1. A student wants to determine the internal resistance *r* and the e.m.f. *ε* of a cell.

The student knows that the internal resistance is approximately 0.1 Ω.

The only other **electrical** equipment available is as follows:

- one voltmeter
- one ammeter
- one sensitive thermistor, known to have resistance of approximately 0.1 Ω at 20 °C
- several connecting wires and crocodile clips.

Describe how the student can determine *r* and *ε* for the cell.

Include how the student should:

- collect and analyse the data
- determine the uncertainties in the values of *r* and *ε*.

[6]

2. A thermistor has a resistance that decreases as temperature increases.

A student makes measurements to plot the variation of resistance with temperature of the thermistor.

They submerge the thermistor into distilled water at 50° C.

They then record measurements from a voltmeter and ammeter as the temperature of the water falls to about 20° C.

Describe how the student obtains sufficient data to plot a graph of resistance against temperature.

Your answer should include a circuit diagram.

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____ **[4]**

3. A copper wire **P** has electrical resistance *R* and number density of charge carriers *n*.

A copper wire **Q** has:

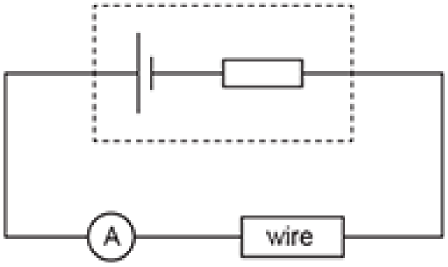
- area of cross section equal to **P**
- twice the length of **P**.

Which row gives the correct values of resistance and number density of charge carriers for **Q**?

	Resistance of Q	**Number density of charge carriers in Q**
A	$\frac{R}{2}$	n
B	$\frac{R}{2}$	$2n$
C	$2R$	n
D	$2R$	$2n$

Your answer ☐ **[1]**

4(a). A student uses the circuit below to investigate the resistivity of a wire.



The cell has e.m.f. ε and internal resistance r. The wire has resistivity ρ and diameter d.

The student takes five measurements of the diameter of the wire, which are shown in the table below.

Diameter / mm	0.460	0.450	0.455	0.495	0.455

i. Suggest how the student made these measurements.

[2]

ii. The student calculates the value of the diameter as d = 0.455 ± 0.005 mm.

Explain how the student calculated the value of the diameter, and its uncertainty, from the data in the table above.

[3]

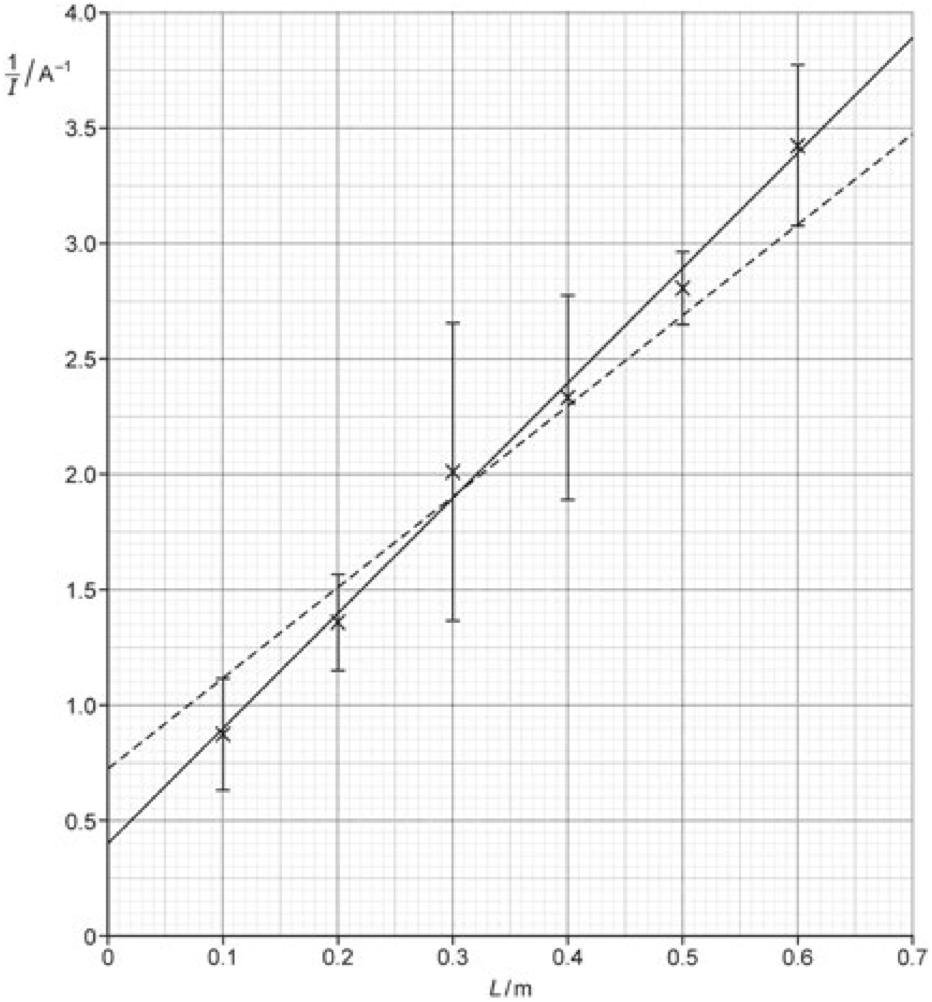
(b). The student varies the length L of the wire in the circuit and records the current I using the ammeter.

i. Show that

$$\frac{1}{I} = \left(\frac{4\rho}{\pi \varepsilon d^2}\right)L + \frac{r}{\varepsilon}$$

[3]

ii. The student plots a graph of $\frac{1}{I}$ against L. The data points, error bars, line of best fit and a line of worst fit are shown in the graph below.



The cell has e.m.f. $\varepsilon = 1.45 \pm 0.05$ V

The wire has diameter $d = 0.455 \pm 0.005$ mm

Calculate the gradient of the best fit line and use this to determine a value for the resistivity ρ of the wire.

1 You are **not** required to determine an uncertainty.

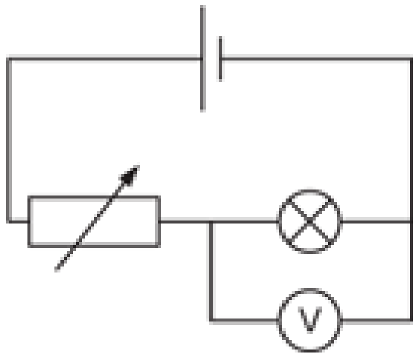
ρ = ...Ω m **[2]**

Determine a value for the internal resistance r of the cell **and** its absolute uncertainty.

2

r = ... ± .... Ω **[4]**

5. A tungsten filament lamp is connected in a circuit as shown.



The variable resistor is adjusted so that the temperature of the filament lamp increases.

What happens to the resistance of the lamp and the reading on the voltmeter?

	resistance of the lamp	**voltmeter reading**
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Your answer ☐ **[1]**

6. Resistance and resistivity are two quantities used to describe the behaviour of a conductor.

How do these quantities change, if at all, when the length of a conductor is increased?

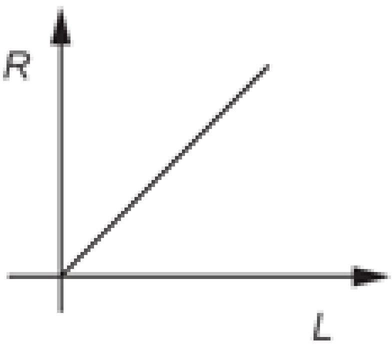
	resistance	**resistivity**
A	constant	constant
B	constant	increase
C	increase	constant
D	increase	increase

Your answer ☐ **[1]**

7. A student investigates a conducting wire of constant cross-sectional area, at constant temperature.

The resistance *R* is measured for a range of lengths *L*.

The following graph is plotted:

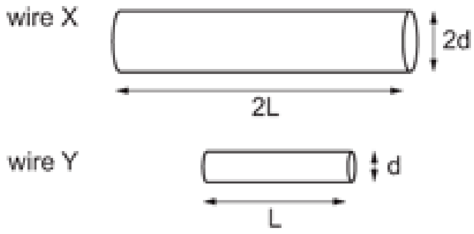


Which expression is equal to the gradient of the graph?

A resistivity
B resistivity × cross-sectional area
C $\frac{\text{resistivity}}{\text{cross-sectional area}}$
D $\frac{\text{cross-sectional area}}{\text{resistivity}}$

Your answer ☐ **[1]**

8. The diagram shows the relative lengths and diameters of two copper wires, labelled wire X and wire Y.

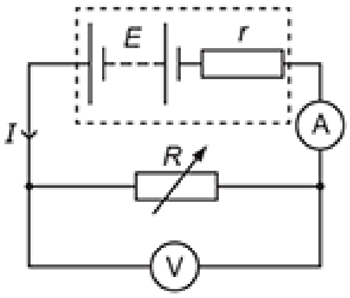


What is the ratio of the resistivity of wire Y to wire X?

A 1 : 1
B 1 : 2
C 1 :4
D 1 : 8

Your answer ☐ **[1]**

9(a). A battery is connected to a variable resistor.



The variable resistor is made from a length of wire. The resistance of the variable resistor is *R*.
The battery has electromotive force (e.m.f.) *E* and internal resistance *r*. The current in the circuit is *I*.

Compare the e.m.f. of the battery and the potential difference (p.d.) across the variable resistor in terms of energy transfers or changes.

____ **[1]**

(b). State which physical quantity of the variable resistor is changed to alter its resistance.

____ **[1]**

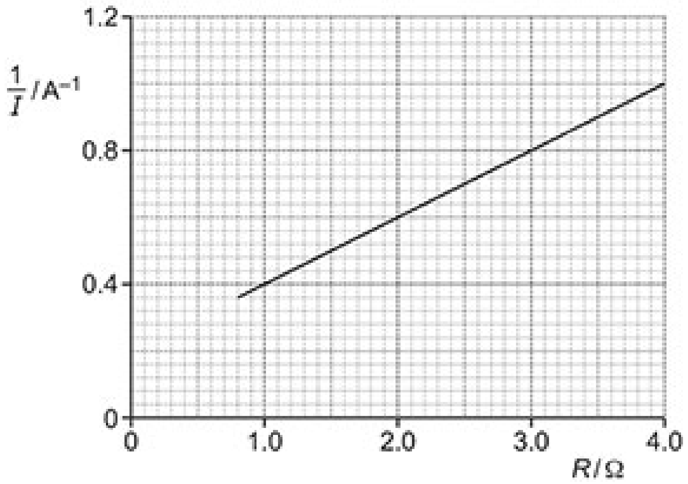
(c). A student connects up the circuit above to determine *r*.

i. Show that $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$

[2]

ii. The student varies R and measures the current I.

The student plots a graph of $\frac{1}{I}$ against R.



Use the graph to determine the power dissipated in the variable resistor when R = 3.0 Ω.

1

power = ... W **[2]**

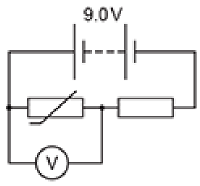
The e.m.f. E of the battery is 5.0 V.

2

Determine r from the intercept of the line with the vertical axis.

r = ... Ω **[2]**

10. A potential divider circuit is shown below.



The battery has electromotive force (e.m.f.) 9.0 V and negligible internal resistance.
At room temperature the potential difference (p.d.) across the thermistor is 4.5 V.
The temperature of the thermistor is increased and its resistance decreases by 20% from its previous value.

What is the p.d. across the thermistor now?

A 3.6 V
B 4.0 V
C 5.0 V
D 5.4 V

Your answer [1]

11(a).

Fig. 25.1 shows an electrical circuit.

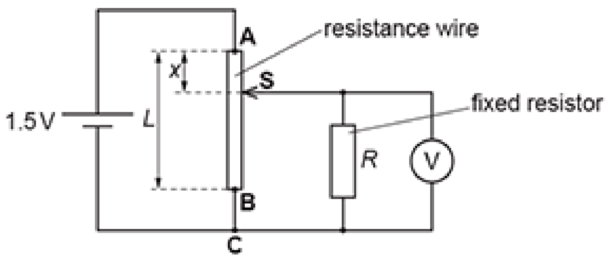


Fig. 25.1

The cell has e.m.f. 1.5 V and negligible internal resistance.

AB is a resistance wire of length *L*. The resistance of this wire is **equal** to the resistance *R* of the fixed resistor.
S is a sliding contact that can be moved on the resistance wire. The distance between **A** and **S** is *x*.
The p.d. across the fixed resistor is *V*.

i. The distance *x* is changed by moving the slider from **A** to **B**.

On **Fig. 25.2**, show the variation of *V* with distance *x*.

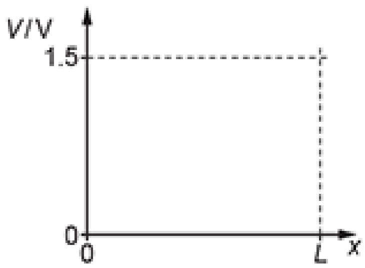


Fig. 25.2

[2]

ii. The connecting wire **BC** is now removed. The rest of the circuit remains unchanged.
Explain the variation of *V* with distance *x* as **S** is moved from **A** to **B**.

____

____

____

____ **[2]**

(b). A power supply of electromotive force (e.m.f.) 14.4 V and negligible internal resistance is connected by two identical metal wires to two filament lamps, as shown in **Fig. 25.3**.

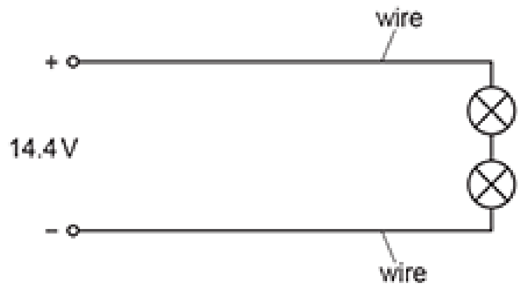


Fig. 25.3

The current in the circuit is 3.0 A.
The potential difference across **each** lamp is 6.0 V.
The **total** length of the metal wire is 25.0 m. The cross-sectional area of the wire is 0.54 mm^2.

i. Calculate the resistivity ρ of the metal from which the wire is made.

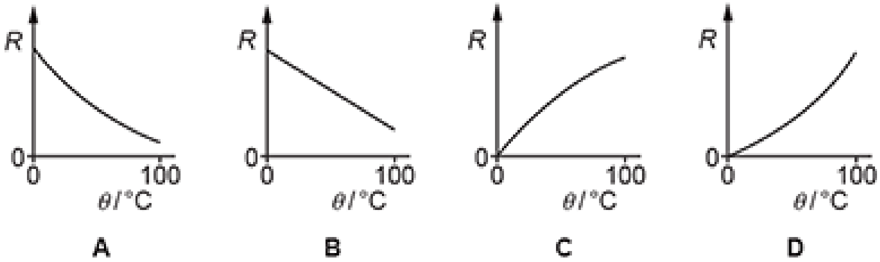
ρ = ... Ω m **[4]**

ii. The number of electrons per unit volume *n* in the metal wire is 8.5×10^{28} m^{-3}.

Calculate the mean drift velocity *v* of the electrons in the metal.

v = ... $m\ s^{-1}$ **[2]**

12. Which graph best represents the way in which the resistance *R* of a negative temperature coefficient (NTC) thermistor depends on its temperature θ in °C?



Your answer ☐ **[1]**

13(a). An electric cooker has two independent heating rings **A** and **B** as shown in **Fig. 7.1**.

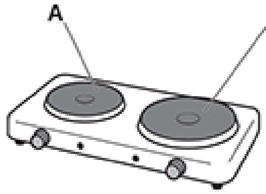


Fig. 7.1

The cooker rings **A** and **B** are connected in parallel to a 230 V power supply. At maximum power, ring **A** has a power of 1100 W and ring **B** has a power of 1700 W.

The filament in ring **A** is a metallic wire of length 11.8 m.
At maximum power the wire has resistance 31 Ω and the metal has resistivity 4.8×10^{-7} Ω m.

Calculate the diameter *d* of the wire.

d = ... m **[3]**

(b). Fig. 7.2 shows the circuit symbol for ring **A**.

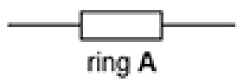


Fig. 7.2

A student uses a battery of four cells, an ammeter and a voltmeter to determine the resistance of the wire in ring **A** experimentally.

i. Complete **Fig. 7.2** to show how the student should connect the circuit to determine the resistance.

[2]

ii. The current in the wire is 0.34 ± 0.02 A and the potential difference across the wire is 6.2 ± 0.2 V.

Calculate the resistance *R* of the wire.

R = ... Ω **[1]**

iii. Calculate the percentage uncertainty in *R*.

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

iv. Suggest why *R* from **(c)(ii)** is less than 31 Ω.

[2]

v. Suggest **two** improvements to the student's experiment to determine *R* experimentally.

1

2

[2]

END OF QUESTION PAPER