AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________________

Forename(s) ______________________________

Candidate signature ______________________________

A-level
PHYSICS

Paper 3
Section A

Thursday 14 June 2018 Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 70 minutes on this section.

Materials

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 45.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
TOTAL	

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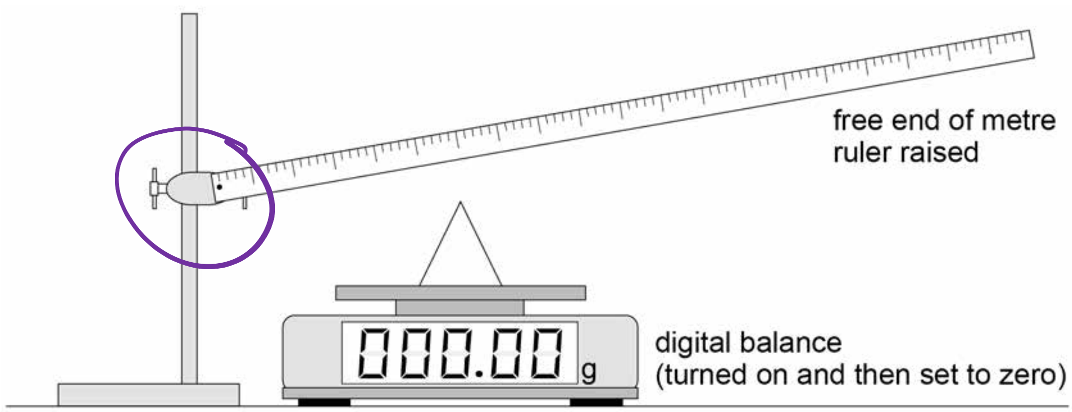
Section A

Answer **all** questions in this section.

0 1 This question is about using a digital balance to investigate the force on a wire placed in a magnetic field when there is an electric current in the wire.

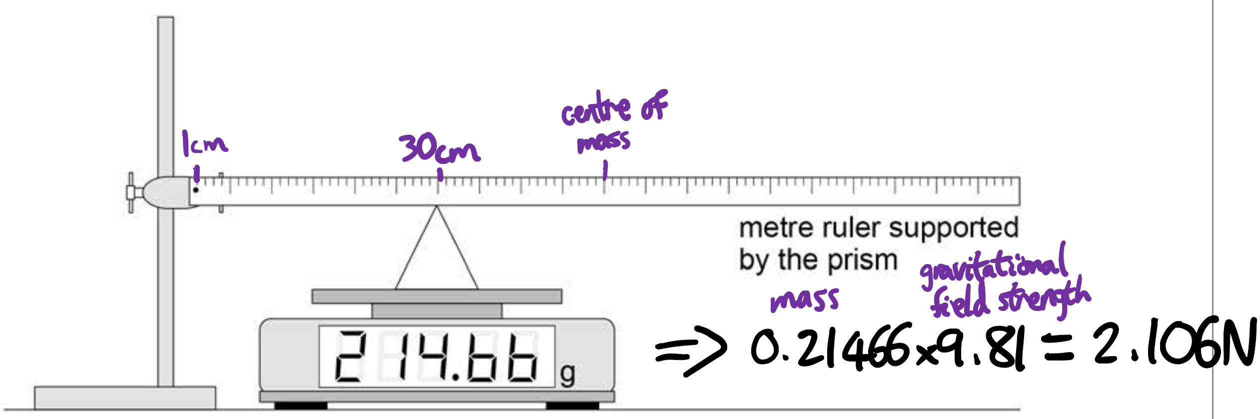
A student carries out the procedure shown in **Figure 1** and **Figure 2**.
A metre ruler is pivoted at the 1.0 cm mark and a prism is placed on a digital balance. The free end of the ruler is raised and the balance is turned on and then set to zero, as shown in **Figure 1**.

Figure 1



The ruler is then supported by the prism with the apex of the prism at the 30.0 cm mark as shown in **Figure 2**. The height of the pivot is adjusted so that the ruler is horizontal.

Figure 2



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0 1 . 1 Deduce the mass of the ruler.
State **one** assumption you make.

moment = force × perpendicular distance from pivot

[3 marks]

Principle of moments:

clockwise moment = anticlockwise moment ✓

weight × 0.49m = force on balance × distance of balance from pivot + $\frac{\text{weight}}{100}$ × 0.01

$$\text{weight} = \frac{\text{force on balance} \times \text{distance of balance}}{0.49 - (\frac{1}{100} \times 0.01)}$$

$$= \frac{2.106 \times 0.29}{0.49 - (0.01 \times 0.01)} = 1.247\text{N}$$

→ mass = $\frac{\text{weight}}{9.81\text{N/kg}}$ = 0.127kg

mass of ruler = 127 ✓ g

assumption The ruler is of uniform density, so that the weight acts at the 50cm mark ✓

Question 1 continues on the next page

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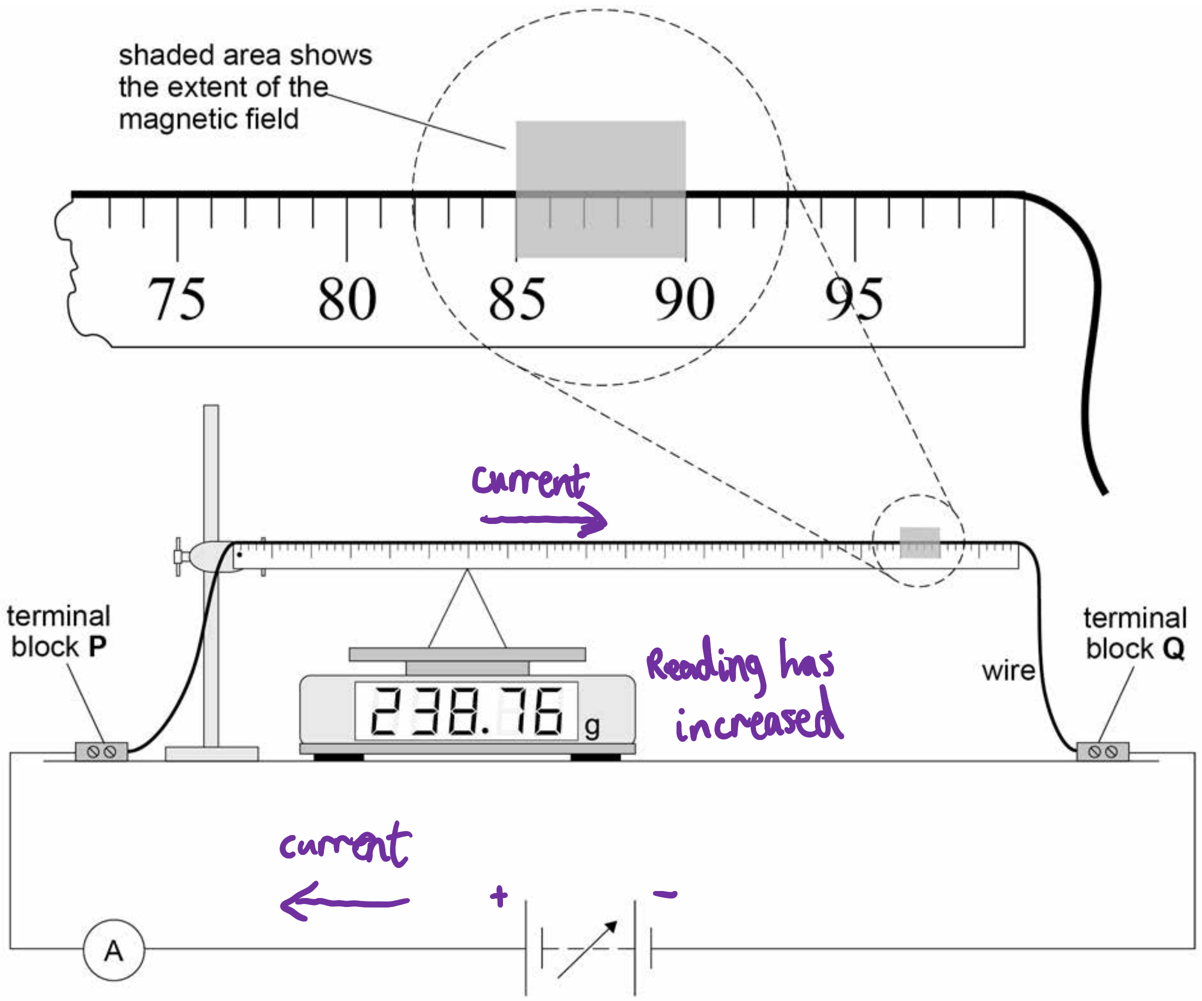
0 1 . 2 The student attaches a uniform wire to the upper edge of the ruler, as shown in **Figure 3**.

The ends of the wire are connected to terminal blocks **P** and **Q** which are fixed firmly to the bench. A power supply and an ammeter are connected between **P** and **Q**.

These modifications cause the balance reading to increase slightly.

A horizontal uniform magnetic field is applied, perpendicular to the wire, between the 85 cm and 90 cm marks, as shown in the close-up diagram in **Figure 3**.

Figure 3



The balance reading M is recorded for increasing values of current I.
A graph of these data is shown in **Figure 4**.

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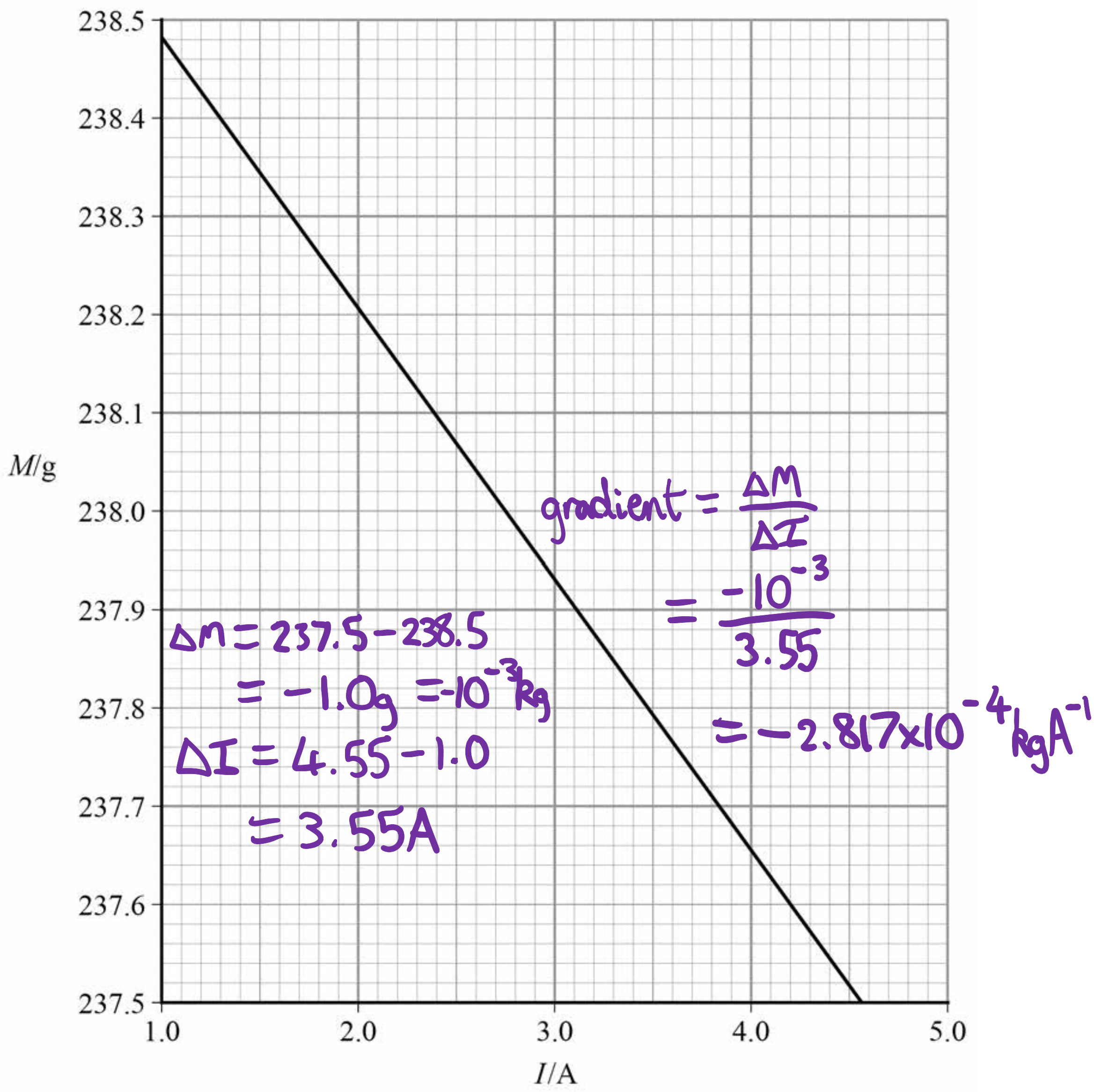
Figure 4



State and explain the direction of the horizontal uniform magnetic field.

[3 marks]

- The force on the wire is acting upwards ✓
- The current in the wire is moving from left to right ✓ (as it is clockwise in the circuit)
- The magnetic field is acting into the page ✓

Question 1 continues on the next page

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0 1 . 3 It can be shown that B, the magnitude of the magnetic flux density of the horizontal uniform magnetic field, is given by

$$B = \frac{\sigma}{3L}$$

where σ = change in force acting on the prism per unit current in the wire
L = length of the region where the magnetic field cuts through the wire.

Determine B. **[3 marks]**

force on prism — $\sigma = F/I = \frac{mg}{I}$ (m — mass reading; g — gravitational field strength; I — current)

$$\sigma = g\frac{\Delta m}{\Delta I} = g(-2.817\times10^{-4})$$ ✓*

$$B = \frac{\sigma}{3L} = \frac{g(-2.817\times10^{-4})}{3L} = \frac{9.81\times(-2.817\times10^{-4})}{3\times0.05}$$ ✓

$$= -0.0184\,T$$ ✓

*$\Delta I \geq 2.0A$

B = 0.0184 T

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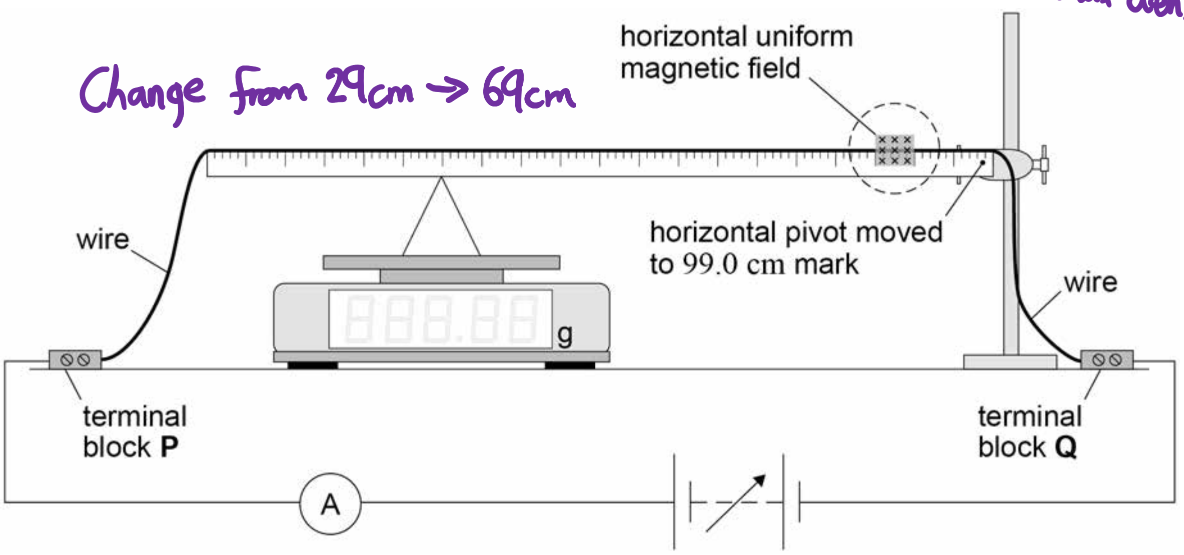
0 1 . 4 The experiment is repeated with the ruler pivoted at the 99.0 cm mark. Nothing else is changed from **Figure 3**.

This arrangement is shown in **Figure 5**.

Figure 5



Tick (✓) **one** box in row 1 and **one** box in row 2 of **Table 1** to identify the effect, if any, on the magnitude of the forces acting on the apparatus as a certain current is passed through the wire.

Tick (✓) **one** box in row 3 and **one** box in row 4 of **Table 1** to identify the effect, if any, on the graph produced for this modified experiment compared with the graph in **Figure 4**.

[3 marks]

Table 1

		Reduced	No effect	Increased
1	Force acting on the current-carrying wire due to the horizontal uniform magnetic field		✓	
2	Force acting on the prism due to the pivoted ruler	✓		
3	Gradient of the graph	✓		
4	Vertical intercept of the graph	✓		

Question 1 continues on the next page

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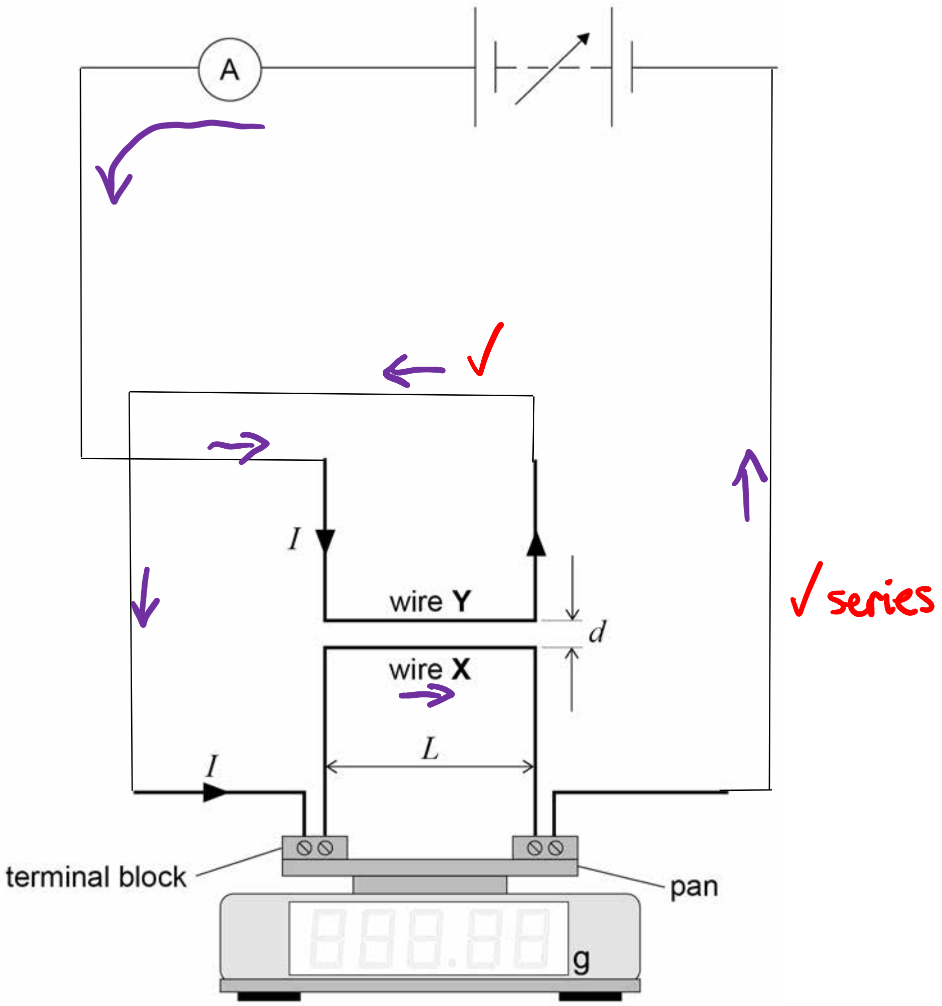
0 1 . 5 **Figure 6** shows the balance being used to measure the forces between two wires. The connections joining these wires to the power supply are not shown.

The pan of the balance moves a negligible amount during use and it supports a straight conducting wire **X** of horizontal length L.
Terminal blocks are used to connect **X** into the circuit. The weight of these does not affect the balance reading.
A second conducting wire **Y** is firmly supported a distance d above **X**.

Show, by adding detail to **Figure 6**, the wire connections that complete the circuit. The currents in **X** and **Y** must have the same magnitude and be in the directions indicated.

[2 marks]

Figure 6



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0 1 . 6 The vertical force F on wire **X** due to the magnetic field produced by wire **Y** is given by

$$F = \frac{kI^2L}{d} \Rightarrow F = \frac{kL}{d} I^2 \ (= mg)$$

where k is a constant
d is the perpendicular distance between **X** and **Y**
I is the current in the wires
and L is the horizontal length of wire **X**.

$$m = \frac{kL}{dg} I^2$$
$$y = m x \ (+c)$$

A student wants to measure k using the arrangement in **Figure 6**.

The student is told that the following restrictions must apply:

- L is fixed
- I must not exceed 5.0 A
- the result for k must be obtained using a **graphical method**
- the experimental procedure must involve **only one** independent variable.

Explain what the student could do to find k.

[5 marks]

$F = mg$ (m – mass readings; g – gravitational field strength) ✓

Strategy: 3× ✓
Analysis: 2× ✓

• Current is the independent variable and mass reading is the dependent variable ✓
• Control variables: L and d ✓
→ These are lengths, so they can easily be measured ✓

• Plot a graph with I^2 on the x-axis and mass reading on the y-axis ✓
• The gradient is equal to $\frac{kL}{dg} \Rightarrow k = \frac{\text{gradient} \times dg}{L}$ ✓

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Turn over ►

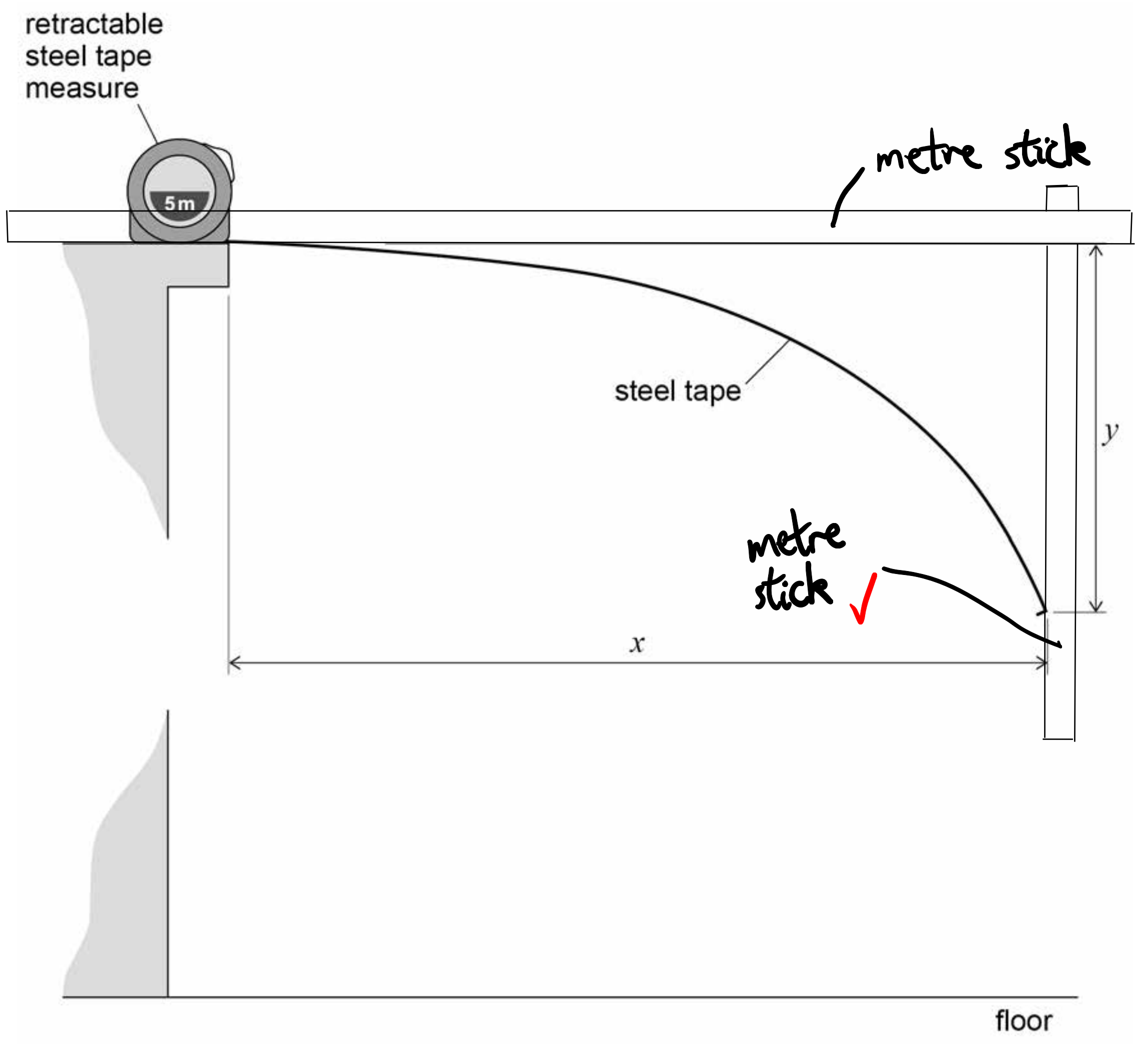
0 2 This question is about an experiment with a retractable steel tape measure.

The tape measure is placed at the edge of the bench and about 1 m of the steel tape is extended so that it overhangs the bench.

The tape is then locked in this position to stop it from retracting.

A student measures the dimensions x and y, the horizontal and vertical displacements of the free end of the tape, as shown in **Figure 7**.

Figure 7



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0 2 . 1 Describe a suitable procedure the student could use to measure *y*.
You may add detail to **Figure 7** to illustrate your answer.

[2 marks]

• See diagram

• The vertical height is measured with a ruler, which is made vertical using a set square ✓

0 2 . 2 By changing the extension of the tape, the student obtains further values of *x* and *y*.

These data are shown in **Table 2**.

Table 2

x / cm	*y* / cm
132.4	61.2
116.8	33.7
105.1	24.3
94.5	15.6
84.3	11.0
73.2	5.7

Suggest why the student chose to make **all** measurements of *x* greater than 70 cm

[1 mark]

Above readings of 70cm, the percentage uncertainty in the x readings will be very small. ✓

Question 2 continues on the next page

0 2 . 3 The data from the experiment suggest that $y = Ax^n$ where n is an integer and A is a constant.

$\log(ab) = \log(a) + \log(b)$

$\log(a^b) = b\log(a)$

These data are used to plot the graph in **Figure 8**.

Determine n using **Figure 8**.

[3 marks]

$\log(y) = \log(Ax^n)$

$= \log A + n\log(x)$

$\log(y) = n\log(x) + \log(A)$

$y = m x + c$

gradient $= n$

$= \frac{\Delta y}{\Delta x} = \frac{1.06}{0.275}$ ✓

$= 3.85$

$\simeq 4$

line of best fit ✓

$n =$ 4 ✓

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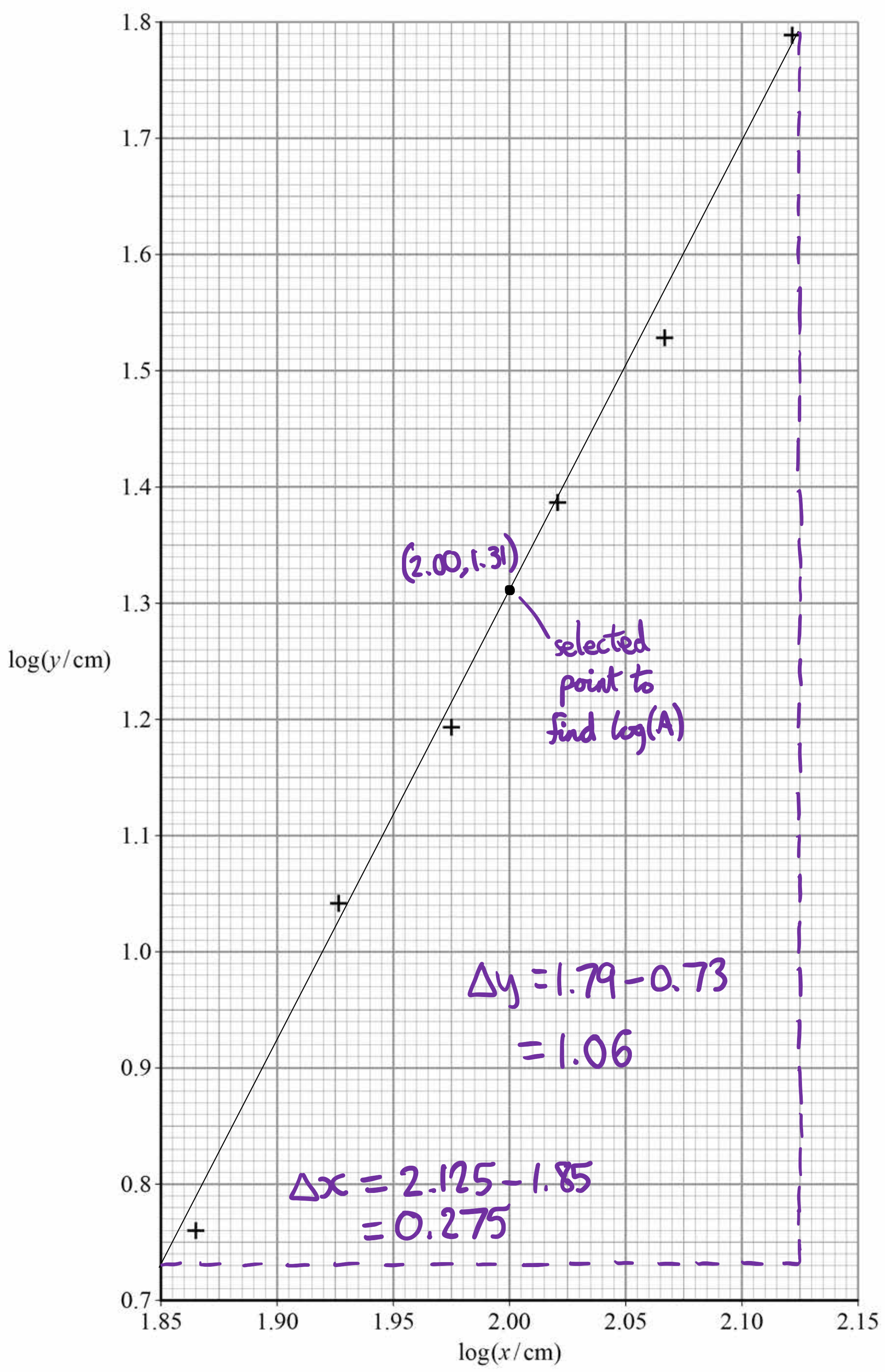
Figure 8



Question 2 continues on the next page

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0 2 . 4 Explain how the numerical value of A can be obtained from **Figure 8**.

[3 marks]

$\log(A)$ = y-intercept ✓

Our graph doesn't show the true y-intercept.

When $\log(x) = 2.00$, $\log(y) = 1.31$ (Select values of $\log(x)$ and $\log(y)$)

$1.31 = 4 \times 2.00 + \log(A)$ (Substitute into equation) ✓

$A = 10^{1.31-(4\times2.00)} = 2.04\times10^{-7}$

($A = 10^{\log(y)-(4\times\log(x))}$ for chosen values) ✓

0 2 . 5 Estimate the order of magnitude of A.
You should use data for x and y from any **one** row in **Table 2** on page 11.
Give your answer with an appropriate unit.

[3 marks]

$x = 105.1 \quad y = 24.3$

$A = \frac{y}{x^n} \Rightarrow A = 10^{\log(y) - n\log(x)}$

$= 10^{\log(24.3) - 4\log(105.1)}$

$= 1.99\times10^{-7}$ ✓ cm^{-3}

If $n = 3.85$ is used

$A = 4.00\times10^{-7}$

So same order of magnitude

y is in cm, x^4 is in cm^4

order of magnitude of A = 10^{-7} ✓ unit cm^{-3} ✓

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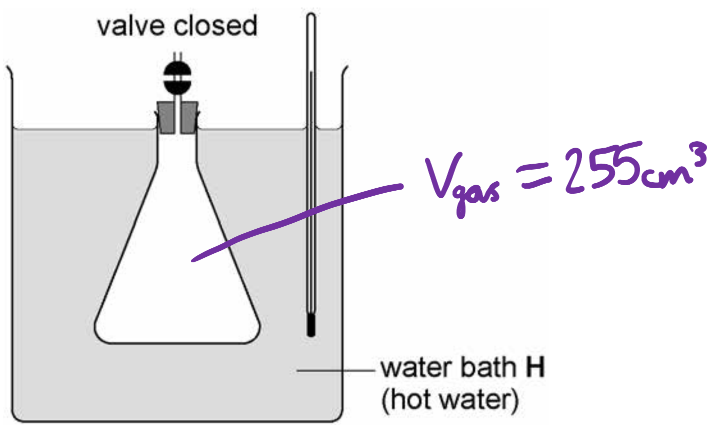
0 3 This question is about an experiment to estimate absolute zero.

Figures 9a to **9d** show the stages in the procedure carried out by a student.

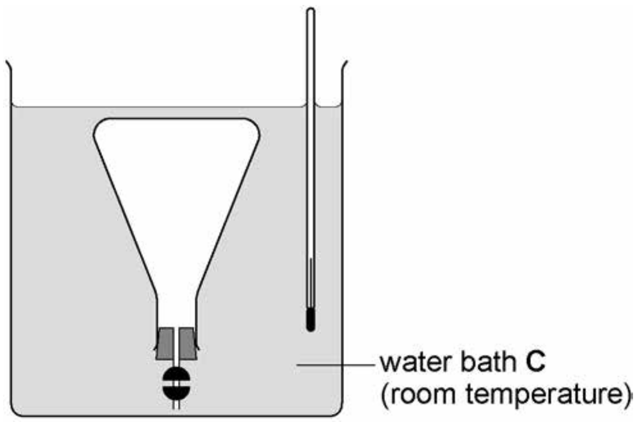
An empty flask fitted with a tube and an open valve is placed in water bath **H** containing hot water. The air inside the flask is allowed to come into thermal equilibrium with the water.
The valve is then closed, trapping a certain volume of air, as shown in **Figure 9a**.

Figure 9a



The flask is inverted and placed in water bath **C** in which the water is at room temperature.
The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 9b**.

Figure 9b



Question 3 continues on the next page

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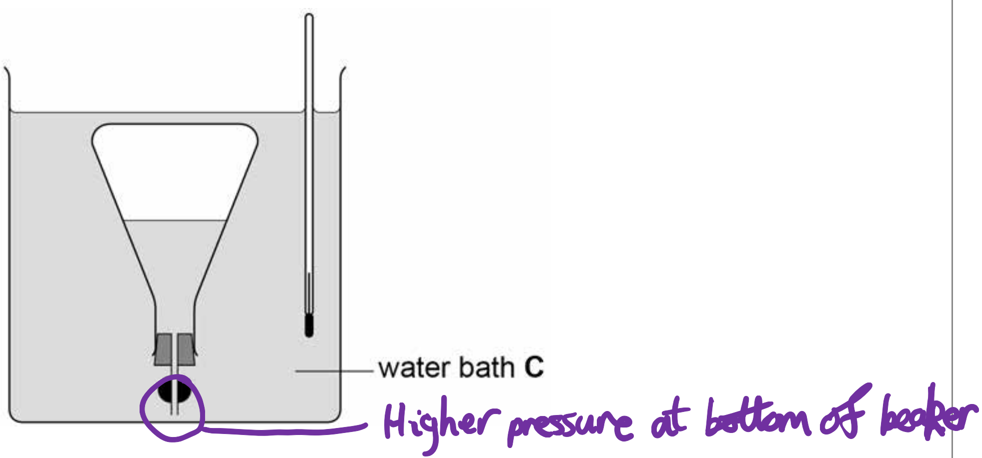
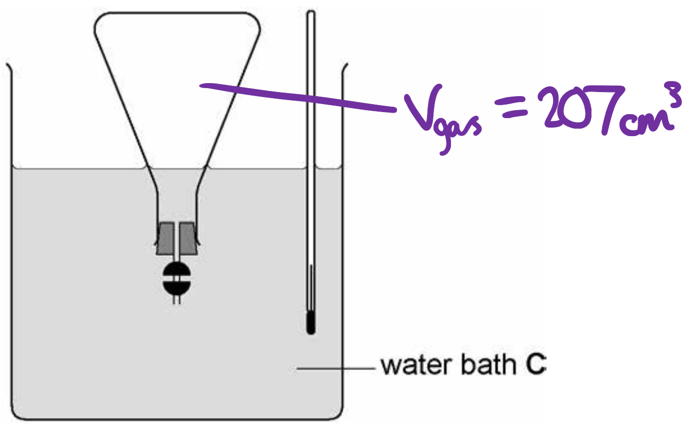
The valve is opened and some water enters the flask, as shown in **Figure 9c**.

Figure 9c



The depth of the inverted flask is adjusted until the level of water inside the flask is the same as the level in the water bath.
The valve is then closed, trapping the air and the water inside the flask, as shown in **Figure 9d**.

Figure 9d



0 3 . 1 Explain why the volume of the air in the flask in **Figure 9c** is less than the volume of the air in the flask in **Figure 9d**.

[2 marks]

• The air pressure is greater in 9c ✓
• Boyle's law says that the pressure and volume will be inversely proportional at this constant temperature ✓

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0 3 . 2 Explain why Charles's Law can be applied to compare the air in the flask in **Figure 9a** with the air in the flask in **Figure 9d**.

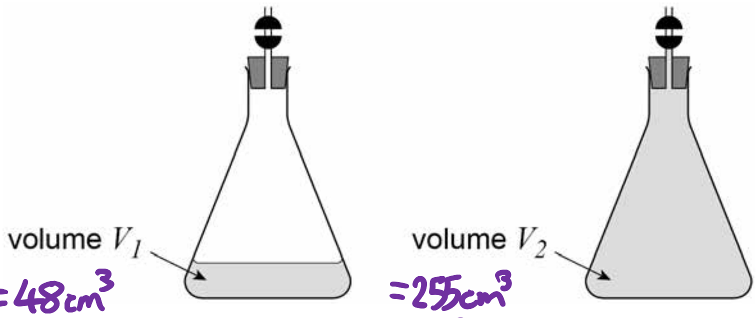
[2 marks]

Charles' law: The volume of a fixed mass of ideal gas is directly proportional to its temperature in kelvin when the pressure is constant.

- The pressure is the same ✓
- The mass of air is the same ✓

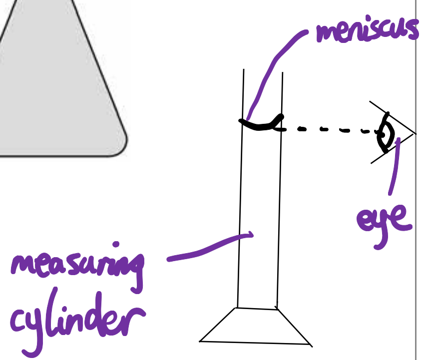
0 3 . 3 The flask is removed from water bath **C** and the valve and stopper are removed.
The volume of the water in the flask is V_1
The flask is then completely refilled with water and the valve and stopper replaced.
The volume of the water now in the flask is V_2
The volumes V_1 and V_2 are shown by the shaded parts in **Figure 10**.

Figure 10



$= 48 cm^3$ Volume of gas $= 207 cm^3$

$= 255 cm^3$ Volume of gas $= 0$



Explain how V_1 and V_2 can be determined.

In your answer you should

- identify a suitable measuring instrument
- explain a suitable procedure to eliminate possible systematic error.

[3 marks]

- Use a measuring cylinder to measure the volume of the liquid ✓
- Your eye level must be at the same height as the bottom of the meniscus ✓ to avoid parallax error ✓

Question 3 continues on the next page

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0 3 . 4 Plot on **Figure 11** points to show the volume V and the temperature θ of the air in the flask when

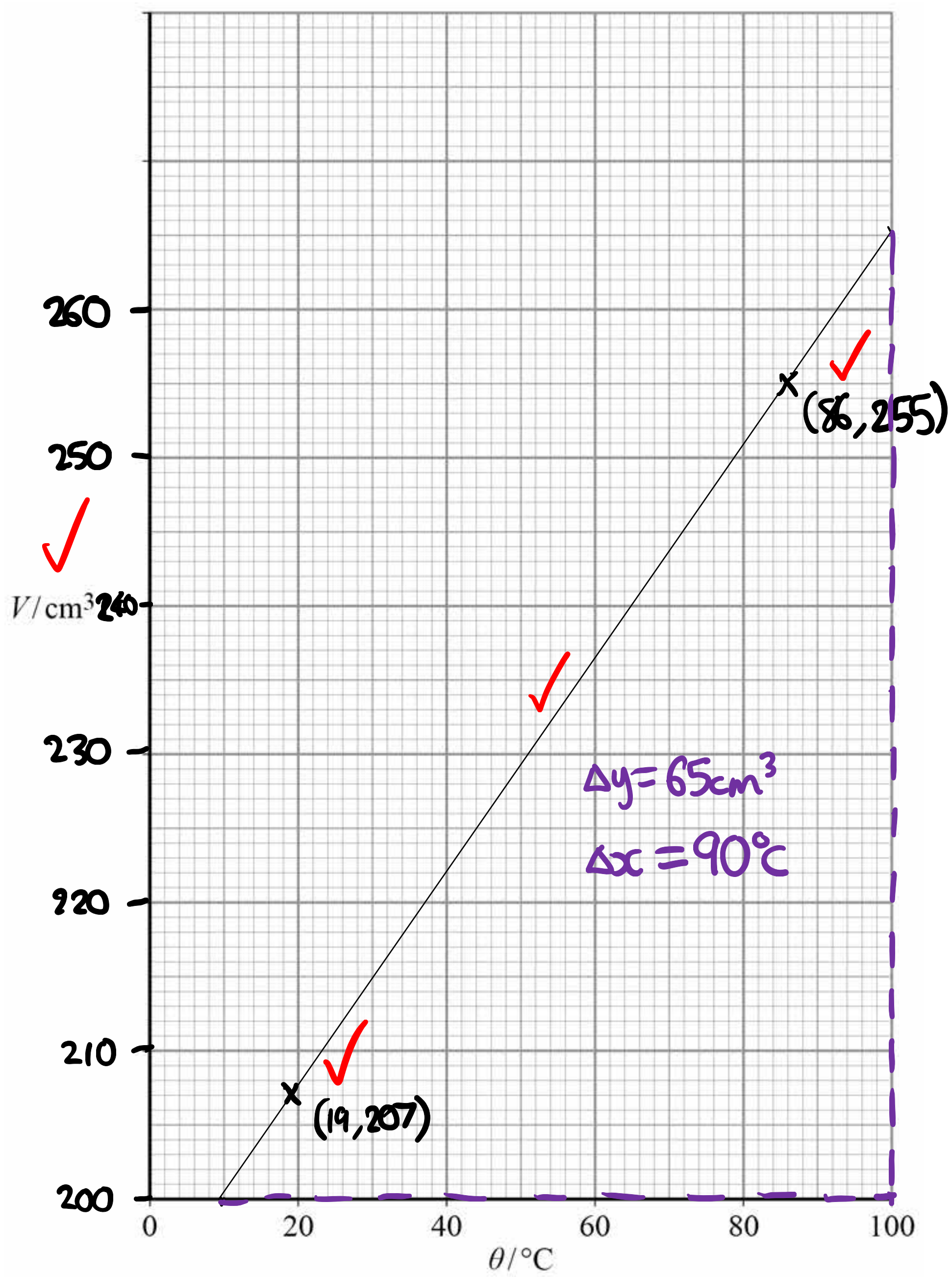
- the flask is as shown in **Figure 9a** — $V_{gas} = 255\text{cm}^3$
- the flask is as shown in **Figure 9d**. — $V_{gas} = 207\text{cm}^3$

The temperature of the hot water bath is 86 °C
Room temperature is 19 °C

$V_1 = 48\ \text{cm}^3$
$V_2 = 255\ \text{cm}^3$

[3 marks]

Figure 11



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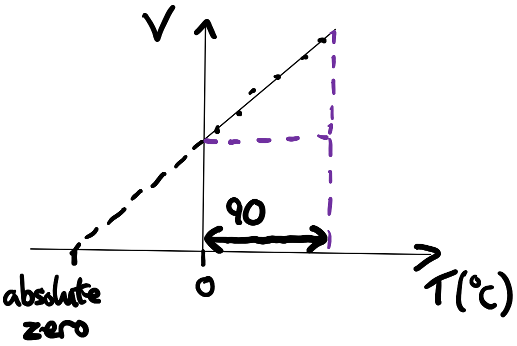
0 3 . 5 Add a best fit line to your graph in **Figure 11** to show how V should vary with θ according to Charles's Law.

[1 mark]

0 3 . 6 Determine the value of absolute zero in °C using your graph in **Figure 11**.

[3 marks]



$y = mx + c$

- Height of triangle increases by a factor of $\frac{265}{65}$
- Width increases by same factor ✓
- $90 \times \frac{265}{65} = 366.92°C$ ✓
- $366.92 - 90 = 276.92°C$

value of absolute zero = −277 ✓ °C

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Alternative Method

correct answer in range (−260°C to −285°C) ✓

- Use $\frac{\Delta y}{\Delta x}$ to calculate gradient
- Substitute this into $y = mx + c$ with a chosen point on the line (x, y) to find c (the y-intercept) ✓
- Use $y = mx + c$ (with the calculated gradient m and y-intercept c) to find the value of x at which $y = 0$ ✓

END OF QUESTIONS

There are no questions printed on this page

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