OCR A Level Physics A (H556) Physics B (H557)

PAG 3: Investigating electrical properties
Practice Exam Questions and Mark Scheme

1. A student correctly uses an ammeter and a voltmeter to measure the resistance of a component. She obtains the readings $I = 0.38 \pm 0.02$ A and $V = 11.75 \pm 0.01$ V.

What is the best estimate for the resistance value and its uncertainty?

A 30.9 ± 1.6 Ω
B 30.92 ± 1.63 Ω
C 30.92 ± 0.03 Ω
D 31 ± 2 Ω

Your answer

[1]

2. A student determines the power *P* dissipated in a resistor. The measured values of the current **I** in the resistor and the resistance *R* of the resistor are:

$$I = (4.0 \pm 0.2)\text{ A and } R = (3.0 \pm 0.3)\Omega$$

The equation $P = I^2R$ is used to calculate *P*.

What is the percentage uncertainty in the value of *P*?

A 15%
B 20%
C 25%
D 30%

Your answer **[1]**

3. A cable consists of 17 tightly packed copper wires, see Fig. 6.3.

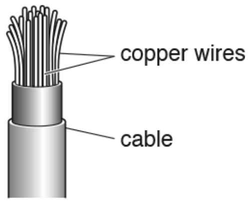

Fig. 6.3 (not to scale)

The student measures the diameter d of one of the copper wires as 0.12 ± 0.01 mm.

i. Explain how the student should measure precisely the diameter of the wire.

--- **[2]**

The student measures the resistance R of the whole **cable** as $1.86 \pm 0.02\ \Omega$.

The length L of the cable is 21.0 ± 0.1 m.

ii. Determine the resistivity ρ of copper.

ρ = Ω m **[3]**

iii. Determine the percentage uncertainty in ρ.

percentage uncertainty = ---------- % **[2]**

4. Fig. 18.1 shows a circuit used by a student to determine the resistivity of the material of a wire.

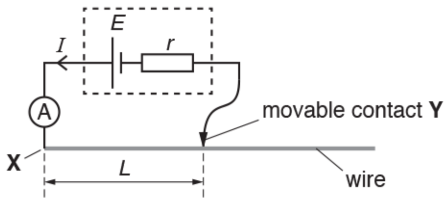

Fig. 18.1

The wire is uniform and has diameter 0.38 mm. The cell has electromotive force (e.m.f.) E and internal resistance r. The length of the wire between **X** and **Y** is L.

The student varies the length L and measures the current I in the circuit for each length.

Fig. 18.2 shows the data points plotted by the student.

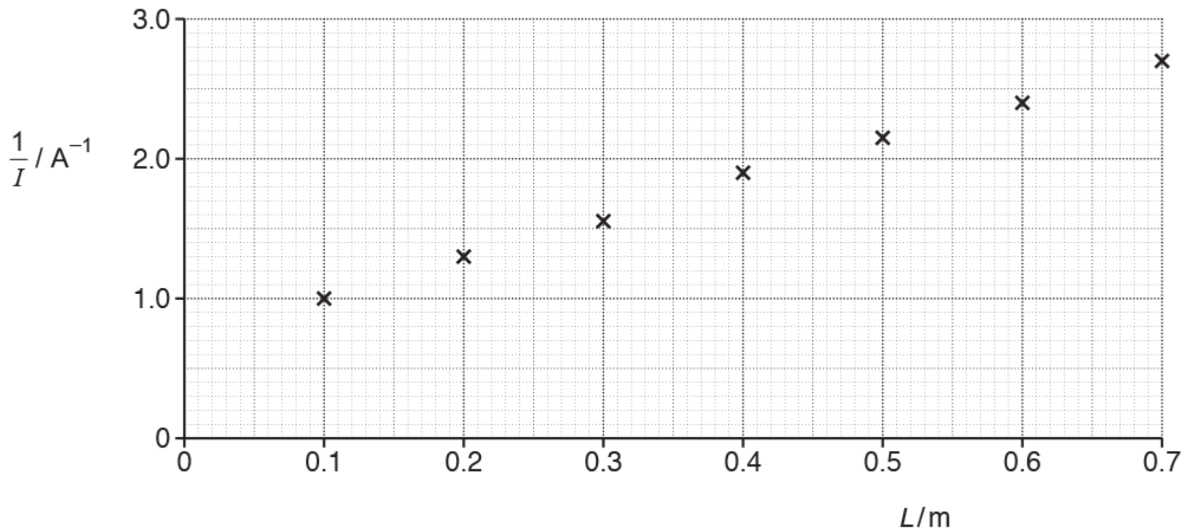

Fig. 18.2

i. On Fig. 18.2 draw the straight line of best fit. Determine the gradient of this line.

gradient = ... A^{-1} m^{-1} **[2]**

ii. Show that the gradient of the line is $\frac{\rho}{AE}$, where ρ is the resistivity of the material of the wire, A is the area of cross-section of the wire and E is the e.m.f. of the cell.

[2]

iii. The e.m.f. E of the cell is 1.5 V. The diameter of the wire is 0.38 mm.

Use your answer to **(i)** and the equation given in **(ii)** to determine ρ.

ρ = ... Ω m **[2]**

iv. Fig. 18.3 illustrates how the student had incorrectly measured all the lengths L of the wire.

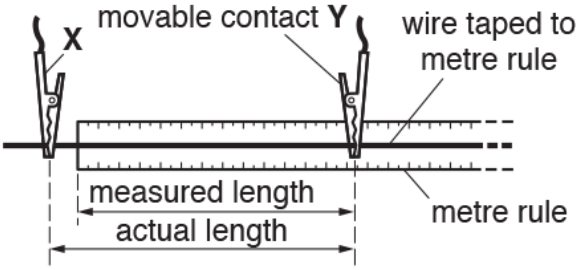

Fig. 18.3

According to the student, re-plotting the data points using the **actual** lengths of the wire will not affect the value of the resistivity obtained in **(iii)**.

Explain why the student is correct.

-- **[2]**

5(a). A student uses the circuit shown in **Fig. 16.1** to determine the resistivity of a metal in the form of a wire.

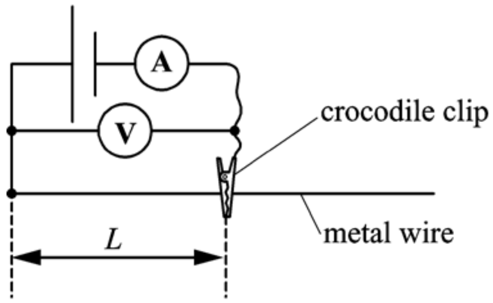

Fig. 16.1

The length L of the wire is changed with the help of a crocodile clip. The current in the wire is I, the p.d. across the wire is V and the wire has resistance R.
The table in **Fig. 16.2** shows the results recorded by the student from the experiment.

L / m	V / V	I / A	R / Ω
0.050	0.40	0.160	2.50
0.200	0.40	0.140	2.86
0.400	0.40	0.072	
0.800	0.40	0.036	11.1
1.000	0.40	0.029	13.8

Fig. 16.3 shows the graph of R against L for this wire.

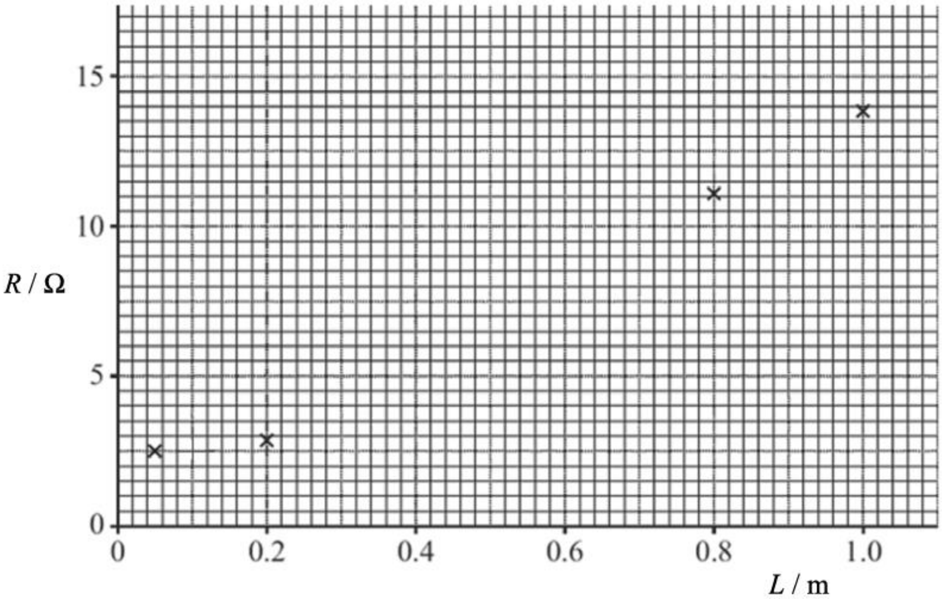

Fig. 16.3

The student observed that the wire was significantly hotter when the shortest length L = 0.050 m was used. The cross-sectional area of the wire is 8.0×10^{-8} m^2.

Use **Fig.16.3** to determine the resistivity of the metal.

resistivity = ... Ω m **[3]**

(b). The voltmeter used in the experiment had a zero error. The potential difference recorded in the experiment was smaller than it should have been.

Discuss how the actual value of the resistivity of the metal would differ from the value calculated in **(b)**.

-- **[3]**

6(a). A student is investigating the resistance of a conducting putty.

The student rolls the putty into a cylinder shape and connects the ends of the cylinder to metal plates as shown in Fig. 5.1. The ohm-meter is used to measure the resistance *R* of the conducting putty.

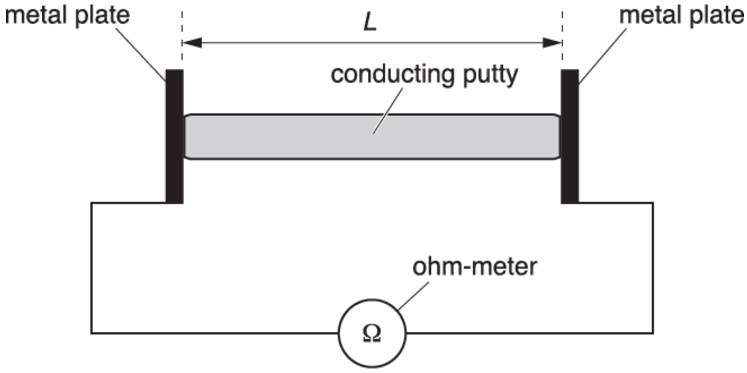

Fig. 5.1

i. Suggest why the student uses large metal plates at the ends of the conducting putty.

-- **[1]**

ii. Describe how the student can check that the diameter of the conducting putty is constant.

-- **[2]**

(b). The student measures the resistance R of the conducting putty for different length L. The volume of the conducting putty is kept constant.

The student's results are shown in Table 5.2.

L / m	R / Ω	L^2 / 10^{-3} m^2
0.049	14	2.4
0.060	21	3.6
0.069	28	4.8
0.081	37	
0.090	46	8.1
0.099	57	9.8

Table 5.2

i. Complete the table for the missing value of L^2.

[1]

ii. Each length is measured to the nearest millimetre using a ruler.

Determine the percentage uncertainty in L^2 for L = 0.049 m.

percentage uncertainty = ...% **[1]**

(c). Fig. 5.3 shows the graph of R (y-axis) against L^2 (x-axis).

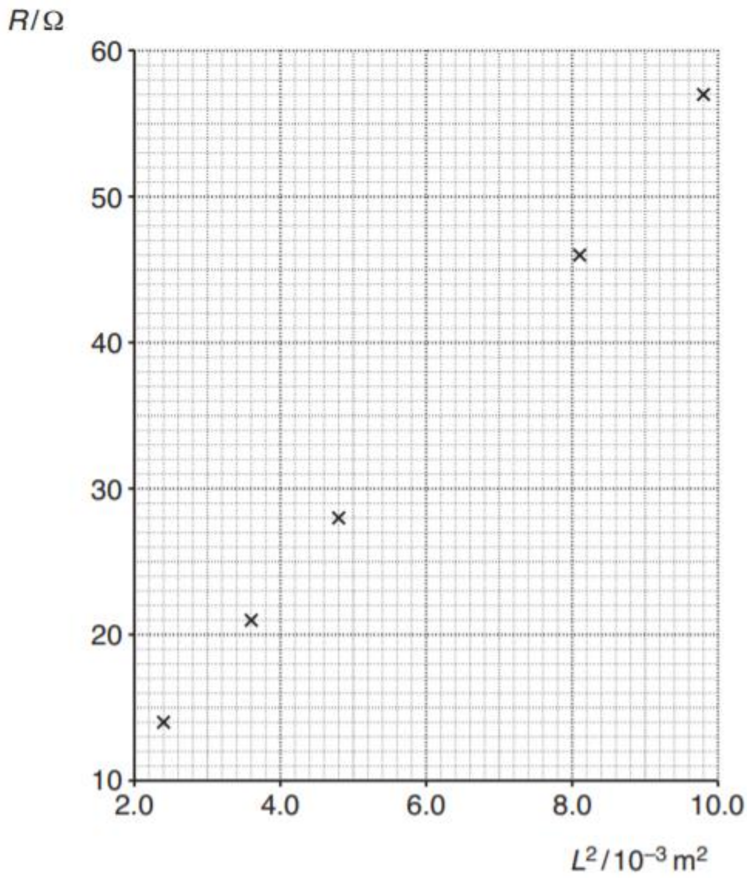

Fig. 5.3

i. Plot the missing data point and draw the straight line of best fit.

[2]

ii. Determine the gradient of the line of best fit.

gradient = ... **[2]**

(d). The relationship between R and L is

$$R = \frac{\rho}{V} L^2$$

where ρ is the resistivity of the conducting putty and V is the volume.

Use your answer to **(ii)** from the previous question and $V = 1.9 \times 10^{-5}$ m^3 to determine a value for ρ. Include an appropriate unit.

ρ = ... unit: .... **[3]**

7. A researcher connects the circuit as shown in **Fig. 24.3** to determine the resistivity of a new metal designed from waste metals.

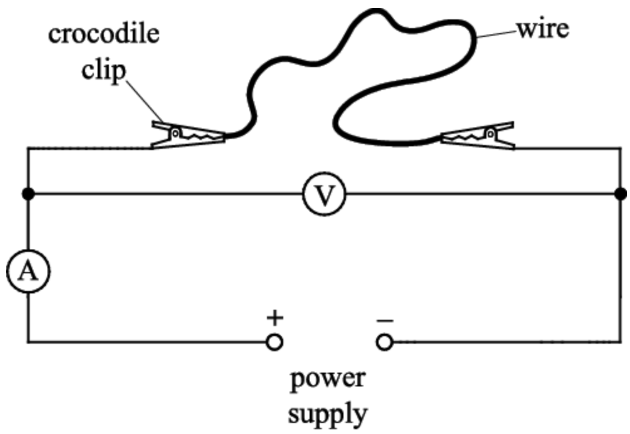

Fig. 24.3

The wire has length 0.75 m and cross-sectional area 1.3×10^{-7} m^2. The ammeter reading is 0.026 A and the voltmeter reading is 1.80 V.

i. Calculate the resistivity of the metal.

resistivity = ... Ω m **[2]**

ii. The resistivity of the metal in **(c)(i)** is larger than the value predicted by the researcher.

Explain **one** possible limitation of the experiment.

--- **[2]**

8. This question is about a resistance wire made of nichrome.

It is suggested that the resistance R of a length of nichrome wire varies with temperature θ in °C according to the equation

$$R = R_0\,(1 + k\theta)$$

where R_0 is the resistance of the wire at 0 °C and k is a constant for the wire.

Fig. 1.1 shows a diagram of the arrangement of apparatus in an experiment to test the relationship between R and θ and to determine the value of k.

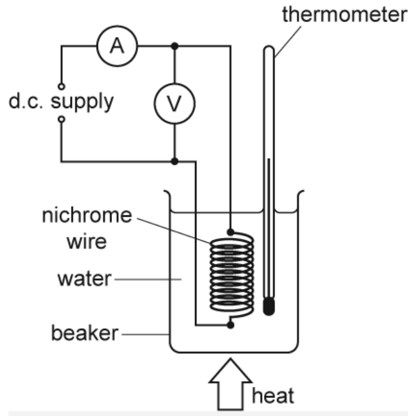

Fig. 1.1

The resistance wire is coiled and placed in a water bath.

Describe how you would carry out the experiment, analyse the data to verify the relationship between R and θ and determine a value for k.
In your description, state any precautions that you would take to improve the accuracy and precision of the measurements.

[6]

9. This question is about an experiment performed in AS physics to determine the internal resistance of a battery (two cells combined in series). The experiment can be set up as shown in **Fig.6.1.**

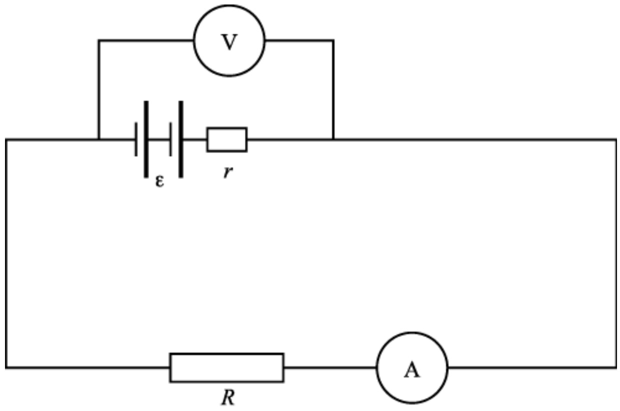

Fig. 6.1

Measurements of p.d. *V* and current *I* for a range of values of resistors *R* are taken in order to determine a value for the combined internal resistance of the cells.
In planning the experiment it is important to select suitable equipment.

Explain why the following equipment was chosen

- A voltmeter with very high internal resistance.
- An ammeter with negligible internal resistance.

[2]

10(a). This question is about an experiment performed in AS physics to determine the internal resistance of a battery (two cells combined in series). The experiment can be set up as shown in **Fig.6.1.**

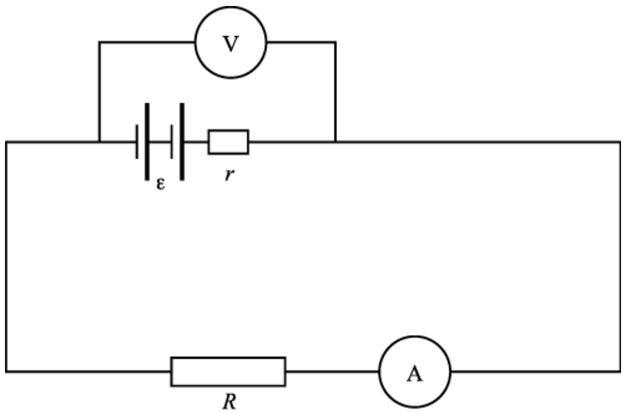

Fig. 6.1

Measurements of p.d. *V* and current *I* for a range of values of resistors *R* are taken in order to determine a value for the combined internal resistance of the cells.
In planning the experiment it is important to select suitable equipment.

Data obtained from the experiment is given in the table below

p.d. / V	***I* / mA**
2.86	286
2.82	352
2.78	462
2.66	666
2.40	1200

Plot a graph of the values on **Fig. 6.2**. Draw a suitable line.

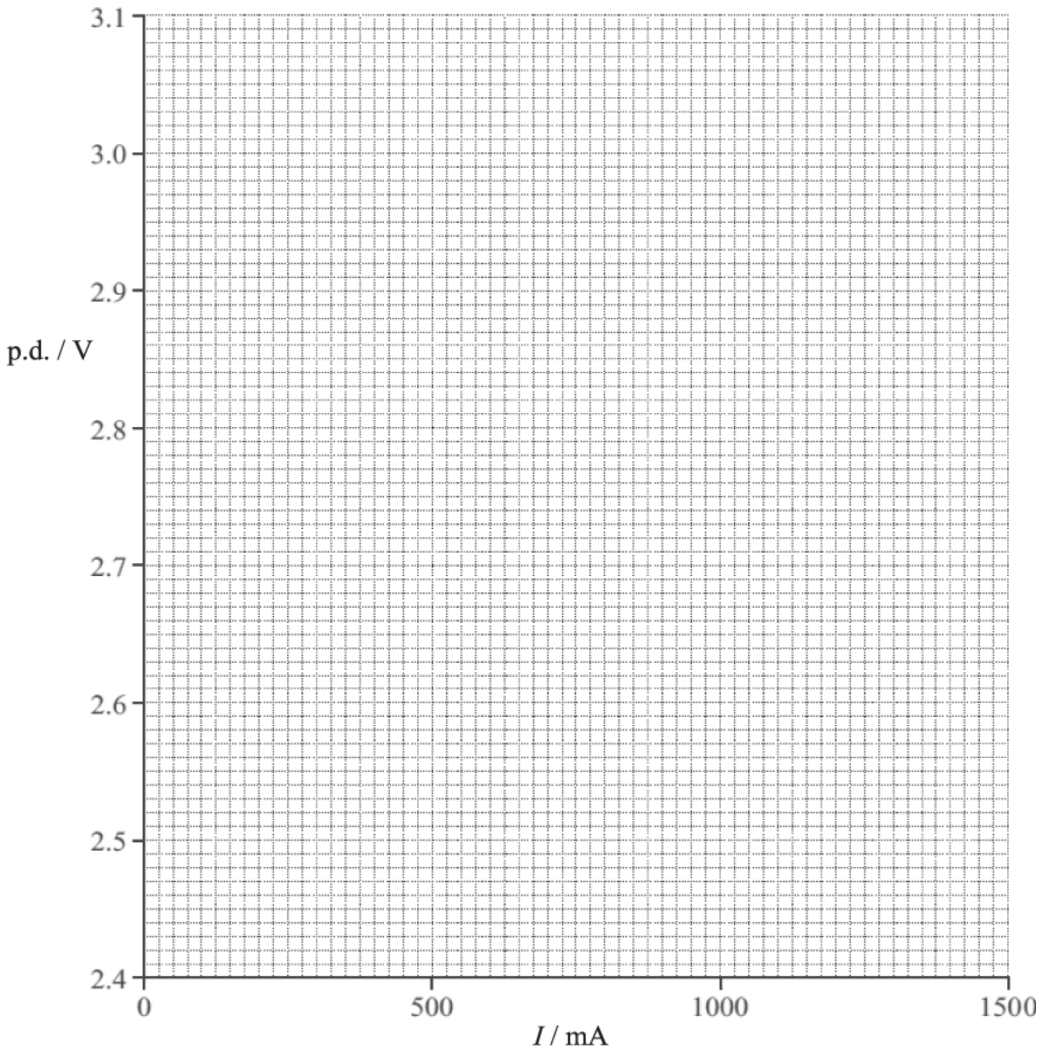

Fig. 6.2

[2]

The equation relating p.d. V and current I is

$V = \mathcal{E} - Ir$

Where $\mathcal{E}$ is the e.m.f. of the battery and r is the internal resistance of the battery.

(b). Use the graph to determine a value for the e.m.f. $\mathcal{E}$ for the cells. Show your working clearly and include the unit in your answer.

e.m.f. $\mathcal{E}$ = ... **[2]**

(c). Determine a value for the internal resistance.

internal resistance = ...Ω **[3]**

(d). * A student suggests three possible variations to extend the experiment.

1. Adding a switch into the circuit so that the circuit can be disconnected between readings.
2. Adding another cell.
3. Reversing one of the cells.

Discuss the effect that each of these three suggested changes would have on the accuracy of the experiment, the uncertainty of measurement and the data collected.

[6]

(e). A student suggests that using much higher value resistors will improve the quality of measurements by reducing the uncertainty in the current readings.

Comment on this suggestion. Explain your reasoning.

[3]

11(a). A student is investigating the resistivity of a metal.

The student has a 1.0 m length of wire made from the metal.

Fig. 26.1 shows the circuit used by the student.

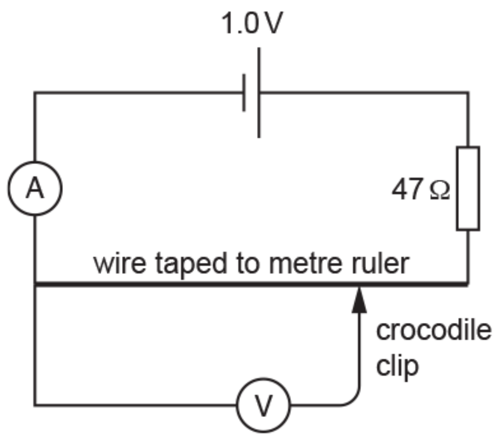

Fig. 26.1

Explain why the voltmeter should have a very high resistance.

[2]

(b). The cell has an e.m.f. of 1.0 V and negligible internal resistance.

The wire has a resistance of 3.0 Ω.

The crocodile clip is connected at the centre of the wire as shown in **Fig. 26.2**.

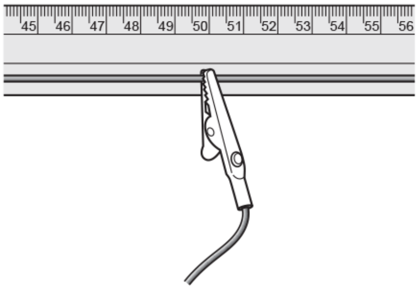

Fig. 26.2

Calculate the voltmeter reading you expect the student to see.

Expected reading = ... V **[2]**

(c). Another student repeats the experiment. The crocodile clip is replaced with a sliding contact which has a sharp edge and measurements are taken as shown in **Fig. 26.3**.

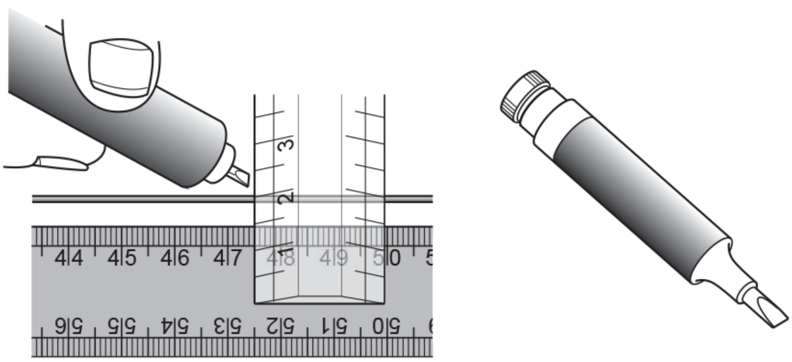

Fig. 26.3

Explain how these changes will affect the quality of the measurements of length.

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[2]

Total: 69

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			**C**	1	
			Total	**1**	
2			**D**	1	
			Total	**1**	
3		i	Micrometer Repeat readings in different directions/along wire/different wires and average	**B1** **B1**	**Allow** calliper **Not** vernier scale
		ii	$A = \frac{\pi \times (0.12 \times 10^{-3})^2}{4} = 1.13 \times 10^{-8}$ OR $\rho = \frac{1.86 \times A}{21}$ $\rho = \frac{17 \times 1.86 \times 1.1 \times 10^{-8}}{21}$ $\rho = 1.7 \times 10^{-8}$ (Ω m)	**C1** **C1** **A1**	**Note** ρ must be the subject **Allow** 2 marks for 1.0×10^{-9} (factor of 17 omitted) **Allow** 2 marks for 6.8×10^{-8} (diameter used instead of radius) **Allow** 2 marks for 0.017 (POT omitted)
		iii	$\frac{0.1}{21}$ or $\frac{0.02}{1.86}$ or $\frac{0.01}{0.12}$	**C1**	**Allow** max/min methods $\rho_{max} = 2.03 \times 10^{-8}$ and $\rho_{min} = 1.41 \times 10^{-8}$ (B1) $\frac{\Delta\rho}{\rho} x100$ (B1) $x100$ (B1)

			$\left(\frac{0.1}{21}+\frac{0.02}{1.86}+2\times\frac{0.01}{0.12}\right)\times 100 = 18\ (.2)\%$	**A1**	**Allow** 17.8% Do not penalise significant figures **Allow** 1 mark for 9.88% **Allow** 20% with evidence of working
			Total	**7**	
4		i	Line of best fit drawn gradient = 2.8	B1 B1	Expect the extrapolated line to have a y-intercept in the range 0.60 to 0.85 **and** at least one data point on each side of the line **Allow** gradient of line in the range 2.60 to 3.00
		ii	$E = I\,(r + \mathrm{R})$ **and** $R = \rho L/A$ $\frac{1}{I} = \frac{r}{E} + \frac{\rho}{AE}L$ (and comparison with $y = mx$ + c leads to gradient $\frac{\rho}{AE}$)	C1 A1	**Allow** $E = V + IR$ **and** $R = \rho L/A$
		iii	(ρ = gradient × AE) $\rho = 2.8 \times \pi \times (0.19 \times 10^{-3})^2 \times 1.5$ $\rho = 4.8 \times 10^{-7}$ (Ω m)	 C1 A1	Possible ECF from **(i)** **Note** not using $A = \pi r^2$ is wrong physics (XP) **Allow** 1 mark for 1.9×10^{-6}, diameter used instead of radius
		iv	The graph / points just shift horizontally (AW) The gradient is unchanged (and ρ will be the same)	B1 B1	**Allow** shifted to the right or left / 'systematic error' / zero error / change in length stays the same / 'no change in vertical values'
			Total	**8**	
5	a		Best fit straight line drawn through the last 4 data points. Gradient of the line determined. ***p***= gradient **x** *A*, hence resistivity = (1.1± 0.1) **x** 10^{-6} (Ω m)	B1 B1 B1	 **Allow** a maximum of 2 marks if the line of best fit is drawn through all 5 data points.

	b		The actual resistance values will be smaller. The gradient of the graph will be lower. Hence resistivity of the metal will be smaller than the value in **(b)**.	B1 B1 B1	
			Total	**6**	
6	a	i	To ensure whole cross-sectional area or end of the conducting putty is in contact with the metal plate (AW)	B1	**Not** good electrical contact / reduces contact resistance / surface area
		ii	Use a (Vernier) caliper / micrometer (screw gauge) Repeat measurements along the conducting putty	B1 B1	**Allow** ruler
	b	i	6.6	B1	**Allow** 6.56 **Ignore** 10^{-3} factor
		ii	$\left(\% \text{ uncertainty} = \frac{2\times0.001}{0.049} \times 100 =\right)$ 4.1 %	B1	**Ignore** significant figures **Allow** 4 %
	c	i	Plots the missing point to less than a half small square Draws straight line of best fit	B1 B1	**Allow** ECF from **(i)** Penalise blob of half a small square or larger **Allow** ECF Expect to be balance of points about line of best-fit. Judge straightness by eye. **Not** a top point to bottom point line / not a top point to (2.0, 10) line
		ii	Gradient $= \frac{y_2-y_1}{x_2-x_1} = \frac{\Delta y}{\Delta x}$ gradient = 5700 (5550 − 5850)	M1 A1	**Not** one R/L^2 value using the line or a data point **Ignore** POT for M1 **Allow** ± 150 for the value of gradient **Ignore** units
	d		$\rho = 5700 \times 1.9 \times 10^{-5}$ $\rho = 0.108$ given to 2 or 3 sf	C1 A1	**Note**: ECF from **(ii)** **Allow** any subject for equation **Not** use of data points from table

			Ω m	B1	
			Total	**12**	
7		i	resistance = 1.80 / 0.026 (= 69.2 Ω) resistivity $= \frac{69.2 \times 1.3 \times 10^{-7}}{0.75}$ = 1.2 × 10^{-5} (Ω m)	C1 A1	
		ii	Contact resistance due to croc clips hence the resistance in the circuit must be greater. **or** Heating of wire hence the resistance of the wire increases. **or** (Finite) resistance of ammeter hence the total resistance of circuit increases. **or** Actual length between croc-clips is shorter or < 0.75 m; hence resistance of wire is greater.	B1 B1	**Allow**: Correct zero error on meters (e.g voltmeter reading is 'higher' or ammeter reading is 'lower') hence the (determined) resistance is greater.
			Total	**4**	
8			**Level 3 (5–6 marks)** Clear description and analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description and some analysis *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description or analysis	**B1 × 6**	**Indicative scientific points may include:** **Description** Determine R_0 using ice water mixture or* Record V and I for various temperatures If wire is not insulated some conduction through water/use insulated wire Use small current to minimise heating effect or connect to supply for short time for readings Stir the water Wait for temperature to stabilise/bath to come to equilibrium Avoid parallax errors when reading instruments Comment about large scale increments on instruments/digital meters for precision of measurements/AW **Analysis**

			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. **0 marks** No response or no response worthy of credit.		• Determine resistance from $R = V/I$ • Graph of R against θ is a straight line / Graph of R/R_0 against θ is a straight line • Correct interpretation of gradient m to find k; i.e. $k = m/R_0$ or $k = m$ • *R_0 by extrapolation from linear graph *descriptors D1 and A4 are alternatives
			Total	**6**	
9			High resistance means that negligible current flows through the voltmeter (1) Negligible resistance means that pd across the ammeter is minimal / reduced so that it does not affect the readings (1)	2	Or resistance of voltmeter-resistor pair is v. close to that of the resistor alone.
			Total	**2**	
10	a		Points plotted correctly (1) Correct line of best fit drawn (1)	2	
	b		3 (V) (1) correct unit (V) (1)	2	Allow ±0.1V. ecf for their line of best fit.
	c		Correct method for calculating gradient (1) x values > 750 mA (1) 0.5Ω (1)	3	Allow ±0.1Ω
	d		*** Level 3 (5–6 marks)** Constructs argument in a clear manner giving clear reasoning at all points. Each part of the question fully covered and the connection made with data on the graph. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)**	6	**Indicative scientific points may include:** **Adding switch** • Idea of reducing heating effect • No energy lost / draining of the battery / cells. • Improved reliability **Adding another cell** • Increase in pd −> increase in current

			Covers at least two aspects of the argument. May not link the aspects together. Shows understanding of the effect on uncertainties. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Makes at least two independent points that are relevant to the argument. Structuring of the answer may be poor. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		• Change to the overall resistance • % uncertainty in current reading reduces • Graph would have a steeper gradient and higher intercept **Reversing the cell** • Reduces the pd −> reduces the current flow • % uncertainty would increase • Overall internal resistance would be the same • Would produce a lower intercept but same gradient
	e		(Suggestion is incorrect) Increased resistance gives lower current (1) Constant absolute uncertainty AW (1) with lower current values give a higher % uncertainty (1)	3	
			Total	**16**	
11	a		So that negligible current passes through it In order that it does not affect the value it's trying to measure	1 1	**Allow** so that (total/combined/parallel) resistance of the wire/voltmeter doesn't change **Do not allow** responses such as "so the reading is accurate". **Do not allow** responses such as "so that more current flows through the wire" for second mark. **Allow** appropriate effect on ammeter e.g otherwise the current on ammeter is through voltmeter and wire (which is larger).
	b		Current = 1 / (47+3) = 20 (mA) p.d. = ½ x 0.02 x 3 = 0.03 (V) or 30mV	1 1	Allow equivalent other working e.g. by proportion or use of potential divider e.g. 1 x 1.5/50 = 0.03V. **Allow** first mark for evaluations of pd as 0.06V.

					Candidates who calculated the voltage across the whole wire were credit with a mark.
	c		(Reduce uncertainty/more accurate/more precise because...) .... the key is narrower than a crocodile clip .... the ruler makes sure the reading is taken in line with the key .... It will reduce parallax error.	2	This statement needs to be made before marks can be awarded. Any two separate marking points. **ALLOW** suitable example values e.g ± 0.5 mm instead of ± 2mm
			Total	**6**	
			Total	**69**	