Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	**Suggested Solutions**
CLASS	**2T**
INDEX NUMBER	

PHYSICS **9749/04**

Paper 4 Practical

21 Aug 2023

2 hour 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the assessment, fasten all your work securely together.
The number of marks is given in brackets [ ] at end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	**/ 15**
2	**/ 6**
3	**/ 22**
4	**/ 12**
Total	**/ 55**

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This paper is the 2020 A-level Paper. Please refer to the Confidential Instructions on the preparation of the apparatus

1. In this experiment, you will investigate the current in an electrical circuit.

(a) You have been provided with two metre rules A and B, each with a resistance wire attached.

Take measurements to determine the resistance per unit length of each of the wires.

The resistance per unit length of the wire attached to rule A is R_A.
The resistance per unit length of the wire attached to rule B is R_B.

Solution:
Resistance of 100.0 cm length of wire A = 15.4 Ω
R_A = 15.4 / 100.0 = 0.154 Ω cm^{-1}

Resistance of 100.0 cm length of wire B = 26.9 Ω
R_A = 26.9 / 100.0 = 0.269 Ω cm^{-1}

R_A = ………………0.154 **Ω cm**$^{-1}$ or 15.4 **Ω m**$^{-1}$……………………

R_B = ………………0.269 **Ω cm**$^{-1}$ or 26.9 **Ω m**$^{-1}$……………………

[2]

(b) Set up the circuit as shown in Fig. 1.1.

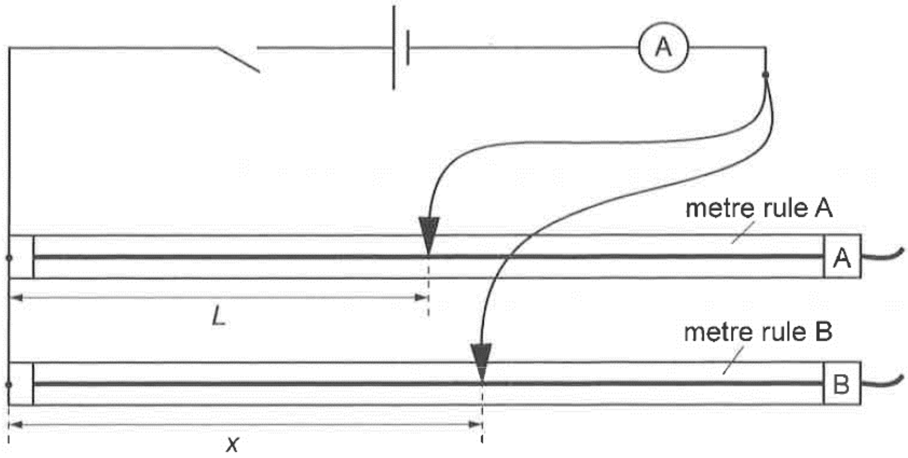


Fig. 1.1

L should be approximately half the length of the rule and *x* should be **greater** than L.

Close the switch.

Measure and record *L*, *x* and the ammeter reading *I*.

L = ………………50.0 cm……………………

x = ………………55.0 cm……………………

I = ………………0.243 A……………………

(c) Vary *x*, obtaining a suitable range of values between 0 cm and 100 cm, repeat **(b)**, keeping *L* constant throughout.

[Turn Over

Solution:

x / cm	I / A	$\frac{1}{x}$ / cm^{-1}
55.0	0.243	0.0182
63.0	0.231	0.0159
70.0	0.226	0.0143
78.0	0.216	0.0128
85.0	0.212	0.0118
90.0	0.211	0.0111

[3]

(d) It is suggested that I and x are related by the expression

$$I = \frac{E}{R_A L} + \frac{E}{R_B x}$$

where E is the electromotive force (e.m.f.) of the cell.

Plot a suitable graph to determine the value of E.

Solution:

Linearised equation : $I = \left(\frac{E}{R_B}\right)\frac{1}{x} + \left(\frac{E}{R_A L}\right)$

Plot a graph of I against $\frac{1}{x}$ to obtain a straight line with gradient $\left(\frac{E}{R_B}\right)$ and vertical intercept $\left(\frac{E}{R_A L}\right)$.

$$\text{Gradient } = \frac{0.245 - 0.210}{0.0188 - 0.0112} = 4.6053 \text{ A cm}$$

Vertical-intercept = 0.245 – (4.6053)(0.0188) = 0.15842 A

$$\frac{E}{R_B} = 4.6053 \text{ A cm} \quad \therefore \ E = 0.269 \times 4.6053 = 1.2388 \text{ V}$$

$$\frac{E}{R_A L} = 0.15842 \text{ A} \quad \therefore \ E = 0.15852 \times 0.154 \times 50.0 = 1.2198 \text{ V}$$

$$\text{Therefore, average } E = \frac{1.2388 + 1.2198}{2} = 1.2293 = 1.23 \text{ V}$$

E = ………………1.23…….……….. V [7]

(e) Without taking further readings, sketch a line on your graph grid to show the results you would expect if the experiment was repeated with *x* measured on metre rule A and the same *L* in **1(b)** measured on metre rule B.

Label this line W. [1]

Solution:

The new equation will be : $I = \dfrac{E}{R_B L} + \dfrac{E}{R_A x}$

(Since $R_A < R_B$, new gradient > 4.6053 A cm and new vertical intercept < 0.15842 A.)

Using earlier answers,

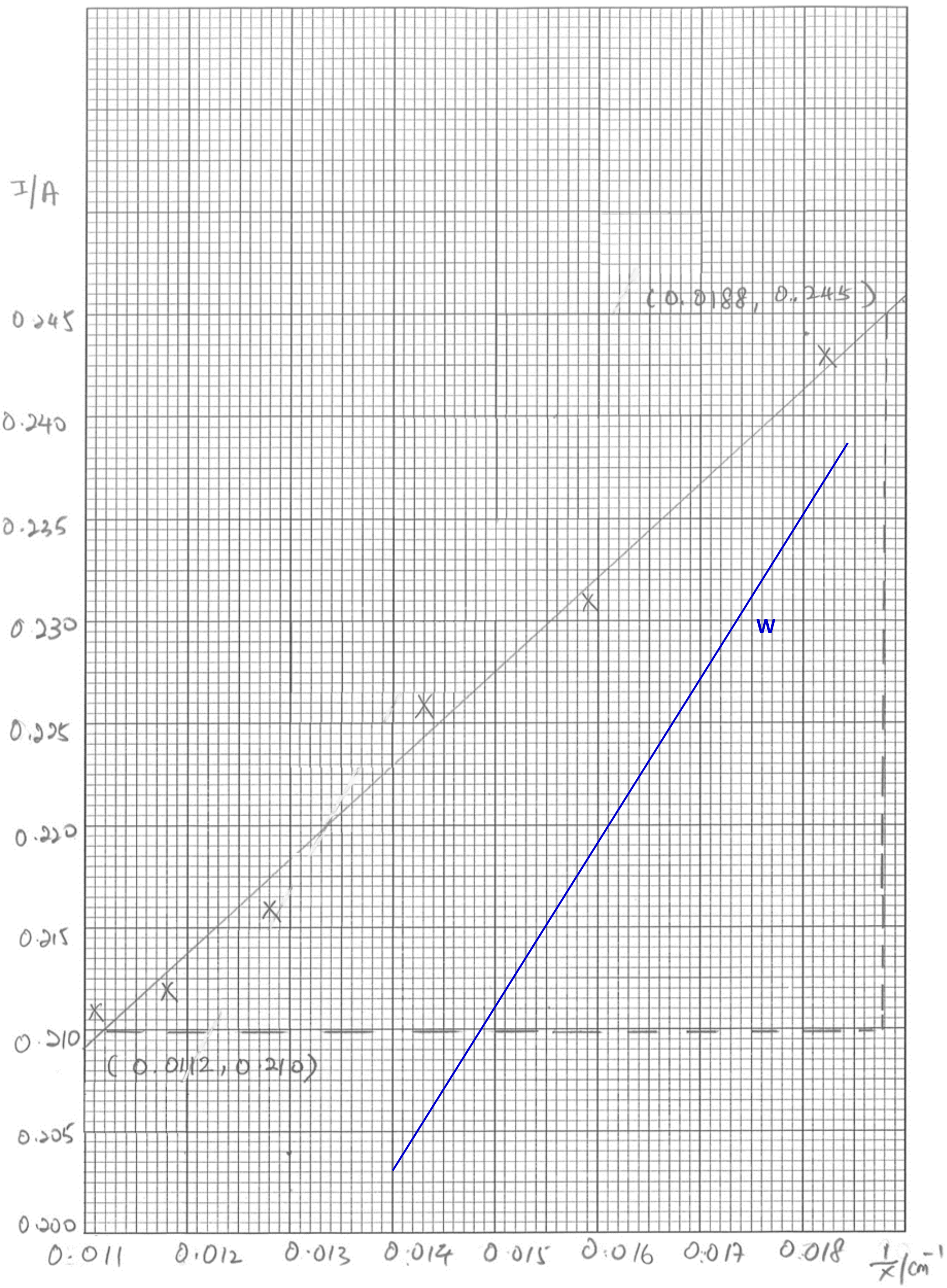
New gradient, $\dfrac{E}{R_A} = \dfrac{1.23}{0.154} = 7.987$

New y-intercept, $\dfrac{E}{R_B L} = \dfrac{1.23}{(0.269)(50.0)} = 0.09145$

Plot Y = 7.987X + 0.09145
When X = 0.014, Y = 7.987(0.014) + 0.09145 = 0.203
When X = 0.017, Y = 7.987(0.017) + 0.09145 = 0.227

If student plotted, *I* against $\dfrac{1}{R_A L} + \dfrac{1}{R_B x}$, the graph should be identical to the original. They need to label the original graph W.

[Total: 15]


I/A
0.245
0.240
0.235
0.230
0.225
0.220
0.215
0.210
0.205
0.200
(0.0188, 0.245)
(0.0112, 0.210)
W
0.011
0.012
0.013
0.014
0.015
0.016
0.017
0.018
1/x /cm⁻¹

2. In this experiment, you will investigate an oscillating system.

(a) Place the wooden strip on the pivot, as shown in Fig. 2.1.

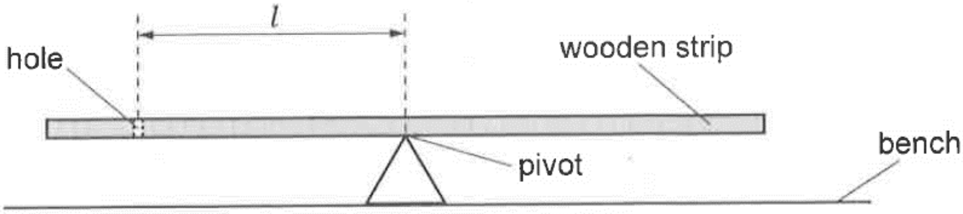


Fig. 2.1

Adjust the position of the wooden strip on the pivot until it balances. The distance between the centre of the hole in the wooden strip and the pivot is l.

Without marking on the wooden strip, measure and record l.

Solution:

l_1 = 18.2 cm , l_2 = 18.1 cm , $l_{ave} = \frac{18.2 + 18.1}{2} = 18.2$ cm

l = ………………18.2 cm………………… [1]

(b) Set up the apparatus as shown in Fig. 2.2.

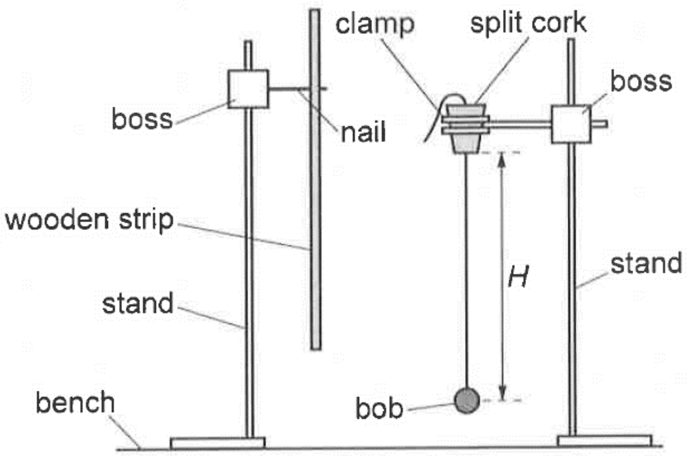


Fig. 2.2

The distance between the bottom of the split cork and the centre of the bob is H.
Adjust the string in the split cork until H is approximately 40 cm.

Displace the bob and the bottom of the wooden strip towards you through a short distance. Release the bob and the strip at the same time. The oscillations of the bob and the strip will be out of phase.

Adjust H so that the oscillations of the bob and the strip remain in phase for several cycles after release.

Measure and record H.

Solution:

$H_1 = 30.4$ cm , $H_2 = 30.5$ cm , $H_{ave} = \dfrac{30.4 + 30.5}{2} = 30.5$ cm

H = ………………30.5 cm…..…..……… [1]

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

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

where b is a constant.

i) Calculate b.

Solution:

$$b = \sqrt{18.2(30.5 - 18.2)} = 14.962 \text{ cm} = 0.147 \text{ m}$$

b = ……………0.147………..……….. m [2]

ii) If you were to repeat this experiment using a similar wooden strip with several holes at different positions along its length, describe the graph that you would plot to determine b.

Solution:

Linearising the above equation into: $lH = l^2 + b^2$

Plot a straight line graph of lH against l^2 where gradient is 1 and the vertical intercept is b^2.

The square root of the vertical intercept gives the value of b.

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……………………………………………………………………………………..... [2]

[Total: 6]

3. In this experiment, you will investigate the stiffness of some metal wires.

A long-handled broom, as shown in Fig. 3.1, must be able to support the weight of the brush at the end without collapsing. Sometimes these brooms are used vertically to reach high places such as ceilings.

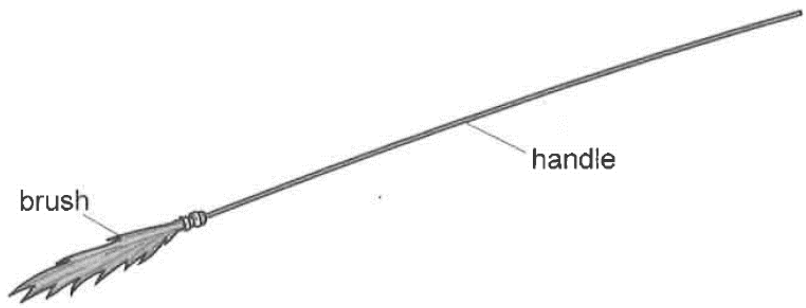

Fig. 3.1

In this experiment, you will model the broom handles using thin metal wires and investigate how the following properties of the wires affect their behaviour:

- length
- diameter
- load
- force constant.

(a) You have been provided with three wires labelled P, Q and R.

Measure and record the diameter *d* of wire P.

Solution:

No zero error (OR zero error = 0.00 mm)

d_1 = 0.45 mm , d_2 = 0.45 mm , $d_{ave} = \frac{0.45+0.45}{2} = 0.45$ mm

d = ……………0.45 mm……..…………… [1]

(b) (i) Attach the sphere of modelling clay to one end of wire P and hold the wire vertically between your thumb and first finger.
The length of wire between the centre of the sphere and the top of your thumb is *h*, as shown in Fig. 3.2.

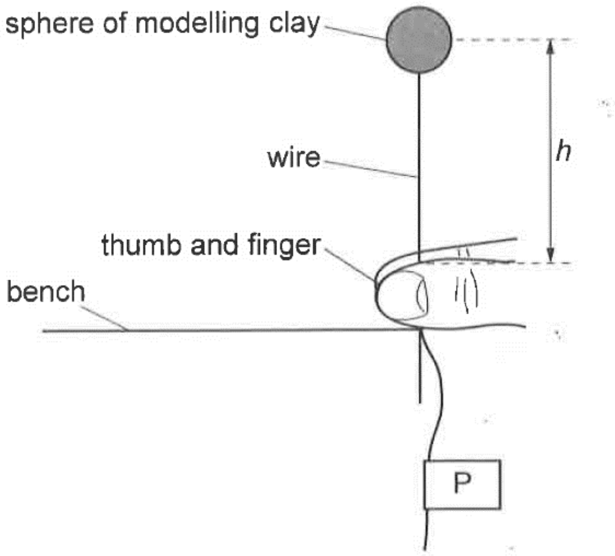

Fig. 3.2

Increase h until the sphere moves down and touches the bench, as shown in Fig. 3.3.

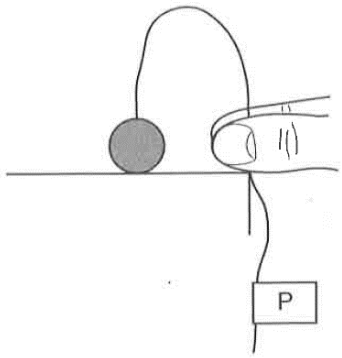

Fig. 3.3

Determine and record h.

Solution:

h_1 = 10.4 cm , h_2 = 10.8 mm , $h_{ave} = \dfrac{10.4 + 10.8}{2} = 10.6$ cm

h = ………………10.6 cm……………… [1]

(ii) Estimate the percentage uncertainty in your value of h.

Solution:

$\Delta h \approx 0.3$ cm

$$\frac{\Delta h}{h} \times 100\,\% = \frac{0.3}{10.6} \times 100\,\% = 2.83\ \% = 3\ \%\ \text{(1 s.f.)}$$

Percentage uncertainty in h = ……………3%………………… [1]

(iii) Suggest one significant source of uncertainty in this experiment.

Solution:

1. It is difficult to determine the **centre of the sphere** and this affects accurate measurement of h.

2. The top of the thumb does provide a good reference point to measure h as it is difficult to ensure the top of the thumb is always horizontal. This affects accurate measurement of h.

3. There are kinks in the wire/ wire is not straight affecting the accurate measurement of h.

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.... [1]

(iv) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(b)(iii)**.

You may suggest the use of other apparatus or a different procedure.

Solution:

1. Use Vernier caliper to mesure the diameter of the sphere of modelling clay to determine the centre of the sphere so that h can be measured accurately.

2. Clamp the wire using split wood to hold the wire instead of using the thumb. The top of the split wood will ensure a clear reference point for accurate measurement of h.

3. Straighten the wire with a pliers or use a new straight wire

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.... [1]

(c) Wire Q is made from the same material as wire P, but has a different diameter.

Repeat **(a)** and **(b)(i)** for wire Q.

Solution:

$d_1 = 0.36$ mm , $d_2 = 0.36$ mm , $d_{ave} = \dfrac{0.36 + 0.36}{2} = 0.36$ mm

h_1 = 6.5 cm , h_2 = 6.7 mm , $h_{ave} = \dfrac{6.5+6.7}{2} = 6.6$ cm

d = ………………0.36 mm…..………………..

h = ……………6.6 cm……..……………….

[3]

(d) It is suggested that

$$h = c\,d^2$$

where c is a constant.

(i) Use your values from **(a)**, **(b)(i)** and **(c)** to determine two values of c.

Give your values for c to an appropriate number of significant figures.

Solution:

Rearranging, $c = \dfrac{h}{d^2}$

$$c_1 = \frac{10.6}{\left(0.45\times 10^{-1}\right)^2} = 5234.56 = 5200\,cm^{-1}$$

$$c_2 = \frac{6.6}{\left(0.36\times 10^{-1}\right)^2} = 5092.59 = 5100\ cm^{-1}$$

first value for c = ……………5200 cm^{-1}……..……………….

second value for c = ……………5100 cm^{-1}……..……………….

[1]

(ii) Justify the number of significant figures given to your values for c.

Solution:

The number of significant figures of c is given to the **least s.f. (2 sf)** of h or d.

……………………………………………………………………………………………

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…………………………………………………………………………………………… [1]

(iii) State whether the results of your experiment support the suggested relationship.
Justify your conclusion by referring to your answer in **(b)(ii)**.

Solution:

Percentage difference $= \dfrac{5200-5100}{5100}\times 100\,\% = 2\%$

……………………………………………………………………………………………

[Turn Over

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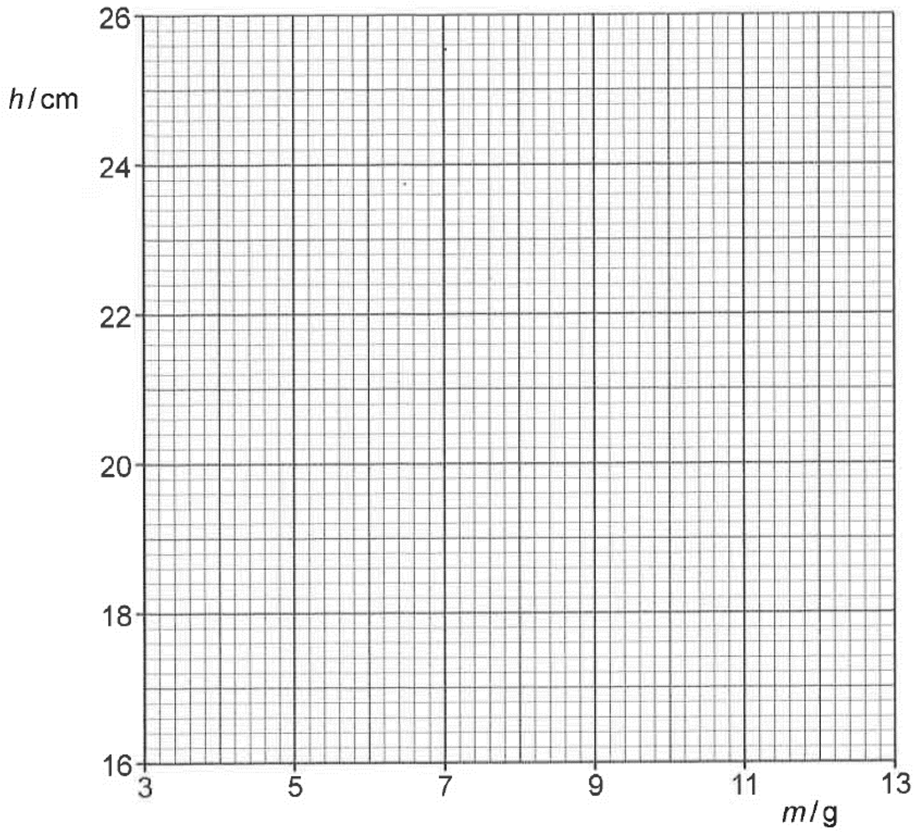
.... [1]

(e) In an investigation, the mass m of the sphere attached to the end of a wire was varied.

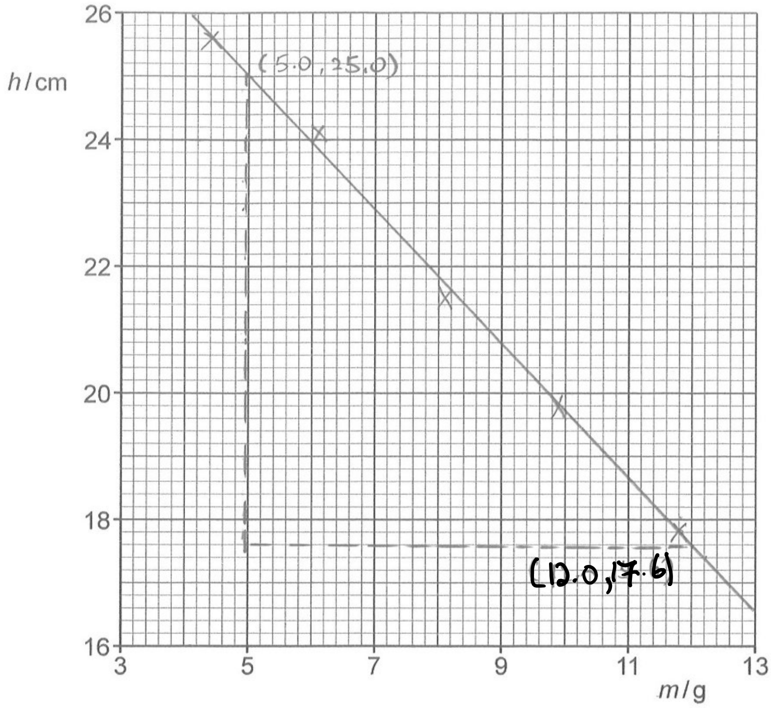
The following results for m and h were recorded.

m /g	4.4	6.1	8.1	9.9	11.8
h / cm	25.6	24.1	21.5	19.8	17.8

(i) Plot h against m on the grid and draw the straight line of best fit. [1]



Solution:



(ii) Use your graph to determine the value h when no sphere is attached to the wire.

Solution:

$$\text{Gradient} = \frac{25.0 - 17.6}{5.0 - 12.0} = -1.0571 \text{ cm g}^{-1}$$

Vertical intercept = 25.0 – (-1.0571)(5.0) = 30.3 cm

When no sphere is attached to the wire, h = vertical intercept = 30.3 cm

h = ……………30.3……………. cm [3]

(f) The force constant k for a wire in tension is defined as

$$k = \frac{YA}{h}$$

where Y is the stiffness of the material of the wire and the cross-sectional area A of the wire is given by $A = \dfrac{\pi d^2}{4}$.

Wires P and R are made from different materials but have the **same** diameter.

Table 3.1 shows the values of Y for the two wires.

Table 3.1

	Wire P	Wire R
Y / GN m^{-2}	170	120

[Turn Over

Take measurements to determine the value of k for each material.

Tabulate your results.

Solution:

	Wire P	**Wire R**
d_{ave} / mm	0.45	0.45
h_1 / mm	10.4	7.8
h_2 / mm	10.8	7.7
h_{ave} / mm	10.6	7.8
A / m^2	$\dfrac{\pi x\left(0.45\times10^{-3}\right)^2}{4}$ = 1.5904×10^{-7}	$\dfrac{\pi x\left(0.45\times10^{-3}\right)^2}{4}$ = 1.5904×10^{-7}
k / N m^{-1}	$\dfrac{\left(170\times10^{9}\right)\left(1.5904\times10^{-7}\right)}{10.6\times10^{-2}}$ = 2.55×10^5	$\dfrac{\left(120\times10^{9}\right)\left(1.5904\times10^{-7}\right)}{7.8\times10^{-2}}$ = 2.45×10^5

[4]

(g) The force constant k of wire P can be found by another method.

Plan an investigation to find k for a fixed length of wire P in tension using the relationship

$$F = kx$$

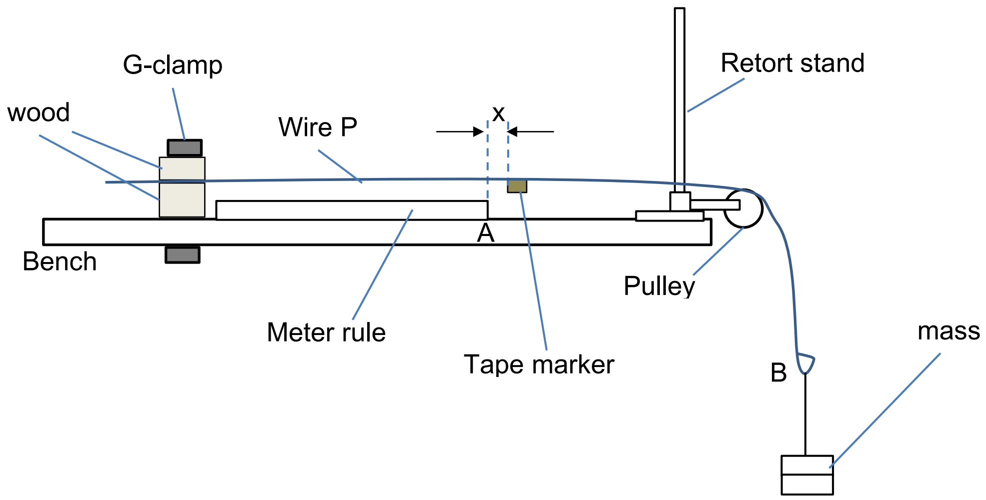
where F is the applied load and x is the extension of the wire.

You would be provided with several masses.

You may suggest the use of any additional apparatus commonly found in a school physics laboratory.

Your answer should include a diagram and your experimental procedure.

Solution:



1. Set up the above without the mass.
2. The tape marker is directly above position A as shown in the diagram when there is no mass attached to wire at B.
3. Add mass at the end of the wire at B to extend the wire. When the wire is extended, the tape marker will move to the right of position A.
4. Record the mass m and calculate F = mg.
5. Measure and record the extension x between position A and the tape marker using a vernier caliper/ metre rule.
6. Repeat Step 3 and 5 to obtain 6 sets of readings.
7. Plot a graph of F against x to obtain a straight line of best-fit, where k is the gradient.

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....[3]

[Total: 22]

4. Fig. 4.1 shows a beaker filled with water and ice cubes all at 0° C.

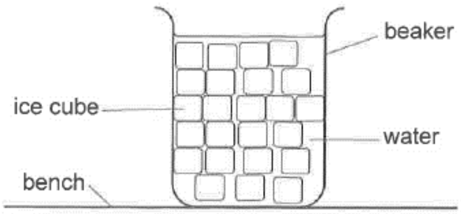

Fig. 4.1

When a constant source of heat is applied to the contents of the beaker, the ice melts.

The initial volume of each ice is the same and the number of ice cubes is n. The total mass of the contents of the beaker is m.

The time taken for the ice to melt is given by $t = k\,n^a m^b$
where k, a and b are constants.

Design an experiment to determine the values of a and b.

You are provided with trays and a freezer to produce ice cubes at 0° C.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to:

- the equipment you would use
- the procedure to be followed
- the control of variables
- any precautions that should be taken to improve the accuracy and safety of the experiment.

Diagram

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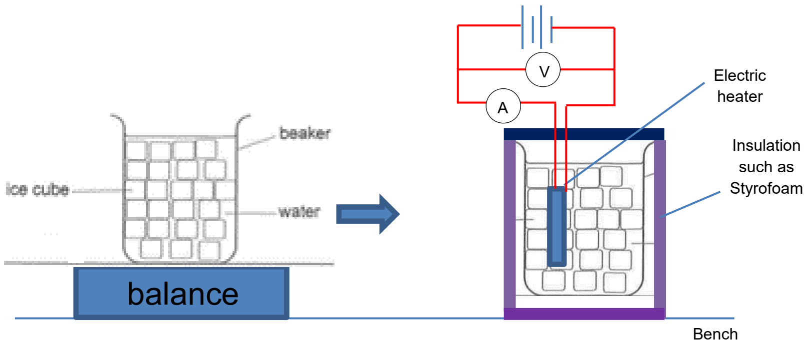
………[12]

[Total: 12]

Solution:

Solution:
There are two parts of the experiment and two straight line graphs drawn to determine *a* and *b*.

Diagram:



<u>1st part: Keeping the number of ice cube *n* constant, varying the mass *m*</u>
Independent variable (IV): mass *m* of ice and water
Dependent variable (DV): time *t* for ice to melt completely
Controlled variables (CV): number of ice cubes *n*, rate of heat transfer to the beaker contents (heating source); rate of heat gain from surroundings.

Procedure:
1. Make about 20 ice cubes at 0 ˚C using the tray and freezer provided.
2. Measure the mass of a beaker that can hold about 20 ice cubes using a weighing balance. Record as M_i. Then, place the 20 ice cubes into the beaker.
3. Add as much water into the beaker such that all ice cubes float. Measure the total mass of the beaker with its contents using the weighing balance. Record as M_f. Calculate $m = M_f - M_i$.
4. Place an electric heater into the beaker with ice and water. Set a constant heat by controlling the power supply to the heater. Use a voltmeter and ammeter to verify that the power supplied to the heater is constant.
5. Place the beaker in a styrofoam insulation and cover the beaker with a thick glass lid .
6. Start the stopwatch when the power supply is switched on. When all ice cube is observed to have melted, stop the stopwatch and record the time *t* it takes for all ice to melt.
7. Repeat step 1 to 5 using similar 20 ice cubes while varying the amount of water added in step 3 for at least 6 sets of readings. In each repeated experiment, the water added must be enough to make all ice cubes float.
8. Plot a graph of lg *t* against lg *m* and obtain a straight line of best fit.
9. Calculate the gradient of the graph. The gradient of the graph gives the value of *b*.

<u>2nd part: Keeping mass *m* constant, vary number of cube *n*</u>
IV : *n*
DV: *t*

CV: m ; rate of heat transfer to the beaker contents (heating source); rate of heat gain from the surroundings.

Procedure:

10. Repeat step 1 to step 5 of the experiment as described in part 1, but with different number of n, reduce from 20, for at least 6 sets of readings.
11. At different n, add water in step 3 above such that each repeated experiment has the same mass m as measured from the weighing balance.
12. Plot a graph of $\lg t$ against $\lg n$ and obtain a straight line of best fit.
13. Calculate the gradient of the graph. The gradient of the graph gives the value if a.

Additional Details:

- Any acceptable details to improve precision and accuracy of results.

Safety:

- Any relevant safety measure.