Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	**MARK SCHEME**		
CLASS	**2T**	**INDEX NUMBER**	

PHYSICS

9749/04

Paper 4 Practical

19 August 2024

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	**/ 23**
4	**/ 11**
Total	**/ 55**

This document consists of **23** printed pages and **1** blank page.

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

(a) *Y*ou have been provided with two identical metre rules, A and B.

Set up the circuit shown in Fig. 1.1.

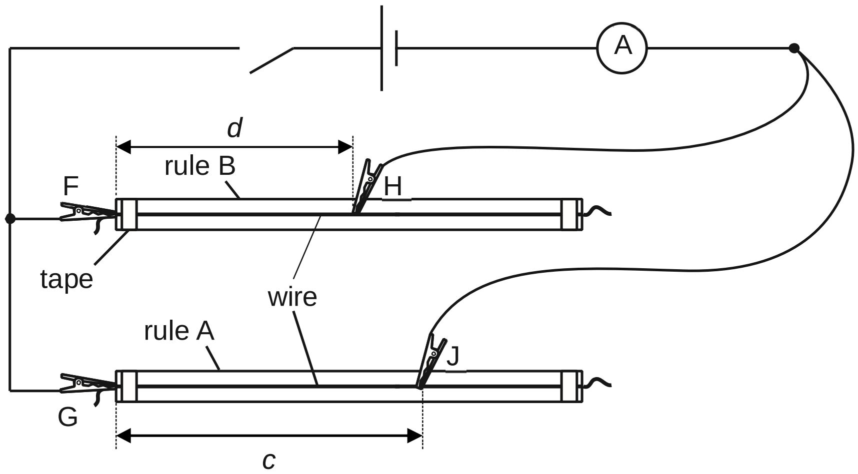


Fig. 1.1

F, G, H and J are crocodile clips of the connecting leads.

(i) Place H approximately half-way along the wire on rule B. The distance between F and H is *d*, as shown in Fig. 1.1.

Place J on the wire on rule A so that the distance between G and J is approximately 60 cm. The distance between G and J is *c*, as shown in Fig. 1.1.

Record *d* and *c*.

d = ...50.0 cm........

c = ...60.0 cm........

[1]

- Correct value of *d* in the range 49.5 – 50.4 cm.
- Correct value of *c* in the range 59.5 – 60.4 cm.
- Correct precision (d.p.) and units: 1 d.p. in cm or 3 d.p. in m.
- Repeated readings not required.

Examiners' Comments:

- *Majority of the candidates obtained full credit.*
- *Candidates are reminded to pay attention to the appropriate d.p. and units.*

(ii) Calculate *n*, where $n = \dfrac{c - d}{d}$.

$$n = \frac{c-d}{d} = \frac{60.0-50.0}{50.0} = 0.200$$

n = ...0.200........

[Turn Over

(iii) Close the switch.

Record the ammeter reading I.

I = ……………144.2 mA……………… [1]

Value of I in the range 75.0 – 175.0 mA with unit.

- Correct value of I in range 75.0 – 175.0 mA.
- Correct units of I.
- Correct precision of I, 1 d.p. in mA or 4 d.p. in A.
- Repeat readings not required (optional).

Examiners' Comments:

- *Majority of the candidates managed to quote the correct d.p. with the corresponding units.*
- *Candidates are reminded* ***not to round off the values shown on the multimeter****.*
- *Candidates that did not obtain full credit had readings that were off the acceptable range.*
- *Candidates need to note that* ***when dealing with electrical circuits, make sure that the connections between wires are not loose. When modifying any part of the experiment, make sure to open the switch first****.*

(iv) Open the switch.

(b) Vary c such that c is greater than d and repeat **(a)(iii)**, keeping d constant throughout.

Present your results clearly.

d = 50.0 cm

c / cm	I / mA	n	$\frac{(n+2)}{(n+1)}$
55.0	151.3	0.100	1.91
60.0	144.2	0.200	1.83
70.0	137.8	0.400	1.71
80.0	132.0	0.600	1.63
90.0	127.5	0.800	1.56
95.0	125.5	0.900	1.53

[5]

1 mark – **6 sets** of readings of c and I showing **correct trend**.
1 mark – **Range maximised: includes a reading of $c \geq 95.0$ cm** and **no values of $c < d$**.
– Award only 1 mark if table only has 5 sets of readings.
1 mark – **Column headings with quantity and correct unit**.
1 mark – All **values of c must be given to the nearest mm (or 1 d.p. in cm or 3 d.p. in m)**.
1 mark – **Correct calculation** of all values of $\frac{(n+2)}{(n+1)}$. n and $\frac{(n+2)}{(n+1)}$ **recorded to least s.f. (3 s.f.)**

Repeat readings not required (optional).

Examiners' Comments:

- *Majority of the candidates did well for this section*
- *Candidates are reminded to* ***always try to maximise their variations (in this case, c).***

(c) It is suggested that I and n are related by the expression

$$I = S\frac{(n+2)}{(n+1)} + T$$

where S and T are constants.

Plot a suitable graph to determine the values of S and T.

Plot a graph of I against $\frac{(n+2)}{(n+1)}$, a straight line graph with gradient S and vertical intercept T should be obtained.

S = gradient = $\frac{156.4 - 125.6}{2.0 - 1.53}$ = 65.532 mA
= 65.5 mA (3 s.f.)

T = vertical intercept = 156.4 – (65.532)(2.0) = 25.336 mA
= 25.3 mA (3 s.f.)

S = ...65.5 mA........

T = ...25.3 mA........

[7]

3 marks – Graph
- Axes labelled with units and good scale (no awkward scale and graph at least half the graph grid both vertically and horizontally).
- All points plotted and plotted accurately to half smallest division.
- Best-fit straight line drawn (satisfies the '3-checks').

1 mark – Gradient calculation
- Correct gradient formula.
- Used 2 coordinates far apart on the best-fit line (separated by at least half the length of the line drawn).
- Read off coordinates accurately to half the smallest division.

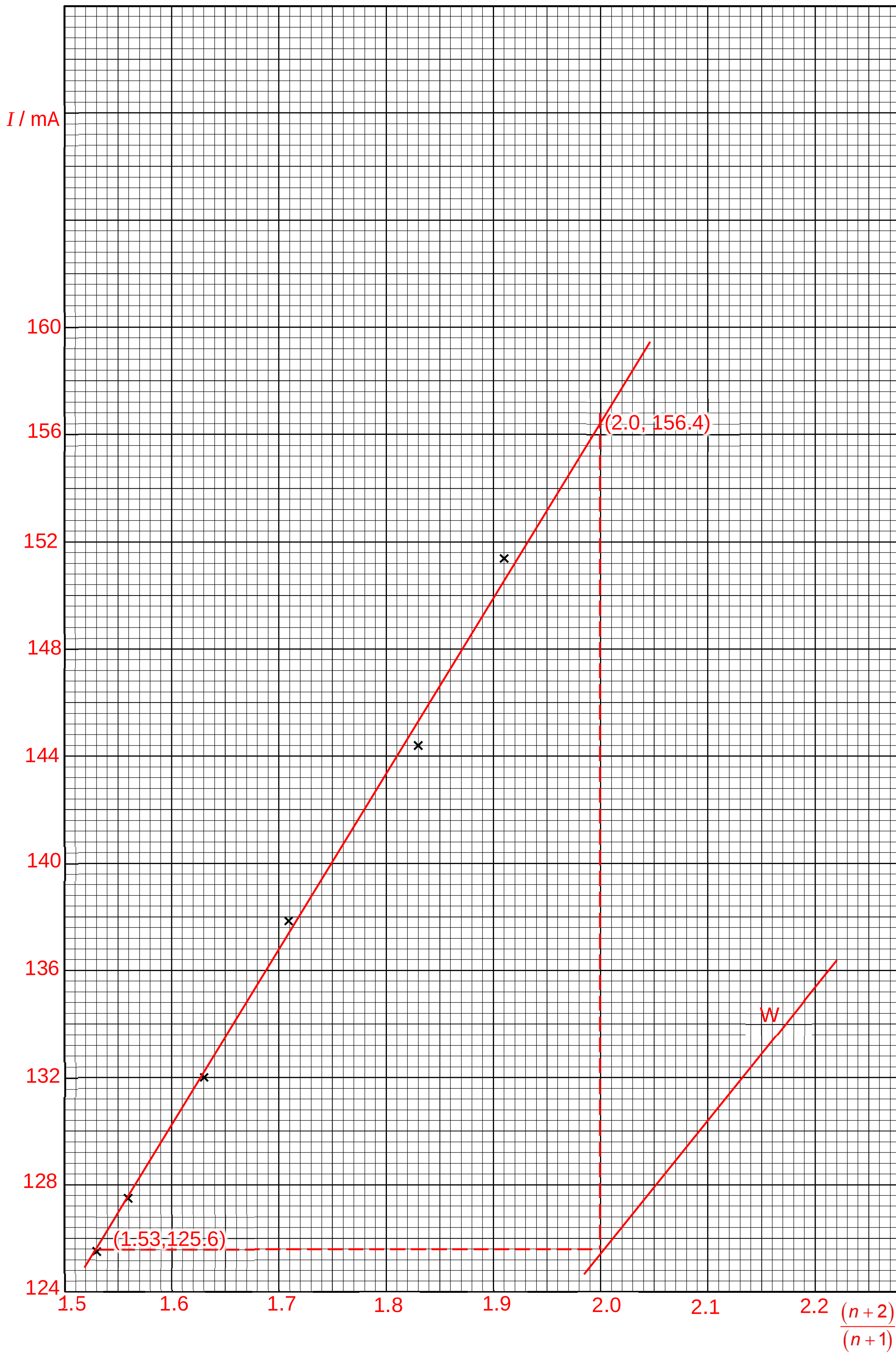
1 mark – *y*-intercept calculation
- Correct formula used. Used coordinates from the best-fit line and not table.
  OR, if graph plotted from x = 0, y-intercept read off graph accurately to ½ smallest division.

1 mark – Determination of S and T
- Equate gradient to S.
- Equate y-intercept to T.

1 mark – Final answer of S and T
- Final values of S and T to 3 sig. fig.
- Correct units of S and T: mA or A.

Examiners' Comments:
- *Majority of the candidates did well for this section.*
- *Candidates are reminded to use appropriate scales.*
- *Candidates are to note that we can only read off the y-intercept when the best fit line cuts at zero for the x-axis. Do not try to start at (0, xxx) to force to read off the y-intercept in expense of being unable to cover at least half the grid size for all points plotted.*
- *Final answers for gradient and y-intercept to keep to 3 s.f.*

- *Best practice for the calculation of y-intercept is when the gradient is obtained, use one of the gradient coordinates to substitute back into the equation.*
- *Candidates are reminded to always pay attention to the units for both gradient and y-intercept.*
- *Candidates are reminded to complete their best fit line and make sure that the gradient triangle covers more than half the length of the best fit line. Pick two coordinates that can be easily read off.*


I / mA
160
156
152
148
144
140
136
132
128
124
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
(n + 2)/(n + 1)
(2.0, 156.4)
(1.53,125.6)
W

(d) Theory suggests that *S* is inversely proportional to *d* and that *T* is independent of *d*. The experiment is repeated using the same equipment but a larger value of *d*.

For this experiment, draw a second line on the graph to show the expected results. Label this line W. [1]

[Total: 15]

1 mark – Correct line W with smaller gradient and vertical intercept same as the first line. (Check and mark for correct vertical intercept if false origin is used. Need to extrapolate students' graphs to check for accurate y-intercept.)

e.g. Let equation of new line be: Y = 50X + 25.3

Examiners' Comments:

- *Majority of the candidates did not obtain full credit.*
- *To obtain full credit,* ***obtain the new equation first (in this case, gradient is smaller and y-intercept remains the same), afterwards, pick two values from the x-axis (n+2 / n+1) and find the corresponding Y values (*** I ***) and then plot.***

2. In this experiment, you will investigate the extension of a spring.

(a) You have been provided with a spring.
Measure and record the length x_0 of the unstretched spring, as shown in Fig. 2.1.

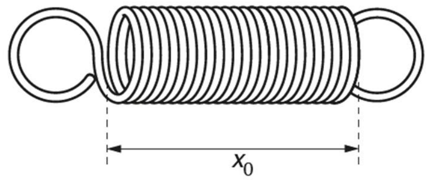


Fig. 2.1

x_0 = ...2.1 cm......................

- Correct value of x in the range 1.8 – 2.4 cm.
- Repeated reading not required.

Examiners' Comments:

- *Majority of the candidates obtained full credit.*

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

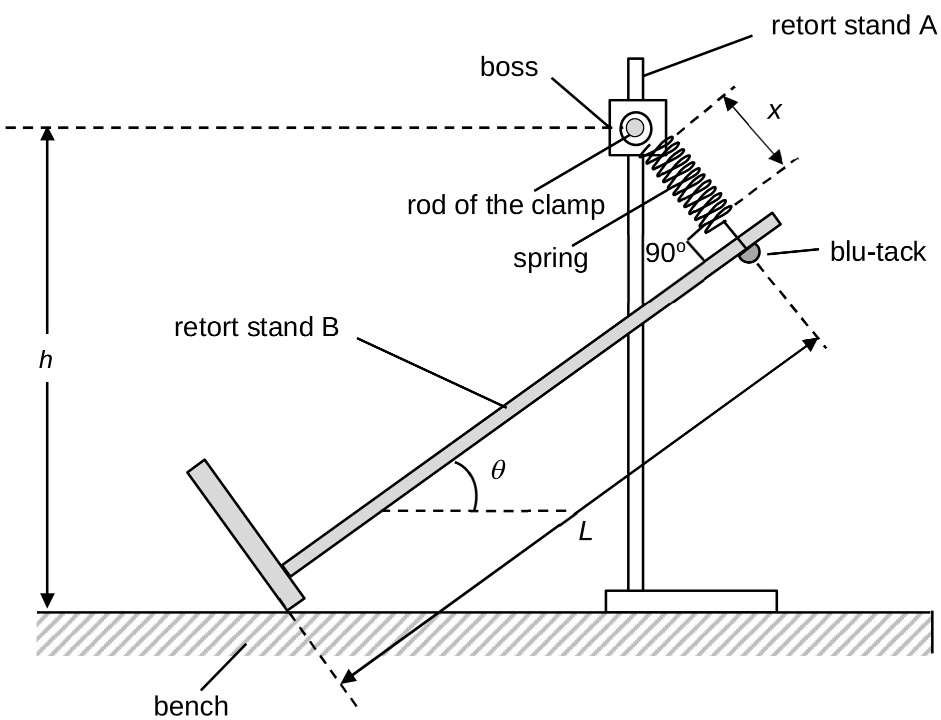


Fig. 2.2

The height h of the rod of the clamp above the bench should be approximately 38 cm.

One loop of the spring should be around the rod of the clamp.

The other loop of the spring should be around the rod of retort stand B close to the top of the rod of retort stand B and secured using blu-tack.

(c) Slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is 90°. CV

The length of the coiled section of the spring is x.
The angle between the rod of retort stand B and the horizontal is θ.
The length between the base of the retort stand B and the spring is L. CV

Measure and record x, θ and L.

$x = 9.8$ cm

$\theta_1 = 22°$
$\theta_2 = 20°$
$$\theta_{average} = \frac{22+20}{2} = 21^0$$

$L_1 = 61.7$ cm
$L_2 = 61.9$ cm
$$L_{average} = \frac{61.7+61.9}{2} = 61.8 \text{ cm}$$

x = ...9.8 cm........

θ = ...21^0........

L = ...61.8 cm........

[2]

1 mark – **Correct d.p and units** of x, θ and L.
1 mark – **Sensible readings** for x, θ and L.

- x measured **ex**cluding the 2 loops of the spring. Accept 9.3 cm < x < 10.3 cm.
- Accept 17° < θ < 27°.
- Accept 60.0 cm < L < 64.0 cm.

– Repeated readings for *θ* and *L*. Repeated readings for x not required (optional).

Examiners' Comments:

- *Majority of the candidates did not obtain full credit.*
- *Candidates are reminded to pay attention to **repeated readings for measurements that are deemed with high uncertainty.***
- *Candidates are reminded to pay attention to the **units and appropriate d.p.***
- *Candidates are **to take note very carefully on how the experiment is supposed to be set-up and follow very closely in terms of what measurements are supposed to be kept constant (i.e. identify the Controlled Variables e.g. 90°, L), as this will affect the accuracy of the Dependant Variables (i.e. x, θ).***

(d) Calculate e where $e = x - x_0$.

$e = 9.8 - 2.1 = 7.7$ cm

e = ...7.7 cm........ [1]

- Correct calculation of e.
- Correct units of e.
- Correct precision of e.

Examiners' Comments:

- *Majority of the candidates obtained full credit.*

(e) Reduce the height *h* of the rod of the clamp to approximately 32 cm. Keeping *L* constant, slide the base of retort stand B until the angle between the rod of retort stand B and the stretched spring is again 90°. $\boxed{\text{2 CVs}}$

Measure and record *x* and θ. Calculate *e*.

x = 11.0 cm θ = 14°

e = 11.0 – 2.1 = 8.9 cm

x = ……………………11.0 cm……………………

θ = ……………………14^0……………………

e = ……………………8.9 cm……………………

- Correct computation of *e* and correct d.p and units of *x* and *θ*.

(f) Theory suggests that the quantities *e* and *θ* are related by the equation

$$e + \frac{mp}{L}\tan\theta\cos\theta = \frac{mq}{L}\cos\theta$$

where *m* is the mass of retort stand B, $p = 0.246\ \text{cm}^2\ \text{g}^{-1}$ and $q = 0.369\ \text{cm}^2\ \text{g}^{-1}$.

It is also found that the force constant of the spring *k* is given by the equation

$$k = \frac{gy}{p}$$

where $g = 9.81\ \text{m s}^{-2}$ and $y = 4.2$ cm.

(i) Calculate *k*.

$$k = \frac{gy}{p} = \frac{(9.81)(4.2\times10^{-2})}{(0.246\times10^{-1})} = 16.749 = 16.7\ \text{N m}^{-1}$$

k = ……………………16.7…………………… N m^{-1} [1]

- Correct calculation of *k*.

Examiners' Comments:

- *Majority of the candidates did not obtain full credit.*
- *Candidates are reminded to **pay attention to the units and convert appropriately**.*

(ii) If you were to repeat this experiment with other values of θ, describe the graph that you would plot to determine *k*.

- **Linearise** the equation: $\frac{e}{\cos\theta} = -\frac{mp}{L}\tan\theta + \frac{mq}{L}$
- Plot a **straight line** graph of $\frac{e}{\cos\theta}$ against tan θ.
- Calculate the **gradient** of the graph which **gives value of** $\left(-\frac{mp}{L}\right)$.
- **Determine** $p = -\frac{L}{m}(gradient)$, **where *m* is measured using an electronic balance, and *L* measured with a metre rule.** [2]
- **From *p*, determine *k*:** $\left(k = \frac{gy}{p}\right)$.

[Total: 6]

1 mark – Correct linearisation of equation.
1 mark – Correct method to determine *k* through value of gradient.

Examiners' Comments:

- *Majority of the candidates did not obtain full credit.*
- *Candidates need to **take note which physical quantities are varying, and which are constants, in order to linearise the equation correctly.***
- *Candidates are reminded not to over-complicate linearising the equation. Focus on which is varying and which is constant. Gradient and y-intercept cannot have quantities that are varying.*
- *Candidates will need to use both equations in **(f)** to obtain k.*

3. In this experiment, you will investigate the motion of a hacksaw blade supported by a G-clamp.

(a) Using the blu-tack, attach the two slotted masses as close as possible to one end of the hacksaw blade, as shown in Fig. 3.1.

Fig. 3.1

(b) **(i)** Using a micrometer screw gauge, measure the thickness u of the hacksaw blade.

u_1 = 0.74 mm
u_2 = 0.76 mm

$$u_{average} = \frac{0.74 + 0.76}{2} = 0.75 \text{ mm}$$

u = ……………0.75 mm…………… [1]

- **Correct value** of thickness in the **range 0.65 mm – 0.85 mm**.
- **Correct precision** to the **2 d.p in mm, with correct unit.**
- **Repeated values** of thickness required.

Examiners' Comments:

- *Majority of the candidates obtained full credit.*
- *Some candidates were unsure about the usage of a micrometer screw gauge and thus obtained readings that were not within the correct range of answers.*
- *Some candidates provided answers with poor precision.*

(ii) Using a vernier caliper, measure the breadth w of the hacksaw blade.

w_1 = 11.9 mm (or 1.19 cm)
w_2 = 12.1 mm (or 1.21 cm)

$$w_{average} = \frac{11.9 + 12.1}{2} = 12.0 \text{ mm}$$

w = ……………12.0 mm…………… [1]

- **Correct value** of breadth in the **range 11.0 mm – 13.0 mm**.
- **Correct precision** to **1 d.p in mm or 2 d.p. in cm, with correct unit**.
- **Repeated values** of breadth required.

Examiners' Comments:

- *Many candidates were confused with the use of the mircrometer screw gauge and the vernier caliper and thus obtained inaccurate answers.*
- *Many candidates recorded the readings with incorrect units.*
- *Some candidates did not record any repeated values.*

(c) **(i)** Set up the apparatus as shown in Fig. 3.2.

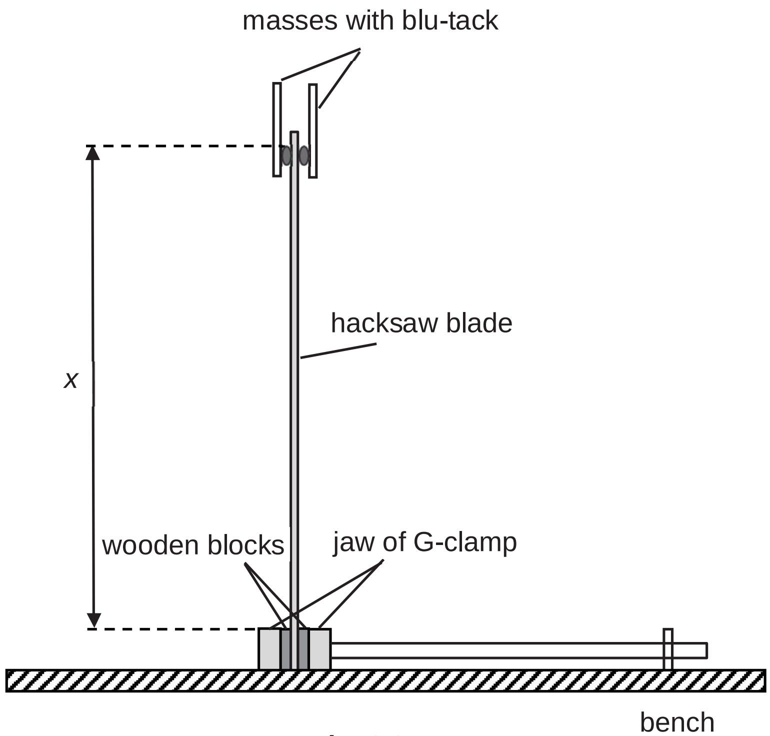


Fig. 3.2

(ii) Measure and record the distance *x* between the top of the jaw of the G-clamp and the centre of the masses, as shown in Fig. 3.2.

x = ……………26.5 cm…………… [1]

- **Correct value** of *x* in the **range 16.0 – 28.5 cm**.
- **Correct precision** of *x* to the **nearest mm, with correct unit**.
- Repeated readings not required (optional).

Examiners' Comments:

- *Very well done.*
- *Some students wrongly recorded to 2 d.p. in cm (or nearest 0.01 cm).*

(iii) Estimate the percentage uncertainty in your value of *x*.

$$\frac{\Delta x}{x}\times 100\% = \frac{2}{26.5}\times 100\%$$
$$= 7.547\ \%$$
$$= 8\ \%$$

percentage uncertainty = ……………8 %…………… [2]

1 mark – **Absolute uncertainty in x in range 0.5 cm – 2 cm**. If repeated readings have been taken, then the uncertainty can be half the range (not zero) only if working shown.

1 mark – **Correct calculation of percentage uncertainty** of *x*, and **final answer to 1 s.f. or 2 s.f.**

Examiners' Comments:

- *Well done.*
- *Note that this **length x has uncertainty <u>greater than</u> the ruler's precision due to: (1) blade not straight when measuring x, and, (2) error in judging centre of mass of slotted mass.***
- *Some students are still wrongly writing precision of metre rule (0.01 cm) as the actual uncertainty. Note that there are judgement + measurement error <u>on top of</u> the precision of instrument.*

(d) (i) Gently displace the top end of the hacksaw blade to the left. Release the blade and watch the movement.

The blade will move to the right and back towards the left, completing a swing as shown in Fig. 3.3.

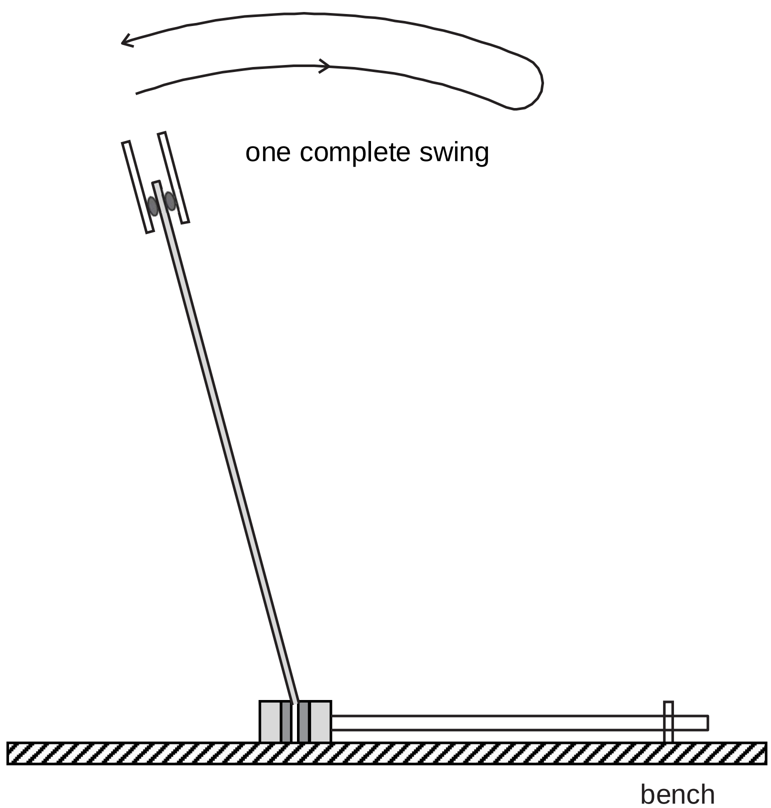


Fig. 3.3

(ii) The time taken for one complete swing is T.

Take measurements to obtain an accurate value for T.

N	t_1 / s	t_2 / s	T / s
45	20.9	20.8	$\frac{20.9+20.8}{90} = 0.464$ s

T = ...0.464 s.......... [3]

1 mark:

- **Raw timings t should be taken for several swings such that $t > 20$ s.**
- **Record of number of swings.**
- **Correct calculation to find T.**

1 mark:

- **Repeated timings** recorded.

1 mark:

- ***t* recorded to 1 d.p. with units s.**
- **Value of *T* to same s.f. as *t*, with units s.**

Examiners' Comments:

- *Well done.*
- *Some students are making mistakes that they shouldn't be making at this point of time, e.g. forgetting to take repeated measurements, wrong s.f. for period T. Note that we do not refer to the s.f. of number of oscillation N as it is an integer number and we assume no error in counting (that is the reason why the least number of s.f. for T is following the least s.f. for t).*

(iii) Calculate the frequency *f* of the swings.

$$f = \frac{1}{T} = \frac{1}{0.464} = 2.16 \text{ Hz}$$

f = ...2.16 Hz........ [1]

- Correct calculation of *f* using $f = \frac{1}{T}$.
- Value of *f* to same s.f. as *T*, and in units Hz (or s^{-1}).

Examiners' Comments:

- *Very well done.*

(e) **(i)** Reduce *x* by attaching the masses to another position on the hacksaw blade.

(ii) Repeat **(c)(ii)** and **(d)**.

x = 16.0 cm

N	t_1 / s	t_2 / s	T / s
70	20.5	20.4	$\frac{20.5 + 20.4}{140} = 0.292$ s

$$f = \frac{1}{T} = \frac{1}{0.292} = 3.42 \text{ Hz}$$

x = ...16.0 cm........

T = ...0.292 s........

f = ...3.42 Hz........

[2]

1 mark – **2nd value of *x* < 1st value of *x*.**

1 mark – **2nd value of *T* < 1st value of *T*.**
(Value of *f* not marked as it was marked for earlier. Ignore d.p., units, repeat timing – marked for earlier.)

Examiners' Comments:

- *Very well done as few students have gotten a wrong range. Mistakes made in this part are typically penalised in previous parts and hence no mark is deducted here.*

(f) It is suggested that the relationship between f and x is

$$f^2 = \frac{k}{x^3}$$

where k is a constant.

(i) Using your data, calculate two values of k.

$$f^2 = \frac{k}{x^3} \Rightarrow k = f^2 x^3$$

When x = 26.5 cm, f = 2.16 Hz;

$k = (2.16)^2 (26.5)^3 = 86825$ s^{-2}cm^3

= 86800 s^{-2}cm^3

When x = 16.0 cm, f = 3.42 Hz;

$k = (3.42)^2 (16.0)^3 = 47908$ s^{-2}cm^3

= 47900 s^{-2}cm^3

first value of k = ………………86800 s^{-2} cm^3………………

second value of k = ………………47900 s^{-2} cm^3………………

[2]

1 mark – **Correct calculation** of both values of k.
1 mark – **Correct units** for both values of k.
(k should be expressed to correct number of sig. fig. – Reasoning marked for in the next part.)

Examiners' Comments:

- *Not well done due to missing units. Generally, calculations are correct except for carelessness in dropping powers / calculator mistakes.*

(ii) Justify the number of significant figures that you have given for your value of k.

The data for t and x are given to 3 significant figures (s.f.). Therefore, the number of s.f. for k will follow the least s.f. for f and x, which is 3 s.f.

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

1 mark – Correct justification for s.f. in k linked to s.f. in t and x. (Do not allow "raw readings".)

Examiners' Comments:

- *Remember to refer to the quantities when justifying which is lower s.f. (even if both have the same least number of s.f.!).*

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

$$\text{percentage difference} = \frac{k_2 - k_1}{k_2} \times 100\% = \frac{86800 - 47900}{86800} \times 100\% = 44.8\%$$

Since the percentage difference between the 2 values of k = 44.8% is more than the estimated percentage uncertainty calculated in **(c)(iii)** of 8%, the results of the experiment do not support the suggested relationship.

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

Correct calculation of percentage difference in values of k.
Correct conclusion based on comparison between percentage difference of k and value from **(c)(iii).**

Examiners' Comments:

- *Well done. Some students should remember to cite the value from (c)(iii) so that the conclusion is valid.*
- *Some students are not familiar with the demands of this question. Note that this question has been appearing in the A levels exam for the past few years.*

(g) **(i)** Suggest one significant source of uncertainty in this experiment.

- The oscillation is too fast (time small / short /vibrates fast / high frequency / oscillates fast / swings fast.), which affects the number of oscillations recorded. / Large uncertainty in time. OR The range of x is too small for measurable times because 30 cm of blade is too short such that frequency is high at low values of x. [1]

(Not as significant as the above):

- Difficulty in judging the centre of masses, which affects the measurement of x.
- Difficult to measure x accurately as blade may not be perfectly vertical when clamped.
- Oscillation is uneven and G-clamp is moving. This affects the measurement of time.

1 mark – Cite a **significant error and its root cause**. **State the measurement whose accuracy is affected**.

Examiners' Comments:

- *Well done.*
- *Some students are not clear in explaining how the* ***high uncertainty in timing is affecting counting of oscillations****. They* ***phrased wrongly as the short period is comparable to human reaction timing but did not recognise that this effect has been minimised through taking total timing > 20s.***

(ii) Suggest an improvement that could be made to the experiment to reduce the uncertainty identified in **(g)(i)**.

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

- Use an improved method of timing, e.g. video with timer / video and view frame by frame / light gate placed at the centre (to timer / datalogger display) to measure accurately the period of oscillation.

(Not as significant as above): [1]

- Clamp G-clamp to table so that G-clamp is fixed and not unstable.
- Use masses without slots / measure to the top and bottom and take average readings of *x*.
- Use of set square to measure *x* more accurately by ensuring *x* is perpendicular to the bench.

1 mark – Cite a significant improvement with elaboration. **Improvement should be relevant to the error cited in (g)(i)**. The **method / the "how" must be clear**.

Examiners' Comments:

- *Well done.*
- ***Those who use data logger + photogate, please note:***
  - ***Must state which sensor to use: photogate***
  - ***Data logger doesn't sense anything. So it cannot work alone.***
  - ***Photogate also cannot work alone without data logger.***
- ***Those who use video recording, please note:***
  - ***State how to use the recorded video, either playback in slow-motion to count the number of oscillations, or to playback frame-by-frame.***
  - ***Need to state how the timing can be obtained from the video. Either by referring to the timeframe of the video or ensure a running stopwatch is recorded in the video as well.***

(h) Fig. 3.4 shows a metronome.

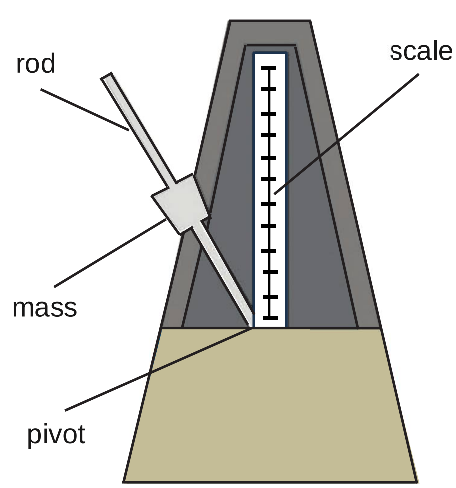


Fig. 3.4

1 oscillation

A metronome is a device used by musicians to set a regular beat in which a rod moves backwards and forwards. The rod must be displaced sideways before it starts to move.

The frequency *f* of the beat of the rod is adjusted by moving a mass along the length *x* of the rod. The position of the mass on the rod determines the frequency of the beat. The position of the mass can be measured on the scale of the metronome.

Most music is within the range 60 to 200 beats per minute.

60 bpm = 1 beat per s = 1 Hz
200 bpm = 3.33 beats per s = 3.33 Hz

A manufacturer wishes to keep the length of the rod of the metronome to 8 cm. The mass on it can be moved between 2 cm to 8 cm from the pivot.

The hacksaw blade, clamped vertically at the bottom end, can be used to model the rod of a metronome.

Plan an investigation to determine the relationship between the length *x* of the rod and frequency *f* of a beat that can be used to calibrate the metronome.

Your account should include:

- your experiment procedure,
- control variables,
- how you would determine a suitable mass to use as the movable mass,
- how you would determine the relationship between *x* and frequency *f*.

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[Total: 23]

Procedure:

1. Set up the apparatus as shown in Fig. 3.3.
2. Fix a single mass (e.g. plasticine) uniformly around the rod. / Attach 2 slotted masses like before on the rod. Use an electronic balance to measure and record the total mass *m* used.
3. Using a metre rule, measure and record the distance x = 8 cm between the top of the jaw of the G-clamp / top of the wooden block and the centre of the mass.
4. Gently displace the top end of the hacksaw blade to the left. Release the blade and allow the blade to oscillate.
5. Since the oscillations are fast, to measure *T* accurately, use a video with timer / video and view frame by frame / light gate placed at the centre of the oscillations (connected to timer/datalogger display; blade cuts the light gate beam twice per oscillation) / stroboscope (start from high flash rate and reduce gradually until blade appears stationary, this frequency value equals *f*).
6. Record the period of oscillation *T*. *[*Contextualise how T (or f) is obtained according to the method used in step (5).]*
7. Calculate the frequency of oscillation $f = \dfrac{1}{T}$.
8. Change the mass *m* used if the frequency is not approximately 1 Hz (60 beats per minute).
9. Repeat step (4) to (7) until the value of *f* is approximately 1 Hz at x = 8 cm.
10. Using the same mass *m*, repeat step (3) to (7) for x = 2 cm.
11. Change the mass *m* used if the frequency is not approximately 3.33 Hz (200 beats per minute).
12. Repeat step (4) to (7) until the value of *f* is approximately 3.33 Hz at x = 2 cm and 1 Hz at x = 8 cm.
13. **With the known mass $m = M_o$, keep this value of mass constant.** Repeat steps (4) to (7) to obtain at least 6 sets of data by moving this mass along the rod to vary x between 2 cm and 8 cm.
14. **Assuming equation of $f = kx^n$. Linearizing the equation,** $\lg f = \lg k + n \lg x$ **. Plot a graph of** $\lg f$ **against** $\lg x$ **. Gradient of straight line graph will give value of *n*. Vertical intercept = lg *k*. Therefore,** $k = 10^{\text{vertical intercept}}$ **.**

1 mark – A1: From earlier investigation, with x shorter, *f* is greater. At x = 2 cm, *f* should be 200 beats per minute; and at x = 8 cm, *f* should be 60 beats per minute. Preliminary investigation: With distance from pivot = 2 cm and also = 8 cm, vary the mass used (e.g. using plasticine) to determine mass that will give *f* between 60 beats per minute (1 Hz) and 200 beats per minute (3.33 Hz).

1 mark – A2: Control of variable: selected mass to be kept constant. (Vary distance x of mass along rod.)

1 mark – A3: Method to measure *f* more accurately since *f* is great. Accept use of manual stopwatch, but use of more accurate method such as video with timer / light gate with datalogger / stroboscope is preferred when measuring period at x = 2 cm. Need to make clear what constitutes a period of oscillation.

1 mark – A4: Method to vary x, with x between 2 cm to 8 cm, and number of data sets.

2 marks – Graphical determination

- 1 mark – A5: Graph to plot.
- 1 mark – A6: How to use features of results to calculate unknown constants to determine the equation relating *f* and x.

Examiners' Comments:

- *Many candidates did not explain clearly how to determine a suitable mass to use as the movable mass.*
- *Many candidates did not realize that the use of a stopwatch to measure the period of oscillation of the mass at x = 2 cm would provide inaccurate readings due to the short time taken for each oscillation.*
- *Some candidates also did not provide any graphical analysis to determine the relationship between the length x of the rod and frequency f.*

4. Fig. 4.1 shows a metal plate placed above a heater of constant power.

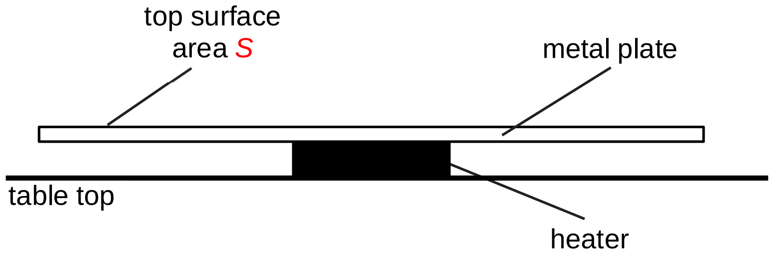

Fig. 4.1

After the metal plate is heated for some time, it reaches an equilibrium temperature θ.

The metal plate is rectangular in shape and has a top surface area S. The metal plate has steady wind flow above it with wind speed v.

Theory suggests that the equilibrium temperature is given by

$$\theta = kS^a v^b$$

where k, a and b are constants.

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

You are provided with rectangular metal plates of different surface areas.

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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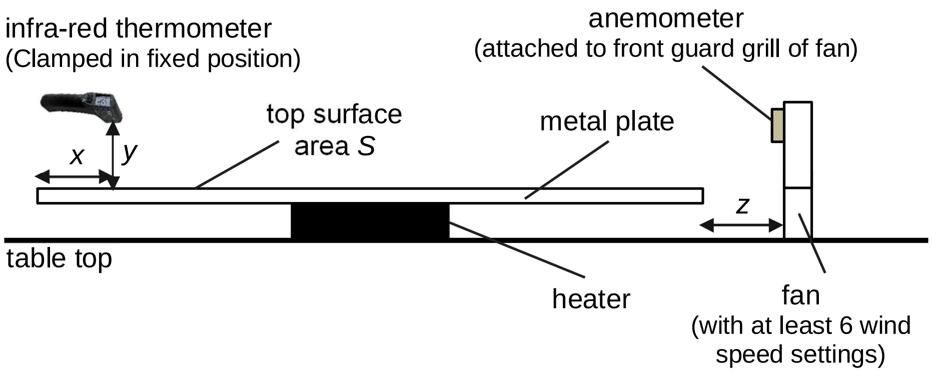
[Total: 11]

Solution:

	[D] – Well labelled diagram (especially relevant to IV and DV/ context of experiment) Suitable thermometer, e.g. infra-red thermometer or thermocouple thermometer or resistance thermometer or temperature sensor connected to datalogger. Do not accept liquid in glass thermometer. Fan with an anemometer [OR, Fan with an air flow rate metre fixed OR wind speed meter on the fan's front guard grill (for small plate) or at the position where temperature is measured (for large plate).].
Part 1: To determine *a*, vary *S* and keep *v* constant **Independent variable (IV)**: *S* **Dependent variable (DV)**: θ **Controlled Variables (CV)**: *v*, orientation of infra-red thermometer and anemometer, distances *z*, constant power heater	
Procedure: 1. Set up the experiment as shown in the diagram above. 2. Clamp the infra-red thermometer at a fixed position and orientation, facing the metal plate squarely. 3. Use a fan with adjustable wind speeds, with an anemometer [OR an air flow rate meter, OR a wind speed meter] attached onto the fan's front guard grill (for small plate) or at the position where temperature is measured (for large plate). 4. Ensure that the anemometer's position is kept constant throughout the experiment by clamping it at this fixed position. 5. Switch on the fan and anemometer and adjust the wind speed to a constant value as shown on the anemometer. Use the same fan speed setting to keep *v* constant throughout this part of the experiment. 6. Using a metre rule, measure the length *L* and breadth *B* of the surface area of the metal plate. 7. Calculate the surface area S of the metal plate by $S = L \times B$.	[CV1] – Method to keep control variable (*v*) constant for part 1. [IV1] Method of measuring *S*

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8. Switch on the infra-red thermometer and record the steady-state temperature of the metal plate θ. 9. Change the metal plate to another metal plate of different surface area. 10. Repeat steps 6 - 9 until at least 6 sets of data with 6 different values of S are obtained. 11. Plot a straight line graph of lg θ against lg S. 12. Calculate the gradient of the graph, which gives the value of a.	[DV] Method of measuring θ [IV2] Varying IV – procedure and suitable number of data sets [A1] Analysis – Suitable graph to plot and feature of graph to use to find a
Part 2: To determine b, vary v and keep S constant **IV**: v **DV**: θ **CV**: S, orientation of infra red thermometer and anemometer, distances z, constant power heater	
Procedure: 13. Select one metal plate. Use the same metal plate throughout to keep S constant for this part of the experiment. 14. Switch on the fan to a particular speed setting. Record v from the anemometer. 15. Switch on the infra-red thermometer and record the steady-state temperature of the metal plate θ. 16. Adjust the fan to a different speed setting. 17. Repeat steps 14 - 16 until at least 6 sets of data with 6 different values of v are obtained. 18. Plot a straight line graph of lg θ against lg v. 19. Calculate the gradient of the graph, which gives the value of b.	[CV2] Method to keep control variable (S) constant for part 2 [IV3] Method of measuring v and procedure for varying v [A2] Analysis – Suitable graph to plot and feature of graph to use to find b
Additional Details: 1. Perform a preliminary experiment to determine a suitable range of values of S and v to use such that any variation in θ are observable. 2. For metal plates with large dimensions: Using a metre rule, measure the horizontal distance of the infra-red thermometer x along the metal plate, and the vertical height y of the infra-red thermometer above the metal plate. Ensure that distances x and y are kept constant by clamping the thermometer at this fixed position. Mark out a spot on the metal plate using a cross, to ensure that the infra-red thermometer is positioned consistently above the spot. Place the anemometer/ air flow rate metre at this spot as well to measure v where θ is measured. 3. For metal plates with small dimensions such that the wind speed is relatively uniform across the plate surface: Use multiple infra-red thermometers to measure the temperature of different parts of the metal plate, and take average to minimise random error. 4. Dimensions of metal plate should be kept small so that wind speed is uniform across the surface area of the metal plate. If dimensions of metal plate used is large, attach the anemometer/ air flow rate meter at the point where the thermometer is so as to measure corresponding θ and v. 5. Ensure distance z is of a small value (e.g. less than a certain distance 50 cm) so that the measured wind speed is the same wind speed across the metal plate.	[AD] – Any 1 accuracy details with reason given Award maximum of 2 AD marks, and maximum of 11 total marks.

6. Ensure the metal plate is mounted on the heater parallel to the table by using a set square. This is to ensure that the volume flow rate of the wind will be kept constant across the metal plate. 7. Allow the temperature of the metal plate to stabilise (temperature reading remains unchanged with time) before recording θ to ensure thermal equilibrium is reached. 8. Keep the heater at constant power e.g. connect the heater to a circuit showing e.m.f., voltmeter, ammeter and rheostat adjusted such that $P = IV$ remains unchanged during the experiment. 9. Conduct the experiment in an enclosed, temperature-controlled (e.g. air-conditioned) room to avoid wind sources other than that used in the experiment and for room temperature to be constant.	
Safety: (any one) 1. Use of protective gloves to handle heater and metal plate. 2. Wear thermal protective suit as the temperature of the hot metal plate may be too high / dangerous to touch. 3. Do not use liquid in glass thermometer as the high temperature may cause the thermometer to crack.	[S] – Any one relevant and significant safety precaution (actions taken with reason)

Marks	
D	Well-labelled diagram that is sensible, including: • Fan with an anemometer/ air flow rate metre/ wind speed metre fixed on the fan's front guard grill (for small plate) or at the position where temperature is measured (for large plate), • Suitable thermometer e.g. infra-red thermometer / thermocouple / resistance thermometer / temperature sensor connected to datalogger. • Sensible setup of the various apparatus. Table/bench top drawn. Distances x, y and z labelled. (Optional)
DV	Method of measuring θ.
CV1	Method to keep control variable v constant for part 1.
IV1	Method of measuring S.
IV2	Varying IV – procedure and suitable number of data sets.
A1	Analysis – Suitable graph to plot and feature of graph to use to find a.
CV2	Method to keep control variable S constant for part 2.
IV3	Method of measuring v and procedure for varying v.
A2	Analysis – Suitable graph to plot and feature of graph to use to find b.
AD	Method to ensure consistent orientation of infra-red thermometer facing the metal plate / Any reliability detail to enhance accuracy, with reason given. **Award maximum of 2 AD marks, and maximum of 11 total marks.**
S	Any one relevant and significant safety precaution (actions taken with reason). It is important to note that actions need to be accompanied with reasoning to be credited here. Not acceptable:

	Warnings "Do not touch", -explain what to do, not what not to do

Examiners' Comments:

- *Diagram:*
  - *Table top/ Bench top/ Ground was missing in several scripts.*
  - *Often a fan is drawn but the Instrument to measure v is not drawn.*
  - *Where an instrument to measure v was drawn, it was sometimes 'flying' or unsupported. Some students used vague terms like 'speed tracker' which does not stipulate what speed this is measuring e.g. WIND speed, or 'instrument to measure v' without naming the instrument. Some students referred to 'wind speed turbine'/'windmill' rather than wind speed sensor/meter. A turbine/windmill primarily converts rotational kinetic energy into electrical energy; cannot assume it's calibrated to measure v. A speedometer is also inappropriate for measuring v. A wind-vane does not measure wind speed.*
  - *Several students used datalogger without specifying the relevant type of sensor e.g. temperature sensor or wind speed sensor.*
  - *Some students did not make clear what type of thermometer is used (i.e. just labelled 'thermometer') and/or drawn what looked like a liquid-in-glass thermometer. Note that 'digital thermometer' is not sufficient to describe the type of thermometer used. Several students placed a beaker of water on the plate with a liquid-in-glass thermometer immersed in the water. This would limit the measurable temperature to the boiling point of water whereas the metal plate can be of higher temperatures, hence not suitable for this experiment investigation.*
- *Identifying IV, DV and CV(s) for each part:*
  - *Vast majority of candidates are able to identify these well.*
  - *However, a handful of candidates are still unclear about the meanings of IV, DV and CV(s) and confused S, v and θ.*
  - *Some candidates named objects rather than variables as the CV, e.g. 'plate used' (object) versus 'thickness/material/volume/mass/density of plate used' (variable). Also CV should have an effect on the DV if not kept constant; a CV is not simply anything kept unchanged in the experiment.*
- *Measuring S, v, θ:*
  - *Some candidates did not specify the instrument used to measure length & width of plate and/or how S could then be calculated from the length & width. Several students just stated values of S to use (e.g. $S = 200$ cm^2, etc.) without explaining how S is measured.*
  - *Many candidates wrote "Set the fan to wind speed of __ m s^{-1}" without specifying an instrument to measure the wind speed v. Several candidates thought that the rotational speed of the fan is the same as the wind speed and suggested an instrument to measure the rotational speed of the fan instead. Some other candidates used a force sensor to measure the wind force F and then suggested to use $v = P/F$, where P was stated to be the power supplied to the fan; however P in $v = P/F$ should be the mechanical power of the wind which is not equal to the electrical power supplied to the fan.*
  - *Some candidates did not specify clearly in their procedure from which instrument θ is recorded from.*
- *Varying S and v, and, Control of variables:*
  - ***It is heartening to see a significant improvement in the vast majority of scripts in terms of the precision of describing how to vary the independent variables and how to keep the control variables constant. Many candidates have learnt correctly to go beyond simply 'measuring' to vary or keep a variable constant, and to describe clearly which part of the setup to adjust/shift/modify.***
  - ***However, there were some candidates who missed out some points** e.g. Forgetting to describe the control of variables for each part when the experiment is repeated. Or, talking about how to vary S and v, but forgetting to describe how to measure S and v.*
- *Linearising Equation & Graphical Analysis to determine a & b:*
  - *Correctly done by the vast majority of students.*
  - *Some candidates wasted time to explain how to determine k, which the question did not ask for.*
- *Additional details for Accuracy:*

  - *Most candidates scored the marks for "Allow the temperature of the metal plate to stabilise (temperature reading remains unchanged with time) before recording θ to ensure thermal equilibrium is reached." and/or "Conduct the experiment in an enclosed, temperature-controlled room to avoid wind sources other than that used in the experiment and for room temperature to be constant."*
- *Safety:*
  - *Most candidates score the mark for "Use of protective gloves to handle heater and metal plate." Note that no mark is awarded if reason is not given, e.g. "Use of protective gloves."*
  - *A minority of candidates mentioned what not to do rather than what to do, e.g. "Do not touch the hot plate." Is not acceptable while "Let the hot plate cool down first before handling it." Is acceptable.*