/voltmeter, then reduce the range, so that the deflection is almost full scale.
Possible causes of errors/inaccuracy	▪ Heating effect of the current ▪ The battery is used up ▪ Bad connection of the sliding contact

4.1 Optics experiment # 1 (focal length and linear magnification):



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Aim	To determine the focal length and the linear magnification of a converging lens.
Theory	▪ Parallel rays from a ***distant*** object converge towards the principal focus of a converging lens. **Note:** the torch is not considered a distant object and is not used in this experiment while determining the focal length. The first part of this experiment should be performed without a torch, only depending on a distant object (may be outside the room/window) ▪ The linear magnification, *m,* of an image is given by: *m = height of* image/height *of object*
Apparatus	Small torch, converging lens, screen/card, metre rule, adhesive/ mounting putty.
Procedure	▪ Focal length ➢ Step 1: Hold the lens up to a distant window and form a sharp image of the window on the screen/wall/a piece of card. ➢ Step 2: Measure and record the distance between the lens and card, the image distance, *V*. ➢ Repeat step 1 and 2 and obtain an average value for the image distance, *V*, which is equal to the focal length, *f*, of the lens. ▪ Magnification: ▪
Difficulties and how to overcome them	▪ Measuring the dimensions/height of the image using a hand ruler away from the image. ▪ Can be overcome by using a translucent screen with a fixed ruler/grid.
Precautions to improve accuracy or to give more reliable results	▪ Dark room. ▪ Object and lens have the same height from the bench. ▪ Mark on lens holder to show position of lens centre. ▪ Repeat and take the average. ▪ Look perpendicular while taking readings. ▪ Object/lens/screen perpendicular to the bench
Common questions	▪ **Draw/describe the image:** ➢ Inverted (upside down) ➢ Magnification $= \frac{\boldsymbol{distance\ of\ image\ from\ the\ length}}{\boldsymbol{distance\ of\ object\ from\ the\ length}}\ (\mathbf{1})$ ***OR*** Magnification $= \frac{\boldsymbol{Height\ of\ image}}{\boldsymbol{Height\ of\ object}}$ **(2)** **Use formula 1 or 2 depending on the question**

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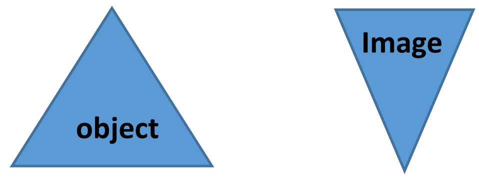
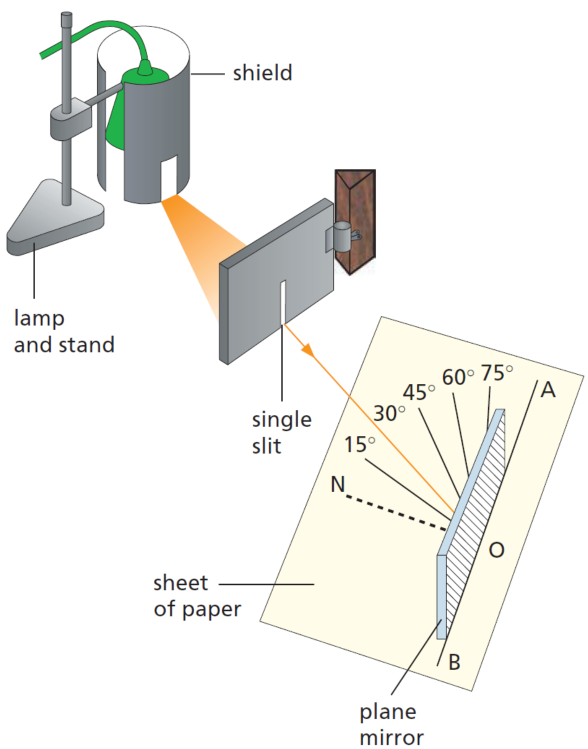
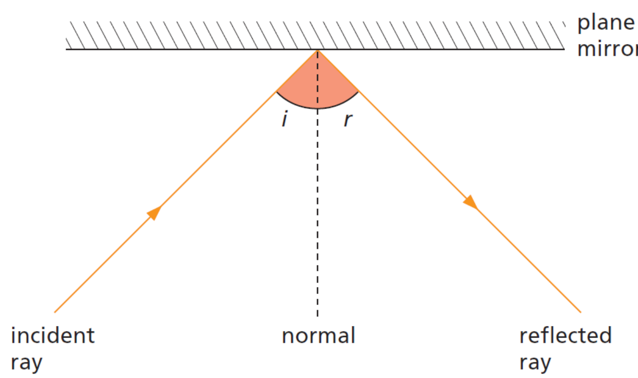
<table>
<tr>
<td></td>
<td>➢ Magnified if:
Image distance > Object distance.


➢ Smaller if:
Object distance > Image distance.

</td>
</tr>
<tr>
<td>Common questions</td>
<td>▪ Why the object, the lens, and the screen should be perpendicular to the bench?
To be able to achieve a sharp/complete/focused image.</td>
</tr>
</table>

4.2 Optics experiment # 2 (Law of reflection):





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Aim	To verify the law of reflection and identify the properties of an image in a plane mirror.
Theory	The law of reflection states that the angle of incidence equals the angle of reflection: $I = r$ Where I is the angle between the incident ray and the normal to the reflecting surface.
Apparatus	(Lamp + single slit) or a ray box, plane mirror, pins, protractor, adhesive
Procedure	▪ Place the plane mirror on a sheet of white paper, holding it vertical with plasticine or a block of wood. ▪ Draw a line along the mirror. ▪ Use the lamp and the single slit / ray box to shine a ray on the mirror. This is called the incident ray. You will see the reflected ray of light. Mark the position of each ray with optical **pins**. ▪ Now take off all the apparatus and use a ruler to join up the optical pins, along the lines of rays of light. ▪ Use a protractor or a set-square to draw a line at right angle (90^0) to the mirror, as shown. This line is called the normal. ▪ Use a protractor to measure the angles on each side of the normal.
Precautions to improve accuracy or to give more reliable results	▪ **Precaution while putting the pins:** ➢ Place the pins as far apart as possible (not less than 5 cm). ➢ Use more pins. ➢ **Place the pins vertical** ▪ Draw the lines so that they are as thin as possible ▪ Look perpendicular while taking readings to avoid parallax error. ▪ Use thin protractor ▪ Look from the base of the pin: ➢ ***No concern about pins being vertical.*** ➢ Base of the pin lies on the ray. ➢ The base is always perpendicular to the plane ▪ Repeat and average
Possible causes of errors/inaccuracy	▪ Thickness of lines ▪ Thickness of protractor ▪ Thickness of pins

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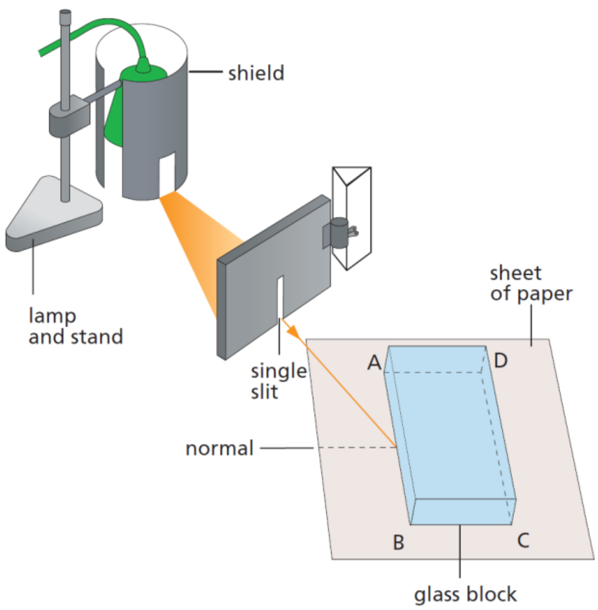
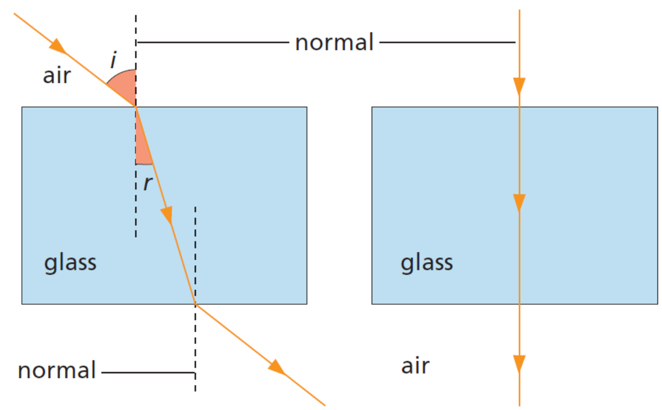
	▪ Pin holes. ▪ Thickness of mirror. ▪ Glass on front of mirror causes double refraction.

4.3 Optics experiment # 3 (Refractive Index):





Aim	To determine the refractive index of glass and observe the path of light rays through a glass block.
Theory	The refractive index, *n*, of a medium is given by: $$n = \frac{\sin i}{\sin r}$$ Where *I* is the angle between the incident ray in air and the normal and *r* is the angle between the refracted ray and normal in the medium.
Apparatus	Lamp, single slit, glass block with lower surface painted white, protractor
Procedure	▪ Place a rectangular block of glass on a white sheet of paper. Trace the edge of the block using a pencil. ▪ Draw a normal to one side of the block. ▪ Let a light ray fall on the point where the normal is drawn. ▪ Observe the emerging ray from the side of the block. ▪ Put pins to determine the path of the incident ray and emergent ray. ▪ Remove the block and draw lines representing the incident and the emerging rays.

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	▪ Measure the angle of incidence and angle of refraction of light then calculate the refractive index.
Precautions to improve accuracy or to give more reliable results	▪ **Precaution while putting the pins:** ➢ Place the pins as far apart as possible (not less than 5 cm). ➢ Use more pins. ➢ **Place the pins vertical** ▪ Draw the lines so that they are as thin as possible ▪ Look perpendicular while taking readings to avoid parallax error. ▪ Use thin protractor ▪ **Look from the base of the pin:** ➢ ***No concern about pins being vertical.*** ➢ Base of the pin lies on the ray. ➢ The base is always perpendicular to the plane ▪ Repeat and average
Possible causes of errors/inaccuracy	▪ Thickness of lines ▪ Thickness of protractor ▪ Thickness of pins ▪ Pin holes.

Exercises #1:

Some students are investigating the magnification produced by a converging lens.
They are using the apparatus shown in Fig. 3.1.

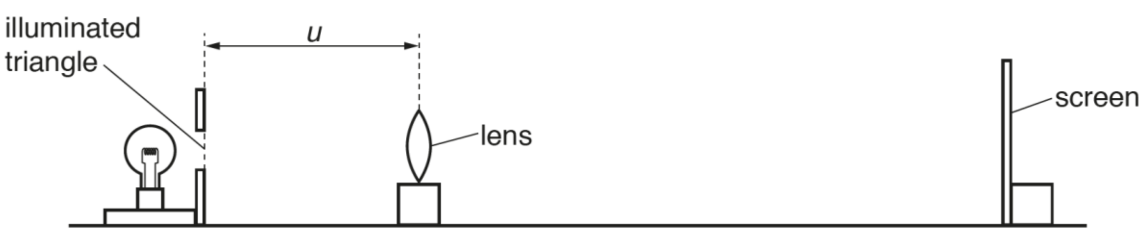

Fig. 3.1

(a) A student sets the distance *u* between the illuminated triangle and the lens to 20.0 cm.
She moves the screen until a sharp image of the triangle is seen on the screen.
The student measures the height of the illuminated triangle h_O.

h_O = ... 1.5 cm ....

Measure and record, in Table 3.1, the height of the image of the triangle h_I on the screen, as shown in Fig. 3.2. [1]

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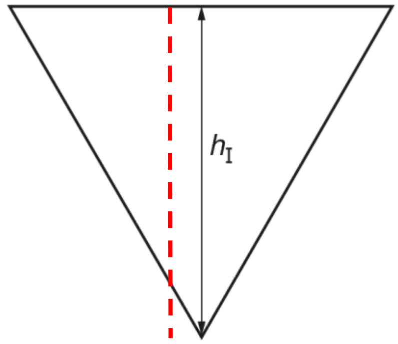

Fig. 3.2

Table 3.1

u/cm	h_I/cm	M
20.0	4.5	4.5/1.5=3
25.0	2.25	2.25/1.5=1.5
35.0	1.10	1.10/1.5 = 0.73
45.0	0.75	0.75/1.5=0.50
55.0	0.55	0.55/1.5=0.37

(b) The student measures the height h_I of the image for u values of 25.0 cm, 35.0 cm, 45.0 cm and 55.0 cm. Her results are shown in Table 3.1.

For each value of u, calculate and record in Table 3.1 a value for the magnification M.
Use the equation $M = h_I/h_O$ and the value of h_O from **(a)**. [1]

(c) Plot a graph of M (y-axis) against u / cm (x-axis).

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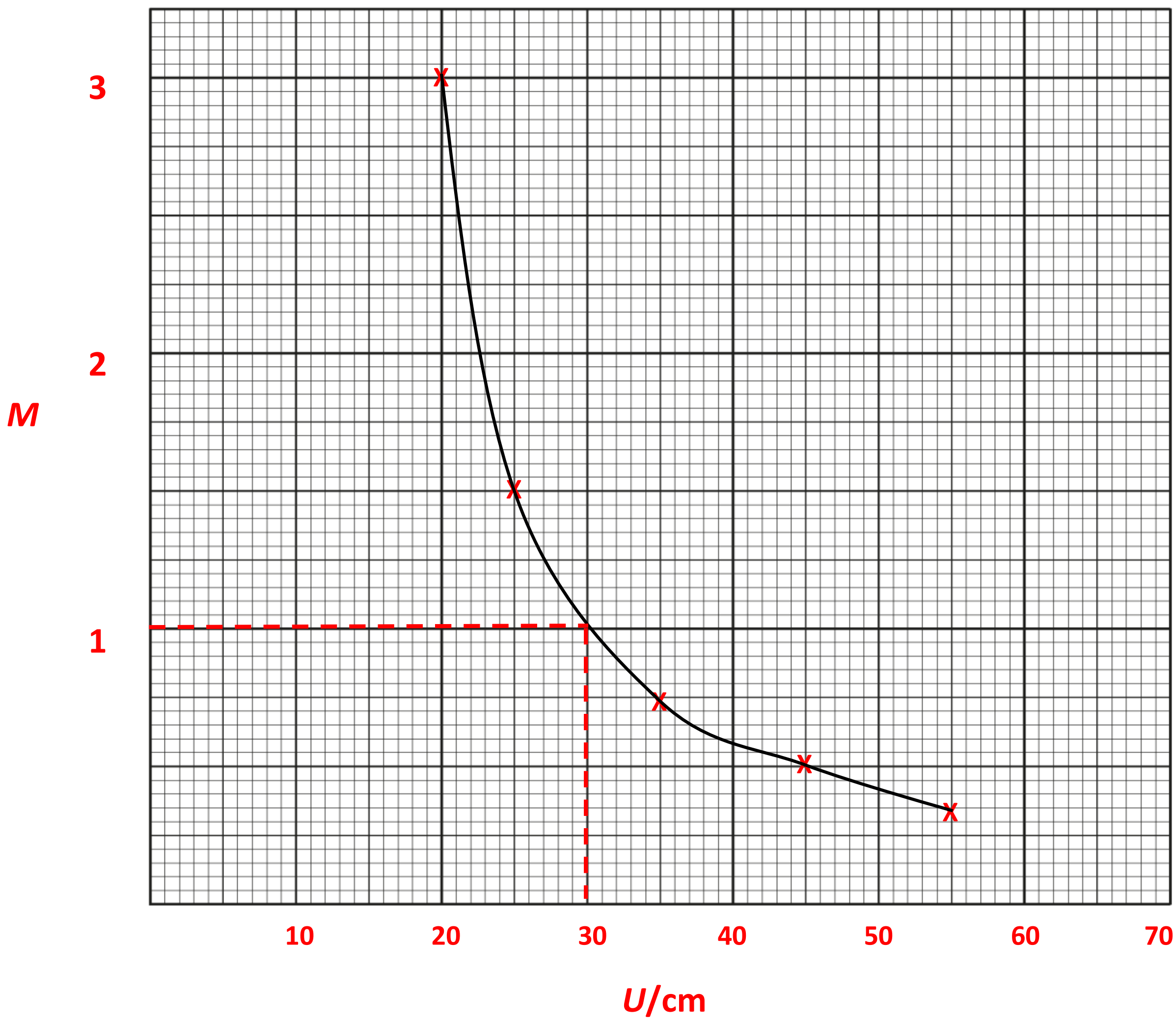

From your graph, determine the value of *u* when *M* = 1.0. Show clearly on your graph how you obtained the information.

U = ...**30.0 cm**............[2]

(e) Describe **one** difficulty that might be experienced when measuring the height of the image in this experiment. Suggest **one** improvement to the apparatus to overcome this.

difficulty .... **Measuring the dimensions/height of the image using a hand ruler away from the image**.......................................

....

improvement ... **Can be overcome by using a translucent screen with a fixed ruler/grid**....................................... [2]

(f) When setting up the apparatus, the student makes sure that the card with the illuminated triangle, the lens and the screen are all perpendicular to the bench.
Explain why this is an important precaution in this experiment.

To be able to achieve a sharp/complete/focused image

....[1]

[Total: 11]

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Exercise # 2:

Some students are investigating how the surrounding temperature affects the rate at which water cools.

They are using the apparatus shown in Fig. 1.1.

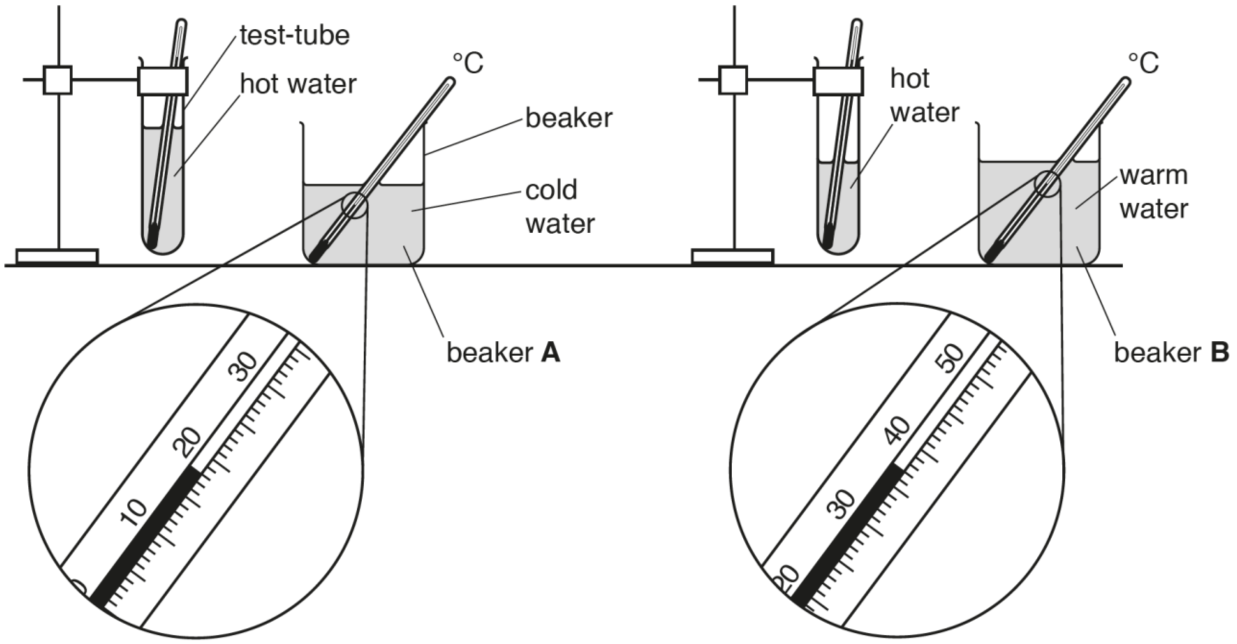

Fig. 1.1

(a) Using Fig. 1.1

- record the temperature θ_A of the cold water in beaker **A**,

θ_A = ...18.0^0 c....................

- record the temperature θ_B of the warm water in beaker **B**.

θ_B = ...37.0^0 c....................

[1]

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(b) The test-tubes of hot water are placed into beakers **A** and **B**.

The students record the temperatures θ of the water in the test-tubes every 30 s. Their readings are shown in Table 1.1.

Complete the units and the time column in Table 1.1.

Table 1.1

time	tube in beaker **A** with cold water	tube in beaker **B** with warm water
t /	θ /	θ /
0	80.5	81.0
30	52.5	64.5
60	42.0	55.0
90	36.0	50.5
120	32.5	48.0
150	30.5	46.5
180	29.0	45.5

[2]

(c) Describe **two** precautions that you would take, before reading the thermometer, to ensure that the temperature readings are as accurate as possible in the experiment.

1. **Stir before reading**

Set the eye perpendicular to scale

2. **Keep thermometer at same level**

Wait until reading stops rising at start

Position clock so that the thermometer and clock can be seen easily. [2]

(d) Write a conclusion stating how increasing the temperature of the surrounding water affects the rate of cooling of the water in the test-tube.

Justify your answer by reference to the results in Table 1.1.

In the cold water beaker the change $\Delta\theta = 80.5 - 29.0 = 51.0^{o}$ C but in the warm water beaker the change $\Delta\theta = 81.5 - 45.5 = 35\ 0^{o}$ C therefore, the cooling rate increases when the surrounding temperature is lower and decrease when the surrounding temperature is higher

[2]

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(e) Suggest **one** change to the experiment shown in Fig. 1.1 to ensure that the comparison of the effect of surrounding temperature on cooling is a fair test.

Explain why the change is an improvement.

change ....**(1) Measure water in test tube / beaker**..........

..........**(2) Use the same starting temperature**..........

explanation ....**(1) To ensure the same volume/amount being used each time as cooling rates are different at different volumes**..........

..........**(2) Cooling rates are different at different temperature.**..........

[2]

(f) The students use a measuring cylinder to measure 200 cm^3 of cold water.

Describe briefly how to read a measuring cylinder to obtain an accurate value for the volume of water. You may draw a diagram.

- **Reading must be taken perpendicular to scale**
- **Reading must be taken at the bottom of the meniscus.**

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Exercise # 3:

A student is investigating how the material of a spring affects its behaviour when stretched.

The following apparatus is available to the student:

wires of different thickness, length and material
a set of 10 g masses and a set of 100 g masses, both with hangers
a wooden rod approximately 1 cm in diameter
other standard laboratory equipment.

Plan an experiment which will enable you to test the extension of springs made from different types of wire.

In your plan, you should include:

- instructions for making a spring from the wire that is provided,
- what you will measure,
- instructions for carrying out the experiment,
- the variables you will keep the same to ensure the comparison is a fair test,
- any precaution which should be taken or difficulty which might occur,
- how you will present your results.

You may draw a diagram if it helps to explain your plan.

- **The spring can be made by winding a wire around the rod**
- **The extension of the spring will be measured against mass / load**
- **Repeat for springs of different materials / thickness**
- **Record the result in suitable annotated table and draw a graph**
- **Same spring diameter**
- **Same spring thickness**
- **Same range of loads**
- **Same length of spring / hangers**
- **Same coil spacing**
- **Difficulties / Precautions**
    - **The clamp retort stand might topple (use small loads)**
    - **Spring might overstretch / the spring is too weak (use loads that don't overstretch the spring)**
    - **Look perpendicular to the scale of the ruler while taking the reading to avoid parallax error**
    - **Wait until the spring stops vibrating**
    - **Make as mall loop by the end of spring to apply load**
    - **Repeat each reading and take the average**
    - **At least 5 loads for each sample if producing a graph**

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Exercise # 4:

A student is investigating the resistance of three wires **A**, **B** and **C**. He is using the circuit shown in Fig. 2.1.

The circuit is set up to test wire **A**. The length, l of each wire is measured and recorded.

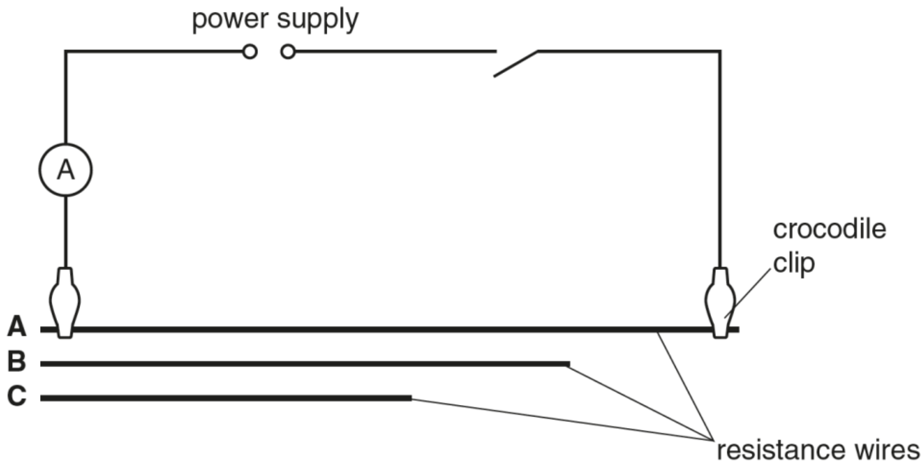
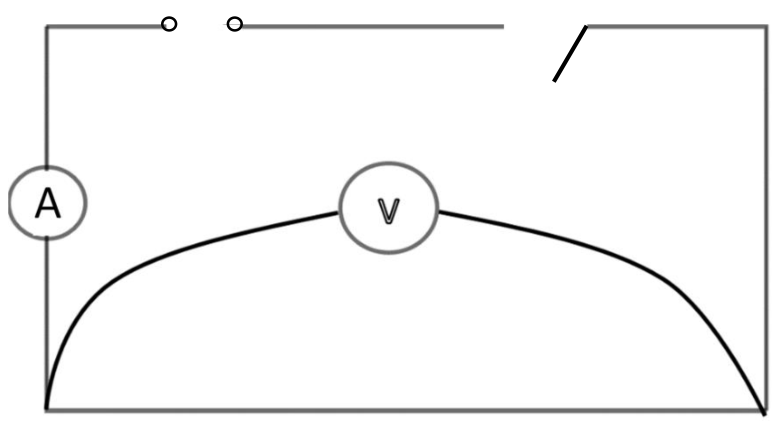


Fig. 2.1

(a) On Fig. 2.1, draw a voltmeter connected so that it will measure the potential difference across wire **A**. [1]



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(b) In the first line of Table 2.1, record the potential difference V and current I for wire **A**, as shown in Figs. 2.2 and 2.3. [2]

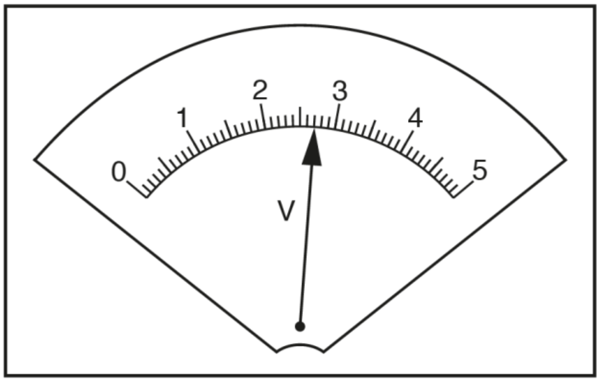

Fig. 2.2

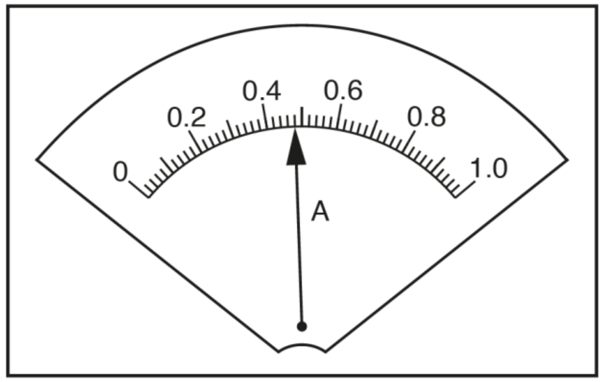

Fig. 2.3

Table 2.1

wire	l/m	V/V	I/A	R/Ω
A	0.900	**2.7**	**0.48**	**5.63**
B	0.500	2.4	0.75	**3.20**
C	0.400	2.2	0.85	**2.59**

(c) The student connects the crocodile clips to wire **B** and then wire **C** in turn. His readings of potential difference and current are shown in Table 2.1.

Calculate, and record in Table 2.1, the resistance R of each wire.

Use the equation $R = \frac{V}{I}$.

R_A= 2.7/0.48 = 5.63 Ω

R_B = 2.4/0.75 = 3.20 Ω

R_C = 2.2/0.85 = 2.59 Ω

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Exercise # 5:

The class is investigating the refraction of light passing through a transparent block. A student is using optics pins to trace the paths of rays of light.

Fig. 2.1 shows the student's ray-trace sheet.

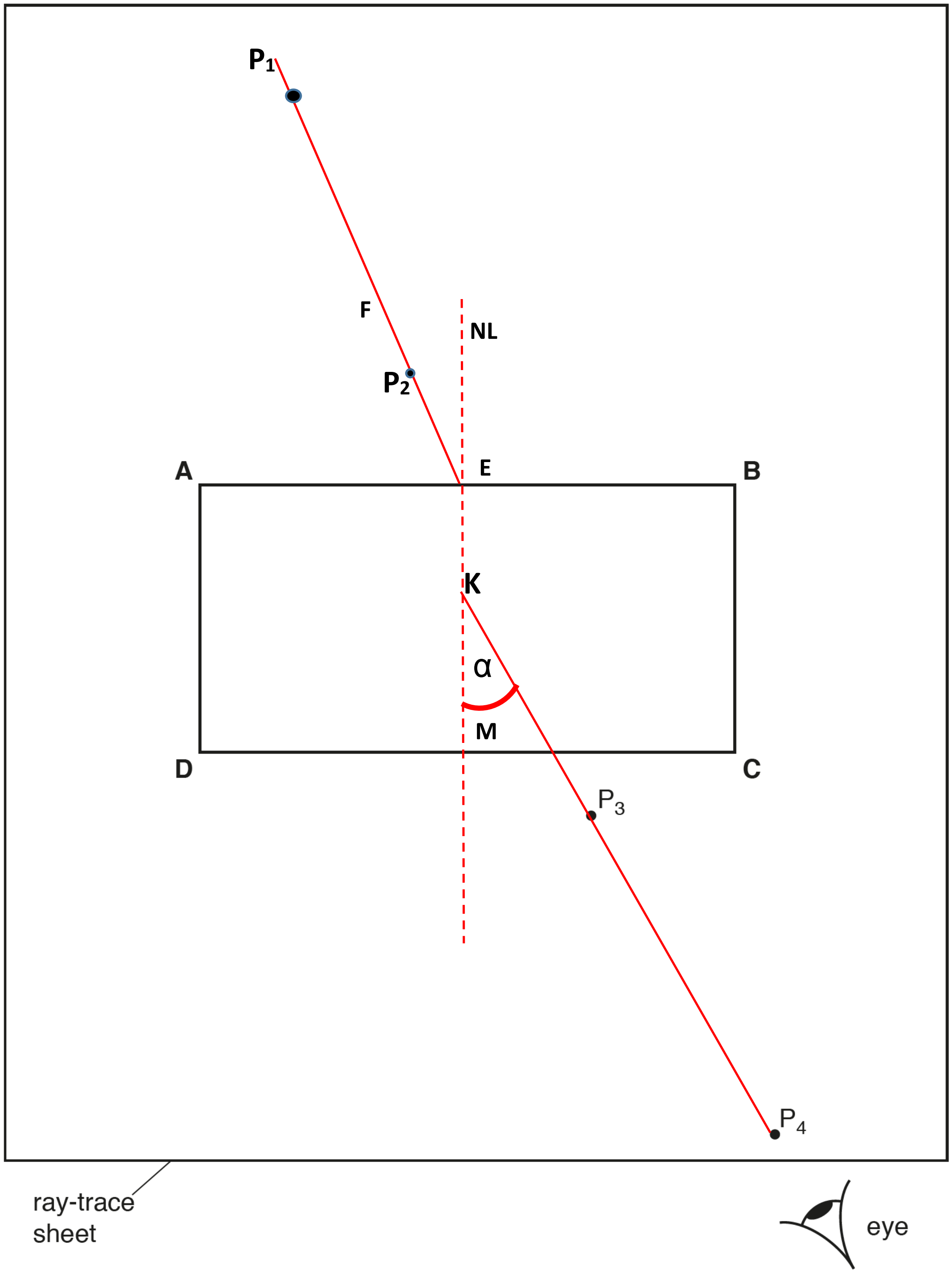

Fig. 2.1

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(a) • On Fig. 2.1, draw a normal at the centre of side **AB**. Label this line **NL**. Label the point **E** where the normal crosses **AB**. Label the point **M** where the normal crosses **CD**.

• Draw a line above **AB** to the left of the normal and at an angle of incidence $i = 30°$ to the normal. Label this line **FE**.

• Label the positions of two pins P_1 and P_2 placed a suitable distance apart on **FE** for accurate ray tracing. [2]

(b) The student observes the images of P_1 and P_2 through side **CD** of the block so that the images of P_1 and P_2 appear one behind the other. He places two pins P_3 and P_4 between his eye and the block so that P_3 and P_4, and the images of P_1 and P_2 seen through the block, appear one behind the other. The positions of P_3 and P_4 are marked on Fig. 2.1.

Draw a line joining the positions of P_3 and P_4. Continue the line until it meets the normal. Label this point **K**. [1]

(c) • Measure and record the angle α between the line joining the positions of P_3 and P_4 and the line **KM**.

α = ...**28º-32º**......

• Measure and record the length x between points **M** and **K**.

x = ...**20-24 mm**......

[2]

(d) The student repeats the procedure with the angle of incidence $i = 50°$.
His readings for α and x are shown.

α = ... 52° ......

x = ... 19 mm ......

A student suggests that the angle α should always be equal to the angle of incidence i.

State whether the results support this suggestion. Justify your answer by reference to the values of α for $i = 30°$ and $i = 50°$.

statement ......**YES, the two angles are very close and almost the same**......

justification ......$\% = \frac{greatest\ angle - smaller\ angle}{greatest\ angle} \times 100 = \frac{52-50}{52} \times 100 = 3.8\ \%$......

AND $\% = \frac{30-28}{30} \times 100 = 6.6\%$ **the two percentages are within the experimental accuracy**

[2]

(e) Suggest **one** precaution that you would take with this experiment to obtain reliable results.

- **Place the pins as far apart as possible.**
- **Use more pins.**
- **Draw the lines so that they are as thin as possible**
- **Look perpendicular while taking readings to avoid parallax error.**
- **Ensure pins are vertical/upright/erect**

[1]

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The class is investigating the motion of a pendulum.

Fig. 4.1 shows the apparatus.

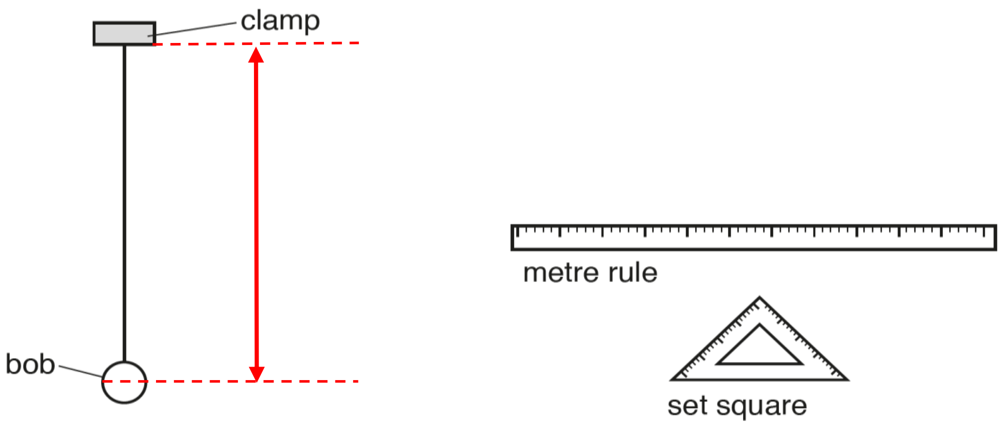

Fig. 4.1

(a) **(i)** On Fig. 4.1, show clearly the length *l* of the pendulum. [1]

(ii) Use Fig. 4.2 to explain how you would measure the length *l* accurately. You may draw on the diagram.

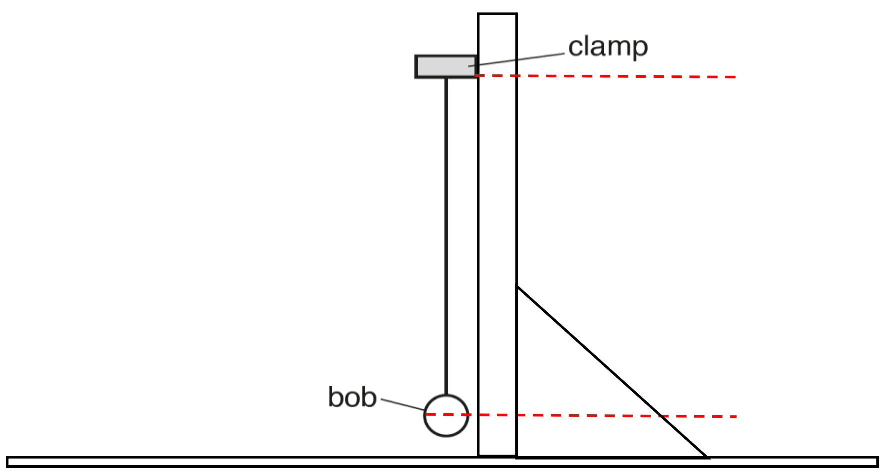

Fig. 4.2

- Put the ruler as close as possible to the pendulum
- Use the set-square as a reference to assure a vertical ruler
- The measurement should be from the bottom of the clamp

[2]

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(b) A student determines the period T of the pendulum. The period is the time taken for one complete oscillation. The student measures the time t for 20 oscillations.

Fig. 4.3 shows the time t.

Fig. 4.3

(i) Calculate the period T of the pendulum.

$$T = \frac{20.22}{20} = 1.01\ sec$$

T = **1.01 sec** ....[1]

(ii) Explain how measuring the time for 20 oscillations rather than one oscillation helps the student to obtain a more reliable value for the period.

To reduce the effect of start, stop error

Taking the average of 20 oscillations reduces the error in calculating one oscillation period and spreads the error over 20 swings

Time of one swing is too small to be measured ....[2]

(c) The student wants to determine a value for the acceleration of free fall from his results. He needs the value of T^2 to do this.

Calculate T^2.

Give your answer to a suitable number of significant figures and include the unit.

T^2 = **1.02 sec²** .... [2]

[Total: 8]

$T^2 = 1.01^2 = 1.02\ sec^2$

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