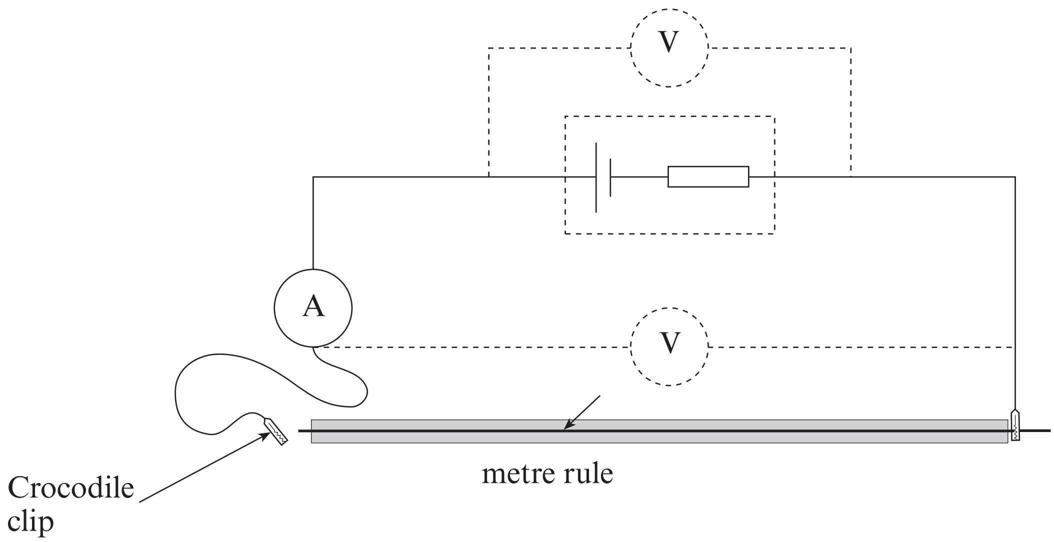
TEST 1 – MARK SCHEME

SECTION B

TASK B4 (45 minutes)

You are going to determine the internal resistance of a cell, and the resistivity of a wire using the circuit shown below. This circuit has already been set up for you.



(a) (i) Add to the circuit diagram a voltmeter to find the e.m.f. of the cell. [1]

Voltmeter indicated across cell [accept across cell and ammeter] - see above

(ii) Now add the voltmeter to the circuit to measure the e.m.f. *E*. [1]

$E =$ ....

e.m.f. to 2 d.p. with units: volt(s)/V

Ask your supervisor to check the position of the voltmeter before continuing

Correct	Incorrect

N.B. There is no penalty for incorrectly connecting the voltmeter.

(iii) State the resolution of the voltmeter, and using this as your uncertainty, calculate the percentage uncertainty in your value for the e.m.f. *E*. [2]

Resolution = 0.01V (1)
% uncertainty correctly calculated (1)

(b) It is suggested that there is a linear relationship between the current, I, through the wire and its length, *l*, and that they vary according to the expression:

$$\frac{1}{I} = \frac{\rho l}{EA} + \frac{r}{E}$$

Where

A = Cross sectional area of the wire
ρ = Resistivity of the wire
r = Internal resistance of the cell

A graph of $\frac{1}{I}$ against l should give a straight line with a positive intercept on the y axis.

Take a suitable set of results to confirm this relationship, and record these results clearly in a table below. Remember to include a column for $\frac{1}{I}$. [5]

Repeat readings are not needed for this experiment

Clear table with headings [l, I, $\frac{1}{I}$ *or in words] (1)*

Units correct for all readings [m/cm, A, A^{-1}*] (1)*
Full length of wire used (1)
At least 5 readings taken (1)

$\frac{1}{I}$ *s.f. same as I s.f. in all cases (1)* *(c)* Draw a graph of $\frac{1}{I}$ (on the *y*-axis) against *l* (on the *x*-axis). [5]

Title and units (e.c.f.) on both axes (1)
Sensible scales (over half page used to plot the points; not multiplies of 3) (1)
All points plotted correctly to within ½ division (2)
(Penalise 1 mark for each incorrect plot to a maximum penalty of 2)
Good line of best fit consistent with data (1)

(d) (i) Calculate the gradient of the graph, including a suitable unit. [3]

Suitable triangle (at least half the graph), drawn on graph (1)
Gradient calculated correctly (1)
Unit given (1)

(ii) Hence find the resistivity of the wire given that its

cross sectional area = $5.73 \times 10^{-8}\,\mathrm{m}^{-3}$ [2]

gradient = $\dfrac{\rho}{EA}$ *[or by implication] (1)*

Resistivity calculated correctly with units (1)
[use of 1 data point to calc. resistivity instead of gradient – 1 mark only]

(e) (i) Write down the intercept of your graph, and by taking its uncertainty to be one small square of the graph paper, calculate the percentage uncertainty in the intercept. [2]

Intercept correct [no unit or s.f. penalty] (1)
% uncertainty correct (1)

(ii) Calculate the internal resistance of the cell. [1]

Internal resistance correct [no unit or s.f. penalty] ±5% of centre value

(iii) By considering the uncertainties in the e.m.f. and the intercept, find the absolute uncertainty in the internal resistance. [2]

Adding (e)(i) and (a)(iii) e.c.f. (1)
Absolute uncertainty correct and expressed to 1 s.f. [e.c.f. from first mark] (1)

SECTION B

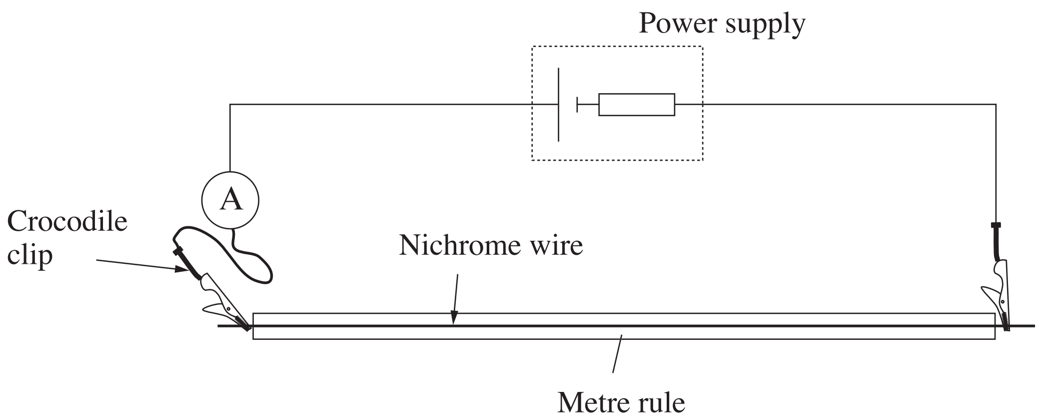
TASK B4

The candidates will be expected to investigate the circuit below.

Test 1

Apparatus required:

- 1 × power supply constructed from two 1.5 V 'D' type cells and a 3.9 Ω resistor in series. The components of the power supply should be concealed from the candidates. The resistor may be soldered to the cells – this will require the use of a soldering iron with a high thermal capacity bit.
- 1 × ammeter of resolution ± 0.01 A
- 2 × crocodile clips
- 0.27 mm diameter (32swg) nichrome wire
- 1 × metre ruler
- 1 × voltmeter of resolution ± 0.01 V
- electrical leads to complete the circuit



The circuit should be set up for the candidates as shown. The Nichrome wire can be taped to the metre ruler with a few centimetres overhanging at each end to allow crocodile clips to be attached.
The voltmeter should have leads so that candidates can attach it to the circuit to measure the e.m.f. of the power supply. Crocodile clips should be provided for this purpose if necessary. If crocodile clips are required these should be made available.

Test 2

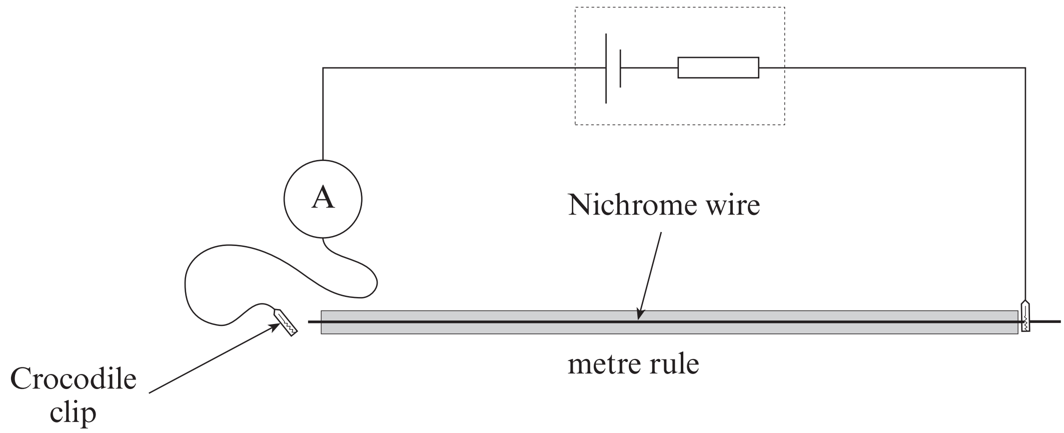
The apparatus required is as for **Test 1** except that 0·38 mm diameter (28 swg) nichrome should be used.

Examiner only

SECTION B

Task B4 (45 minutes)

You are going to use the circuit below to determine the internal resistance of a power supply and the resistivity of a wire. The circuit has already been set up for you.



(a) (i) Add to the circuit diagram a voltmeter to find the e.m.f. of the power supply. [1]

(ii) Now add the voltmeter to the circuit to measure the e.m.f. E.

State the value of E. E = ... V [1]

Ask your supervisor to check the position of the voltmeter before continuing.

For supervisor's use only [Tick one box (✓)]	
Correct connection	
Incorrect connection	

(iii) State the resolution of the voltmeter, and using this as your uncertainty, calculate the percentage uncertainty in your value for the e.m.f. E. [2]

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Examiner only

(b) It is suggested that the current through the wire, I, varies with the length of wire, l, according to the equation:

$$\frac{1}{I} = \frac{\rho}{EA} l + \frac{r}{E} ,$$

where, A = cross-sectional area of the wire
ρ = resistivity of the wire
r = internal resistance of the power supply.

A graph of $\frac{1}{I}$ against l should give a straight line with a positive intercept on the y axis.

Take a suitable set of results to confirm this relationship, and record these results clearly in a table below.

Remember to include a column for $\frac{1}{I}$. [5]

Repeat readings are not needed for this experiment.

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(c) Plot a graph of $\frac{1}{I}$ (vertical axis) against l (horizontal axis). [5]

Examiner only

(d) (i) Calculate a value for the gradient of the graph and include a suitable unit. [3]

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(ii) Hence find the resistivity of the wire, given that its cross sectional area is $5.73 \times 10^{-8}\,\text{m}^2$. [2]

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(e) (i) Write down the intercept of your graph, and by taking its uncertainty to be one small square of the graph paper, calculate the percentage uncertainty in the intercept. [2]

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(ii) Calculate the internal resistance of the cell. [1]

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Examiner only

(iii) By considering the uncertainties in the e.m.f. and the intercept, find the absolute uncertainty in the internal resistance. [2]

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Question 2

You are going to carry out an experiment to determine the internal resistance of a power supply.

(a) Draw a diagram of the circuit that has been set up for you. [2]

(b) Without closing the switch record the reading on the voltmeter. This is the e.m.f., *E*, of the power supply. [1]

E = ...V

(c) Close the switch and record the voltage, *V* across the power supply with the 3·3 Ω resistor in place. Repeat this for **each** of the resistors provided, and also for every possible **series** combination. Record your results in a suitable table. [5]

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(d) For the circuit provided it can be shown that

$$E = I(R + r)$$

Where R = resistance of the combination of resistors
r = internal resistance of the power supply

Using the above equation and the definition of resistance, which should be stated, show that

$$r = R\left(\frac{E}{V} - 1\right)$$

[3]

(e) (i) From your results calculate a value for r using **each** of your results obtained in *(c)*. [2]

(ii) Hence determine an average value for the internal resistance of the cell. [1]

(iii) Using the expressions given on page 2 calculate the uncertainty in your result. [2]

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(iv) Where do you think the main error arose in your experiment? Explain what you could do to reduce error. [2]

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(f) The resistors chosen for this experiment have a power rating of 1 W. Use your results to calculate the maximum power that was dissipated in the resistors during your experiment. [2]

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Experiment 2

Candidates will be expected to determine the internal resistance of a power supply.

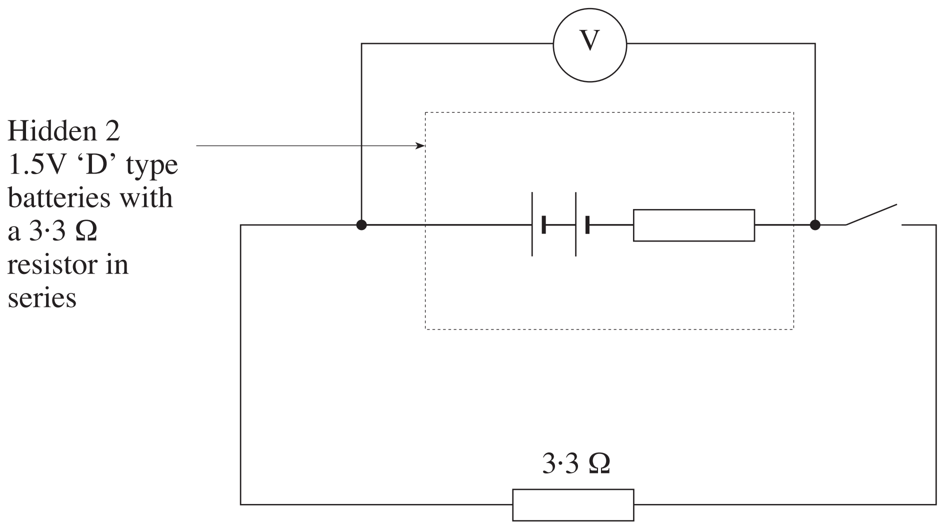
Test 1

Apparatus required:

2 × 'D' type 1·5 V cells arranged in series
2 × 'D' type battery holders
1 × 3·3 Ω resistor permanently attached in series to the cells. The cells and resistor should be enclosed so they are hidden from candidates and then labelled 'power supply'.
1 × 3·3 Ω resistor labelled '3·3 Ω'
1 × 4·7 Ω resistor labelled '4·7 Ω'
1 × 6·6 Ω resistor labelled '6·6 Ω'
1 × Voltmeter accurate to 0·01 V
1 × push to make switch – e.g. morse key switch.
7 × 4 mm leads to make up the circuit

Note: It is advisable to use high-power resistors for this circuit. The 3·3 Ω "internal resistor" should be capable of surviving a short circuit for a short period - a power dissipation of about 3 W. A ceramic wire-wound resistor is suggested. The other resistors should have a power rating of at least 1 W.

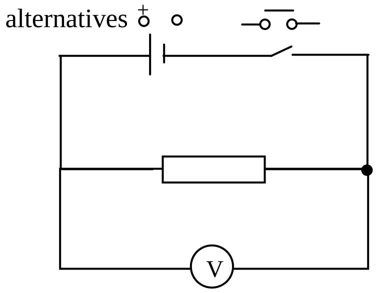
The following circuit is to be set up for the candidates. The candidates will be expected to draw the circuit.



The candidates will need to replace the 3·3 Ω resistor with the other individual resistors and series combinations of the resistors. It is permissible for the resistors to be mounted, e.g. on trunking, and provided with suitable connecting sockets, e.g. 4 mm.

Test 2

The apparatus is as for **Test 1**, except that the hidden resistor in the power supply should be a **4·7 Ω resistor**. It should be capable of dissipating at least 2 W for a short period.

Experiment	Answers / Explanatory notes	Marks Available
2. *(a)*	Circuit diagram:  All symbols correct (1) Correct circuit. (1)	2
(b)	Reading to 2 d.p.	1
(c)	Table: Titales and units (1) All series combinations used (1) Correct / consistent s.f.s (1) [allow 1 mistake] Repeats and means (1) Clear table [resistances calculated](1)	5
(d)	Use of $R = \frac{V}{I}$ (1) ; subst for I and manipulation (1)	2
(e) (i)	All readings used in $r = R\left(\frac{E}{V} - 1\right)$ (1) Calculations correct [ignore unit] (1)	2
(ii)	Correct mean to 3 s.f.	1
(iii)	Uncertainty (1); units (1)	2
(iv)	Sensible suggestion (1) and precaution (1) e.g. Battery discharging (✓) switch off between readings (✓) Variation of switch pressure (✓); use toggle switch (✓)	2
(f)	Use of $P = I^2R, P = \frac{V^2}{R}$ or $P = IV$ (1) Correct values used [minimum number: 3·3 Ω and 4·7 Ω] (1)	2
		[20]