



Rewarding Learning

ADVANCED
General Certificate of Education
2022

Centre Number

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Candidate Number

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Physics

StemUp Model Solution

Assessment Unit A2 3B

assessing

Practical Techniques
and Data Analysis



[APH32]

APH32

WEDNESDAY 11 MAY, MORNING

TIME

1 hour.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.

You must answer the questions in the spaces provided.

Do not write outside the boxed area on each page or on blank pages.

Complete in black ink only. **Do not write with a gel pen.**

Answer **all four** questions.

INFORMATION FOR CANDIDATES

The total mark for this paper is 50.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.

You may use an electronic calculator.



- 1 Hubble's law states that the recessional velocity of distant galaxies is directly proportional to the distance of the galaxy from the observer.

A plot of the recessional velocity and its distance from Earth is shown in **Fig. 1.1**.

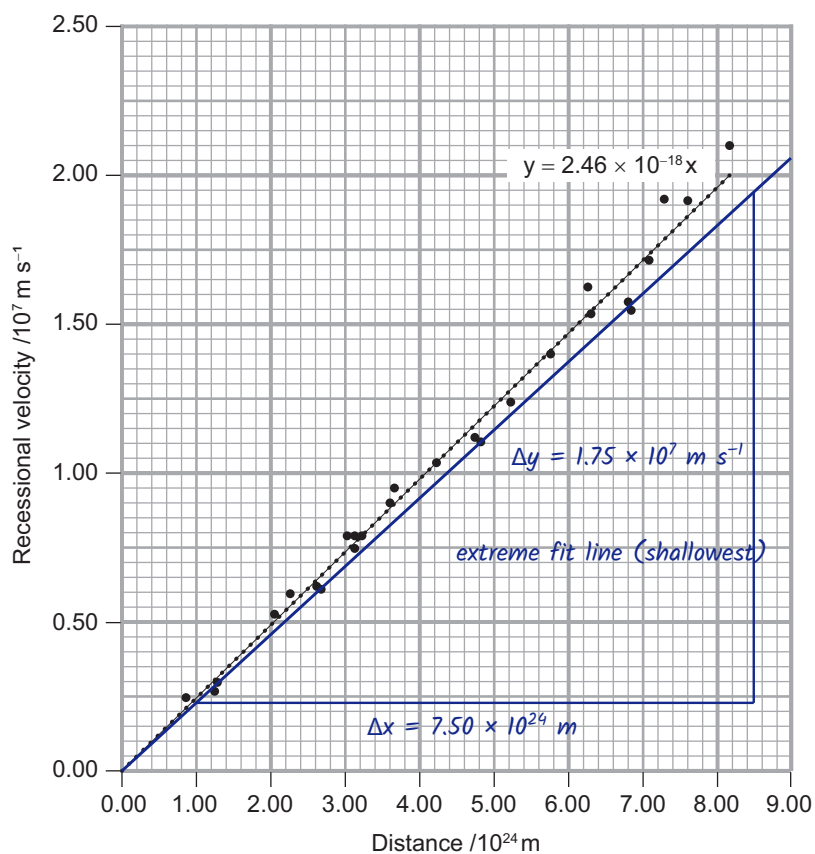


Fig. 1.1



The age of the universe can be determined by calculating the reciprocal of the gradient.

- (a) The equation for the straight line of best fit is given on the graph. Use this to calculate the age of the universe and state the unit.

$$\text{gradient} = 2.46 \times 10^{-18} \text{ s}^{-1}$$

$$\text{age} = 1 / \text{gradient} = 1 / 2.46 \times 10^{-18} = 4.07 \times 10^{17} \text{ s}$$

$$\text{age} = \underline{4.07 \times 10^{17}}$$

$$\text{unit} = \underline{\text{s}} \quad [2]$$

- (b) (i) On **Fig. 1.1**, draw an extreme fit line that would allow you to estimate the maximum age of the universe. [2]

- (ii) Use this extreme fit line to calculate the maximum age of the universe.

My extreme fit line on Fig. 1.1 is the shallowest line through the origin that still fits the points, so it gives the maximum age.

Large triangle on it: from (1.00, 0.233) to (8.50, 1.98)

$$\text{gradient} = \Delta y / \Delta x = (1.75 \times 10^7) / (7.50 \times 10^{24})$$

$$= 2.33 \times 10^{-18} \text{ s}^{-1}$$

$$\text{maximum age} = 1 / \text{gradient} = 1 / 2.33 \times 10^{-18} = 4.29 \times 10^{17} \text{ s}$$

$$\text{Maximum age} = \underline{4.29 \times 10^{17} \text{ s}} \quad [3]$$

[Turn over]



- 2 A student is provided with a tuning fork which has a frequency stated to be $440 \text{ Hz} \pm 5\%$. The student uses a cathode ray oscilloscope to determine the precise frequency of the tuning fork.

- (a) (i) State the name of the other piece of equipment the student needs to allow the oscilloscope to display a sound wave.

Microphone

[1]

- (ii) Fig. 2.1 shows the trace on the screen of the cathode ray oscilloscope immediately after the tuning fork has been struck. Which of the time-base settings shown on Fig. 2.1 must the student be using?

$T = 1/f = 1/440 = 2.27 \times 10^{-3} \text{ s} = 2.27 \text{ ms}$, so one wave is about 2 to 3 cm wide on the 1 ms cm^{-1} setting; a few whole waves fit across the screen. (0.1 ms cm^{-1} would show under half a wave; 10 ms cm^{-1} about 44 waves.)

time-base setting = 1 ms cm^{-1}

[3]



- (iii) The student has initially set the Y-sensitivity to 1 V cm^{-1} . State the value for the Y-sensitivity that the student should select to ensure the full extent of the wave remains on the screen but is as large as possible.

Y-sensitivity setting = 0.2 V cm^{-1}

[1]

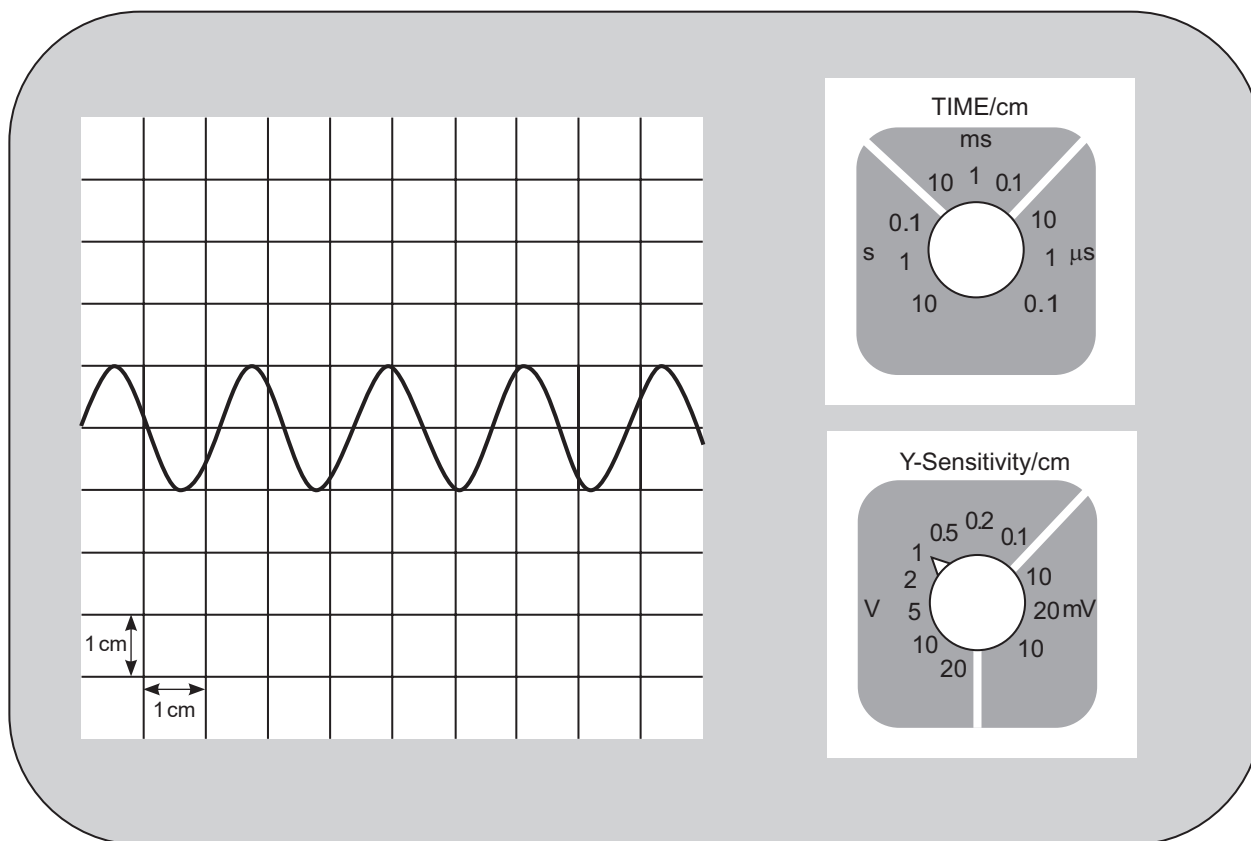


Fig. 2.1

[Turn over]



- (b) Fig. 2.2 shows the display of the oscilloscope screen after the student has adjusted the Y-sensitivity setting. The time-base setting is unchanged.

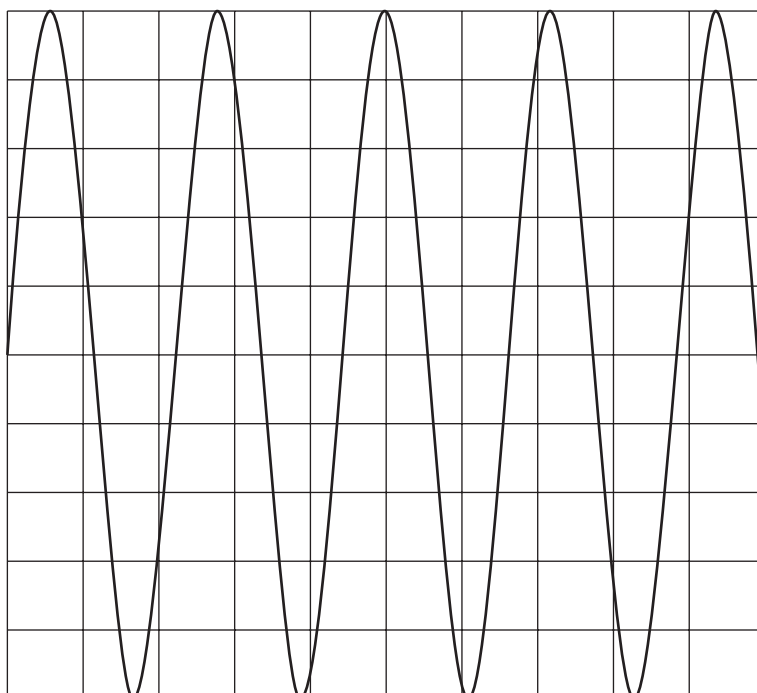


Fig 2.2

- (i) Use Fig. 2.2 to determine an **accurate** value for the time period of the wave.
Measure across as many waves as possible: 1st peak to 5th peak

$$= 4 \text{ waves} = 8.8 \text{ cm, so } 1 \text{ wave} = 8.8 / 4 = 2.2 \text{ cm}$$

$$T = 2.2 \text{ cm} \times 1 \text{ ms cm}^{-1} = 2.2 \text{ ms}$$

$$\text{Time period} = \underline{2.20 \times 10^{-3}} \text{ s}$$

[2]



- (ii) State whether the frequency of the tuning fork falls within the range stated by the manufacturer. **Show calculations to support your conclusion.**

$$f = 1 / T = 1 / 2.20 \times 10^{-3} = 455 \text{ Hz}$$

$$5\% \text{ of } 440 \text{ Hz} = 0.05 \times 440 = 22 \text{ Hz}$$

$$\text{Stated range} = 440 \pm 22 \text{ Hz, i.e. } 418 \text{ Hz to } 462 \text{ Hz}$$

455 Hz lies between 418 Hz and 462 Hz (it is only (455 -

440)/440 $\times$ 100 = 3.4% above 440 Hz, less than 5%),

so yes, the frequency falls within the range stated.

[3]

[Turn over



- 3 Warm water was poured into an empty beaker submerged in an ice bath. The temperature T of the water in the beaker was then measured by a student every 2 minutes as the temperature of the water decreased. The results the student recorded are shown in **Table 3.1**.

Table 3.1

Time / s	$T / ^\circ\text{C}$	$\ln(T / ^\circ\text{C})$
120	64	4.16
240	50	3.91
360	39	3.66
480	30	3.40
600	23	3.14
720	18	2.89

The temperature of the water T at time t is given by **Equation 3.1**.

$$T = T_0 e^{-t/k} \quad \text{Equation 3.1}$$

where:

T_0 is the initial temperature of the water in the beaker
 k is a constant



- (a) (i) Show that a graph of $\ln(T)$ against t is a straight line.

$T = T_0 e^{-t/k}$. Take natural logs of both sides:

$$\ln T = \ln (T_0 e^{-t/k}) = \ln T_0 + \ln e^{-t/k} = \ln T_0 - t/k \quad (\text{as } \ln e = 1)$$

$$\text{so } \ln T = (-1/k) t + \ln T_0$$

compare with $y = mx + c$: $y = \ln T$, $x = t$, gradient $m = -1/k$ (a constant),
intercept $c = \ln T_0$ (a constant), so $\ln T$ against t is a straight line.

[3]

- (ii) State how the value for the constant k could be determined from the graph.

Find the gradient of the line using a large triangle; gradient =

$-1/k$, so $k = -1/\text{gradient}$.

[2]

- (b) (i) Calculate the values for $\ln(T/^\circ\text{C})$ and insert them into the final column of Table 3.1. Record these values to 2 decimal places.

[2]

[Turn over]



- (ii) Draw a graph of $\ln T$ against t on the grid of **Fig. 3.1**. Choose suitable scales for the axes, plot the points and draw the best fit line for the points. [5]

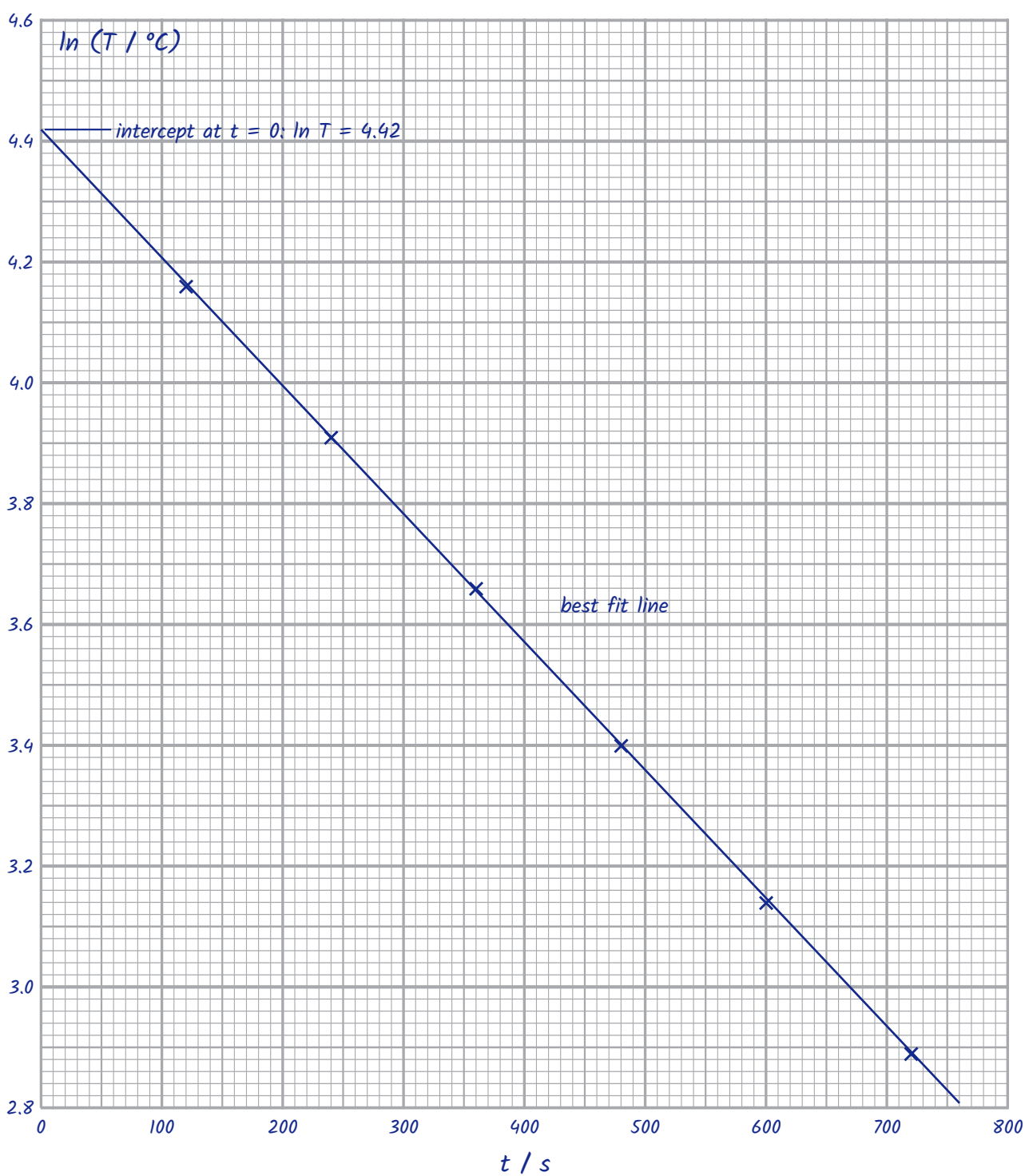


Fig. 3.1



(iii) Use your graph to find the initial temperature T_0 of the water.

Extend the best fit line to $t = 0$: the intercept on the $\ln T$ axis = 4.42

intercept $c = \ln T_0$, so $\ln (T_0 / ^\circ\text{C}) = 4.42$

$$T_0 = e^{4.42} = 83.1 ^\circ\text{C} \approx 83 ^\circ\text{C}$$

$$T_0 = \underline{83} ^\circ\text{C}$$

[3]

[Turn over]



- 4 A student wishes to determine the resistivity of a metal wire whose length is greater than 50 cm and diameter is less than 1 cm.

(a) The student measured the potential difference across and the current through the wire using digital meters. The circuit is shown in **Fig. 4.1**.

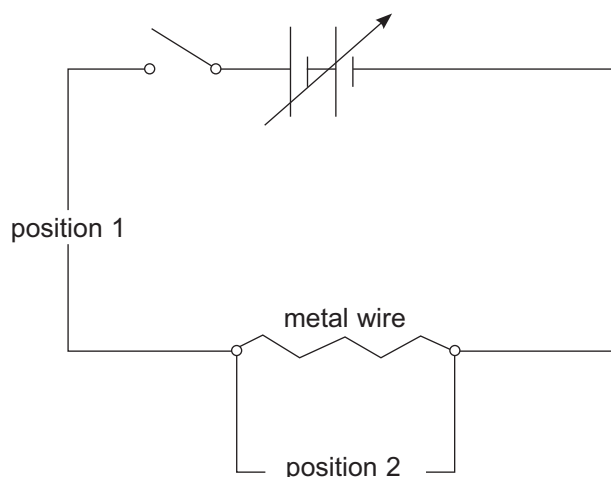


Fig. 4.1

- (i) State the names of the measuring instruments that need to be placed in position 1 and position 2.

Position 1 Ammeter

Position 2 Voltmeter

[2]

- (ii) Explain why it is important to include a switch in this circuit.

The resistance (resistivity) of the metal depends on its
temperature, and the current heats the wire.

The switch lets the current be switched off between readings so
the wire can cool down and stays at a constant temperature.

[2]



- (iii) State which instrument should be used to measure the following quantities and how, in addition to repeating and averaging, the instrument should be used for each reading to ensure it is as accurate as possible.

Quantity: Length of wire

Instrument: Metre rule

How to gain an accurate value:

Pull the wire straight and lay it along the edge of the rule; read
both ends with my eye directly above the mark (in line with the
scale) to avoid parallax error.

Quantity: Diameter

Instrument: Micrometer screw gauge

How to gain an accurate value:

Check for (and correct) any zero error before measuring; close the
jaws gently using the ratchet so the wire is not over-tightened or
squashed.

[4]

[Turn over



(b) The resistance R of a wire of cross-section area A is given by **Equation 4.1**.

$$R = \rho \frac{L}{A} \quad \text{Equation 4.1}$$

(i) Using **Equation 4.1** as a starting point, show that the resistivity ρ is given by **Equation 4.2**.

$$\rho = \frac{\pi V d^2}{4 L I} \quad \text{Equation 4.2}$$

where V is voltage, I is current, L is length and d is diameter.

$$R = \rho L / A, \text{ so } \rho = RA / L$$

$$R = V / I \text{ and } A = \pi d^2 / 4 \text{ (circular cross-section of diameter } d)$$

$$\rho = (V / I) \times (\pi d^2 / 4) / L$$

$$\rho = \pi V d^2 / 4 L I$$

[2]

(ii) The readings the student obtained are given in **Table 4.1**. State the absolute uncertainty and percentage uncertainty in each of the readings.

Table 4.1

Quantity	Reading	Absolute uncertainty	Percentage uncertainty
Voltage	0.41 V	$\pm 0.01 \text{ V}$	2.44 %
Current	1.06 A	$\pm 0.01 \text{ A}$	0.94 %
Length	91.2 cm	$\pm 0.1 \text{ cm}$	0.11 %
Diameter	2.64 mm	$\pm 0.01 \text{ mm}$	0.38 %

[4]



- (iii) Calculate the resistivity of the metal and the percentage uncertainty in the quantity.

$$\rho = \pi V d^2 / 4 L$$

$$= \pi \times 0.41 \times (2.64 \times 10^{-3})^2 / (4 \times 0.912 \times 1.06)$$

$$= 8.977 \times 10^{-6} / 3.867 = 2.32 \times 10^{-6} \Omega m \approx 2.3 \times 10^{-6} \Omega m$$

$$\% \text{ uncertainty in } \rho = \%V + \%l + \%L + 2 \times \%d$$

$$= 2.44 + 0.94 + 0.11 + (2 \times 0.38)$$

$$= 4.25 \%$$

$$\rho = \underline{2.3 \times 10^{-6}} \Omega m \pm \underline{4.25} \% \quad [3]$$

- (iv) Using your answer to part (iii), calculate the absolute uncertainty in the resistivity.

$$\text{absolute uncertainty} = 4.25 \% \text{ of } 2.32 \times 10^{-6} \Omega m$$

$$= 0.0425 \times 2.32 \times 10^{-6} = 9.9 \times 10^{-8} \Omega m \approx 1 \times 10^{-7} \Omega m$$

$$\text{Absolute uncertainty} = \underline{1 \times 10^{-7}} \Omega m \quad [1]$$



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Question Number	Marks
1	
2	
3	
4	

Total Marks	
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Examiner Number

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