Mark Scheme (Results)

Summer 2023

Pearson Edexcel GCE
In Physics (9PH0)
Paper 03 General and Practical Principles in Physics

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate.

Mark scheme notes

Underlying principle

The mark scheme will clearly indicate the concept that is being rewarded, backed up by examples. It is not a set of model answers.

1. Mark scheme format

1.1 You will not see ‘wtte’ (words to that effect). Alternative correct wording should be credited in every answer unless the MS has specified specific words that must be present. Such words will be indicated by underlining e.g. ‘<u>resonance</u>’
1.2 Bold lower case will be used for emphasis e.g. ‘**and**’ when two pieces of information are needed for 1 mark.
1.3 Round brackets ( ) indicate words that are not essential e.g. “(hence) distance is increased”.
1.4 Square brackets [ ] indicate advice to examiners or examples e.g. [Do not accept gravity] [ecf].

2. Unit error penalties

2.1 A separate mark is not usually given for a unit but a missing or incorrect unit will normally mean that the final calculation mark will not be awarded.
2.2 This does not apply in ‘show that’ questions or in any other question where the units to be used have been given, for example in a spreadsheet.
2.3 The mark will not be awarded for the same missing or incorrect unit only once within one clip in epen.
2.4 Occasionally, it may be decided not to insist on a unit e.g the candidate may be calculating the gradient of a graph, resulting in a unit that is not one that should be known and is complex.
2.5 The mark scheme will indicate if no unit error is to be applied by means of [no ue].

3. Significant figures

3.1 Use of too many significant figures in the theory questions will not be prevent a mark being awarded if the answer given rounds to the answer in the MS.
3.2 Too few significant figures will mean that the final mark cannot be awarded in ‘show that’ questions where one more significant figure than the value in the question is needed for the candidate to demonstrate the validity of the given answer.
3.3 The use of one significant figure might be inappropriate in the context of the question e.g. reading a value off a graph. If this is the case, there will be a clear indication in the MS.
3.4 The use of g = 10 m s^{-2} or 10 N kg^{-1} instead of 9.81 m s^{-2} or 9.81 N kg^{-1} will mean that one mark will not be awarded. (but not more than once per clip). Accept 9.8 m s^{-2} or 9.8 N kg^{-1}

3.5 In questions assessing practical skills, a specific number of significant figures will be required e.g. determining a constant from the gradient of a graph or in uncertainty calculations. The MS will clearly identify the number of significant figures required.

4. Calculations

4.1 Bald (i.e. no working shown) correct answers score full marks unless in a 'show that' question.
4.2 If a 'show that' question is worth 2 marks. then both marks will be available for a reverse working; if it is worth 3 marks then only 2 will be available.
4.3 **use** of the formula means that the candidate demonstrates substitution of physically correct values, although there may be conversion errors e.g. power of 10 error.
4.4 **recall** of the correct formula will be awarded when the formula is seen or implied by substitution.
4.5 The mark scheme will show a correctly worked answer for illustration only.

1. Quality of Written Communication
1.1 Indicated by QoWC in mark scheme. QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.
1.2 Usually it is part of a max mark, the final mark not being awarded unless the QoWC condition has been satisfied.

2. Graphs
2.1 A mark given for axes requires both axes to be labelled with quantities and units, and drawn the correct way round.
2.2 Sometimes a separate mark will be given for units or for each axis if the units are complex. This will be indicated on the mark scheme.
2.3 A mark given for choosing a scale requires that the chosen scale allows all points to be plotted, spreads plotted points over more than half of each axis and is not an awkward scale e.g. multiples of 3, 7 etc.
2.4 Points should be plotted to within 1 mm.

- Check the two points furthest from the best line. If both OK award mark.
- If either is 2 mm out do not award mark.
- If both are 1 mm out do not award mark.
- If either is 1 mm out then check another two and award mark if both of these OK, otherwise no mark.

For a line mark there must be a thin continuous line which is the best-fit line for the candidate's results.

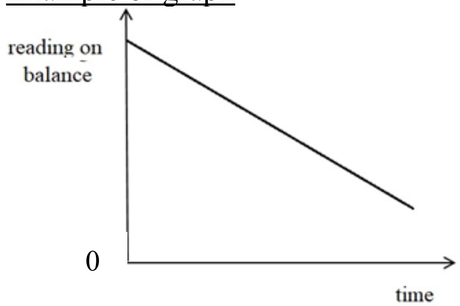
Question Number	Acceptable Answer		Additional Guidance	Mark
1(a)	• Use of $\tan\theta = \frac{x}{D}$ • Use of $d\sin\theta = n\lambda$ • Use of $d = \frac{1}{\text{number of lines per metre}}$ • λ = 520 nm so spacing of pattern was consistent **Or** x = 43.5 cm so spacing of pattern was consistent **Or** $d = 3.32 \times 10^{-6}$ m ≈ 3.33×10^{-6} m, so spacing is consistent **Or** number of lines per mm = 301 (≈300 mm^{-1}), so spacing is consistent **Or** θ = 8.97° ≈ 8.99°, so spacing is consistent	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> $\tan\theta = \frac{0.435\text{ m}}{2.75\text{ m}} = 0.158$ $\theta = 8.99°$ $d = \frac{1}{3 \times 10^5\text{ m}^{-1}} = 3.33 \times 10^{-6}\text{ m}$ $\lambda = 3.33 \times 10^{-6}\text{ m} \times \sin 8.99° = 5.20 \times 10^{-7}\text{ m}$	4
1(b)	**MAX 3** • The metre rule has a <u>resolution</u> of 0.1 cm **Or** The metre rule has a <u>resolution</u> not a precision • Precision is how closely grouped (repeated) readings are • Accuracy is how close the measured value is to the actual value • Systematic error may shift measured values away from the actual values **Or** It may be difficult to judge the positions of the maxima	**(1)** **(1)** **(1)** **(1)**	MP4 Accept an example of systematic error e.g. a zero error **Or** a reference to parallax error	3

(Total for Question 1 = 7 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
2(a)	• Use of $P = \frac{V^2}{R}$ • Use of sum of e.m.fs = sum of p.d.s • Use of $R = \frac{V}{I}$ to calculate a p.d. • V = 10.5 V	**(1)** **(1)** **(1)** **(1)**	Use of $P = VI$ and $R = \frac{V}{I}$ to calculate R scores MP1 Use of $V = \epsilon - Ir$ scores MP2 and MP3 Allow use of potential divider equation for MP2 and MP3 <u>Example of calculation</u> $R = \frac{(12\text{ V})^2}{40\text{ W}} = 3.6\ \Omega$ $I = \frac{12\text{ V}}{(3.6 + 0.5)\ \Omega} = 2.93\text{ A}$ $V = 2.93\text{ A} \times 3.6\ \Omega = 10.5\text{ V}$ Allow $V = \left(\frac{3.6\ \Omega}{3.6\ \Omega + 0.50\ \Omega}\right) \times 12\text{ V} = 10.5\text{ V}$	**4**

2(b)	An explanation that makes reference to the following points: **EITHER** • Current (from battery) increases **(1)** • Therefore terminal p.d. decreases **(1)** • So brightness of bulb 1 decreases **(1)** **OR** • The resistance of the (external) circuit decreases **(1)** • So there is a smaller proportion of p.d across the bulbs **(1)** • So brightness of bulb 1 decreases **(1)**	MP3 dependent upon MP2 MP3 dependent upon MP2	**3**

(Total for Question 2 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)	• The ammeter should be in series with the heater **Or** ammeter is not measuring current through the heater **(1)** • The range of the ammeter (mA) is too small **(1)**		**2**
3(b)(i)	• Both axes labelled **(1)** • Straight line with negative gradient **(1)** • Reading on balance does not cut the time axis **(1)**	MP3 dependent upon MP2 Example of graph  	**3**
3(b)(ii)	• Use of $W = VIt$ **(1)** • Use of $\Delta E = mL$ **(1)** • $L = 2.4 \times 10^6$ J kg^{-1} **(1)**	Example of calculation $W = 12\text{ V} \times 4.2\text{ A} \times (6 \times 60)\text{s} = 1.81 \times 10^4\text{ J}$ $L = \dfrac{1.81 \times 10^4\text{J}}{7.5 \times 10^{-3}\text{kg}} = 2.41 \times 10^6\text{ J kg}^{-1}$	**3**
3(b)(iii)	An explanation that makes reference to the following points: • Energy is transferred (from the beaker/heater/water) to the surroundings **(1)** • So the calculated value of L will be larger than the true value **(1)**		**2**

(Total for Question 3 = 10 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*4</td>
<td>This question assesses a student’s ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.

Indicative content:

IC1 Most of the particles are not deflected as they pass through the gold foil

IC2 This indicates that there is mostly empty space inside the gold atom

IC3 Some particles were deflected from their path by small angles

IC4 This indicates a charged centre (was deflecting alpha particles)

IC5 A very small proportion of particles were deflected through more than 90^{o}

IC6 This indicates that most of the mass of the atom is concentrated in the nucleus</td>
<td>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
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<tr><td>5–4</td><td>3</td></tr>
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Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
<table>
<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>6</td>
</tr>
</table>

(Total for Question 4 = 6 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
5(a)(i)	• Changes (in recorded length) due to the support bending are minimised **Or** changes (in recorded length) due to temperature are minimised **Or** it allows use of a vernier scale (to determine extension) **(1)**		**1**
5(a)(ii)	• To keep the reference wire taut/straight **Or** to keep the reference wire under tension **(1)**		**1**
5(b)	An explanation that makes reference to the following points: • A thin wire has a large stress (for a given load) **(1)** • A long/thin wire has a large extension (for a given stress) **(1)** • Hence the percentage uncertainty in the length/extension is reduced **(1)**		**3**

5(c)	• Calculates A **(1)** • Determine gradient **(1)** • Substitutes $\sigma = \frac{F}{A}$ **and** $\varepsilon = \frac{\Delta x}{x}$ into $E = \frac{\sigma}{\varepsilon}$ **(1)** • Uses $E = \frac{1}{\text{gradient}} \times \frac{x}{A}$ **(1)** • $E = 1.1 \times 10^{11}$ N m^{-2} **(1)**	<u>Example of calculation</u> $A = \frac{\pi \times (5.60 \times 10^{-4}\text{m})^2}{4} = 2.46 \times 10^{-7}\text{m}^2$ $E = \frac{F/A}{\Delta x/x} = \frac{F}{\Delta x} \times \frac{x}{A}$ $\text{Grad} = \frac{\Delta x}{F} \therefore E = \frac{1}{\text{gradient}} \times \frac{x}{A}$ $\text{Grad} = \frac{(3.6 - 0.75) \times 10^{-3}\text{m}}{(32.0 - 5)\text{ N}}$ $= 1.06 \times 10^{-4}\text{ m N}^{-1}$ $\therefore E = \frac{1}{1.06 \times 10^{-4}\text{ m N}^{-1}} \times \frac{2.75\text{ m}}{2.46 \times 10^{-7}\text{m}^2}$ $\therefore E = 1.057 \times 10^{11}\text{ N m}^{-2}$	**5**

(Total for Question 5 = 10 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
6(a)	• Time a number of (complete) oscillations and divide this time by the number of (complete) oscillations • Repeat measurement (of time) **and** determine a mean value • Use a (fiducial) marker (so easier to see when trolley passes a particular point) • Time from the mid-point of the oscillation **Or** Wait for oscillation to settle before starting to time	**(1)** **(1)** **(1)** **(1)**	[Allow 1 mark for reference to using light gates and a data logger if no other marks awarded]	**4**
6(b)	• T read from oscilloscope trace • Use of time-base setting • Use of $\omega = 2\pi / T$ **Or** Use of $f = 1/T$ • Use of $v = (-)A\omega \sin \omega t$ • $v = 0.75 \text{ m s}^{-1}$	**(1)** **(1)** **(1)** **(1)** **(1)**	Use of $\omega = 2\pi f$ <u>Example of calculation</u> $T = 2 \text{ div} \times 250 \text{ ms div}^{-1} = 500 \text{ ms}$ $\omega = \frac{2\pi}{0.50 \text{ s}} = 12.6 \text{ rad } s^{-1}$ $v = 6.0 \times 10^{-2} \times 12.6 \text{ rad s}^{-1} = 0.754 \text{ m s}^{-1}$	**5**

6(c)(i)	An explanation that makes reference to the following points: • (As the frequency is increased) the amplitude increases to a maximum at a frequency of 2 Hz (and then decreases) **(1)** • This is the natural frequency (of oscillation) of the trolley **(1)** • When the vibrator drives the trolley at its natural frequency there is a maximum transfer of energy (from the vibrator to the trolley) **(1)** • This is resonance **(1)**		**4**
6(c)(ii)	• Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • k = 140 N m^{-1} **(1)**	<u>Example of calculation</u> $0.5\text{ s} = 2\pi \times \sqrt{\frac{0.87\text{ kg}}{k}}$ $\therefore k = \frac{4\pi^2 \times 0.87\text{ kg}}{(0.5\text{ s})^2} = 137\text{ N m}^{-1}$	**2**

(Total for Question 6 = 15 marks)

<table>
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<tr>
<td>*7(a)</td>
<td>
This question assesses a student’s ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.

Indicative content:

IC1 The electric current is a movement of electrons (between the electrodes)
[Accept “charge carriers” for “electrons”]

IC2 The electrons collide with neon atoms
[Accept “interact” for “collide”]

IC3 Energy is transferred to the neon atoms (in the collisions)

IC4 Electrons in the neon (atoms) are promoted to higher energy states
Or electrons in neon (atoms) are excited

IC5 (After a short time) electrons in the neon (atoms) return to their normal/ground state
Or electrons in neon (atoms) de-excite

IC6 When an electron returns to a lower energy state it emits a <u>photon</u> (of electromagnetic radiation)
</td>
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Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
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</table>
</td>
<td>6</td>
</tr>
</table>

7(b)	• Use of $E = hf$ **(1)** • Use of $E_k = ½ mv^2$ **(1)** • Use of $hf = \phi + \frac{1}{2}mv_{\max}^2$ **(1)** • $\phi = 3.36 \times 10^{-19}$ (J) so metal is caesium **(1)**	<u>Example of calculation</u> $E = hf = 6.63 \times 10^{-34}$ J s $\times 5.56 \times 10^{14}$ J $\therefore E = 3.69 \times 10^{-19}$ J Max $E_k = ½ mv^2$ $= 0.5 \times 9.11 \times 10^{-31}$ kg $\times (2.68 \times 10^{5}$ m s$^{-1})^2$ $= 3.27\times 10^{-20}$ J $\therefore \phi = 3.69 \times 10^{-19}$ J -3.27×10^{-20} J $\phi = 3.36 \times 10^{-19}$ J	**4**

(Total for Question 7 = 10 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th></th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>8(a)</td><td>

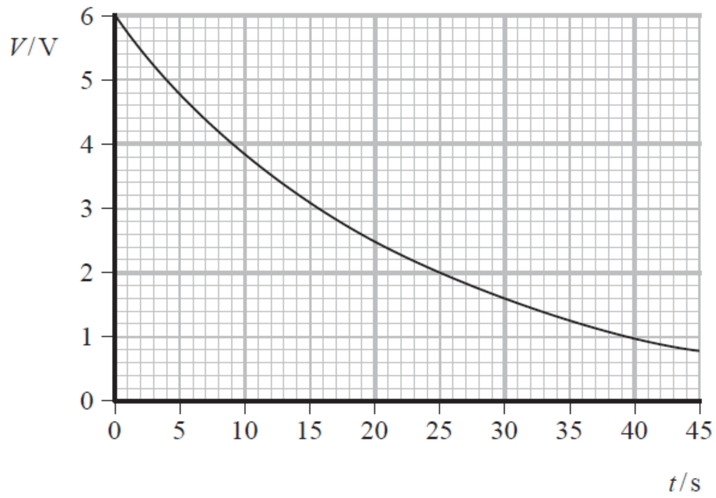
A pair of corresponding V and t values read from graph
Use of $V = V_0 e^{-\frac{t}{RC}}$
Or Use of time constant = RC
C = 270 μF
Use of ±20% with 220 μF
[Largest C = 264 μF, smallest C = 176 (μF)]
Comparison of 264 (μF) [176 (μF) if their calculated C is too low] with calculated value of C from graph and conclusion consistent with this

</td><td>(1)

(1)

(1)

(1)

(1)</td><td>


Allow use of tangent at t = 0 to determine intercept on x-axis and obtain value for time constant; then calculate C gives MP1, MP2 and MP3

MP3:Value should be correct and have units

<u>Example of calculation</u>
$1.0 = 6.0e^{-\frac{40\text{ s}}{82\times10^3\,\Omega\times C}}$
$\therefore \ln\left(\frac{1.0\text{ V}}{6.0\text{ V}}\right) = -\frac{40\text{ s}}{82\times10^3\,\Omega\times C}$
$\therefore C = \frac{-40\text{ s}}{-1.79\times82\times10^3\,\Omega} = 2.72\times10^{-4}\text{ C}$

Largest value of capacitance = 1.2 × 220 μF = 264 μF
</td><td>5</td></tr>
</table>

8(b)	• The data has to be collected in a short time **Or** Data logger has high sampling rate Or Data logger enables readings to be taken more frequently **(1)** • It would be difficult to read the voltmeter and stopwatch simultaneously **(1)** • So the suggestion is correct [dependent on MP1 or MP2] **(1)**	MP1: Data logger can take more readings in the time for capacitor to discharge	**3**

(Total for Question 8 = 8 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
9(a)(i)	• Bottom plate marked positive **Or** bottom terminal of power supply marked positive **(1)**	Accept top plate marked negative or top terminal of power supply marked negative	**1**
9(a)(ii)	• Calculates volume of oil drop **(1)** • Use of $\rho = \frac{m}{V}$ **(1)** • Use of $E = \frac{V}{d}$ **(1)** • Use of $F = mg$ **and** $F = Eq$ **(1)** • Use of $N = \frac{q}{e}$ **(1)** • N = 4.2 so student's expectation not supported by data **Or** N = 4.2 which is not a whole number **Or** N = 4.2 so taking experimental error into account student's expectation may be supported by data **(1)**	Example of calculation $V = \frac{4}{3}\pi \times (1.78 \times 10^{-6}\ \mathrm{m})^3 = 2.36 \times 10^{-17}\ \mathrm{m}^3$ $m = 2.36 \times 10^{-17}\mathrm{m}^3 \times 920\ \mathrm{kg\ m}^{-3} = 2.17 \times 10^{-14}\ \mathrm{kg}$ $E = \frac{4870\ \mathrm{V}}{1.55 \times 10^{-2}\ \mathrm{m}} = 3.14 \times 10^5\ \mathrm{V\ m}^{-1}$ $q = \frac{2.17 \times 10^{-14}\ \mathrm{kg} \times 9.81\ \mathrm{N\ kg}^{-1}}{3.14 \times 10^5\ \mathrm{N\ C}^{-1}} = 6.78 \times 10^{-19}\ \mathrm{C}$ $N = \frac{6.78 \times 10^{-19}\mathrm{C}}{1.60 \times 10^{-19}\ \mathrm{C}} = 4.23$	**6**

9(b)(i)	An explanation that makes reference to **max two** of the following points: • The oil drop initially accelerates **Or** it takes time for the oil drop to reach terminal velocity **(1)** • (Initially) weight of oil drop not balanced by the drag force (+ upthrust) **Or** Weight of oil drop must be balanced by the drag force (+ upthrust) **(1)** • (If measurements are taken immediately) the calculated velocity will be less than the terminal velocity **(1)**	Accept use of standard symbols	**2**
9(b)(ii)	• Positions from scale used to determine displacement **(1)** • Use of $v = \frac{s}{t}$ **(1)** • $v = 3.4 \times 10^{-5}$ m s^{-1} $\rightarrow$ 3.5×10^{-5} m s^{-1} **(1)**	<u>Example of calculation</u> Displacement = 6.65 mm – 2.50 mm = 4.15 mm $v = \frac{4.15 \times 10^{-3}}{2 \times 60\ \mathrm{s}} = 3.46 \times 10^{-5}\ \mathrm{m\ s^{-1}}$	**3**
9(c)	• The maxima are for charges of e, 2e, 3e etc. **Or** 24 drops had charge as (an integer) multiple of e **(1)** • But there is a significant number of non-integer charged oil drops **Or** comment related to only $\frac{24}{50}$ having integer value **Or** comment related to only 48% having integer value **(1)** • The evidence from the bar chart is inconclusive **Or** Reference variation due to experimental uncertainties **(1)**	MP2: Accept just less than half the drops have an integer multiple of charge	**3**

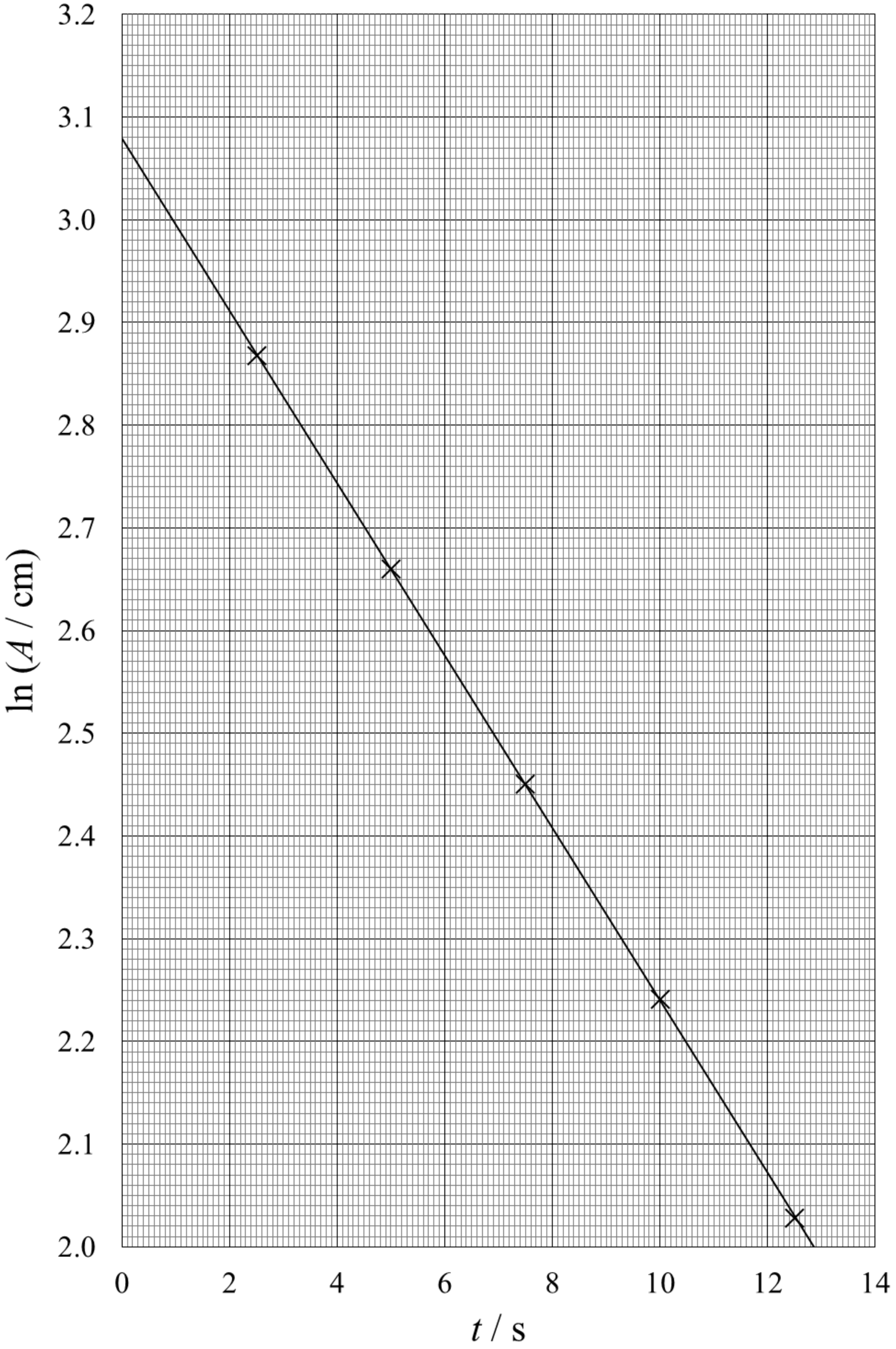
(Total for Question 9 = 15 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
10(a)(i)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ • ℓ = 1.55 m	(1) (1)	<u>Example of calculation</u> $\ell = \frac{(2.50\ \text{s})^2 \times 9.81\ \text{m s}^{-2}}{4\pi^2} = 1.55\ \text{m}$	2
10(a)(ii)	An explanation that makes reference to the following points: • Resistive forces act on the pendulum **Or** The oscillation is damped • Work is done against the resistive/damping forces • So the energy **and** amplitude of the oscillation/pendulum decreases	(1) (1) (1)	Accept "energy is transferred from the system" for "energy decreases"	3
10(b)(i)	An explanation that makes reference to the following points: • Shows expansion $\ln(A) = -\left(\frac{k}{T}\right)t + \ln A_0$ • Compares with $y = mx + c$ and states/indicates that gradient is $-\frac{k}{T}$ (which is a constant) **OR** • Shows expansion $\ln(A) = \ln A_0 - \left(\frac{k}{T}\right)t$ • Compares with $y = c +$ mx and states/indicates that gradient is $-\frac{k}{T}$ (which is a constant)	(1) (1) (1) (1)		2

10(b)(ii)	• Ln values correct and all to 2 decimal places **Or** Ln values correct and all to 3 decimal places • Labels and unit • Scales • Plots • Line of best fit	**(1)** **(1)** **(1)** **(1)** **(1)**	see table below	**5**
10(b)(iii)	• Inverse ln of intercept determined • A_0 = 22 cm to 2 or 3 sf [Allow answers that round to 21 cm or 22 cm] • Gradient determined using large triangle • k = 0.21 to 2 or 3 sf [Answers must round to 0.21]	**(1)** **(1)** **(1)** **(1)**	Only withhold mark for incorrect s.f. once in this part Example of calculation $\text{grad} = \frac{(3.08 - 2.00)}{(0 - 12.9)\ \text{s}} = -0.0837\ \text{s}^{-1}$ $k = 0.0837\ \text{s}^{-1} \times 2.50\ \text{s} = 0.209$ $\ln A_0 = 3.08$ $A_0 = \text{e}^{3.08} = 21.8\ \text{cm}$	**4**

***t* / s**	***A* / cm**	**ln (A/cm)**	**ln (A/cm)**
2.5	17.6	2.868	2.87
5.0	14.3	2.660	2.66
7.5	11.6	2.451	2.45
10.0	9.4	2.241	2.24
12.5	7.6	2.028	2.03

(Total for Question 10 = 16 marks)


3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
ln (A / cm)
0
2
4
6
8
10
12
14
t / s

Question Number	Acceptable Answer	Additional Guidance	Mark
11(a)	**MAX 3** • The rule has a resolution of 1 mm **(1)** • The rule is not suitable to measure *t*, as the % uncertainty would be too large **(1)** • She should use vernier/digital calipers instead **(1)** • Vernier calipers have a resolution of 0.1 mm **Or** Digital calipers have a resolution of 0.01 mm **(1)**	MP3L Accept micrometer for MP3 Then, MP4; micrometer has resolution of 0.01 mm	**3**
11(b)	• Stack the washers together **(1)** • This increases the distance being measured **(1)** • So the % uncertainty is reduced **(1)**	MP1: Accept measure *t* in multiple places on washer and calculate a mean	**3**

11(c)(i)	• Uncertainty added for sums and difference **(1)** • % uncertainty calculated for sum and difference **(1)** • % uncertainties added for product **(1)** • % uncertainty in A = 2.6 (%) **(1)**	<u>Example of calculation</u> % uncertainty in $(d_1 + d_2) = \frac{2\times 0.02\text{ cm}}{(4.52+2.53)\text{ cm}} \times 100\% = 0.57\ \%$ % uncertainty in $(d_1 - d_2) = \frac{2\times 0.02\text{ cm}}{(4.52-2.53)\text{ cm}} \times 100\% = 2.0\ \%$ % uncertainty in $(d_1 + d_2)(d_1 - d_2)$ = 0.6% + 2.0% = 2.6 %	**4**
11(c)(ii)	• Mean t = 4.1 (mm) **(1)** • Use of half range value to calculate % U in t **(1)** • Calculates volume from area and thickness **(1)** • Use of $\rho = \frac{m}{V}$ **(1)** • Calculates % U in density (ecf from (c)(i)) **(1)** • Range of density is from 6.6 g cm^{-3} to 7.6 g cm^{-3}, so washer is made of iron. **(1)**	<u>Example of calculation</u> $\bar{t} = \frac{(4.3 + 4.2 + 4.1 + 3.9 + 4.0)\text{ mm}}{5} = 4.1\text{ mm}$ $\%\ U \text{ in } t = \frac{(4.3 - 3.9)\text{ mm}/2}{4.1\text{ mm}} \times 100\ \% = 4.9\ \%$ $V = \frac{\pi}{4}(4.52 + 2.53)\text{cm} \times (4.52 - 2.53)\text{cm} \times 0.41\text{cm} = 4.52\text{ cm}^3$ $\rho = \frac{32.0\text{ g}}{4.52\text{ cm}^3} = 7.08\text{ g cm}^{-3}$ % U in ρ = 2.6 % + 4.9 % = 7.5 % Maximum value of ρ = 1.075 ×7.08 g cm^{-3} = 7.61 g cm^{-3} Minimum value of ρ = 0.925 ×7.08 g cm^{-3} = 6.55 g cm^{-3} Only iron has a density within range, so the washers are made from iron	**6**

(Total for Question 11 = 16 marks)

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