Pearson Edexcel

Mark Scheme (Results)

Summer 2022

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

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Summer 2022
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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. 'resonance'
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)	• Data not recorded to the same s.f./d.p. • Position of mass holder not recorded	**(1)** **(1)**		**2**
1(b)	• Calculate mean value of position of mass (holder) by taking loading and unloading positions of mass (holder) **Or** calculate mean value by taking repeat readings/measurements (for each mass) • Use a pointer on mass (holder to ensure that position of mass holder is read correctly) **Or** take readings at eye level (to ensure that position of mass holder is read correctly) **Or** use a set square to take readings from metre rule (to ensure that position of mass holder is read correctly) **Or** bring metre rule as close as possible to mass (holder) • Check that metre rule is vertical **Or** fix metre rule in position	**(1)** **(1)** **(1)**		**3**

(Total for Question 1 = 5 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
2(a)	An explanation that makes reference to the following points: • Measure the thickness of a stack of slides and divide by number of slides **(1)** • the uncertainty would be the same but the measurement would be larger (so the percentage uncertainty would be less) **(1)**		**2**
2(b)	• Precision refers to the spread of values (so the reference to precision is incorrect) **(1)** • Accuracy refers to how close the value is to the true value **(1)** • The resolution (of the balance) is 0.01 g **Or** the uncertainty (of the readings) is (half of) 0.01 g **(1)** • Repeating the measurement doesn't reduce the effect of random error **Or** Repeating the measurement and calculating a mean reduces the effect of random error **(1)**		**4**

(Total for Question 2 = 6 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
3(a)	• Use of $E_K = \frac{1}{2}mv^2$ • Use of $\Delta E = mc\Delta\theta$ • Use of 8000 **Or** use of (energy required) / (energy per slap) • Use of 65% with input energy • Energy from 8000 slaps would be 1.78×10^5 J which is less than the energy required to raise the temperature to 165 °C (2.20×10^5 J) **Or** final temperature would be 138 °C, so not enough **Or** 9900 slaps would be needed, so not enough **Or** temperature rise from 8000 slaps is 115 K which is less than required temperature rise of 142 K	(1) (1) (1) (1) (1)	Example of calculation $E_K = \frac{1}{2} \times 1.75\text{ kg} \times (6.25\text{ m s}^{-1})^2 = 34.2\text{ J}$ $\Delta E = 0.65 \times 8000 \times 34.2\text{ J} = 1.78 \times 10^5\text{ J}$ $\Delta E = 0.875\text{ kg} \times 1770\text{ J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\text{ J}$ $E_K = \frac{1}{2} \times 1.75\text{ kg} \times (6.25\text{ m s}^{-1})^2 = 34.2\text{ J}$ $\Delta E = 0.65 \times 34.2\text{ J} = 22.2\text{ J}$ $\Delta E = 0.875\text{ kg} \times 1770\text{ J kg}^{-1}\text{K}^{-1} \times (165 - 23)\text{K}$ $\therefore \Delta E = 2.20 \times 10^5\text{ J}$ Number of slaps $= \frac{2.20 \times 10^5\text{ J}}{22.2\text{ J}} = 9910$ $E_K = \frac{1}{2} \times 1.75\text{ kg} \times (6.25\text{ m s}^{-1})^2 = 34.2\text{ J}$ $\Delta E = 0.65 \times 8000 \times 34.2\text{ J} = 1.78 \times 10^5\text{ J}$ $1.78 \times 10^5\text{J} = 0.875\text{ kg} \times 1770\text{ J kg}^{-1}\text{K}^{-1} \times (T_f - 296)\text{K}$ $\therefore T_f = \frac{1.78 \times 10^5\text{ J}}{1.55 \times 10^3\text{ J K}^{-1}} + 296\text{ K} = 411\text{ K}$ $\therefore \theta_f = (411 - 273)\text{ K} = 138\ ^\circ\text{C}$ MP5: must see a correct value as part of the conclusion	**5**

3(b)	• There is no way to insulate the chicken from the surroundings **Or** there will be energy transfer if there is a temperature difference with the surroundings **Or** there will be energy transfer unless the chicken is in thermal equilibrium with the surroundings **Or** energy will be transferred to the surroundings between slaps **Or** it would take a long time for 8000 slaps so there will be energy transfer **(1)** • So the assumption is unrealistic (dependent mark) **(1)**	MP1: accept lag	**2**

(Total for Question 3 = 7 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
4	• Time a number of (complete) oscillations and divide this time by the number of (complete) oscillations **(1)** • This increases the total time recorded **Or** this reduces the effect of reaction time (Dependent on MP1) **(1)** • Time from the mid-point of the oscillation **(1)** • Use a marker to identify the mid-point of the oscillation **Or** pendulum is travelling fastest at the mid-point **(1)** • Each method reduces the (percentage) uncertainty (in the value for *T*) **(1)**	Allow: MP1:Use a light gate with a data logger **Or** video oscillation and play back frame by frame MP2: this reduces the effect of reaction time (Dependent on MP1) MP3: accept equilibrium point for mid-point MP5: can't be awarded on its own.	**5**

(Total for Question 4 = 5 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*5</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 As the magnet moves through the coil there is a change in magnetic flux linkage (with coil)
Or as the magnet moves through the coil the coil cuts (lines of) magnetic flux
Or as the magnet moves through the coil the coil cuts magnetic field lines
IC2 An <u>e.m.f.</u> is induced across the coil
IC3 This generates a current in the (capacitor) circuit
IC4 The diode only allows current in one direction
IC5 So capacitor is charged (repeatedly)
IC6 When switch is closed capacitor discharges through the LED
</td>
<td>
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
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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>
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</table>
</td>
<td>6</td>
</tr>
</table>

(Total for Question 5 = 6 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
6(a)	• He should have moved the microphone over more in-phase positions (to determine multiple wavelengths) • This would reduce the uncertainty in the value (for *d*) (dependent upon MP1)	(1) (1)	**Alternative:** MP1: move microphone between antiphase positions MP2: as it is easier to judge when waves are in antiphase (peak corresponds to a trough)	2
6(b)	• No of divisions read from oscilloscope trace • Use of time base setting • Use of $f = 1/T$ • Use of $v = f\lambda$ • $v = 340\ \text{m s}^{-1}$	(1) (1) (1) (1) (1)	MP1: Must be for a recognised part of wave <u>Example of calculation</u> $T = 3 \times 0.20 \times 10^{-3}\ \text{s} = 6.0 \times 10^{-4}\ \text{s}$ $f = \dfrac{1}{6.0 \times 10^{-4}\ \text{s}} = 1.67 \times 10^{3}\ \text{Hz}$ $v = 1.67 \times 10^{3}\ \text{s}^{-1} \times 0.205\ \text{m} = 342\ \text{m s}^{-1}$	5

(Total for Question 6 = 7 marks)

Question Number	Acceptable Answer		Additional Guidance	Mark
7(a)	• Use of $E_{\text{grav}} = mg\Delta h$ • Use of $E_K = \frac{1}{2}mv^2$ for block and projectile • Use of $p = mv$ • Use of conservation of momentum • Use of $E_K = \frac{1}{2}mu^2$ for projectile • ΔE = 490 J	(1) (1) (1) (1) (1) (1)	MP1: Use of suvat equation to calculate u MP2: Use of $E_K = \frac{1}{2}mv^2$ for block and projectile **Or** use of $E_{\text{grav}} = mg\Delta h$ <u>Example of calculation</u> $E_{\text{grav}} = (2.4 + 0.065)\text{kg} \times 9.81 \text{ m s}^{-2} \times 0.55 \text{ m} = 13.3 \text{ J}$ (of block and projectile) $13.3 \text{ J} = \frac{1}{2} \times (2.4 + 0.065)\text{kg} \times v^2$ $\therefore v = \sqrt{\frac{13.3 \text{ J}}{0.5 \times 2.465 \text{ kg}}} = 3.28 \text{ m s}^{-1}$ $0.065 \text{ kg} \times u = 2.465 \text{ kg} \times 3.28 \text{ m s}^{-1}$ $\therefore u = \frac{8.10 \text{ kg m s}^{-1}}{0.065 \text{ kg}} = 124.6 \text{ m s}^{-1}$ $E_K = \frac{1}{2} \times 0.065 \text{ kg} \times (125 \text{ m s}^{-1})^2 = 504 \text{ J}$ $\therefore \Delta E = (504 - 13.3) \text{ J} = 491 \text{ J}$	6
7(b)	• Total energy is constant, but kinetic energy decreases **Or** reference to an inelastic collision • Projectile does work on block **Or** internal energy of block increases	(1) (1)		2

(Total for Question 7 = 8 marks)

Question Number	Acceptable Answer	Additional Guidance	Mark
8(a)	• α radiation would be absorbed by the plastic bottle **(1)** • β radiation can penetrate the plastic bottle therefore it could/must be β radiation **(1)**		**2**
8(b)(i)	• Smooth best fit curve drawn on graph **(1)** • Time for count rate to fall by half once **(1)** • Time for count rate to fall by half twice and mean time calculated **(1)** • $t_{1/2}$ = 60 s → 80 s **(1)**	Alternative approaches for MP2 and MP3 Read 2 values from graph and use exponential equation **Or** draw tangent to curve at t = 0 and read off the time intercept <u>Example of calculation</u> 9.0 s^{-1} → 4.5 s^{-1} t = 75 s 4.5 s^{-1} → 2.25 s^{-1} t = 75 s If background count is taken into consideration, t will be lower	**4**
8(b)(ii)	An explanation that makes reference to the following points: • There will be background radiation **Or** decay is exponential and so count rate will "never" reach zero **(1)** • The data logger output includes counts due to background radiation as well as the source radiation **Or** The count rate can't be corrected automatically **(1)**	MP2: accept references to GM-tube	**2**

(Total for Question 8 = 8 marks)

<table>
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<tr>
<td>*9(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 Both circuits are suitable because they allow readings of p.d./current for the lamp

IC2 For circuit 1 the minimum p.d. across the lamp is 0 V (when the slider is at the left)
Or For circuit 2 the minimum p.d. across the lamp is greater than 0 V

IC3 For circuit 1 the maximum p.d. across the lamp is the supply p.d (when the slider is at the right)

IC4 For circuit 2 adjusting the resistor changes the circuit resistance (so the current is varied)
Or for circuit 2 the battery p.d. is shared between lamp and variable resistor

IC5 So for circuit 2 the minimum p.d. depends upon the resistance of the variable resistor,

IC6 Circuit 1 is better because it allows a bigger range
Or Circuit 1 is better because it allows p.d.s down to 0 V to be used</td>
<td>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
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<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td>
<td>6</td>
</tr>
<tr>
<td>9(b)(i)</td>
<td>• Use of $R = V/I$ (1)
• $V = 2.2$ V (1)</td>
<td><u>Example of calculation</u>
$V = 17.5 \times 10^{-3}\ \text{A} \times 560\ \Omega = 9.8\ \text{V}$
$\therefore V_{\text{LED}} = (12 - 9.8)\text{V} = 2.2\ \text{V}$</td>
<td>2</td>
</tr>
</table>

9(b)(ii)	An explanation that makes reference to the following points: **Either** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The combination has a smaller fraction of the total circuit resistance **(1)** • Hence a smaller fraction of the supply p.d. falls across the lamp **(1)** **OR** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The total circuit resistance decreases and the current increases **(1)** • So the p.d. across the resistor increases (so the p.d. across the lamp must decrease) **(1)** **OR** • Current flows through voltmeter **(1)** • So circuit current increases **(1)** **Or** current through resistor increases • So the p.d. across the resistor increases **(1)**		**3**

(Total for Question 9 = 11 marks)

Question Number	Acceptable Answer	Additional Guidance	
10(a)	• The first rubber band is too near the surface of the honey (so the ball won't be at its terminal velocity) **(1)** • There is no method for checking that the ball is falling at terminal velocity (when he times) **(1)**	Accept statements for how procedure could be improved consistent with MP1 and MP2 e.g. there should be multiple bands for timing e.g. they haven't videoed the falling ball	**2**
10(b)(i)	• Mean time calculated **(1)** • Use of $s = ut$ **(1)** • u = 0.039 (m s^{-1}) **(1)**	Credit individual velocities and then mean velocity being calculated <u>Example of calculation</u> $t_{av} = \frac{6.40 + 6.35 + 6.36 + 6.38)\text{ s}}{4} = 6.37\text{ s}$ $u = \frac{0.25\text{ m}}{6.37\text{ s}} = 3.92 \times 10^{-2}\text{ m s}^{-1}$	**3**
10(b)(ii)	• Use of $\eta = \frac{2r^2 g(\rho_B - \rho_H)}{9v}$ **(1)** • $\eta = 10.8$ (Pa s), so it is honey A **(1)**	Show that value gives 10.5 Pa s 10.7 Pa s if 0.0392 m s^{-1} used Allow ecf from (b)(i) <u>Example of calculation</u> $\eta = \frac{2 \times (5.50 \times 10^{-3})^2 \times 9.81\text{ m s}^{-2} \times (7750 - 1360)\text{ kg m}^3}{9 \times 3.9 \times 10^{-2}\text{ m s}^{-1}}$ $\therefore \eta = 10.8\text{ Pa s}$	**2**

(Total for Question 10 = 7 marks)

Question Number	Acceptable Answer		Additional Guidance	
11(a)	An explanation that makes reference to the following points: • The number of (free) charge carriers (per unit volume) in the thermistor decreased • (Hence) the resistance of the thermistor increased • And a larger fraction of supply p.d. is across the thermistor	**(1)** **(1)** **(1)**	MP1: Electrons okay for charge carriers MP3: Current in circuit decreases, so p.d. across fixed resistor decreases, therefore p.d. across thermistor increases	**3**
11(b)(i)	An explanation that makes reference to the following points: • Shows expansion $\ln(V) = \ln(V_0) - b\theta$ • Compares with $y = mx + c$ and shows that m is $(-)b$	**(1)** **(1)**		**2**

<table>
<tr><td>11(b)(ii)</td><td>

- Ln values correct and to 2 or 3 decimal places **(1)**
- Labels and unit **(1)**
- Scales **(1)**
- Plots **(1)**
- Line of best fit **(1)**

</td><td>

θ /°C	V /V	ln (V/V)	ln (V/V)
89.0	1.9	0.642	0.64
74.0	2.9	1.065	1.06
53.5	4.9	1.589	1.59
32.5	9.1	2.208	2.21
18.5	12.6	2.534	2.53
3.5	18.7	2.929	2.93

</td><td>5</td></tr>
<tr><td>11(b)(iii)</td><td>

- Gradient determined using large triangle **(1)**
- b in range (0.026 → 0.028) $^{o}C^{-1}$ to 2 or 3 sf with unit **(1)**
- Inverse ln of intercept determined **(1)**
- V_0 in range (19 → 22) V **(1)**

</td><td>

MP2: unit can be K^{-1}

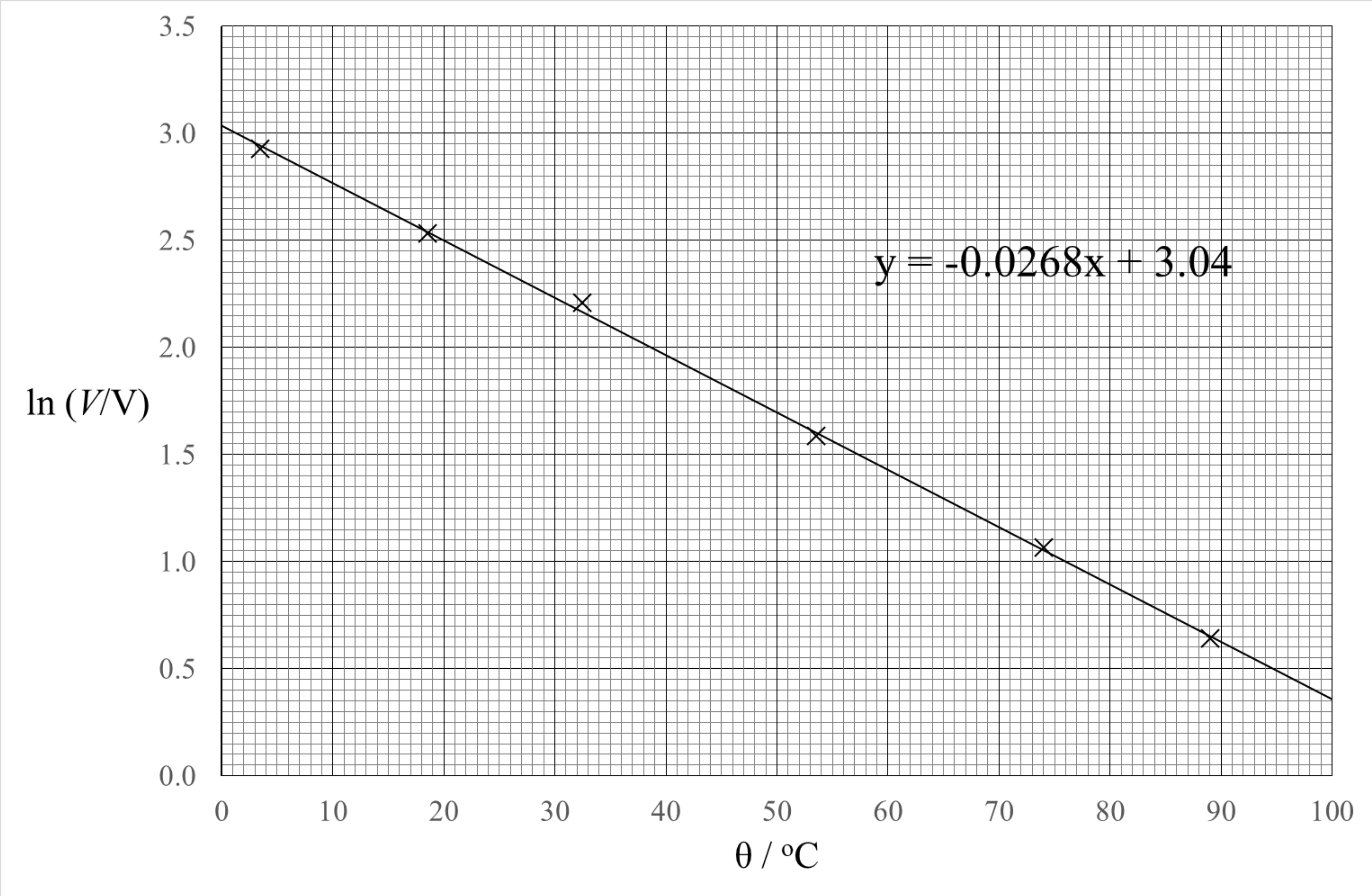
Example of calculation:

$$\text{gradient} = \frac{(3.04 - 0.35)}{(0 - 100)\ ^{o}\text{C}} = -0.027\ \ ^{o}\text{C}^{-1}$$

$$V_0 = e^{3.0}\ \text{V} = 20.1\ \text{V}$$

</td><td>4</td></tr>
</table>

(Total for Question 11 = 14 marks)



3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ln (V/V)
y = -0.0268x + 3.04
0
10
20
30
40
50
60
70
80
90
100
θ / °C

Question Number	Acceptable Answer		Additional Guidance	Mark
12(a)(i)	• Top line correct • Bottom line correct	(1) (1)	Example of equation $^{137}_{55}\mathrm{Cs} \rightarrow {}^{137}_{56}\mathrm{Ba} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\overline{\nu}_{e}$	2
12(a)(ii)	• Use of $\lambda = \frac{\ln 2}{t_{1/2}}$ • Use of 5000 m^3 • Use of $A = A_0 e^{-\lambda t}$ • t = 1400 year	(1) (1) (1) (1)	Example of calculation $\lambda = \frac{\ln 2}{30 \text{ year}} = 0.0231 \text{ year}^{-1}$ $100 \text{ Bq} = (5000 \times 2.35 \times 10^{12})\text{Bq} \times e^{-0.0231 \text{ year}^{-1} \times t}$ $\therefore t = \frac{\ln(8.51 \times 10^{-15})}{-0.0231 \text{ year}^{-1}} = 1402 \text{ year}$	4
12(b)	• Calculation of number of half-lives elapsed • Use of number of half-lives to calculate number of iodine nuclei remaining • Calculation of number of iodine nuclei decayed • Conversion of temperature to kelvin • Use of $pV = NkT$ • Pressure is 1.1×10^5 Pa (compared with 1.0×10^5) and so there is sufficient gas **Or** 1.1×10^{28} gas atoms needed to give required pressure compared with 1.2×10^{28} actual gas atoms, so there is sufficient gas	(1) (1) (1) (1) (1) (1)	MP1 & MP2: Allow use of $\lambda = \frac{\ln 2}{t_{1/2}}$ and $A = A_0 e^{-\lambda t}$ Example of calculation $N = \frac{N_0}{2^4} = \frac{1.25 \times 10^{28}}{16} = 7.81 \times 10^{26}$ $N = 1.25 \times 10^{28} - 7.81 \times 10^{26} = 1.17 \times 10^{28}$ $p \times 450 \text{ m}^3 = 1.17 \times 10^{28} \times 1.38 \times 10^{-23} \text{ J K}^{-1} \times (20 + 273)\text{K}$ $\therefore p = \frac{4.73 \times 10^7 \text{ J}}{450 \text{ m}^3} = 1.05 \times 10^5 \text{ Pa}$	6

12(c)	• Maximum value of a read from graph [8 m s^{-2} → 9 m s^{-2}] **(1)** • Value for period determined from time for at least 3 cycles **(1)** • Use of $\omega = \frac{2\pi}{T}$ **(1)** • Use of $a = (-)A\omega^2 \cos \omega t$ **(1)** • A = 0.33 m, so report is correct **(1)** [Accept value for A in range 0.25 m → 0.40 m with appropriate conclusion]	<u>Example of calculation</u> $T = \frac{(89.2 - 81.0)\text{ s}}{7} = 1.2\text{ s}$ $\omega = \frac{2\pi}{1.2\text{ s}} = 5.2\text{ rad s}^{-1}$ $x = \frac{a}{\omega^2} = \frac{9\text{ m s}^{-2}}{(5.2\text{ rad s}^{-1})^2} = 0.33\text{ m}$	5

(Total for Question 12 = 17 marks)

Question Number	Acceptable Answer		Additional Guidance	
13(a)	• Waves are reflected from the opposite bridge • Waves meet in phase (at mid-point of wire) and superpose • Constructive interference occurs giving a maximum displacement	**(1)** **(1)** **(1)**		**3**
13(b)(i)	• Wear safety glasses (to protect eyes from breaking wire) **Or** wear suitable footwear (to protect feet from falling masses) **Or** place sand tray under masses (to catch them if they fall)			**1**
13(b)(ii)	• $\lambda = 2L$ substituted into $v = f\lambda$ • v substituted into $v = \sqrt{\frac{T}{\mu}}$ • Correct re-arrangement into $y = mx + c$ format	**(1)** **(1)** **(1)**	$v = f\lambda$ and $\lambda = 2L$ so $v = 2fL$ $v = \sqrt{\frac{T}{\mu}}$, so $4f^2L^2 = \frac{T}{\mu}$ $L^2 = \left(\frac{T}{4\mu}\right).\frac{1}{f^2}$, so gradient is $\frac{T}{4\mu}$	**3**
13(b)(iii)	• Gradient calculated • Use of gradient = $\frac{T}{4\mu}$ • $\mu = 1.8\ (\mathrm{g\ m^{-1}})$ • SWG consistent with their calculated value of μ (24 swg)	**(1)** **(1)** **(1)** **(1)**	<u>Example of calculation</u> gradient $= \frac{(0.043 - 0)\mathrm{m}^2}{(15.0 - 0.0) \times 10^{-6}\mathrm{s}^2} = 2.87 \times 10^3 \mathrm{m}^2\mathrm{s}^{-2}$ $\mu = \frac{2.1\ \mathrm{kg} \times 9.81\ \mathrm{m\ s^{-2}}}{4 \times 2.87 \times 10^3 \mathrm{m}^2\mathrm{s}^{-2}} = 1.79 \times 10^{-3}\ \mathrm{kg\ m^{-1}}$ $\therefore \mu = 1.79\ \mathrm{g\ m^{-1}}$	**4**

13(c)(i)	An explanation that makes reference to the following points: **Either** • Take readings in different positions/orientations along the wire (and calculate a mean) **(1)** • As wire diameter may not be uniform **(1)** **OR** • Check (and correct for) for zero error **(1)** • Zero error reduces the accuracy of the measurement **Or** Zero error moves the value away from the true value **(1)**	**Accept:** use ratchet to close up micrometer to avoid squashing the wire MP2 accept cross section for diameter MP2: accept to reduce the effect of random error MP2 accept systematic error not changed by repeat measurements	**2**
13(c)(ii)	• Use of half range value to calculate % uncertainty in *d* **Or** use of max value from mean to calculate % uncertainty in *d* **(1)** • % uncertainty in area = 2 × (% uncertainty in *d*) **(1)** • Calculation of % uncertainty in density **(1)** • % uncertainty in density added to % uncertainty in area **(1)** • Use of $\mu = \frac{m}{L}$ with $\rho = \frac{m}{V}$ **(1)** • $\mu = 2.2 \times 10^{-3}$ kg m^{-1} $\pm$ 0.2×10^{-3} kg m^{-1}, so the stated value is supported by the student's data **(1)**	<u>Example of calculation</u> $\check{d} = \frac{(0.55 + 0.59 + 0.57 + 0.58)\text{ mm}}{4} = 0.57\text{ mm}$ % uncertainty in $d = \frac{0.02\text{ mm}}{0.57\text{ mm}} \times 100 = 3.5$ $\therefore$ % uncertainty in area $= 2 \times 3.5 = 7.0$ % uncertainty in density $= \frac{200\text{ kg m}^{-3}}{8700\text{ kg m}^3} \times 100 = 2.3$ % uncertainty in $\mu = 2.3 + 7.0 = 9.3$ $\mu = \frac{m}{L} = \frac{\rho A L}{L} = 8700\text{ kg m}^{-3} \times \pi \times \left(\frac{0.57 \times 10^{-3}\text{ m}}{2}\right)^2$ $\mu = 2.2 \times 10^{-3}\text{ kg m}^{-1}$ $\text{Range} = \pm\frac{9.3}{100} \times 2.2 \times 10^{-3}\text{ kg m}^{-1} = 2.05 \times 10^{-4}\text{ kg m}^{-1}$ So $2.0 \times 10^{-3}\text{kg m}^{-1} < \mu < 2.4 \times 10^{-3}\text{ kg m}^{-1}$	**6**

(Total for Question 13 = 19 marks)

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