1(a). Explain what is meant by.

i. internal resistance of a cell

_____

_____ **[1]**

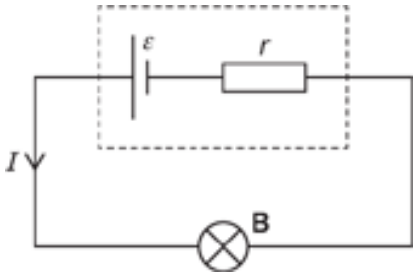
ii. e.m.f. of a cell.

_____

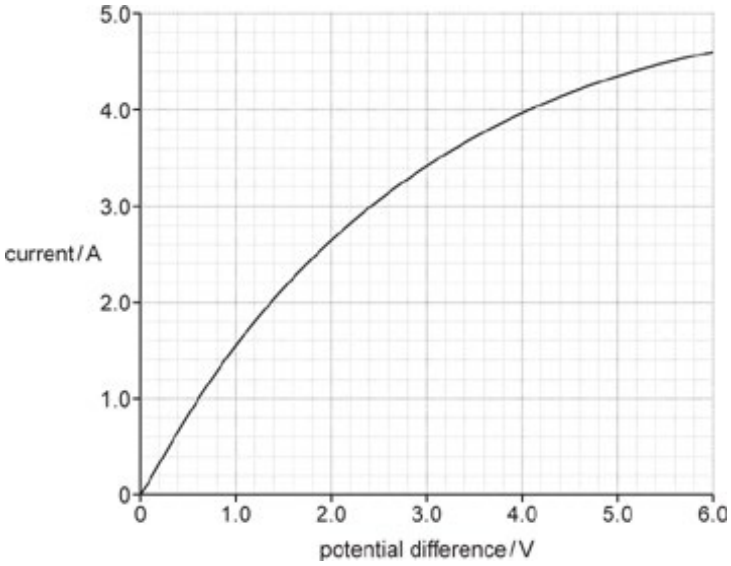
_____ **[1]**

(b). A cell has internal resistance r = 1.2 Ω and e.m.f. ε = 5.6 V.

When the cell is connected to a filament lamp **B**, as shown in the circuit diagram below, the current in the circuit is I.



The I-V characteristic for **B** is shown in the figure below.



Determine the current I in the circuit.

current = ... A **[3]**

(c). 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:

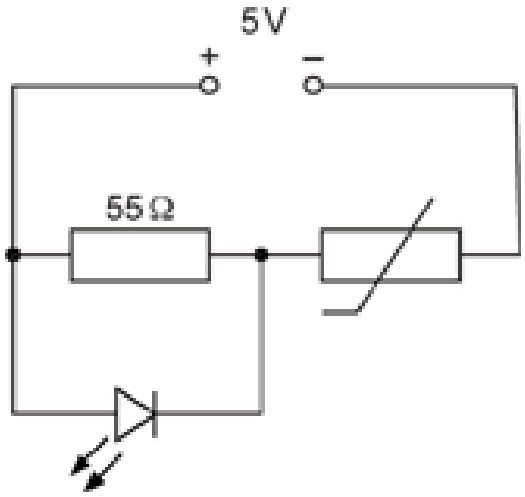
- collect and analyse the data
- determine the uncertainties in the values of r and ε.

[6]

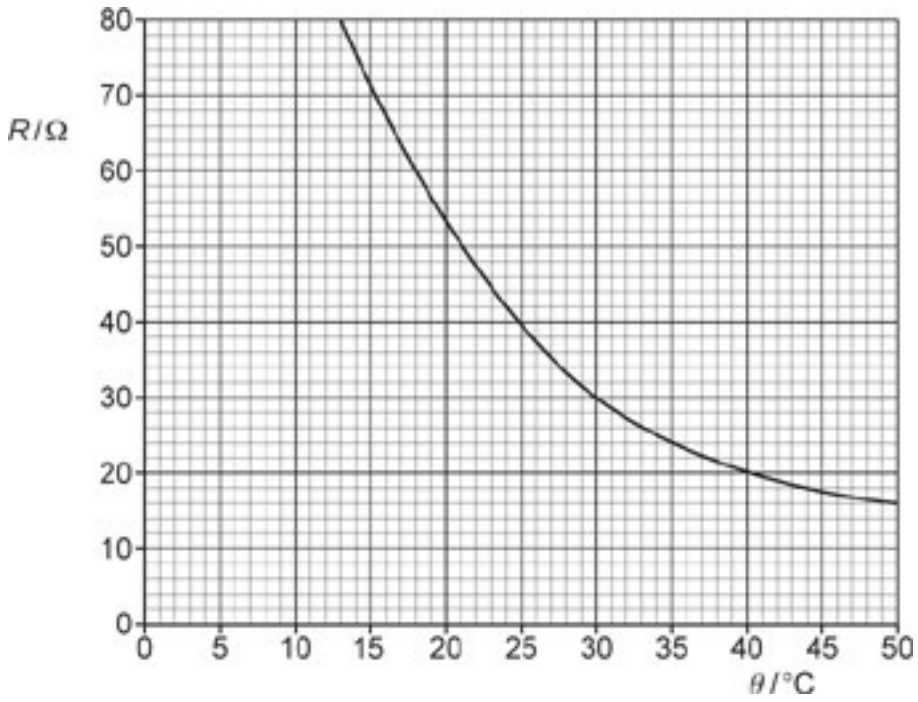
2. A thermistor has a resistance that decreases as temperature increases.

The circuit diagram shows a potential divider circuit using a thermistor to detect changes in temperature.

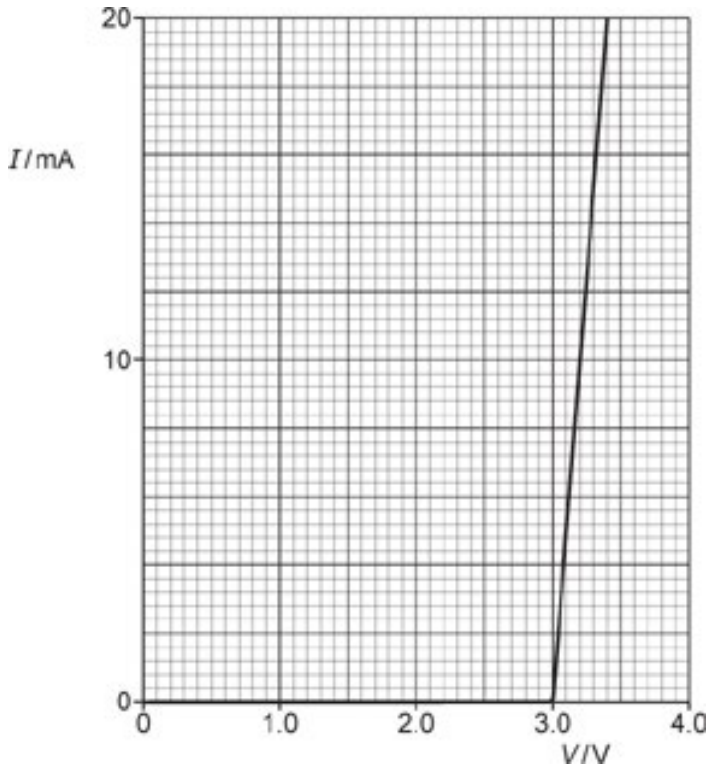
The LED switches on to indicate when the temperature is above 30˚ C.



The variation of the resistance *R* of the thermistor with temperature *θ* is shown below.



The I-V characteristic of the LED, within its operating range, is shown below.



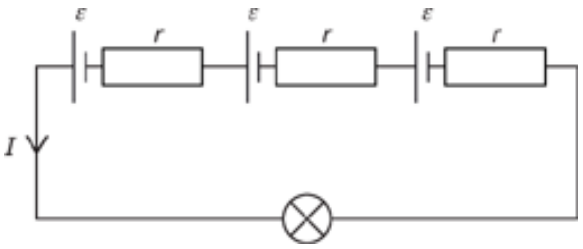
Explain why the LED will switch on when the temperature of the thermistor is above 30° C.

You may assume that the resistance of the LED is always much greater than 55Ω.

[4]

3(a). A torch uses three identical cells connected in series to a bulb.

Each cell has e.m.f. ε and internal resistance r.



The current in the circuit is I.

Show that the power P delivered to the bulb is given by

$P = 3I(\varepsilon - Ir)$

[3]

(b). Suggest why a torch battery with a large internal resistance may be undesirable.

[2]

4. The diagrams show the currents entering and leaving a junction in an electric circuit.

Which diagram could be correct?

A

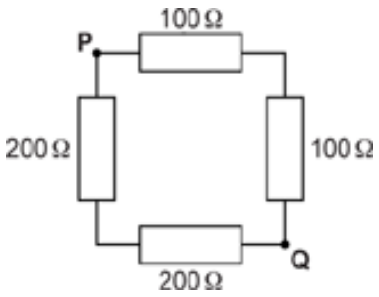
B

C

D

Your answer ☐ **[1]**

5. The diagram below shows a network of four resistors.



What is the total resistance between the points **P** and **Q**?

A 50Ω
B 133Ω
C 150Ω
D 600Ω

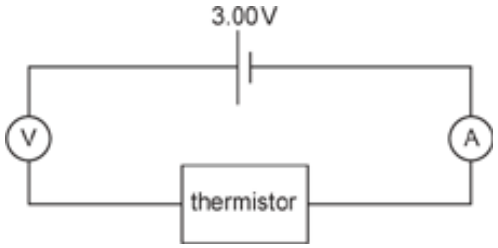
Your answer ☐ **[1]**

6(a). Thermistors are circuit components whose resistance varies with temperature.

There are two major types; negative temperature coefficient (NTC) thermistors, whose resistance decreases with increasing temperature and positive temperature coefficient (PTC) thermistors, whose resistance increases with increasing temperature.

A student is investigating how the resistance of a thermistor varies with temperature by measuring current and voltage. The thermistor is placed in a water bath and the temperature of the water measured using a thermometer.

The diagram below shows how the student set up the experiment (water bath not shown). The circuit has been set up **incorrectly**.



Describe how the student should change the circuit.

_____

_____ **[1]**

(b). The circuit was corrected and then used to collect data.

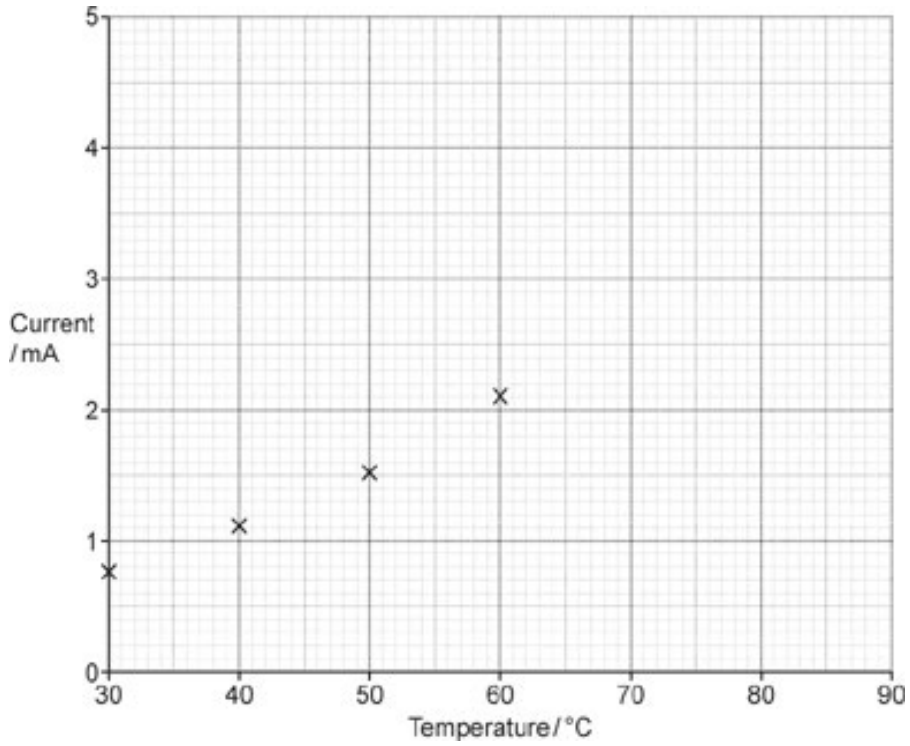
The table shows data collected from the investigation.

Temperature/°C	Current/mA	Voltage/V
30	0.75	3.00
40	1.10	3.00
50	1.51	3.00
60	2.10	3.00
70	2.80	3.00
80	3.66	3.00
90	4.76	3.00

i. The axes below show a plot of current against temperature. The first four points from the table have been plotted. Plot the remaining points.

[1]

ii. Draw a suitable line of best fit through the data points.



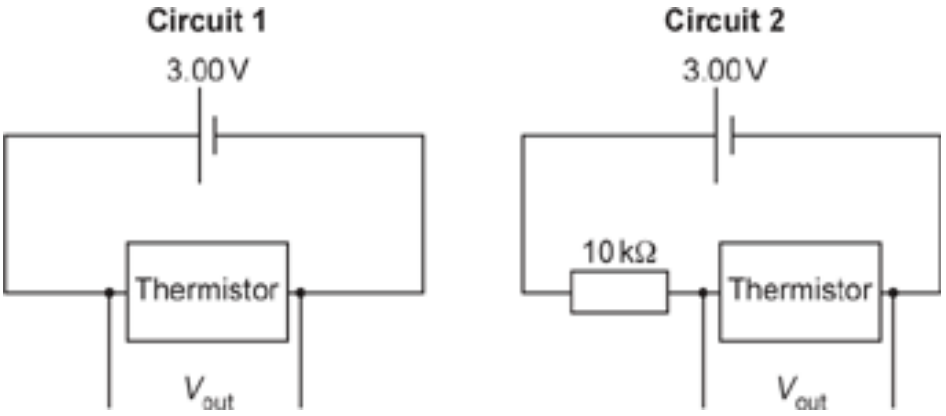
[1]

(c). Describe, using the graph and calculations using data from the table, how the resistance of the thermistor varies for increasing temperature.
Hence determine whether the thermistor the student used was an NTC or a PTC thermistor.

[3]

(d). The thermistor is used in a temperature-sensing circuit for a heating system to warm milk for a baby.

The student considers two possible designs for the circuit which are shown below.

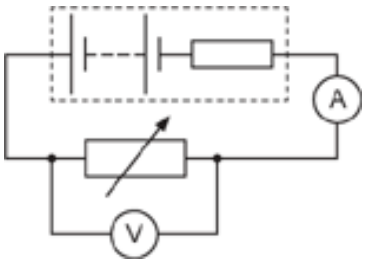


In each circuit, the voltage V_{out} across the thermistor is connected to the heating system for warming the milk.

Discuss which circuit may be suitable for the heating system by considering the response of the circuit to changes in temperature.

[4]

7. A student uses the circuit below to determine the electromotive force (e.m.f.) and internal resistance of a battery.



They measure the current and potential difference (p.d.) across the variable resistor for different resistor values.

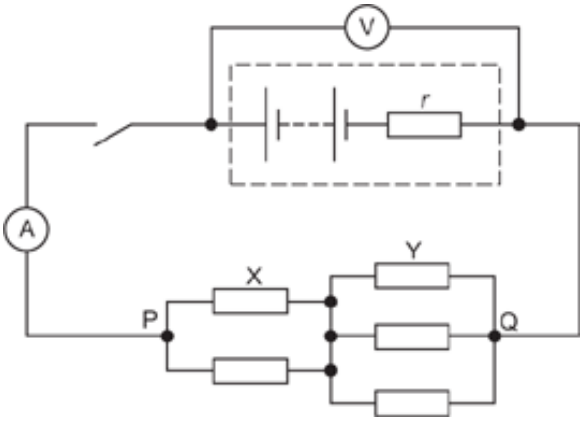
A graph is drawn with p.d. on the *y*-axis and current on the *x*-axis.

Which row is correct for calculating the e.m.f. and the internal resistance of the battery?

	e.m.f	**internal resistance**
A	magnitude of gradient	intercept on *y*-axis
B	magnitude of $\frac{1}{\text{gradient}}$	intercept on *y*-axis
C	intercept *y*-axis	magnitude of $\frac{1}{\text{gradient}}$
D	intercept *y*-axis	magnitude of gradient

Your answer ☐ **[1]**

8(a). A battery of electromotive force (e.m.f.) ε and internal resistance r is connected to five identical wire wound resistors in a circuit.



Each resistor between points P and Q has a resistance of 300Ω. Two of the resistors are labelled X and Y as shown.

The table shows the ammeter and voltmeter readings when the switch is open and when the switch is closed.

Switch position	Ammeter reading	Voltmeter reading
open	0.0 mA	4.57 V
closed	18.0 mA	4.50 V

i. Suggest why a student deduces that the e.m.f. ε of the battery has the value of 4.57 V.

[1]

ii. Show that the resistance r is approximately 3.9 Ω.

[1]

iii. Show that the total resistance of the resistors between P and Q is 250 Ω.

[1]

(b). The switch is closed for 300 s.

Calculate:

i. the energy E dissipated in r.

E = ... J **[1]**

ii. the number of electrons N passing through r.

N = ... **[2]**

iii. the ratio

$$\frac{\text{mean drift speed of electrons in resistor X}}{\text{mean drift speed of electrons in resistor Y}}$$

ratio = ... **[2]**

(c). Resistor Y is removed from the circuit.

The switch is closed.

Complete the sentences to state the change, if any, in the meter readings.

Choose from **increases, decreases,** or **stays the same**.

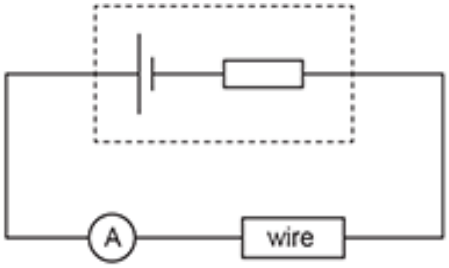
i. The ammeter reading

_____ **[1]**

ii. The voltmeter reading

_____ **[1]**

9. 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.

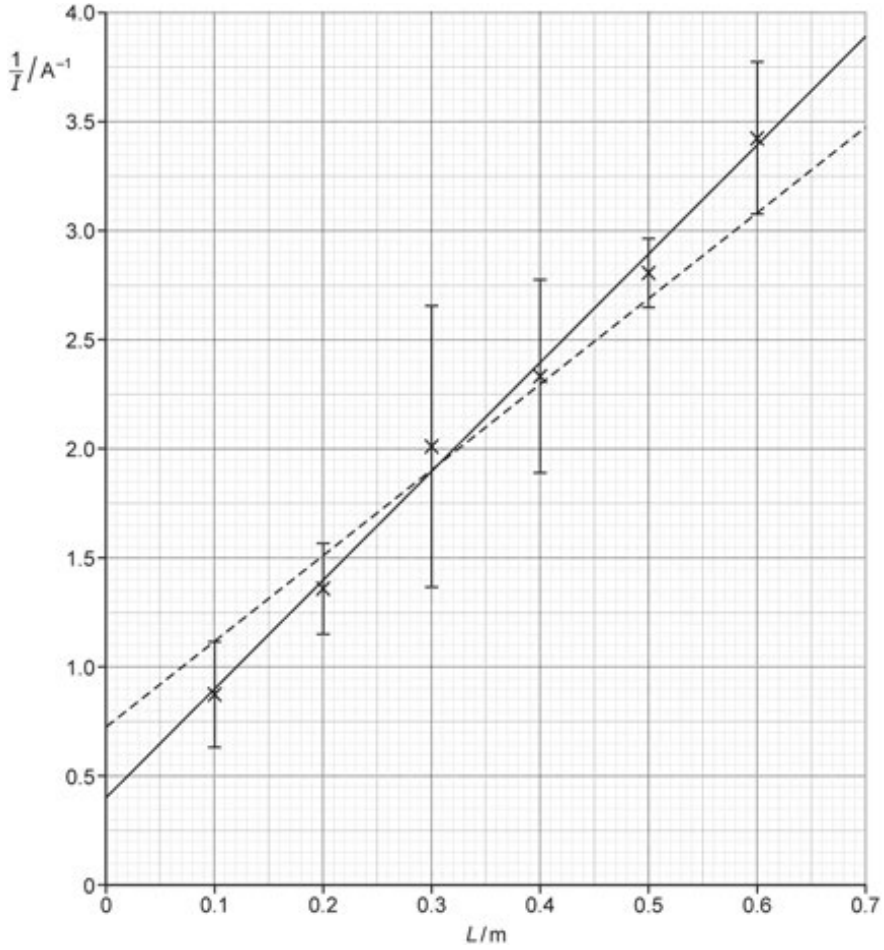
The student varies the length L of the wire in the circuit and records the current I using the ammeter.

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 $\frac{1}{f}$ 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. ε = 1.45 ± 0.05 V

The wire has diameter *d* = 0.455 ± 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.

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

1

ρ = ...Ω m **[2]**

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

2

r = ... ± ..... Ω **[4]**

10(a). A switch, resistor of resistance *R* and a component **Z** are connected to a battery of electromotive force (e.m.f.) *E* and internal resistance *r*. An ammeter and voltmeter are also connected to the circuit as shown in **Fig. 6.1**.

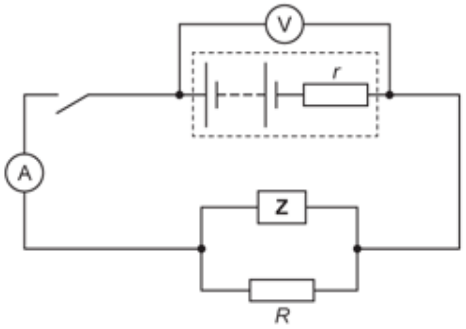


Fig. 6.1

Fig. 6.2 shows the current *I* and potential difference *V* characteristic for the electrical component **Z**.

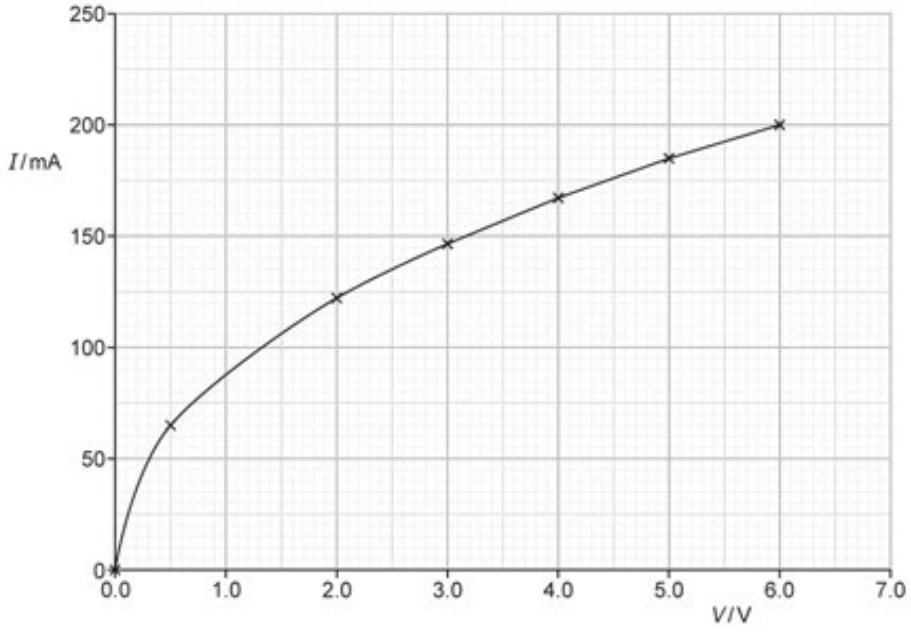


Fig. 6.2

State the name of component **Z**.

---------- **[1]**

(b). The switch is initially open.

The voltmeter reading is 5.72 V

The following voltmeters are available:

A: 0–2 V, ± 0.001 V	**B:** 0–2 V, ± 0.01 V	**C:** 0–2 V, ± 0.1 V
D: 0–20 V, ± 0.001 V	**E:** 0–20 V, ± 0.01 V	**F:** 0–20 V, ± 0.1 V

State the voltmeter, **A** to **F**, that has been used in this experiment.

Voltmeter ..... **[1]**

(c). The switch is now closed.
The ammeter and voltmeter readings are:
Ammeter reading = 220 mA
Voltmeter reading = 4.80 V

i. Show that the resistance of *R* is 120 Ω.

[2]

ii. Determine values for *E* and *r*.

E = ... V

r = ... Ω

[3]

(d). The resistor *R* is changed to a lower value.

State and explain the change, if any, in the ammeter and voltmeter readings when the switch is closed.

[4]

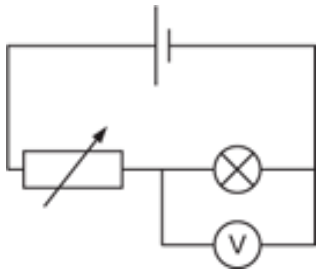
11. The diagram shows the currents passing in and out of a point in a circuit.

What is the value of the current *I*?

A 0.3A
B 0.5A
C 2.5A
D 3.0A

Your answer ☐ **[1]**

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



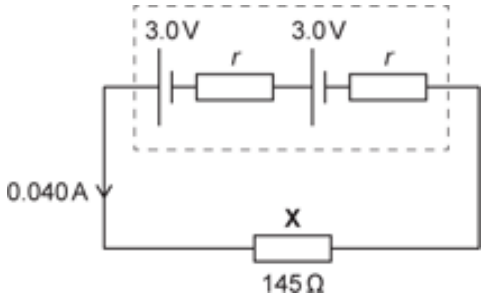
The variable resistor is adjusted so that the temperature of the filament lamp increases.

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]**

13. Two identical cells are connected in series in a circuit with a resistor **X** of resistance 145 Ω. The e.m.f. of each cell is 3.0 V. The current in **X** is 0.040A.



What is the internal resistance *r* of one of the cells?

A 0.10 Ω
B 0.20 Ω
C 2.5 Ω
D 5.0 Ω

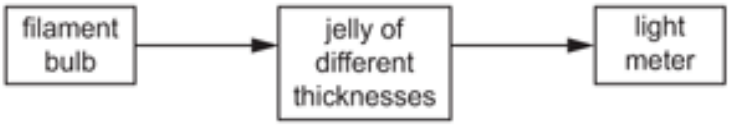
Your answer ☐ **[1]**

14. As light passes through a substance its intensity decreases exponentially with distance.

$I_x = I_0 e^{-\mu x}$

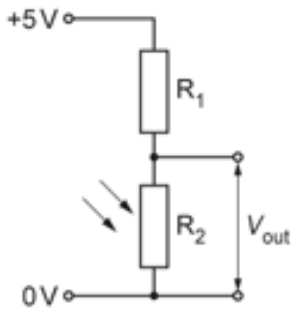
I_x is the intensity of light at a given thickness of jelly
I_0 is the intensity of light immediately before it enters the jelly
μ is the constant of proportionality
x is the thickness of the jelly that the light has passed through.

Some students are studying the absorption of visible light by red jelly. They set up the experiment below.



- The power to the bulb is kept constant.
- The distance between the bulb and the light meter is kept constant.
- Blocks of jelly of different thickness are used.
- They measure the intensity of light using a light meter.

The students decide to make their own light meter using this circuit.



The value of R_1 is 5 kΩ. The value of R_2 was 100 Ω when 1 mm jelly was used and 8 kΩ when 5 mm jelly was used.

i. Calculate the output voltage range obtained in this experiment.

range = ... V **[2]**

ii. Describe **two** ways the output voltage range could be increased.

1 _____

_____

2 _____

_____

[2]

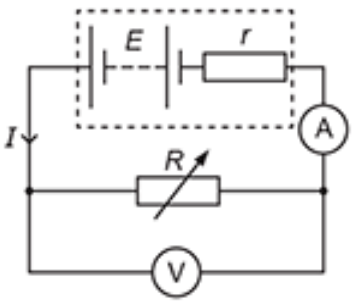
iii. Explain how the circuit responds to a change in light intensity.

_____

_____

[1]

15(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]

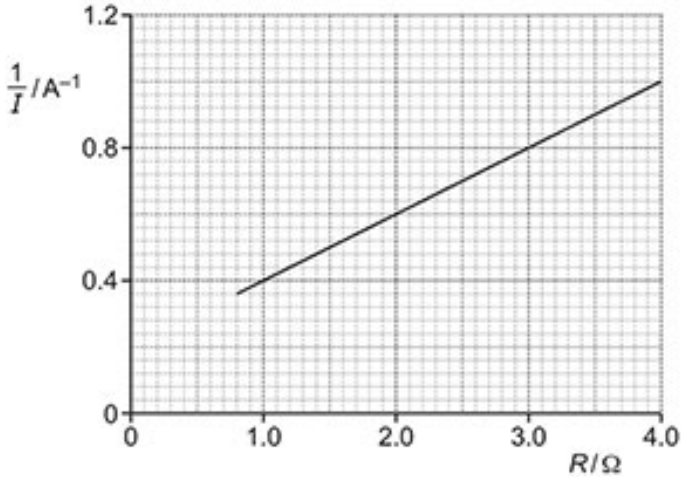
(c). A student connects up the circuit above to determine *r*.

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

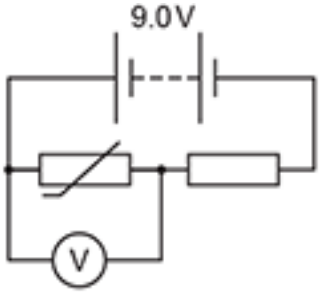
power = ... W **[2]**

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]**

16. 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]**

17.

Fig. 25.1 shows an electrical circuit.

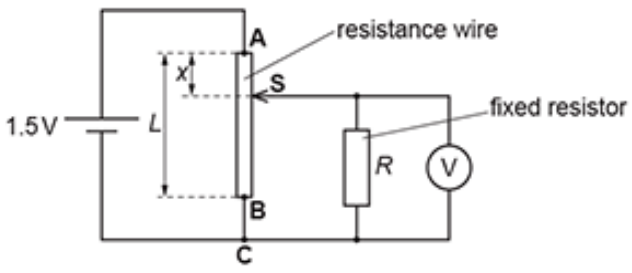


Fig. 25.1

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*.

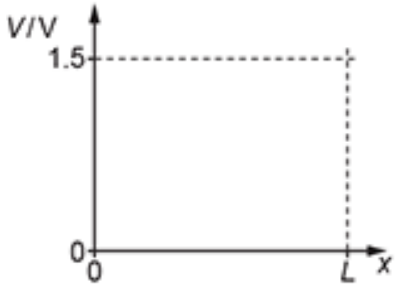


Fig. 25.2

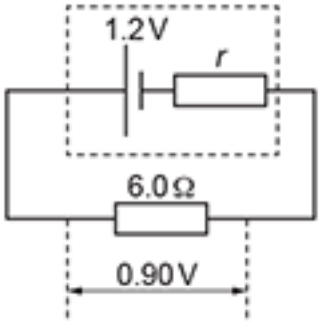
[2]

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]

---

18. A cell of electromotive force (e.m.f.) 1.2 V is connected to a wire of resistance 6.0 Ω.



The potential difference across the wire is 0.90 V.
What is the internal resistance *r* of the cell?

A 0.15 Ω
B 0.30 Ω
C 2.0 Ω
D 8.0 Ω

Your answer ☐ **[1]**

19. A resistor of resistance 12 Ω is connected in **parallel** with another resistor of resistance *R*. The total resistance of the circuit is 4.0 Ω.
What is the value of *R*?

A 0.17 Ω
B 6.0 Ω
C 8.0 Ω
D 16 Ω

Your answer ☐ **[1]**

20. Which term is **not** used in either of Kirchhoff's two laws?

A charge
B current
C electromotive force
D potential difference

Your answer ☐ **[1]**

END OF QUESTION PAPER