ANDERSON SERANGOON JUNIOR COLLEGE
PHYSICS 9749

2025 JC2 Prelim Paper 4 Solution & Mark Scheme

Q1	Answer	Mark
(a)(i)	There is no zero error. d_1 = 0.25 mm, d_2 = 0.24 mm $d = \frac{0.25+0.24}{2} = 0.25\,\text{mm}$ Value of d to 0.01 mm. 0.21 mm ≤ d ≤ 0.27 mm, repeated reading *<u>Examiner's Comments:</u>* *Many students did not take repeated measurements. Some students did not record the measurement to the correct precision and some had their values out of range.*	1
(a)(ii)	$A = \frac{\pi}{4}\left(\frac{0.25}{1000}\right)^2 = 4.9\times10^{-8}$ m^2	-
(b)(iv)	l = 0.500 m V = 0.505 V l measured to the nearest mm with unit. 0.45 m ≤ l ≤ 0.55 m V measured to the nearest 0.001 V with unit. 0.1 V < V < 2.0 V *<u>Examiner's Comments:</u>* *Some students did not record the measurements to the correct precision. The setting on the DMM may be wrong for students who recorded the voltmeter reading to 2 d.p. Marks are only awarded if all measurements recorded in b(iv), (c) and (d) are correct.*	1 1
(b)(v)	I = 53.1 x 10^{-3} A I measured to the nearest 0.0001 A. *<u>Examiner's Comments:</u>* *A handful of students did not record the measurements to the correct precision. Some students did not realise the measurements taken ar ein mA. Students are expected to convert from mA to the given unit A and present the answer to the correct precision. It is not acceptable to change given the unit to mA.*	1
(c)(iii)	l = 0.650 m V = 0.442 V *<u>Examiner's Comments:</u>* *Any errors in unit and precision penalised in (b)(iv)*	-

Q1 **Answer** **Mark**

(d)

l / m	V / V	$\frac{1}{l}$ / m^{-1}	$\frac{V}{l}$ / Vm^{-1}
0.100	0.781	10.0	7.81
0.200	0.699	5.00	3.50
0.350	0.595	2.86	1.70
0.500	0.505	2.00	1.01
0.650	0.442	1.54	0.680
0.800	0.363	1.25	0.454

Successfully collected 6 sets of values for l and V with no intervention or assistance provided. 2

Range of l : $\Delta l \geq 60$ cm 1

Each column heading must contain a quantity and unit. 1

Examiner's Comments:
Any errors in unit and precision of V and l penalised in (b)(iv).
Most students who had assistance rendered was due to the connection of the rheostat. Majority of the students did not meet the criteria of a wide range for l. Students are expected to use a wide range for independent variable when no range is stipulated in the question. For a straight line graph, 6 points are needed. Students are remined to record their data using pen and draw the table with clear headings.

(e)

$$\frac{V}{l} = \frac{M}{l} - N$$

Plot a graph of $\frac{V}{l}$ against $\frac{1}{l}$ where gradient = M and y-intercept = $-N$

(*alternative:* Plot a graph of V against l where gradient = $-N$ and y-intercept = M)

$$\text{Gradient} = \frac{9.10 - 1.20}{11.8 - 2.2} = 0.823$$

$$y = mx + c$$

$$9.10 = 0.823(11.8) + c$$

$$c = -0.611$$

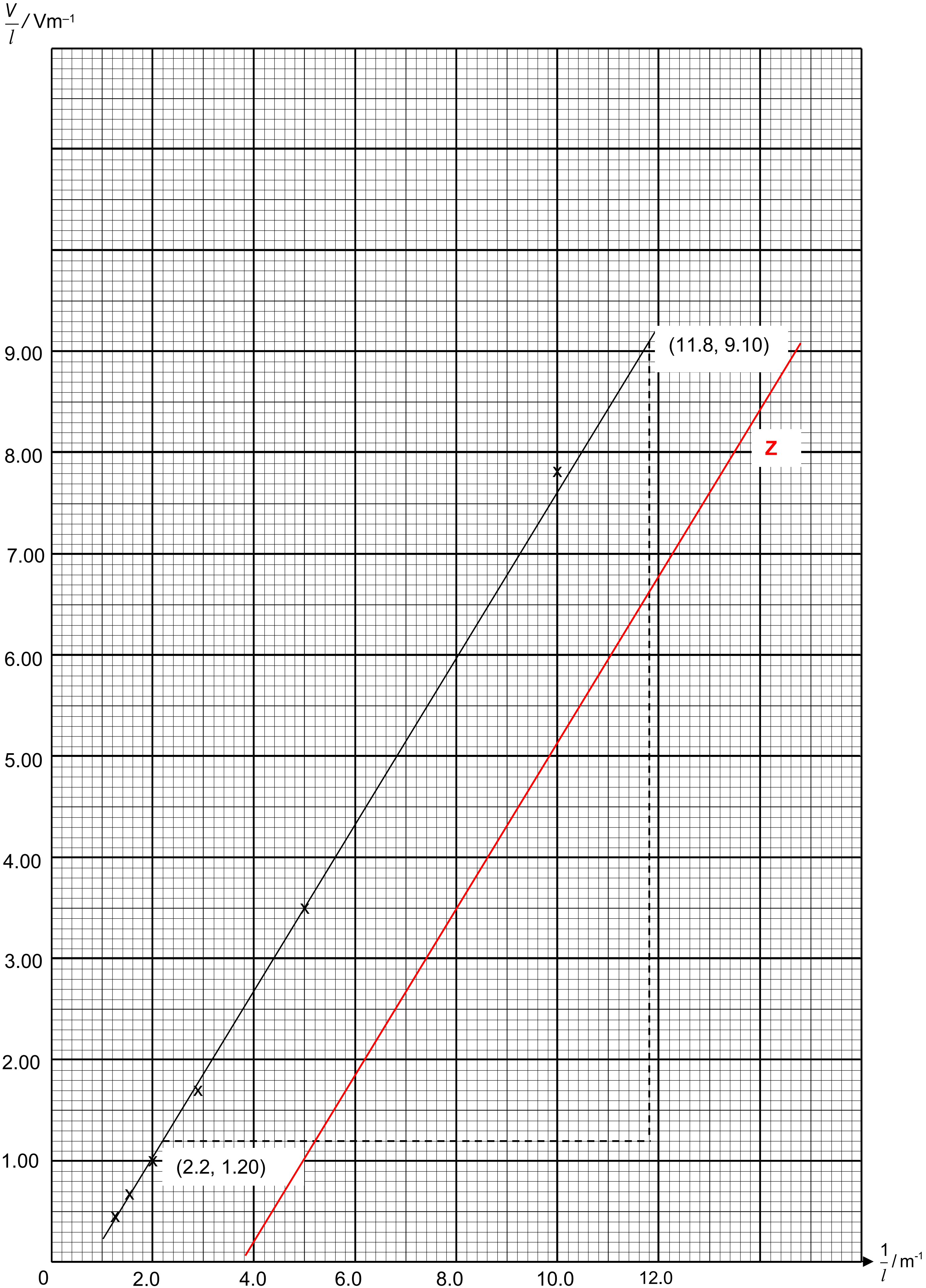
M = 0.823 V
N = 0.611 Vm^{-1}

Axes: 1
Sensible scales must be used, no awkward scales (e.g. 3:10).
Scales must be chosen so that the plotted points occupy at least half the graph in both x and y directions.
Scales must be labelled with the quantity which is being plotted.

Plotting of points: 1
All observations must be plotted on the grid. Work to an accuracy of half a small square.

Q1	Answer	Mark
	Line of best fit There must be a fair scatter of points on either side of the line. (accept: 1 vs 1, 2 vs 1 but not 4 vs 2). and in each half of the line there should be roughly the same number of points above as below. **Gradient** • The hypotenuse of the Δ must be greater than half the length of the drawn line. • Read-offs must be accurate to half a small square • Check for Δy/Δx (i.e. do not allow Δx/Δy). • No unit for gradient. Rounded to 3 s.f. **y-intercept** • Correct method used to find y-intercept: E.g: y-intercept read correctly from graph if the x-axis starts from zero. Or sub a point on the straight line into the eqn to find y-intercept. Using a pt on the table to find the y-intercept is acceptable provided the pt lies on the straight line. • Read-offs must be accurate to half a small square if y-intercept is read directly from graph (same as gradient's coordinate readings) ***M* and *N***: Recorded to 3 s.f with units. *M* is equated to gradient. Unit for *M* is V. *N* is equated to negative of *y*-intercept of graph. Unit for *N* is V m^{-1}. *Examiner's Comments:* *Most students were able to linearise and plot the correct graph. Students are reminded to use sharp 2B pencil to draw the graph. Some students still use odd scale and had points plotted wrong. Points should be plotted accurately on the graph grid and all points recorded in the table must be plotted. A handful of students did not fulfil the 2nd criteria of the best fit line. Students should adopt the good practice of calculating gradient and y-intercept separately before relating to the constants, Most students did not recorded to final answer of M and N to the correct s.f and unit.*	1 1 1 1
(f)	$\rho = \frac{NA}{I} = \frac{0.611\times 4.9\times 10^{-8}}{53.1\times 10^{-3}} = 5.6\times 10^{-7}\ \Omega\,\text{m}$ Correct substitution of values consistent with units 2.0 x 10^{-7} Ωm ≤ ρ ≤ 9.9 x 10^{-7} Ωm *Examiner's Comments:* *Most students did not gain credit to this part as the answers are usually out of range which may due to POT errors or inaccurate data collected.*	1
(g)	Since $\rho \propto N$, when ρ increases *N* increases, hence Graph Z will have the same gradient but more negative y-intercept (i.e. below the original graph) (alternative: for graph of *V* against *l*, Z will have a greater gradient and same y-intercept)	1

Q1	Answer	Mark
	<u>Examiner's Comments:</u> *Majority of the students did not gain credit as they did not realise is ρ proportional to N. Those who realized failed to keep M constant.*	


$\frac{V}{l}$ / Vm^{-1}
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
2.0
4.0
6.0
8.0
10.0
12.0
$\frac{1}{l}$ / m^{-1}
(11.8, 9.10)
(2.2, 1.20)
Z

<table>
<tr><th>Q2</th><th>Answer</th><th>Mark</th></tr>
<tr><td>(b)</td><td>
No. of oscillations = 10

<table>
<tr><th>α / °</th><th>t_1 / s</th><th>t_2 / s</th><th>T / s</th><th>k / m s^{-2}</th></tr>
<tr><td>45</td><td>14.8</td><td>14.6</td><td>1.47</td><td>6.5</td></tr>
<tr><td>60</td><td>12.7</td><td>12.8</td><td>1.28</td><td>7.0</td></tr>
</table>

$$k = \frac{6.5 + 7.0}{2} = 6.8 \text{ m s}^{-2}$$

Successfully collected at least 2 sets of (α and t) without assistance or intervention. Correct trend, $\Delta\alpha \geq 10$ °

α with unit and recorded to nearest 1°

$t > 10$ s and measured to nearest 0.1 s.
Evidence of repeated reading

T calculated to correct s.f, with correct unit
1.0 s ≤ T ≤ 2.0 s

k calculated correctly to 2 s.f.

<i><u>Examiner's Comments:</u></i>
<i>Students are reminded that the question required the results to be presented clearly and it is a good practice to tabulate the results as many who recorded their data failed to take care of the units, precision of the raw data. Many also did not take care of the s.f of the calculated data.</i>
<i>For oscillations, raw timing, t, for N oscillations must be >10.0s, repeated and recorded. Many students just recorded final period which will lead to no credit for raw data as well as period T. Students are also penalize for not stating N, no of oscillations as T cannot be determined without N.</i>
<i>Some students were careless in the calculation of k and did not record k to the correct sf.</i>
</td><td>

1

1

1

1

1
</td></tr>
<tr><td>(c)</td><td>
<u>It is difficult to determine the centre of the pendulum bob</u> as there is a lack of reference. This will <u>affect the accuracy of <i>L</i>.</u>
Or
<u>It is difficult to keep the protractor still when measuring</u> angle α as the hands are not steady. This will affect the accuracy of α.

Error must relate to this experiment, and the measurement of t and θ .
<i><u>Examiner's Comments:</u></i>
<i>Many students did not gain credit. Sources of error such as human reaction time, wind affect oscillations, board too thick, obstruction of wooden strip/G-clamp, lack of reference, cannot align the baseline of the protractor to the board are not accepted.</i>
<i>Students to take note that the sources of error must stated with the measurement that the error affects.</i>
</td><td>1</td></tr>
</table>

<table>
<tr><th>Q3</th><th>Answer</th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>There is no zero error.
$d = \dfrac{0.21 + 0.22}{2} = 0.22\text{ cm}$

Value of <i>d</i> to 0.01 cm. 0.20 cm ≤ <i>d</i> ≤ 0.30 cm

<u><i>Examiner’s Comments:</i></u>
<i>Many students have values which are out of range or incorrect dp.</i></td><td>1</td></tr>
<tr><td>(a)(ii)</td><td>percentage uncertainty in <i>d</i> = $\dfrac{0.02}{0.22} \times 100\% = 9.1\%$

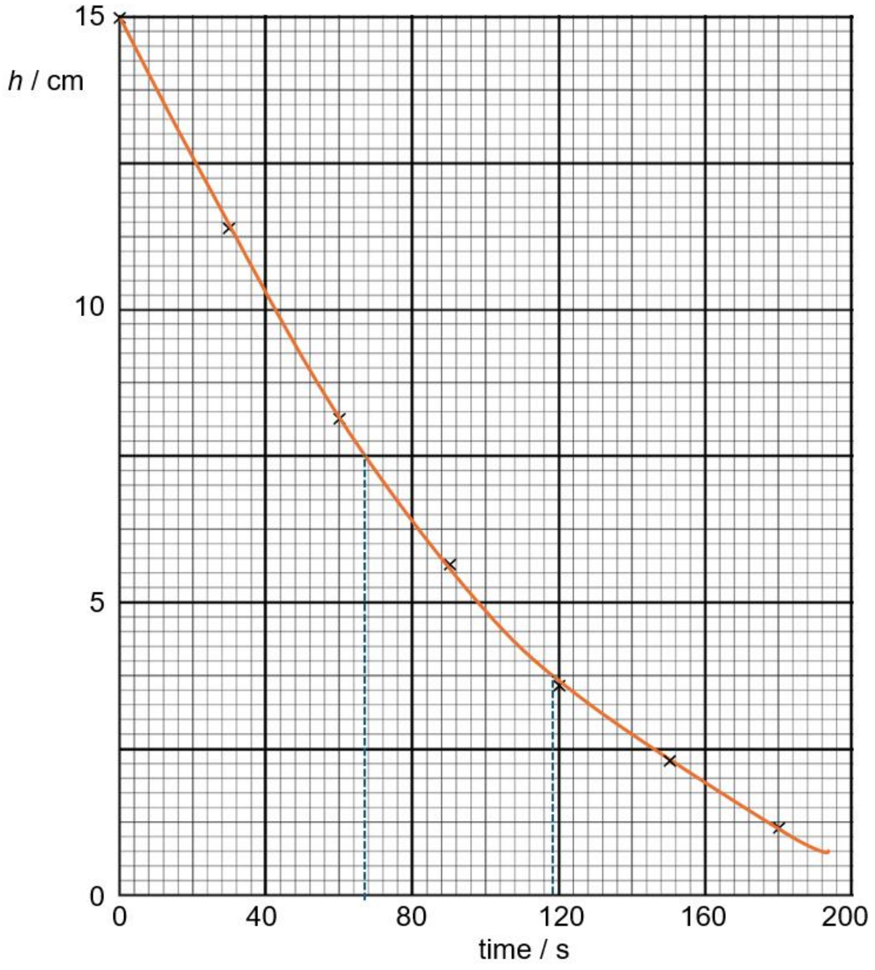
Percentage uncertainty of <i>d</i> calculated correctly to <u>2 s.f</u>.
0.02 cm ≤ Δ<i>d</i> ≤ 0.05 cm

<u><i>Examiner’s Comments:</i></u>
<i>Note that the actual uncertainty used in the numerator is 1 s.f.</i></td><td>1</td></tr>
<tr><td>(b)</td><td>
<table>
<tr><th><i>t</i> / s</th><th><i>h</i> / cm</th></tr>
<tr><td>0.0</td><td>15.0</td></tr>
<tr><td>30.0</td><td>11.4</td></tr>
<tr><td>60.0</td><td>8.2</td></tr>
<tr><td>90.0</td><td>5.7</td></tr>
<tr><td>120.0</td><td>3.6</td></tr>
<tr><td>150.0</td><td>2.3</td></tr>
<tr><td>180.0</td><td>1.2</td></tr>
</table>
Successfully collected at least 6 sets of data without assistance or intervention.

<i>t</i> increases in step of 30 s, correct precision of raw data, correct table headings with units.

<u><i>Examiner’s Comments:</i></u>
• <i>Many students missed out the first set of data (t = 0, h = 15.0 cm).</i>
• <i>Not advisable to leave t in minutes as many made mistakes for the dp. Leaving t in s and 1dp will be easier.</i></td><td>1

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

Q3	Answer	Mark
(c)(i)	 All observations must be plotted to an accuracy of half a small square. (No mark awarded for plotting if the data in table in part (b) is unclear.) Best fit curve correctly drawn.	1 1
(c)(ii)	From graph, When h = 7.5 cm, t = 68 s First value of T = 68 s When h = 3.75 cm, t = 118 s Second value of T = 118 – 68 = 50 s (remember to subtract first T value) Mean value of T = (68 + 50) / 2 = 59 s Read off T to an accuracy of half a small square with unit. Mean value of T calculated correctly with unit. *Examiner's Comments:* *1st mark is not awarded if poor data is collected. Data collected should allow student to read off two consecutive T values (at h = 7.5 cm & 3.75 cm).*	1 1

<table>
<tr><th>Q3</th><th>Answer</th><th>Mark</th></tr>
<tr><td>**(d)(i)**</td><td>
There is no zero error.
$d = \dfrac{0.45 + 0.43}{2} = 0.44 \text{ cm}$
<table>
<tr><th>t / s</th><th>h / cm</th></tr>
<tr><td>0.0</td><td>15.0</td></tr>
<tr><td>5.0</td><td>12.2</td></tr>
<tr><td>10.0</td><td>10.1</td></tr>
<tr><td>15.0</td><td>8.0</td></tr>
<tr><td>20.0</td><td>6.1</td></tr>
<tr><td>25.0</td><td>4.6</td></tr>
<tr><td>30.0</td><td>3.3</td></tr>
</table>
d larger than (a)(i), 0.30 <u>cm</u> ≤ d ≤ 0.50 <u>cm</u>
Successfully collected at least 6 sets of data without assistance or intervention with t less than 1 minute.
<u>Examiner’s Comments:</u>
Some students continued to take multiple data even when h has decreased to minimum, which is not meaningful. Should have taken more data when h is decreasing.
</td><td>1
1</td></tr>
<tr><td>**(d)(ii)**</td><td>
Since decay is exponential,
$h = h_0 \left(\dfrac{1}{2}\right)^n$
$h = h_0 \left(\dfrac{1}{2}\right)^{\frac{t}{t_{1/2}}}$
$3.3 = 15.0\left(\dfrac{1}{2}\right)^{\frac{30.0}{t_{1/2}}} \Rightarrow t_{1/2} = T = 14 \text{ s}$
Sound method (need clear explanation) to estimate T.
T smaller than (c)(ii). 10 s ≤ T ≤ 20 s
<u>Examiner’s Comments:</u>
• *As T is an estimation, should be left in 1 s.f. or 2 s.f.*
• *Incorrect to use proportion in the estimation process as the flow rate is not constant.*
</td><td>1
1</td></tr>
<tr><td>**(d)(iii)**</td><td>
percentage uncertainty in T = $\dfrac{2}{14} \times 100\% = 14\%$
Percentage uncertainty of T calculated correctly to <u>2 s.f.</u>
2 s ≤ ΔT ≤ 5 s (1 s.f. for actual uncertainty)
</td><td>1</td></tr>
</table>

Q3	Answer	Mark
(e)(i)	$Q = Td^2$ $Q_1 = (59)(2.2\times10^{-3})^2 = 2.9\times10^{-4}$ s m^2 $Q_2 = (14)(4.4\times10^{-3})^2 = 2.7\times10^{-4}$ s m^2 Q calculated with correct units.	1
(e)(ii)	*Q* is 2 s.f. as the no. of s.f. follows the least s.f. of *T* and *d*. Justification based on number of significant figures in *T* and *d*.	1
(e)(iii)	Criterion for supporting relationship is percentage difference in *Q* is smaller than percentage uncertainty of Td^2. Percentage difference in *Q* = $\frac{2.9-2.7}{2.9}\times100\% = 6.9\%$ (Note: Use first *Q* value for denominator) Percentage uncertainty of Td^2 = 14 + 2 x 9.1 = 32% Since the percentage difference in Q is less than percentage uncertainty of Td^2, the results support the suggested relationship. Draw conclusion based on comparison between percentage difference in Q with percentage uncertainty in Td^2. Percentage uncertainty in Td^2 calculated using correct rules to combine uncertainties.	1
(f)(i)	1. Measure and record the temperature of the room θ_R using thermometer. 2. Prepare hot water in a beaker 3. Start stopwatch. Measure and record the temperature of water θ using thermometer and time taken to reach temperature θ using stopwatch at regular interval as the water cools. 4. Plot a graph of θ against *t* to determine $\frac{d\theta}{dt}$ by drawing a tangent to the curve and calculating its gradient at regular interval of t or θ in step 3. 5. Calculate the temperature difference, $\theta - \theta_R$ for each value of $\frac{d\theta}{dt}$. 6. Plot a graph of $\frac{d\theta}{dt}$ against $(\theta - \theta_R)$. If a straight line through the origin is obtained, then the relationship is valid. Procedure to measure temperature difference Sound method to determine change in temperature Correct graphs to plot to determine $\frac{d\theta}{dt}$ (gradient of tangent) and to determine validity of relationship	1 1 1

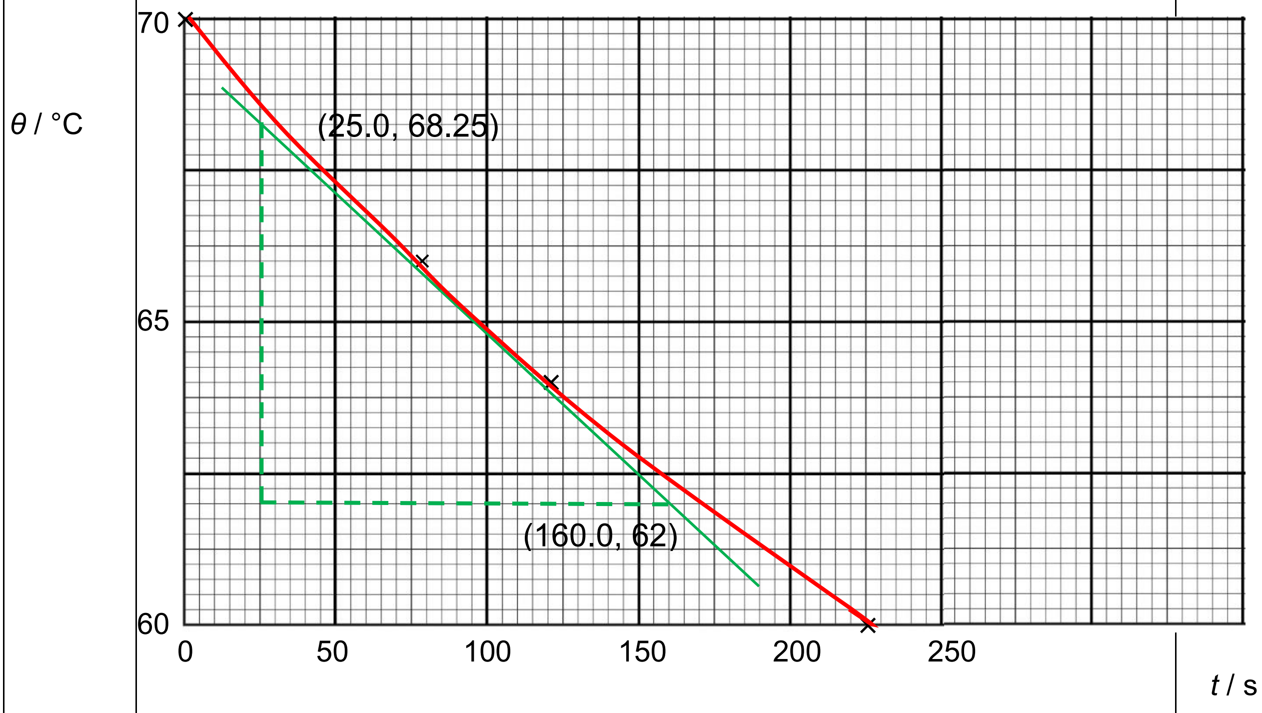
Q3	Answer	Mark
	Examiner's Comments:	

Many students misunderstood that $\frac{d\theta}{dt} = \frac{\Delta\theta}{\Delta t} = \frac{\theta_f - \theta_i}{\Delta t}$ *without mentioning the need to draw tangent for graph of θ against t and* $\frac{d\theta}{dt}$ *= gradient.*

Other common mistakes include incorrect graph / feature to look out for e.g. plotting graph of θ against t and a straight line through origin to show that relationship is valid.

(f)(ii)

t / s	θ / °C
0.0	70.0
35.0	68.0
56.0	67.0
78.0	66.0
96.0	65.0
121.0	64.0
172.0	62.0
225.0	60.0



$$\text{gradient of tangent at } 75°\text{C} = \frac{68.25 - 62}{25.0 - 160.0} = -0.0463$$

$$\frac{d\theta}{dt} = -0.0463 \text{ °C s}^{-1}$$

Turn Over

Q3	Answer	Mark
	Successfully collected at least 6 sets of data without assistance or intervention for 60 °C ≤ θ ≤ 70 °C. Correct trend. Tangent drawn at θ = 65 °C Equate Gradient to $\frac{d\theta}{dt}$, negative value *Examiner's Comments:* • *2nd mark is not awarded if there is best fit straight line / incorrect curve / poorly drawn best fit curve.* • *Hint that it is a best fit curve is given in the question – find* $\frac{d\theta}{dt}$ *at 65 °C.*	1 1 1

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Prelim P4 Q4 Suggested Solutions and Mark Scheme

Suggested Solution:

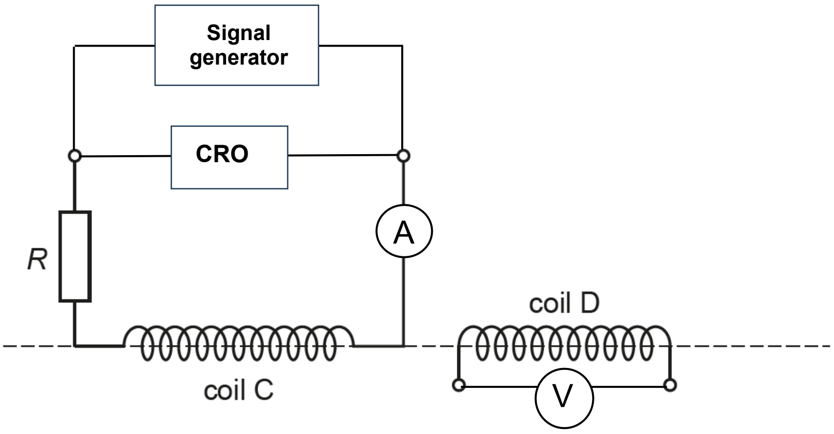
1) E vs f

Independent variable	Dependent variables	Control variables
What? f	E	I
How? Oscilloscope connected across coil C and resistor, period T = time-base × horizontal distance **and** $f = 1 / T$ Adjust signal generator to vary f.	Oscilloscope connected across coil D, E = y-gain × vertical distance	Use same resistor

2) E vs I

Independent variable	Dependent variables	Control variables
What? I	E	f
How? a.c. ammeter connected in series with Coil C,	Oscilloscope connected across coil D, E = y-gain × vertical distance	Keep frequency of signal generator unchanged

Diagram



Procedure
Set up the apparatus as shown in the diagram.

(i) How E varies with f keeping the I constant.

1. Read from oscilloscope: period T = time-base × horizontal distance, $f = 1 / T$.
2. E = voltmeter reading $V \times \sqrt{2}$
3. Vary f on the signal generator to obtain 6 sets of E and f

(ii) How E varies with I keeping the f constant.

1. Vary I by using different resistors to obtain 6 sets of E and I

Control of Variables

1. Experiment (i): Keep I constant by using the same resistor.
2. Experiment (ii): Keep f constant by keeping the frequency of signal generator unchanged.

Analysis

1. Given that $E = k f^a I^b$ where k, a and b are constants.

2. For experiment (i), $\lg E = a \lg f + \lg (kI^b)$
   Plot a graph of lg E against lg f.
   Calculate gradient to find a.

3. For experiment (ii), $\lg E = b \lg I + \lg (kf^a)$
   Plot a graph of lg E against lg I.
   Calculate gradient to find b.

Accuracy and Safety

1. Take preliminary readings to find suitable range of f, R, distance between the coils to obtain measurable values of E.
2. keep distance between the coils constant by clamping coils to bench
3. use gloves to handle hot coil/resistor OR switch off circuit and wait for hot coil/resistor to cool

Marking Scheme

Diagram shows

Workable circuit for coil C:
- signal generator connected parallel to coil C and resistor, D1
- oscilloscope connected parallel to signal generator
- (a.c.) ammeter in series with resistor D2

Workable circuit for coil D: D3
- (a.c.) voltmeter connected parallel to coil D
- Coils C and D placed with their axes on a straight line

Examiners' Comments:

In this experiment, an alternating current needs to be set up in coil C, via correct arrangement of the signal generator to produce alternating voltage. Since current in a coil generates a magnetic field, this results in changing flux linkage in coil D, leading to e.m.f. induced in coil D. The e.m.f. in coil D will also be alternating. This process is similar to what happens in transformers.

Many students did not realise the need to set up an alternating current in coil C, and used a D.C. supply instead.

Some misunderstood what a signal generator is for, leading to wrong arrangements. A signal generator allows an alternating voltage to be generated, and we can adjust the frequency and amplitude of this signal through the generator. However, from the signal generator, it is difficult to determine the exact frequency and amplitude of the signal generated.

To determine the frequency of the signal, we can connect an oscilloscope parallel to the signal generator. A trace will be produced on the CRO, and the period of the signal can be determined by: period T = time-base × horizontal distance. The peak voltage of the signal can also be determined by: E = y-gain × vertical distance, so if the oscilloscope is connected parallel to coil D, this is a workable method to determine E.

Some responses included a galvanometer in series to coil C and the experimenter needed to observe and count the number of oscillations in the galvanometer in a given time interval. This is not workable, since the frequency can be too high (more than 10 Hz) for counting.

Most students were able to show correct arrangements for the ammeter and voltmeters. Due to the a.c. current and voltage, the readings from the ammeter in series with coil C and *voltmeter parallel to coil D will be the r.m.s. value, using the a.c. mode of the DMM. Subsequently, there is a need to determine the peak values from the r.m.s. values. This understanding is not shown in most responses.*

Basic procedure

Expt 1: Vary *f* on the signal generator to obtain <u>6 sets</u> of *E* and *f* P1

Expt 2: Vary I <u>by using different resistors</u> OR <u>by changing amplitude on signal generator</u> to obtain 6 sets of *E* and I P2

<u>Examiners' Comments:</u>
The requirements here are to indicate clearly the independent variable to vary, workable method to do so, and the collection of 6 sets of named independent and dependent variables. Students who are not familiar end up writing a lot but not fulfilling the requirements.

Control of variables

Experiment (i): Keep I constant by using the same resistor OR by keeping the amplitude of signal generator unchanged. C1

Experiment (ii): Keep *f* constant by keeping the frequency of signal generator unchanged. C2

<u>Examiners' Comments:</u>
The requirements here are to indicate clearly the variable to be kept constant, and workable method to do so. Refrain from using the phrase "The controlled variable is f", use the word 'constant' instead.

Analysis / graph:

For experiment (i), $\lg E = a \lg f + \lg (kI^b)$

Plot a graph of lg *E* against lg *f*. Calculate gradient to find *a*. G1

For experiment (ii), $\lg E = b \lg I + \lg (kf^a)$

Plot a graph of lg *E* against lg I. Calculate gradient to find *b*. G2

<u>Examiners' Comments:</u>
This part was done well by those who were prepared. A few responses included finding the constant k, which is not required by the question. In the event if the question requires determination of k, the correct approach will be:
Based on experiment (ii), $\lg E = b \lg I + \lg (kf^a)$,
Using the values of a from experiment (i) and constant f, substitute into
y-intercept, $c = \lg (kf^a)$
$k = 10^c / f^a$

Accuracy /safety (1A + 1S)

1. Take preliminary readings to find suitable range of *f, R,* distance between the coils to obtain measurable values of *E* **OR** Method to increase E e.g. use iron core, place coils closer A1
2. keep distance between the coils constant by clamping coils to bench A2
3. keep number of turns on each coil constant by using the same coils A3
4. Oscilloscope connected correctly to circuit and method to determine *f* from oscilloscope, e.g. period *T* = time-base × horizontal distance **and** *f* = 1 / *T* A4
5. (If use $I = V/R$) Determination of *V* across *R* (workable method using oscilloscope or (a.c.) voltmeter) and determination of R using ohmmeter connected across resistor only. A5

6. (If use a.c. ammeter or voltmeter) $I = I_{\text{rms}} \times \sqrt{2}$ (where I_{rms} is reading from a.c. ammeter) or E = voltmeter reading $V \times \sqrt{2}$ A6
7. (If use oscilloscope to determine E) from oscilloscope, E = y-gain × vertical distance A7
8. Remove magnetic materials from surroundings as they may affect the flux through the coils. A8
9. (If use current or voltage sensor connected to datalogger) determine E or I by reading the maximum value from the current-time or voltage-time graph. A9
10. Workable method to check and ensure axes of the coils are on a straight line. A10
11. use gloves to handle hot coil/resistor OR switch off circuit and wait for hot coil/resistor to cool (accept switch off circuit when not in use to prevent overheating in hot coil/resistor) S1

Examiners' Comments:
Provide sufficient details by always including the workable method (including apparatus) and reason.
For safety, describe what to do, instead of what not to do. So the preferred phrasing is "switch off circuit and wait for hot coil to cool", as opposed to "don't touch the coil when the circuit is closed". Risk of electrocution as a reason is not accepted since signal generators typically provide low voltage.