CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Units 9 & 10: Electricity

Past Papers 2021 – 2025

QUESTION PAPER 40 Questions

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Question 1

(a) State Kirchhoff's first law.

....

....

.... [2]

(b) The circuit shown in Fig. 5.1 contains a battery of electromotive force (e.m.f.) *E* and negligible internal resistance connected to four resistors R_1, R_2, R_3 and R_4, each of resistance *R*.

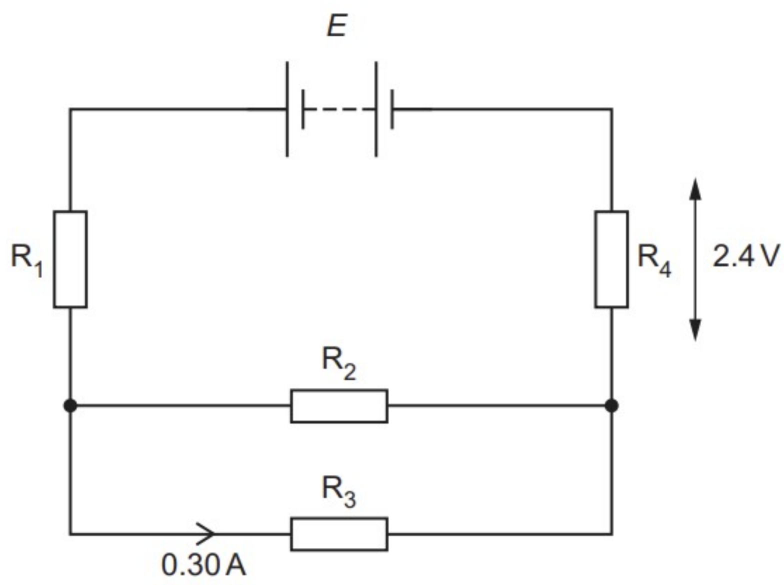

Fig. 5.1

The current in R_3 is 0.30 A and the potential difference (p.d.) across R_4 is 2.4 V.

(i) Show that *R* is equal to 4.0 Ω.

[2]

(ii) Determine the e.m.f. *E* of the battery.

E = ... V [2]

(c) The battery in **(b)** is replaced with another battery of the same e.m.f. *E* but with an internal resistance that is not negligible.

State and explain the change, if any, in the total power produced by the battery.

....

....

.... [2]

(d) The resistors in the circuit of Fig. 5.1 are made from nichrome wire of uniform radius 240 μm. The length of this wire needed to make each resistor is 0.67 m.

Calculate the resistivity of nichrome.

resistivity = ... Ω m [3]

[Total: 11]

Question 2

A cell of electromotive force (e.m.f.) 0.48 V is connected to a metal wire X, as shown in Fig. 6.1.

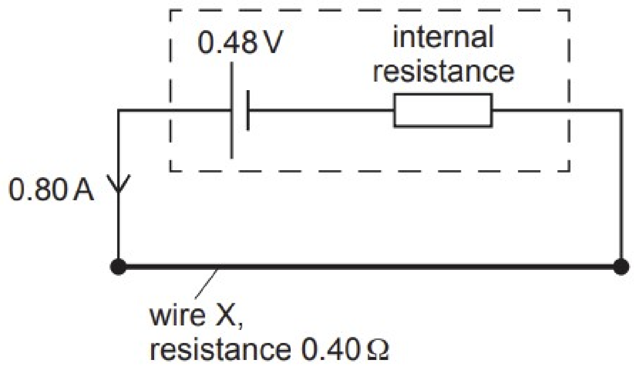

Fig. 6.1

The cell has internal resistance. The current in the cell is 0.80 A.

Wire X has length 3.0 m, cross-sectional area $1.3 \times 10^{-7}\,m^2$ and resistance 0.40 Ω.

(a) Calculate the charge passing through the cell in a time of 7.5 minutes.

charge = ... C [2]

(b) Calculate the percentage efficiency with which the cell supplies power to wire X.

efficiency = ... % [3]

(c) There are 3.2×10^{22} free (conduction) electrons contained in the volume of wire X.

For wire X, calculate:

(i) the number density *n* of the free electrons

n = ... m^{-3} [1]

(ii) the average drift speed of the free electrons.

average drift speed = ... $m\,s^{-1}$ [2]

(d) A wire Y has the same cross-sectional area as wire X and is made of the same metal. Wire Y is longer than wire X.

Wire X in the circuit is now replaced by wire Y. Assume that wire Y has the same temperature as wire X.

State and explain whether the average drift speed of the free electrons in wire Y is greater than, the same as, or less than that in wire X.

....

....

....

....

....

.... [3]

[Total: 11]

Question 3

(a) A resistance wire of uniform cross-sectional area $3.3 \times 10^{-7}\,\text{m}^2$ and length 2.0 m is made of metal of resistivity $5.0 \times 10^{-7}\,\Omega\,\text{m}$.

Show that the resistance of the wire is $3.0\,\Omega$.

[2]

(b) The ends of the resistance wire in **(a)** are connected to the terminals X and Y in the circuit shown in Fig. 6.1.

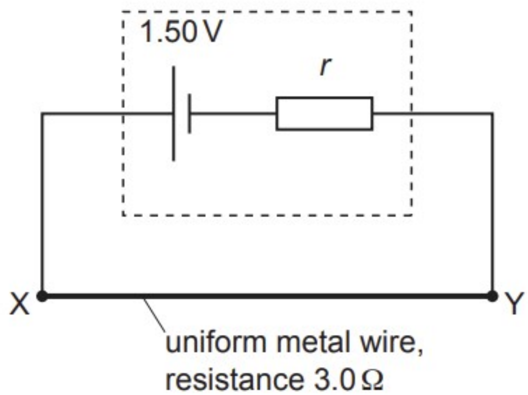

Fig. 6.1

The cell has an electromotive force (e.m.f.) of 1.50 V and internal resistance r. The potential difference between X and Y is 1.20 V.

Calculate:

(i) the current in the circuit

current = ... A [1]

(ii) the internal resistance r.

r = ... Ω [2]

(c) A galvanometer and a cell of e.m.f. E with negligible internal resistance are connected to the circuit in **(b)**, as shown in Fig. 6.2.

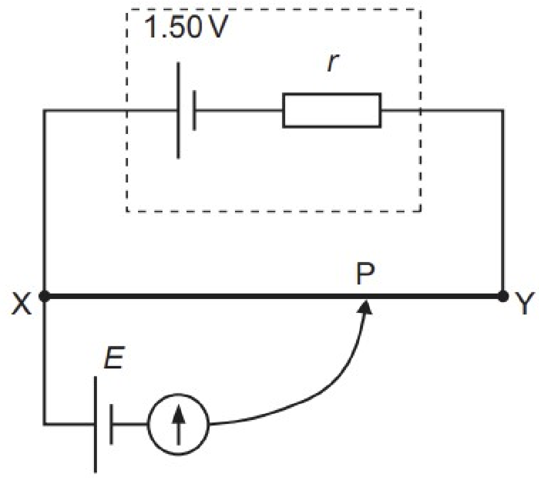

Fig. 6.2

The resistance wire between X and Y has a length of 2.0 m. The galvanometer has a reading of zero when the connection P is adjusted so that the length XP is 1.4 m.

Determine the e.m.f. E of the cell.

E = ... V [2]

(d) The circuit in Fig. 6.2 is modified by replacing the original resistance wire with a second resistance wire. The second wire has the same length as the original wire and is made of the same metal.

The second wire has a smaller cross-sectional area than the original wire.

Connection P is adjusted on the second wire so that the galvanometer has a reading of zero.

State and explain whether length XP for the second wire is shorter than, longer than or the same as length XP for the original wire when the galvanometer reading is zero.

....

....

....

....

.... [3]

[Total:10]

Question 4

(a) State Kirchhoff's second law.

....

....

.... [2]

(b) A battery has electromotive force (e.m.f.) 4.0 V and internal resistance 0.35 Ω. The battery is connected to a uniform resistance wire XY and a fixed resistor of resistance *R*, as shown in Fig. 5.1.

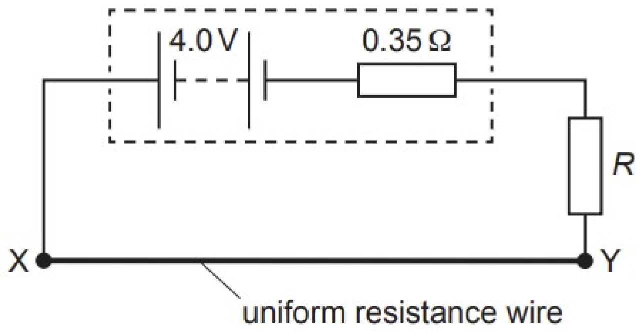

Fig. 5.1

Wire XY has resistance 0.90 Ω. The potential difference across wire XY is 1.8 V.

Calculate:

(i) the current in wire XY

current = ... A [1]

(ii) the number of free electrons that pass a point in the battery in a time of 45 s

number = ... [2]

(iii) resistance *R*.

R = ... Ω [2]

(c) A cell of e.m.f. 1.2 V is connected to the circuit in **(b)**, as shown in Fig. 5.2.

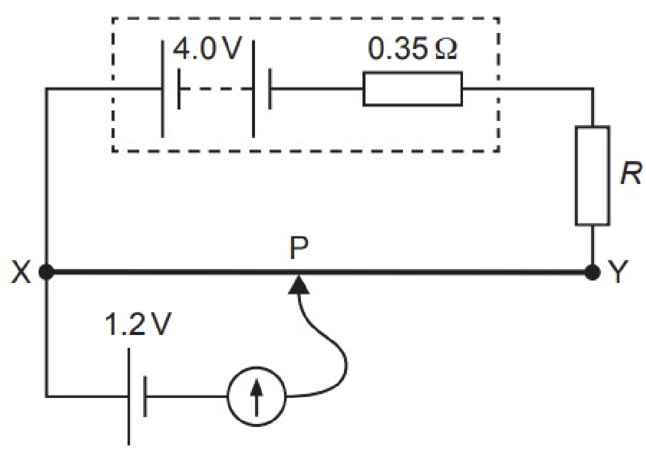

Fig. 5.2

The connection P is moved along the wire XY. The galvanometer reading is zero when distance XP is 0.30 m.

(i) Calculate the total length L of wire XY.

L = ... m [2]

(ii) The fixed resistor is replaced by a different fixed resistor of resistance greater than R.

State and explain the change, if any, that must be made to the position of P on wire XY so that the galvanometer reading is zero.

....

....

....

.... [2]

[Total: 11]

Question 5

(a) Define the *ohm*.

....

.... [1]

(b) A wire is made of metal of resistivity ρ. The length L of the wire is gradually increased. Assume that the volume V of the wire remains constant as its length is increased.

Show that the resistance R of the extending wire is proportional to L^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 5.1.

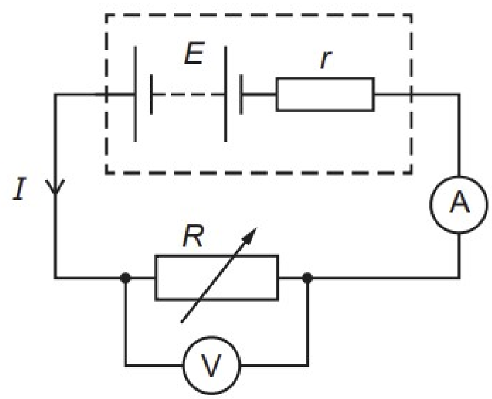

Fig. 5.1

An ammeter measures the current I in the circuit. A voltmeter measures the potential difference V across the variable resistor.

The resistance R is now varied to change the values of I and V.

The variation with I of V is shown in Fig. 5.2.

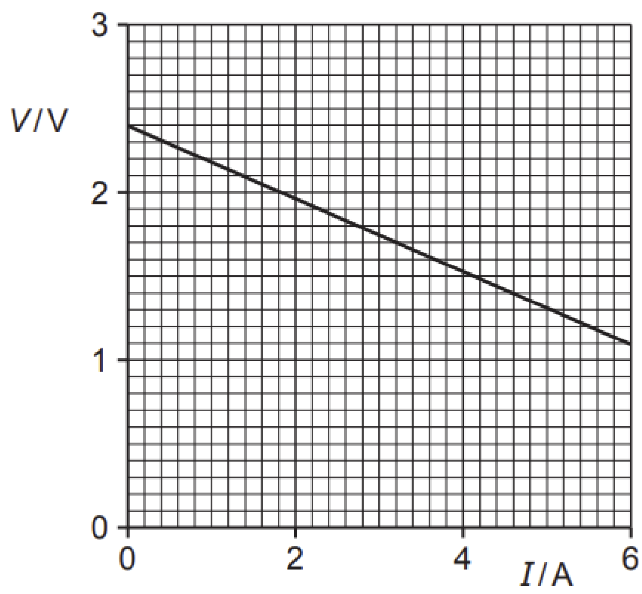

Fig. 5.2

(i) Use Fig. 5.2 to state the e.m.f. E of the battery.

E = ... V [1]

(ii) Use Fig. 5.2 to determine the power dissipated in the variable resistor when there is a current of 5.0A.

power = ... W [3]

(iii) State what is represented by the value of the gradient of the graph.

.... [1]

[Total: 8]

Question 6

(a) Define the *electromotive force* (*e.m.f.*) of a source.

....

....

.... [2]

(b) The circuit shown in Fig. 5.1 contains a battery of e.m.f. E that has internal resistance r, a variable resistor, a voltmeter and an ammeter.

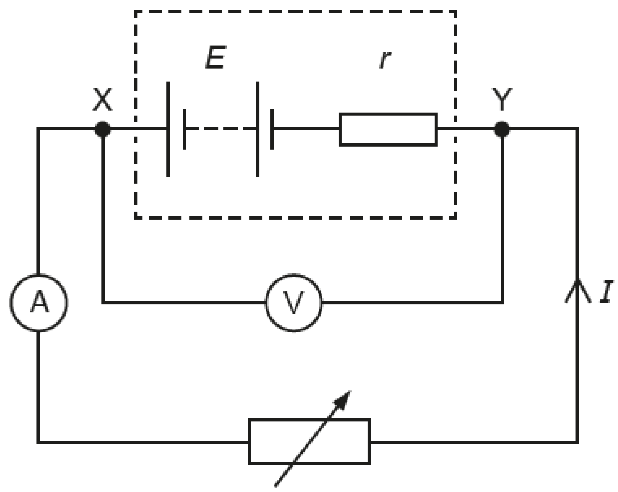

Fig. 5.1

Readings from the two meters are taken for different settings of the variable resistor. The variation with current I of the potential difference (p.d.) V across the terminals XY of the battery is shown in Fig. 5.2.

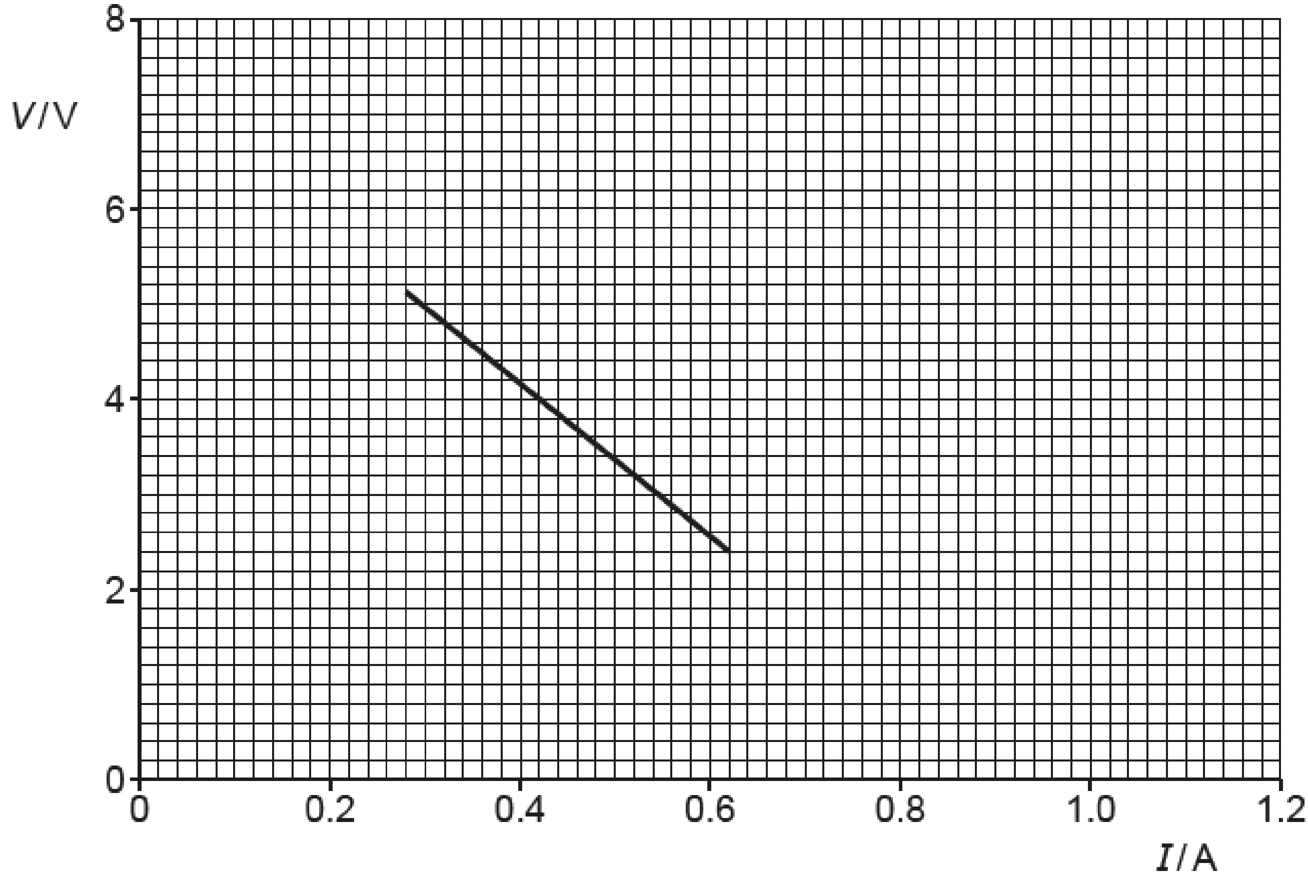

Fig. 5.2

Explain why V is not constant.

....

....

....

.... [3]

(c) For the battery in **(b)**, use Fig. 5.2 to determine:

(i) the e.m.f. E

E = ... V [1]

(ii) the maximum current that the battery can supply

maximum current = ... A [1]

(ii) the maximum current that the battery can supply

maximum current = ... A [1]

(iii) the internal resistance *r*.

r = ... Ω [2]

(d) On Fig. 5.2, sketch a line to show a possible variation with I of V for a battery with a lower e.m.f. and a lower internal resistance than the battery in **(b)**. Your line should extend over at least the same range of currents as the original line. [2]

[Total: 11]

Question 7

(a) State Kirchhoff's first law.

....

.... [1]

(b) A battery of electromotive force (e.m.f.) 12.0 V and internal resistance r is connected to a filament lamp and a resistor, as shown in Fig. 6.1.

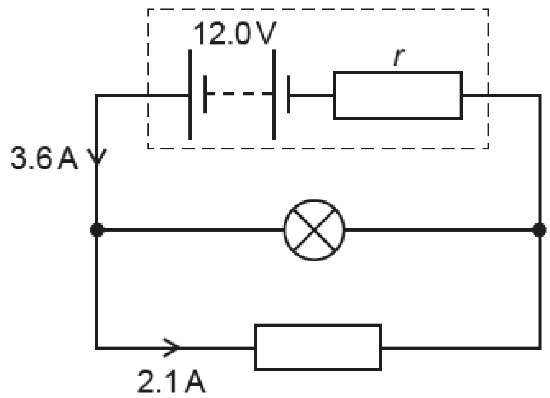

Fig. 6.1

The current in the battery is 3.6A and the current in the resistor is 2.1A. The I-V characteristic for the lamp is shown in Fig. 6.2.

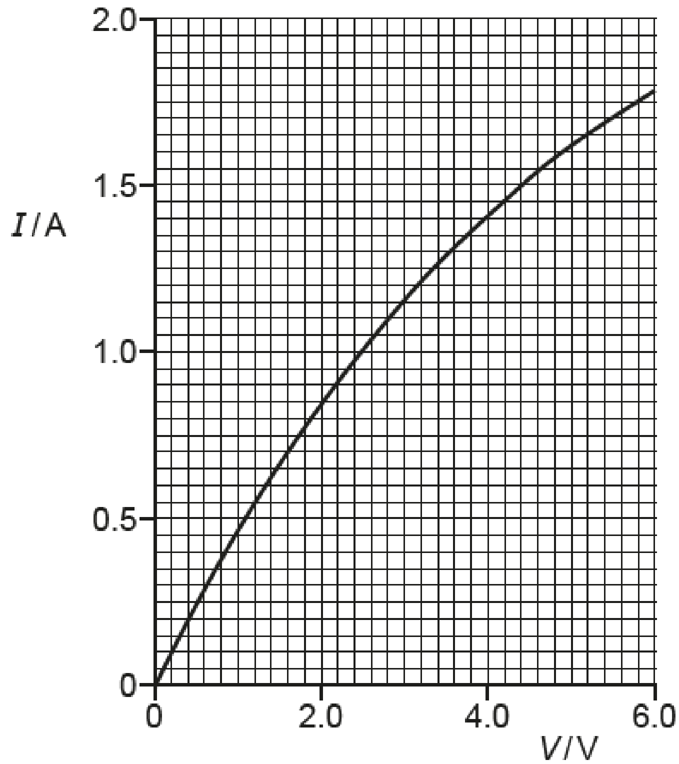

Fig. 6.2

(i) Determine the resistance of the lamp in Fig. 6.1.

resistance = ... Ω [3]

(ii) Determine the internal resistance *r* of the battery.

r = ... Ω [2]

(iii) The initial energy stored in the battery is 470 kJ. Assume that the e.m.f. and the current in the battery do not change with time.

Calculate the time taken for the energy stored in the battery to become 240 kJ.

time = ... s [2]

(iv) The filament wire of the lamp is connected in series with the adjacent copper connecting wire of the circuit, as illustrated in Fig. 6.3.

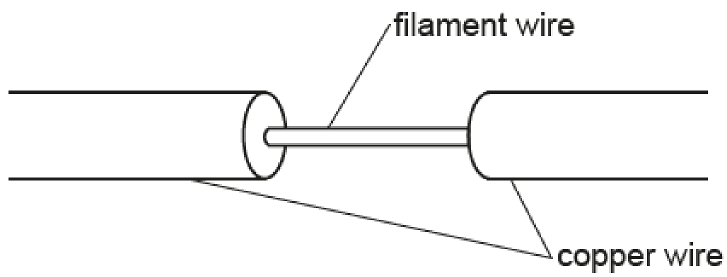

Fig. 6.3 (not to scale)

Some data for the filament wire and the adjacent copper connecting wire are given in Table 6.1.

Table 6.1

	filament wire	copper wire
cross-sectional area	A	$360\,A$
number density of free electrons	n	$2.5\,n$

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire}}{\text{average drift speed of free electrons in copper wire}}.$$

ratio = ... [2]

[Total: 10]

Question 8

The ends of a metal resistance wire are connected to a battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance, as shown in Fig. 6.1.

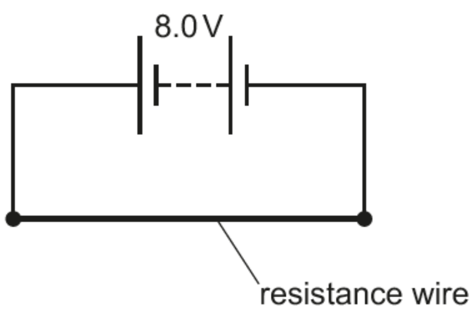

Fig. 6.1

The power dissipated by the resistance wire is 36 W.

(a) Calculate:

(a) Calculate:

(i) the current in the resistance wire

current = ...A [2]

(ii) the number of free electrons that pass through the resistance wire in a time of 50 s

number = ... [2]

(iii) the resistance of the wire.

resistance = ... Ω [2]

(b) The metal of the resistance wire in the circuit has a resistivity of $1.4 \times 10^{-6}\,\Omega\,m$. The cross-sectional area of the wire is $0.25\,mm^2$.

Determine the length of the wire.

length = ... m [2]

(c) The circuit shown in Fig. 6.1 is modified by replacing the original resistance wire with a second resistance wire. The second wire has a greater diameter than the original wire. There are no other differences between the second wire and the original wire.

By reference to resistance, state and explain whether the power dissipated by the second wire is more than, less than or the same as the power dissipated by the original wire.

....

....

....

.... [2]

(d) The circuit shown in Fig. 6.1 is modified by connecting a second battery, of e.m.f. 8.0 V and negligible internal resistance, in parallel with the original battery and the original resistance wire, as shown in Fig. 6.2.

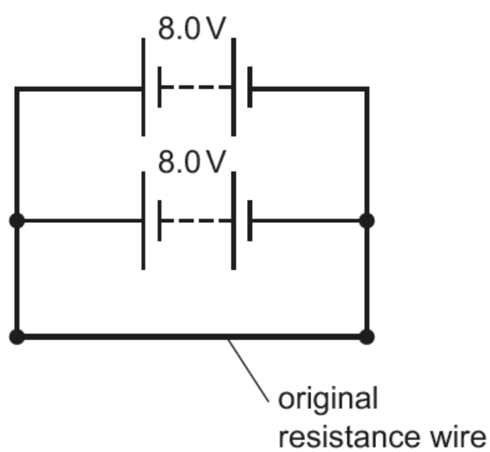

Fig. 6.2

By reference to the current in the resistance wire, state and explain whether the addition of the second battery causes the power in the original resistance wire to decrease, increase or stay the same.

....

....

....

.... [2]

[Total: 12]

Question 9

(a) State Kirchhoff's first law.

....

.... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

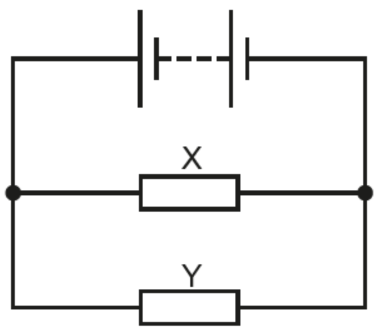

Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

(i) State and explain which resistor dissipates more power.

....

....

....

....

.... [3]

(ii) The two resistors are made of wires that have the same length. Both wires are made from metal of the same resistivity.

State and explain which resistor is made of wire with the larger cross-sectional area.

....

....

.... [2]

(c) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a light-dependent resistor (LDR) and a fixed resistor of resistance 1800 Ω, as shown in Fig. 6.2.

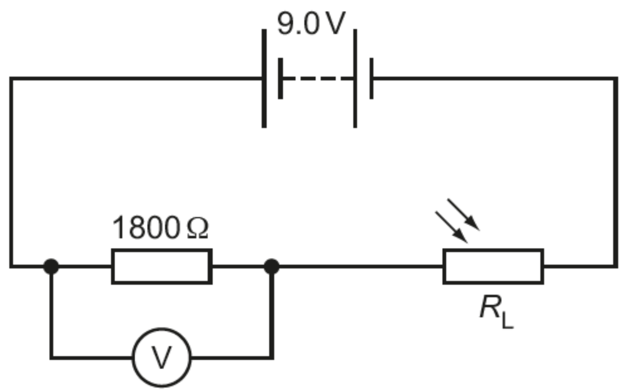

Fig. 6.2

A voltmeter is connected across the fixed resistor. The reading on the voltmeter is 5.4 V.

(i) Calculate the current in the circuit.

current = ... A [1]

(ii) Calculate the resistance R_L of the LDR.

R_L = ... Ω [2]

(iii) The intensity of the light illuminating the LDR increases.

By reference to the current in the circuit, state and explain the change, if any, to the voltmeter reading.

....

....

....

.... [2]

[Total: 11]

Question 10

(a) A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

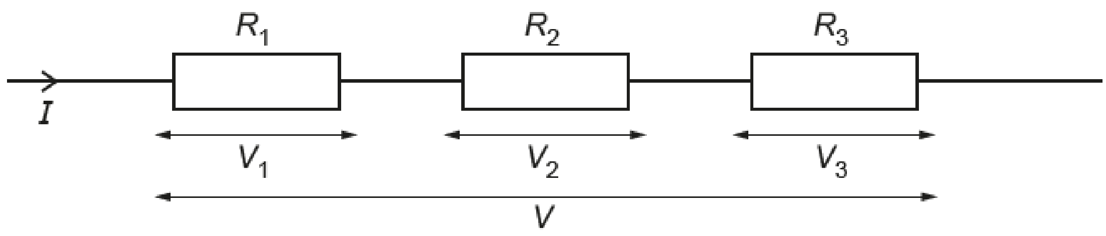

Fig. 6.1

The individual potential differences across the resistors are V_1, V_2 and V_3. The current in the combination of resistors is I and the total potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$R = R_1 + R_2 + R_3.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance is connected to a thermistor, a switch X and two fixed resistors, as shown in Fig. 6.2.

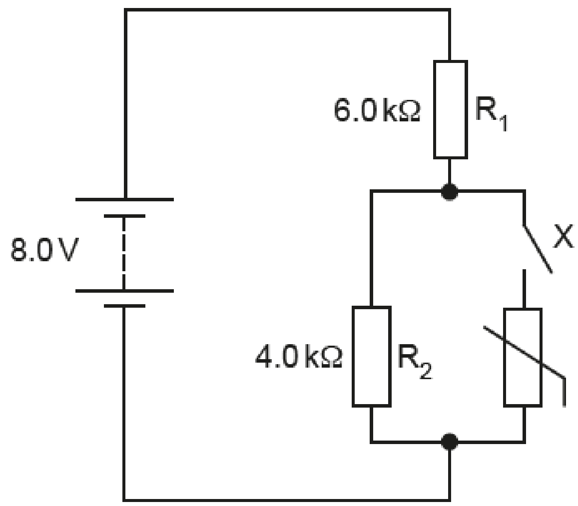

Fig. 6.2

Resistor R_1 has resistance 6.0 kΩ and resistor R_2 has resistance 4.0 kΩ.

(i) Switch X is open.

Calculate the potential difference across R_1.

potential difference = ... V [2]

(ii) Switch X is now closed. The resistance of the thermistor is 12.0 kΩ.

Calculate the current in the battery.

current = ... A [2]

(c) The switch X in the circuit in **(b)** remains closed. The temperature of the thermistor decreases.

By reference to the current in the battery, state and explain the effect, if any, of the decrease in temperature on the power produced by the battery.

....

....

....

....

.... [3]

[Total: 9]

Question 11

(a) **(i)** On Fig. 6.1, sketch the I–V characteristic of a filament lamp.

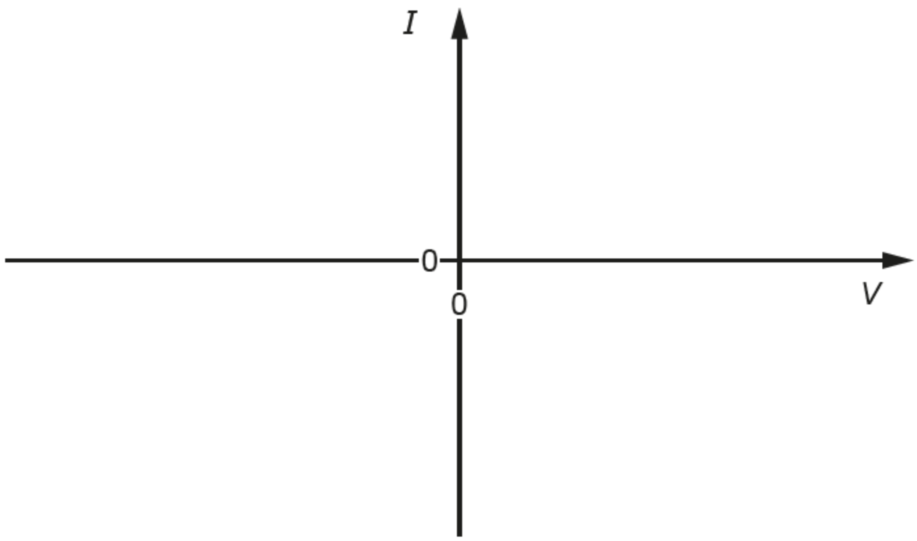

Fig. 6.1

[2]

(ii) Explain the shape of the line in **(a)(i)**.

....

....

....

.... [3]

(b) A conducting wire has length 5.8 m and cross-sectional area $3.4 \times 10^{-8}\,m^2$. The resistivity of the metal of the wire is $5.6 \times 10^{-8}\,\Omega\,m$.

Calculate the resistance of the wire.

resistance = ... Ω [2]

(c) A resistor of resistance R is placed in a circuit with a cell of negligible internal resistance, two switches S_1 and S_2, a second resistor of resistance $2R$ and three ammeters X, Y and Z. The circuit is shown in Fig. 6.2.

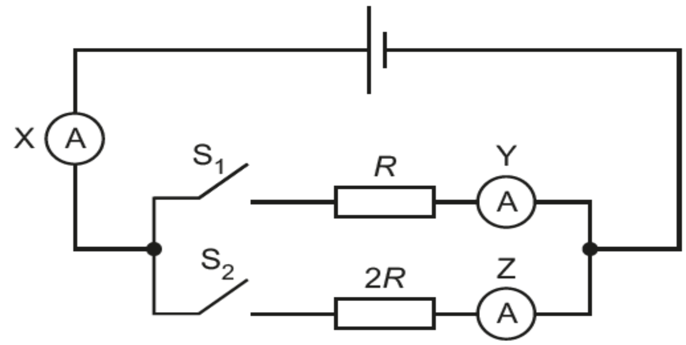

Fig. 6.2

The reading on X is 1.0 A when S_1 is open and S_2 is closed.

Complete Table 6.1.

Complete Table 6.1.

Table 6.1

position of switches		ammeter readings		
S_1	S_2	reading on X / A	reading on Y / A	reading on Z / A
open	open	0	0	0
open	closed	1.0		
closed	open			
closed	closed			

[4]

[Total: 11]

Question 12

(a) State Ohm's law.

....

....

.... [2]

(b) The variation of current I with potential difference V for a filament lamp is shown in Fig. 5.1.

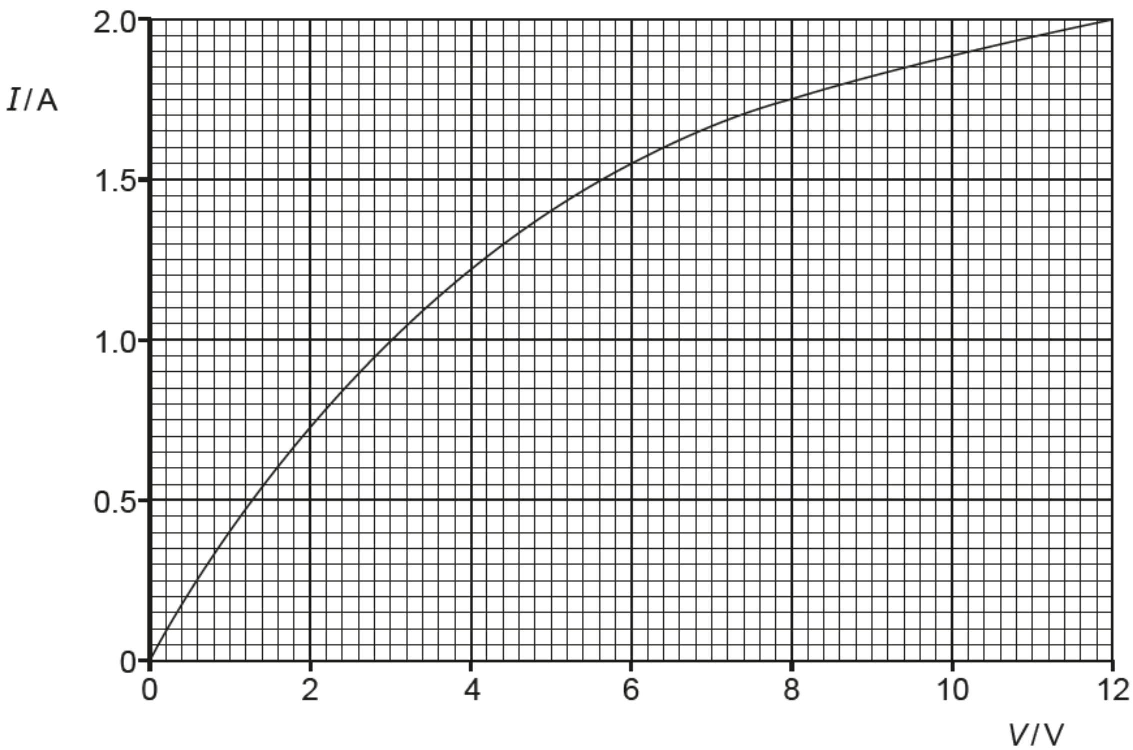

Fig. 5.1

The resistance of the filament lamp increases with potential difference.

(i) State how Fig. 5.1 shows this.

....

.... [1]

(ii) Explain why the resistance varies in this way.

....

.... [1]

(c) Fig. 5.2 shows a circuit with a battery of electromotive force (e.m.f.) 12.0 V connected to a linear potentiometer AB and two identical filament lamps P and Q.

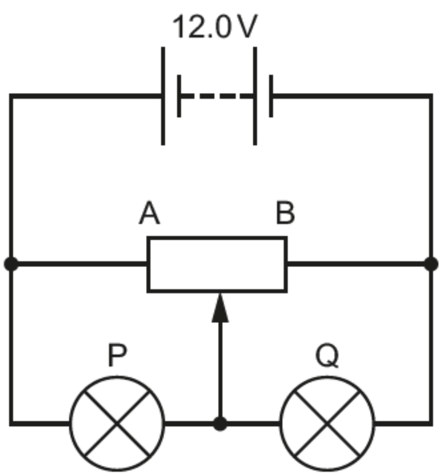

Fig. 5.2

The battery has negligible internal resistance and the lamps each have the same I–V characteristic shown in Fig. 5.1.

When the slider of the potentiometer is at its midpoint, as shown in Fig. 5.2, the current I in the battery is 1.78A.

Determine:

(i) the current in lamp P

current = ... A [1]

(ii) the total power dissipated in lamps P and Q

total power = ... W [2]

(iii) the resistance of the potentiometer between its ends A and B.

resistance = ... Ω [2]

(d) The slider of the potentiometer in **(c)** is moved to end A.

State and explain the effect on the brightness of lamps P and Q.

lamp P: ....

....

lamp Q: ....

....

[2]

[Total: 11]

Question 13

(a) Define electric potential difference.

....

.... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

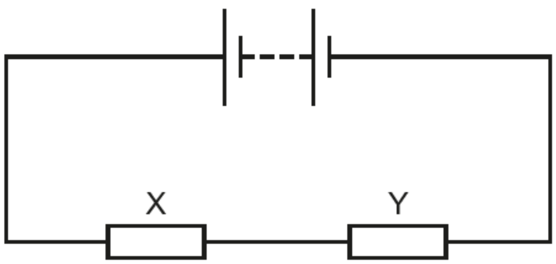

Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

State and explain which resistor dissipates more power.

....

....

....

....

.... [3]

(c) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors P and Q, as shown in Fig. 6.2.

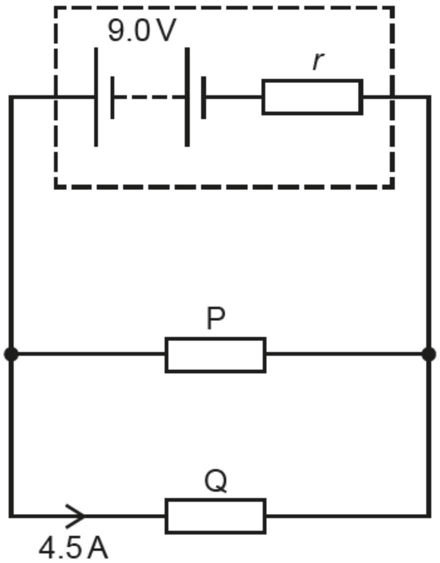

Fig. 6.2

A total charge of 650 C moves through resistor P in a time interval of 540 s. During this time resistor P dissipates 4800 J of energy. The current in resistor Q is 4.5 A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor P

current = ... A [2]

(ii) the potential difference across resistor P

potential difference = ... V [2]

(iii) the internal resistance *r* of the battery.

r = ... Ω [2]

[Total: 10]

Question 14

(a) State Kirchhoff's second law.

....

....

.... [2]

(b) Three identical cells, each of electromotive force (e.m.f.) 1.5 V and internal resistance 590 mΩ, are connected in parallel across a conductor, as shown in Fig. 5.1.

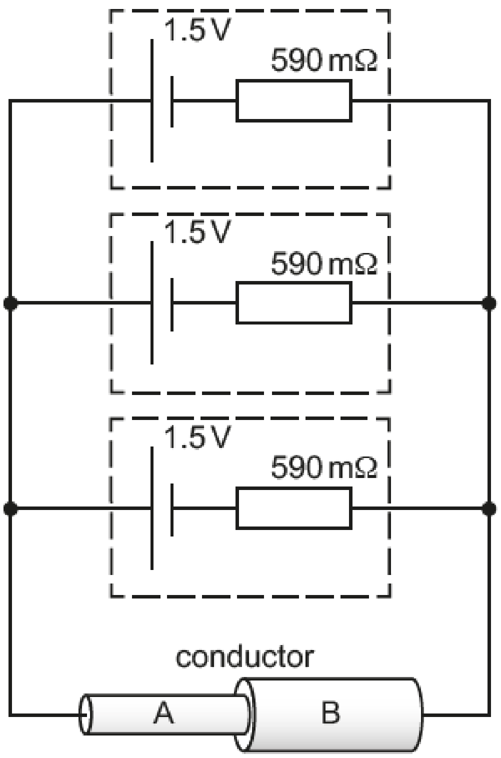

Fig. 5.1

The conductor is composed of two cylindrical sections A and B.
The total resistance of the circuit is 2.2 Ω.

(i) Show that the resistance of the conductor is 2.0 Ω.

[2]

(ii) Calculate the current in the conductor.

current = ... A [2]

(c) The two cylindrical sections A and B of the conductor in Fig. 5.1 are made from the same material and have the same length.
The diameter of section A is 4.3 mm and the diameter of section B is 7.6 mm.
The resistance of section A is R_A and the resistance of section B is R_B.

(i) Calculate the ratio $\dfrac{R_A}{R_B}$.

$\dfrac{R_A}{R_B}$ = ... [3]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of free electrons in section A}}{\text{average drift speed of free electrons in section B}}.$$

Explain your reasoning.

ratio = ... [2]

(d) The circuit of Fig. 5.1 is altered by removing one of the cells.

State and explain the effect, if any, of this change on the potential difference across the conductor.

....

....

....

....

.... [3]

[Total: 14]

Question 15

(a) Define the potential difference across a component.

....

.... [1]

(b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

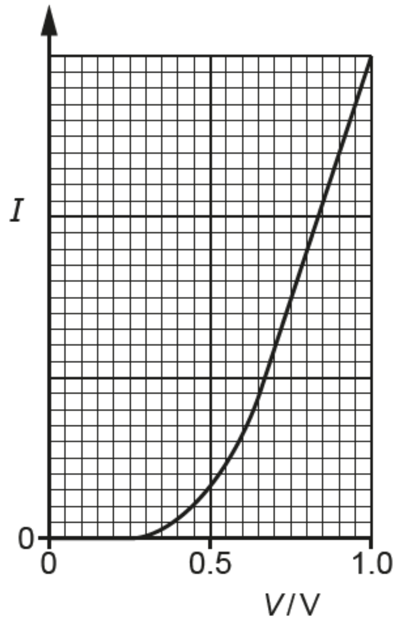

Fig. 6.1

Use Fig. 6.1 to describe qualitatively:

(i) the resistance of the diode in the range $V = 0$ to $V = 0.25\,\text{V}$

.... [1]

(ii) the variation, if any, in the resistance of the diode as V changes from $V = 0.75\,\text{V}$ to $V = 1.0\,\text{V}$.

.... [1]

(c) A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a uniform resistance wire XY, a fixed resistor and a variable resistor, as shown in Fig. 6.2.

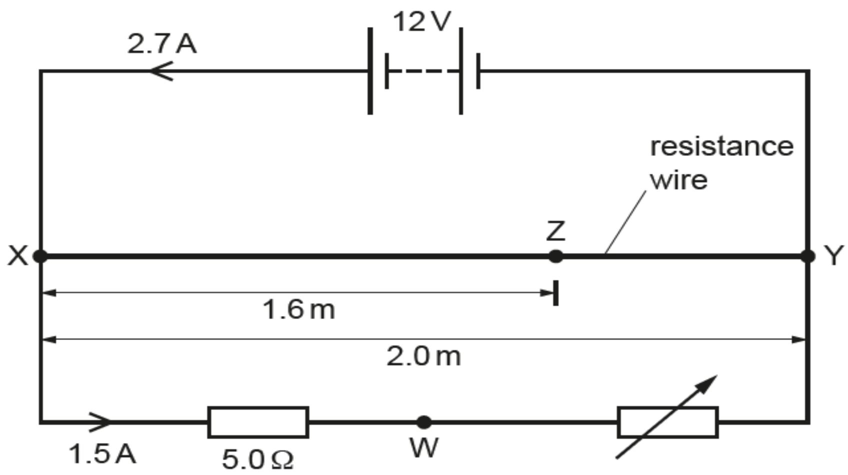

Fig. 6.2 (not to scale)

The fixed resistor has a resistance of 5.0 Ω. The current in the battery is 2.7 A and the current in the fixed resistor is 1.5 A.

The fixed resistor has a resistance of 5.0 Ω. The current in the battery is 2.7 A and the current in the fixed resistor is 1.5 A.

(i) Calculate the current in the resistance wire.

current = ... A [1]

(ii) Determine the resistance of the variable resistor.

resistance = ... Ω [2]

(iii) Wire XY has a length of 2.0 m. Point Z on the wire is a distance of 1.6 m from point X. The fixed resistor is connected to the variable resistor at point W.

Determine the potential difference between points W and Z.

potential difference = ... V [3]

(iv) The resistance of the variable resistor is now increased.

By considering the currents in every part of the circuit, state and explain whether the total power produced by the battery decreases, increases or stays the same.

....

....

....

....

....

.... [3]

[Total: 12]

Question 16

A metal wire in a circuit has a length of 1.8 m and a cross-sectional area of $1.5 \times 10^{-6}\,m^2$.
The total number of free electrons (charge carriers) in the wire is 2.3×10^{23}.

There is a current in the wire so that a charge of 172 C moves past a fixed point in the wire in a time of 2.5 minutes.

(a) Show that the number density of the free electrons in the wire is $8.5 \times 10^{28}\,m^{-3}$.

[1]

(b) Calculate the average drift speed of the free electrons.

average drift speed = ... $m\,s^{-1}$ [3]

[Total: 4]

Question 17

A battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance is connected in series with two fixed resistors and a thermistor, as shown in Fig. 7.1.

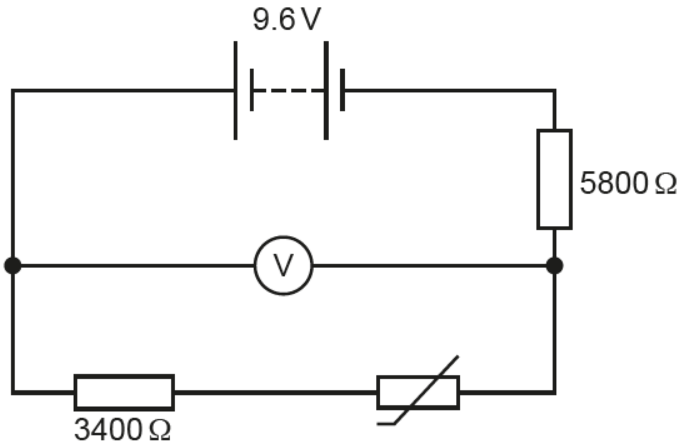

Fig. 7.1

The fixed resistors have resistances of 3400 Ω and 5800 Ω. The reading on the voltmeter in the circuit is 6.0 V.

(a) Calculate the current in the resistor of resistance 5800 Ω.

current = ...A [2]

(b) Calculate the resistance of the thermistor.

resistance = ... Ω [2]

(c) The initial energy stored in the battery is 2.6×10^4 J.

Assume that the e.m.f. of the battery is constant.

Determine the final energy stored in the battery after a charge of 330 C has moved through it.

final stored energy = ... J [2]

(d) The environmental conditions change causing an increase in the resistance of the thermistor.

State whether there is a decrease, increase or no change to:

(i) the temperature of the thermistor

.... [1]

(ii) the current in the thermistor

.... [1]

(iii) the potential difference across the thermistor.

.... [1]

[Total: 9]

Question 18

(a) The current in a filament lamp decreases.

State and explain how the resistance of the lamp changes.

....

.... [1]

(b) A cylindrical wire has length L and resistance R. The **total** number of free electrons (charge carriers) contained in the volume of the wire is N. Each free electron has charge e. The potential difference between the ends of the wire is V.

Determine expressions, in terms of some or all of the symbols e, L, N, R and V for:

(i) the current in the wire

current = ... [1]

(ii) the average drift speed of the free electrons

average drift speed = ... [2]

(iii) the average time taken for a free electron to move along the full length of the wire.

time taken = ... [1]

[Total: 5]

Question 19

(a) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected to a light-dependent resistor (LDR) and a fixed resistor, as shown in Fig. 7.1.

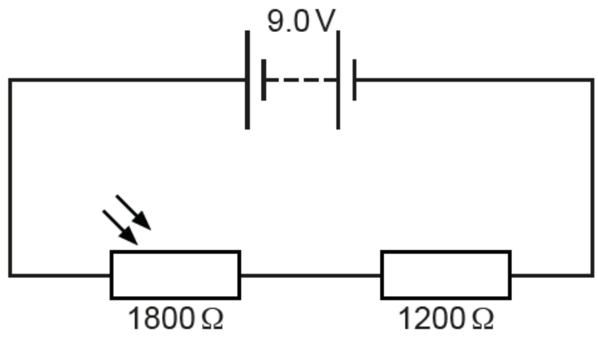

Fig. 7.1

The LDR and fixed resistor have resistances of 1800 Ω and 1200 Ω respectively.

Calculate the potential difference across the LDR.

potential difference = ... V [2]

(b) The circuit in **(a)** is now modified by adding a uniform resistance wire XY and a galvanometer, as shown in Fig. 7.2.

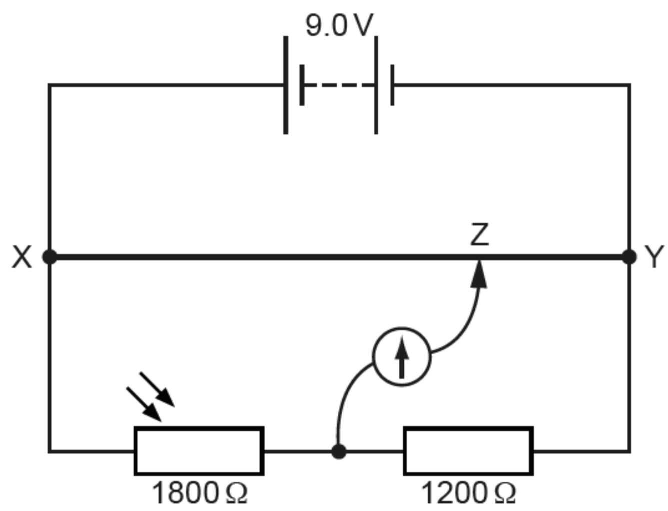

Fig. 7.2 (not to scale)

The length of the wire XY is 1.2 m. The movable connection Z is positioned on the wire XY so that the galvanometer reading is zero.

(i) Calculate the length XZ along the resistance wire.

length XZ = ... m [2]

(ii) The environmental conditions change causing a decrease in the resistance of the LDR. The temperature of the LDR remains constant.

State whether there is a decrease, increase or no change to:

- the intensity of the light illuminating the LDR

....

- the total power produced by the battery

....

- the length XZ so that the galvanometer reads zero.

....
[3]

[Total: 7]

Question 20

A student sets up a circuit with a battery, an ammeter, a heater and a light-dependent resistor (LDR) all in series.

The battery has negligible internal resistance.

A voltmeter is connected across (in parallel with) the heater.

(a) On Fig. 5.1, complete the circuit diagram of this arrangement.

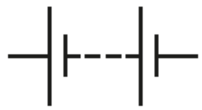

Fig. 5.1

[3]

(b) The heater is a wire made of metal of resistivity $1.1 \times 10^{-6}\,\Omega\,\text{m}$. The wire has length 2.0 m and cross-sectional area $3.8 \times 10^{-7}\,\text{m}^2$.

The reading on the voltmeter is 4.8 V.

Calculate:

(i) the resistance of the heater

resistance = ... Ω [2]

(ii) the reading on the ammeter.

reading on ammeter = ... A [1]

(c) The heater is replaced by a new wire. The new wire is made of the same metal as the wire in **(b)** and has the same length but a larger diameter.

The resistance of the LDR remains constant.

(i) State and explain whether the new wire has a resistance that is greater than, less than or the same as that of the wire in **(b)**.

....

....

.... [2]

(ii) State and explain whether the new reading on the voltmeter is greater than, less than or equal to 4.8 V.

....

....

.... [2]

[Total: 10]

(c) The heater is replaced by a new wire. The new wire is made of the same metal as the wire in **(b)** and has the same length but a larger diameter.

The resistance of the LDR remains constant.

(i) State and explain whether the new wire has a resistance that is greater than, less than or the same as that of the wire in **(b)**.

....

....

.... [2]

(ii) State and explain whether the new reading on the voltmeter is greater than, less than or equal to 4.8 V.

....

....

.... [2]

[Total: 10]

Question 21

A battery is connected in a circuit with a light-dependent resistor (LDR), two fixed resistors and a voltmeter, as shown in Fig. 6.1.

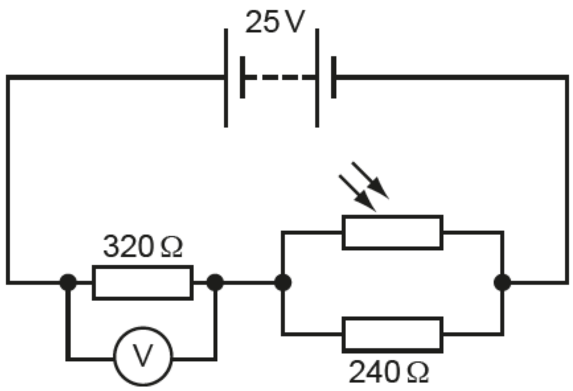

Fig. 6.1

The battery has an electromotive force (e.m.f.) of 25 V and negligible internal resistance.
The resistors have resistances of 320 Ω and 240 Ω.

(a) The voltmeter displays a reading of 16 V.

(i) Show that the current in the battery is 0.050 A.

[1]

(ii) Calculate the resistance of the LDR.

resistance = ... Ω [3]

(iii) Determine the ratio

$$\frac{\text{power dissipated in the LDR}}{\text{power dissipated in the } 240\,\Omega \text{ resistor}}.$$

ratio = ... [2]

(b) The intensity of the light incident on the LDR increases.

State and explain what happens to the voltmeter reading.

....

....

....

.... [3]

[Total: 9]

Question 22

(a) A metal wire has a resistance per unit length of $0.92\,\Omega\,m^{-1}$. The wire has a uniform cross-sectional area of $5.3 \times 10^{-7}\,m^2$.

Calculate the resistivity of the metal of the wire.

resistivity = ... Ωm [2]

(b) A battery of electromotive force (e.m.f.) *E* and negligible internal resistance is connected in series with a fixed resistor and a light-dependent resistor (LDR), as shown in Fig. 6.1.

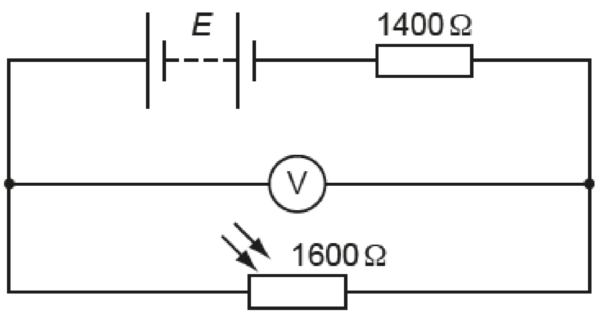

Fig. 6.1

The resistance of the fixed resistor is 1400 Ω. The intensity of the light illuminating the LDR causes it to have a resistance of 1600 Ω. A voltmeter connected across the LDR reads 6.4 V.

(i) Show that the current in the LDR is 4.0×10^{-3} A.

[1]

(ii) Calculate the number of free electrons passing through the LDR in a time of 3.2 minutes.

number of free electrons = ... [2]

(iii) Calculate the e.m.f. E.

E = ... V [2]

(iv) Determine the ratio

$$\frac{\text{power dissipated in LDR}}{\text{power dissipated in fixed resistor}}.$$

ratio = ... [2]

(c) The environmental conditions change causing a decrease in the resistance of the LDR in **(b)**. The temperature of the environment does not change.

State whether there is a decrease, increase or no change to:

(i) the intensity of the light illuminating the LDR

.... [1]

(ii) the current in the battery

.... [1]

(iii) the reading of the voltmeter.

.... [1]

[Total: 12]

Question 23

(a) State Ohm's law.

....

....

.... [2]

(b) A battery of electromotive force (e.m.f.) 6.2 V and negligible internal resistance is connected in a circuit to a uniform resistance wire, a voltmeter, a fixed resistor and a switch, as shown in Fig. 7.1.

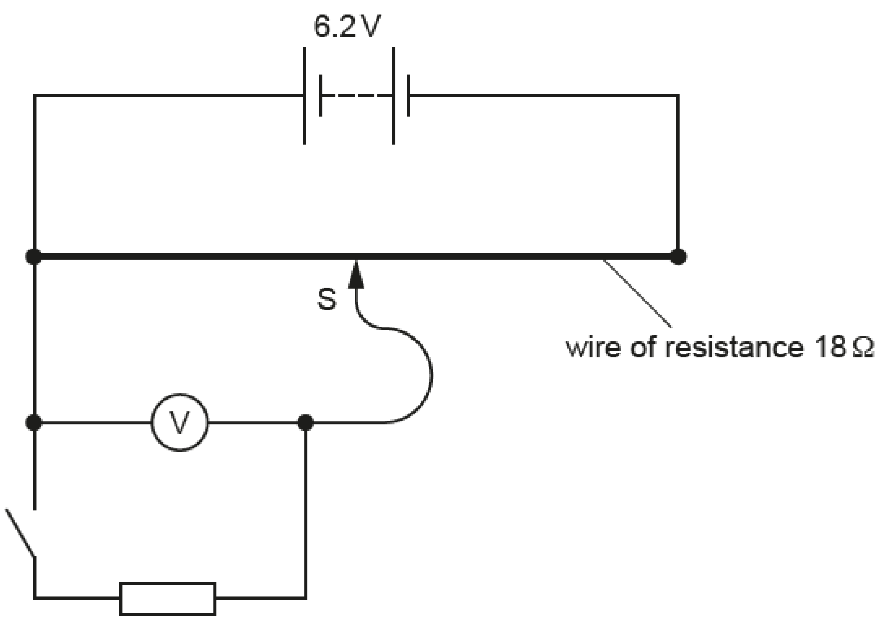

Fig. 7.1

The resistance wire has resistance 18 Ω, length 0.94 m and cross-sectional area $7.2 \times 10^{-8}\,m^2$. The slider S is positioned half-way along the length of the wire.

(i) Calculate the resistivity ρ of the material of the resistance wire.

ρ = ... Ω m [2]

(ii) The switch is open.
State the reading on the voltmeter.

voltmeter reading = ... V [1]

(iii) The switch is now closed.

State whether there is an increase, decrease or no change to:

- the current in the battery

  ....

- the voltmeter reading.

  ....
[2]

(iv) The switch remains closed. The slider S is moved along the resistance wire so that the voltmeter reading is 3.1 V.

On Fig. 7.1, draw a cross (×) on the resistance wire to show a possible new position of the slider. [1]

(iv) The switch remains closed. The slider S is moved along the resistance wire so that the voltmeter reading is 3.1 V.

On Fig. 7.1, draw a cross (×) on the resistance wire to show a possible new position of the slider. [1]

(c) The circuit in **(b)** is altered by changing the battery for one of a different e.m.f. The switch is open.

A student records the following data for the resistance wire:

current in the wire	0.93 A
mean drift speed of charge carriers	$1.3 \times 10^{-3}\,\text{m s}^{-1}$
number density of charge carriers	$9.0 \times 10^{28}\,\text{m}^{-3}$.

(i) Determine the charge q of a charge carrier in the wire suggested by this data.

q = ... C [2]

(ii) With reference to the value of q, explain why the data recorded by the student cannot be correct.

....

.... [1]

[Total: 11]

Question 24

(a) Define electric potential difference.

....

.... [1]

(b) A cell of electromotive force (e.m.f.) 1.8 V and internal resistance *r* is connected in parallel with a resistor of resistance 6.0 Ω and a filament lamp, as shown in Fig. 7.1.

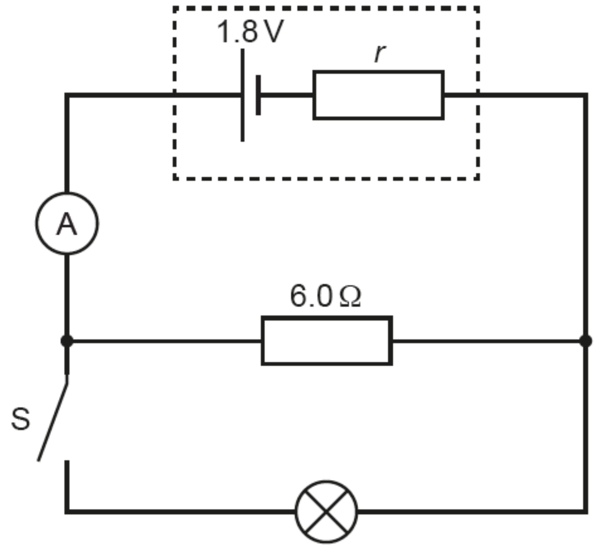

Fig. 7.1

The switch S is open. The ammeter reading is 0.25 A.

Determine the internal resistance *r* of the cell.

r = ... Ω [3]

(c) At time t_1 switch S in Fig. 7.1 is closed. Fig. 7.2 shows the variation with time t of the ammeter reading I.

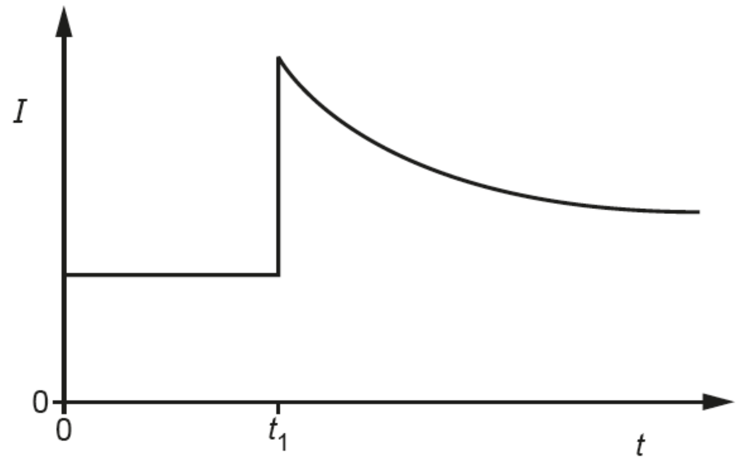

Fig. 7.2

(i) State whether the e.m.f. of the cell after t_1 is greater than, less than or the same as it was before t_1.

.... [1]

(ii) By considering the effect of the lamp on the total resistance of the circuit, explain the variation of the ammeter reading shown in Fig. 7.2.

....

....

....

....

....

.... [3]

[Total: 8]

Question 25

(a) State Kirchhoff's first law.

....

.... [1]

(b) A cell with internal resistance r is connected to two resistors of resistances R_1 and R_2 as shown in Fig. 6.1.

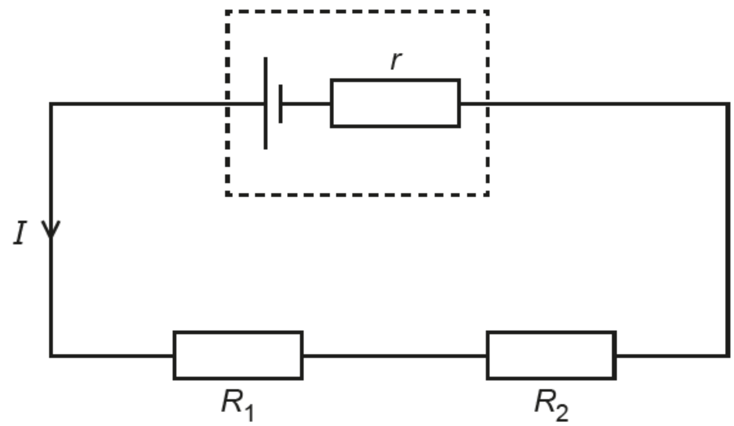

Fig. 6.1

The potential differences (p.d.s) across R_1 and R_2 are V_1 and V_2 respectively.
The terminal p.d. across the cell is V.
The current in the circuit is I.

Use Kirchhoff's laws to show that the total resistance R_T of the external circuit is given by

$$R_T = R_1 + R_2 .$$

[2]

(c) The electromotive force (e.m.f.) of the cell in Fig. 6.1 is 1.50 V.

The values of R_1 and R_2 are 10 Ω and 15 Ω respectively. The terminal p.d. of the cell is 1.35 V.

Calculate the internal resistance r of the cell.

r = ... Ω [3]

(d) A resistor of resistance R_3 is added to the circuit in Fig. 6.1, so that the circuit is as shown in Fig. 6.2.

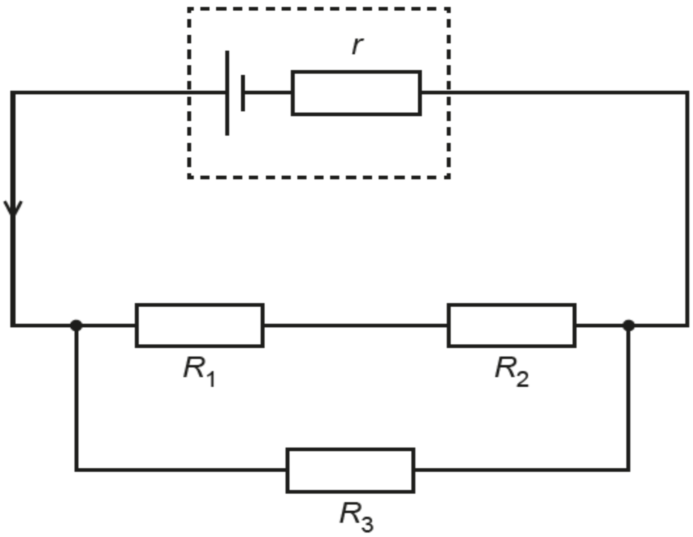

Fig. 6.2

State and explain the effect, if any, of this change on:

State and explain the effect, if any, of this change on:

(i) the current in the cell

....

....

.... [2]

(ii) the terminal p.d. of the cell.

....

....

.... [2]

[Total: 10]

Question 26

(a) State Kirchhoff's second law.

....

.... [1]

(b) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a variable resistor X and a thermistor Y as shown in Fig. 5.1.

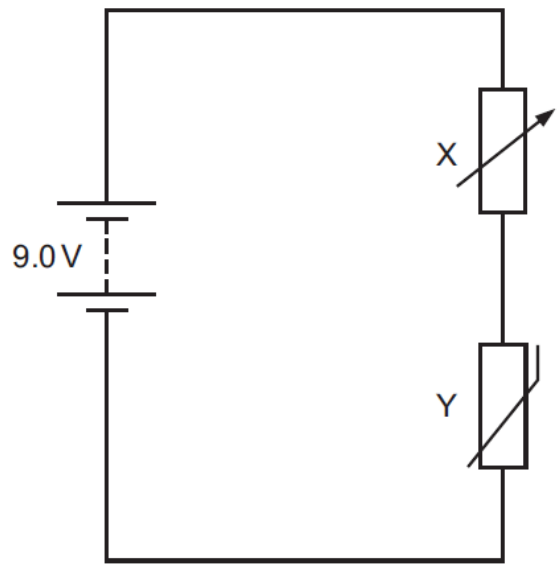

Fig. 5.1

Fig. 5.2 shows the relationship between temperature and resistance for the thermistor.

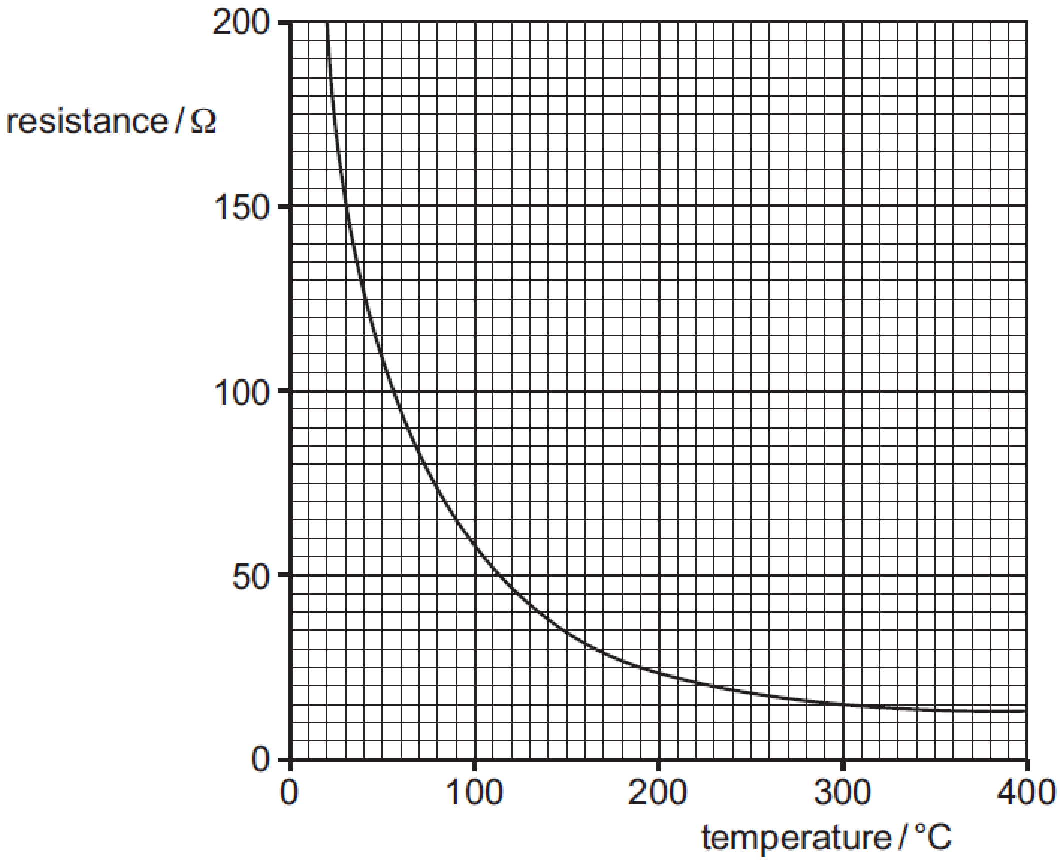

Fig. 5.2

(i) The current in the circuit is 1.1×10^{-2} A. The potential difference across Y is 4.0 V.

Calculate the resistance of X.

resistance = ... Ω [2]

(ii) The temperature of Y is changed to 190 °C. The resistance of X remains unchanged.

Determine the new potential difference across Y.

potential difference = ... V [3]

(iii) The resistance of X is increased. The temperature of Y remains at 190 °C.

By reference to the current in the circuit, state and explain the effect of this change, if any, on the potential difference **across Y**.

....

....

....

....

....

.... [3]

[Total: 9]

Question 27

(a) **(i)** State Kirchhoff's second law.

....

....

.... [1]

(ii) State the conservation law that gives rise to Kirchhoff's second law.

.... [1]

(b) A circuit contains a cell of internal resistance r and two resistors of resistances R_1 and R_2, as shown in Fig. 5.1.

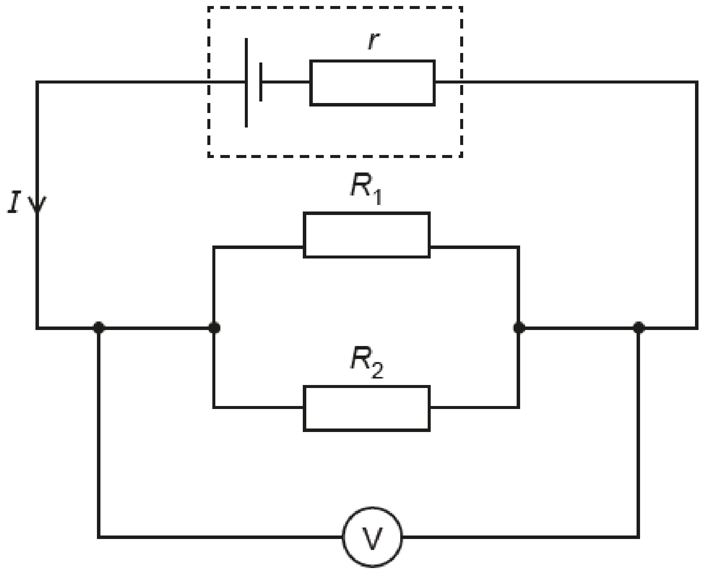

Fig. 5.1

The potential difference (p.d.) across the two resistors is V.

The current in the cell is I.

(i) Use Kirchhoff's laws to show that the total resistance R_T of the external circuit is given by

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}.$$

[2]

(ii) The electromotive force (e.m.f.) of the cell is 1.50 V.

When the values of R_1 and R_2 are 10 Ω and 15 Ω respectively, the p.d. measured by the voltmeter is 1.38 V.

Calculate the internal resistance r of the cell.

r = ... Ω [3]

(c) A third resistor is added in parallel with R_1 and R_2 in the circuit in Fig. 5.1.

State and explain the effect, if any, of this change on:

(i) the current in the cell

....

....

.... [2]

(ii) the p.d. measured by the voltmeter.

....

....

.... [2]

[Total: 11]

Question 28

(a) Fig. 7.1 shows two resistors connected in series with a cell of electromotive force (e.m.f.) 1.50 V and internal resistance 0.28 Ω.

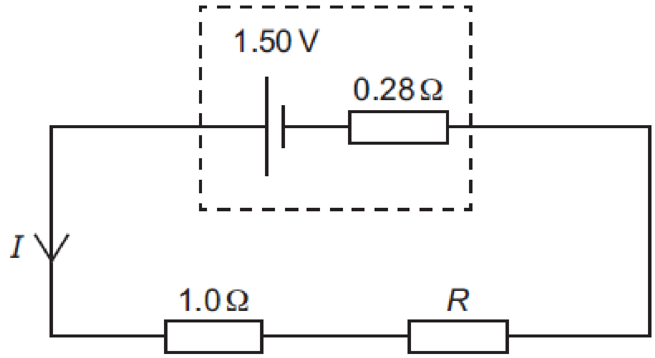

Fig. 7.1

One of the resistors has resistance 1.0 Ω. The other resistor has resistance *R*.
The terminal potential difference (p.d.) across the cell is 1.36 V.

(i) Show that the current *I* in the circuit is 0.50 A.

[2]

(ii) Calculate the combined resistance of the two resistors.

resistance = ... Ω [2]

(iii) Use your answer in **(a)(ii)** to determine resistance *R*.

R = ... Ω [1]

(b) The circuit in Fig. 7.1 is disconnected and the two resistors are reconnected to the cell, now in parallel with each other.

(i) On Fig. 7.2, complete the circuit diagram to show this arrangement.

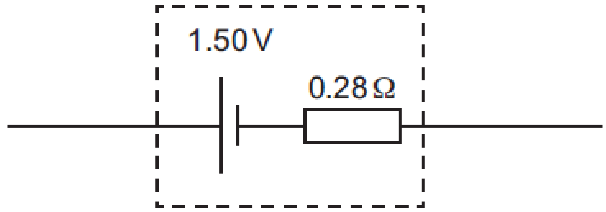

Fig. 7.2

[1]

(ii) Explain, without calculation, whether the terminal p.d. across the cell is now less than, equal to or greater than 1.36 V.

....

....

.... [2]

[Total: 8]

Question 29

(a) Define electric potential difference (p.d.).

....

.... [1]

(b) A power supply, three resistors and a component X are connected in the circuit shown in Fig. 5.1.

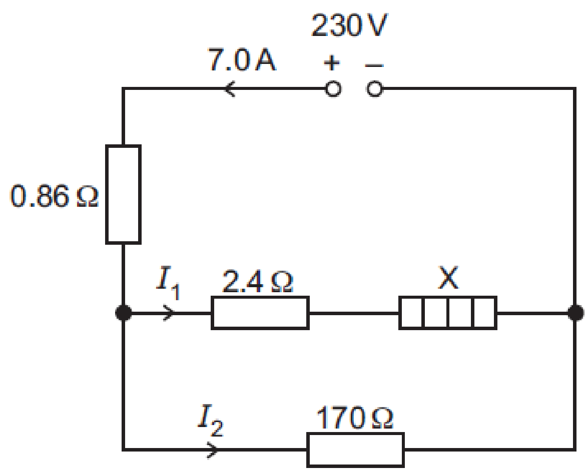

Fig. 5.1

The power supply has an electromotive force (e.m.f.) of 230 V and negligible internal resistance. The current in the power supply is 7.0 A.

(i) Identify component X.

.... [1]

(ii) Show that the p.d. across the resistor of resistance 0.86 Ω is 6.0 V.

[1]

(iii) Determine the current I_1.

I_1 = ... A [2]

(iv) Calculate the p.d. across component X.

p.d. = ... V [2]

(v) Calculate the power dissipated in component X.

power = ... W [2]

(vi) The purpose of the circuit is to provide power to component X.

Determine the percentage efficiency of the circuit.

efficiency = ...% [2]

(vii) The resistor of resistance 170 Ω is removed, leaving an open circuit in the lower branch of the circuit. There is no change to the resistance of component X.

State whether the current in the power supply increases, decreases or remains the same.

.... [1]

[Total: 12]

Question 30

(a) Define resistance.

....

.... [1]

(b) A cylindrical metal wire of length 2.4 m and cross-sectional area $8.0 \times 10^{-6}\,m^2$ has a resistance of $0.33\,\Omega$. There is a current in the wire of 4.7 A.

(i) Determine the resistivity of the metal from which the wire is made.

resistivity = ... Ωm [2]

(ii) Calculate the charge that passes through the wire in a time of 5.0 minutes.

charge = ... C [2]

(iii) The free electrons (charge carriers) in the wire have an average drift speed of $0.16\,\text{mm}\,\text{s}^{-1}$.

Determine the number density of charge carriers in the metal.

number density = ... m^{-3} [2]

(c) The wire in **(b)** may be considered to be a fixed resistor. It is connected in series with a thermistor to a battery that has negligible internal resistance.

(i) Use circuit symbols to complete Fig. 6.1 to show the circuit diagram of this arrangement.

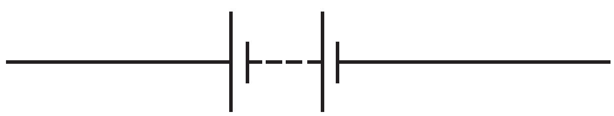

Fig. 6.1

[1]

(ii) Explain, without calculation, how the power dissipated in the wire changes as the temperature of the thermistor is increased.

....

....

....

.... [2]

[Total: 10]

Question 31

A cylindrical copper wire P of length 0.24 m is shown in Fig. 6.1.

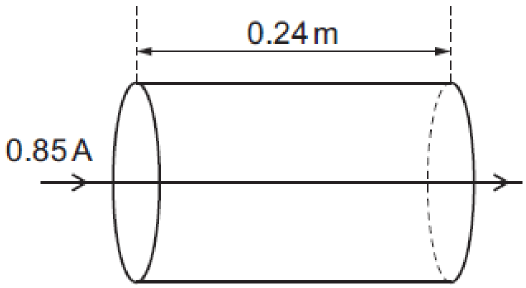

Fig. 6.1 (not to scale)

The current in the wire is 0.85 A.
The resistance of the wire is 3.3 mΩ.
The **total** number of charge carriers *N* in the wire is 2.6×10^{22}.
The resistivity of copper is 1.8×10^{-8} Ω m.

(a) Calculate the potential difference between the two ends of the wire.

potential difference = ... V [2]

(b) **(i)** Show that the cross-sectional area of the wire is $1.3 \times 10^{-6}\,m^2$.

[2]

(ii) Show that the number density of charge carriers in the wire is $8.3 \times 10^{28}\,m^{-3}$.

[1]

(iii) Calculate the average drift speed of the charge carriers (electrons) in the wire.

average drift speed = ... $m\,s^{-1}$ [2]

(c) A different copper wire Q has the same volume as wire P, but non-uniform radius, as shown in Fig. 6.2.

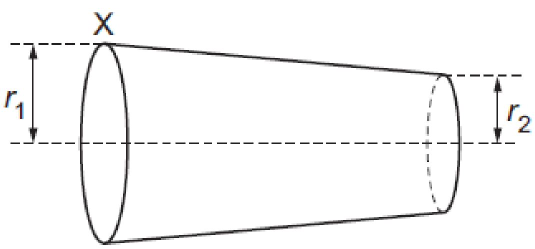

Fig. 6.2 (not to scale)

The radius r_1 at end X of wire Q is the same as the radius of wire P. Radius r_2 is less than r_1.

(i) State and explain how the resistance of wire Q compares with the resistance of wire P.

....

....

....

....

....

....

.... [4]

(ii) On Fig. 6.3, sketch a graph of the variation of the average drift speed of the charge carriers with distance from end X of wire Q.

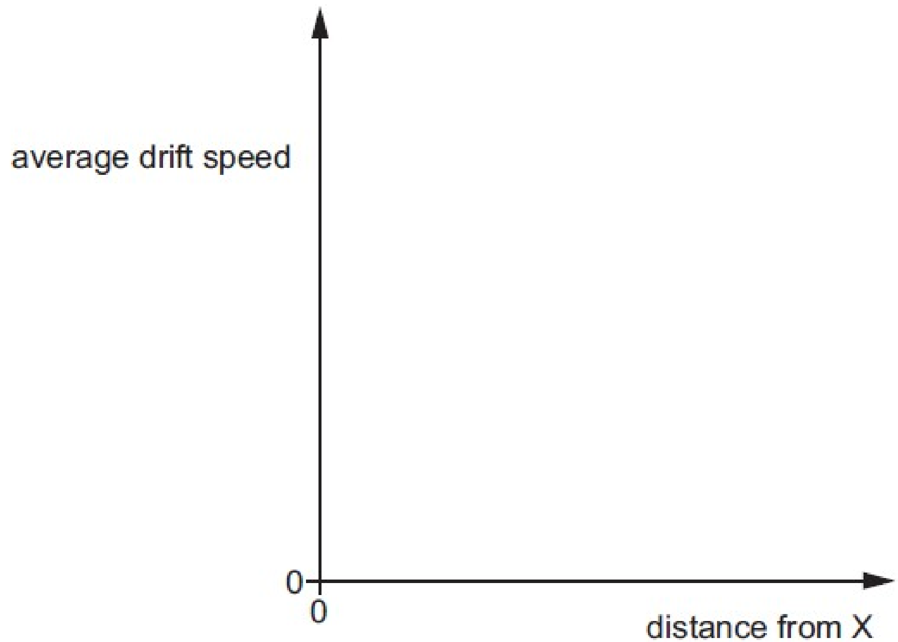

Fig. 6.3

[2]

[Total: 13]

Question 32

A nichrome wire X of length 45 cm and cross-sectional area $4.7 \times 10^{-7}\,m^2$ is connected into the circuit shown in Fig. 6.1.

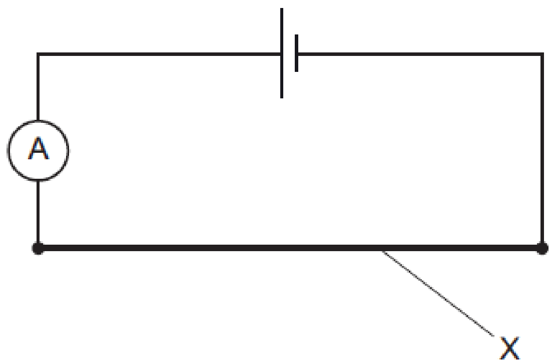

Fig. 6.1

The resistance of X is 1.1 Ω. The cell has electromotive force (e.m.f.) 1.3 V and negligible internal resistance.

(a) **(i)** Calculate the current in X.

current = ... A [1]

(ii) The number density of charge carriers (electrons) in nichrome is $8.5 \times 10^{28}\,m^{-3}$.

Calculate the average drift speed of the charge carriers in X.

average drift speed = ... $m\,s^{-1}$ [2]

(iii) Calculate the resistivity of the nichrome.

resistivity = ... $\Omega\,m$ [3]

(b) Wire Y is identical to wire X. Wire Y is added to the circuit in parallel with wire X, as shown in Fig. 6.2.

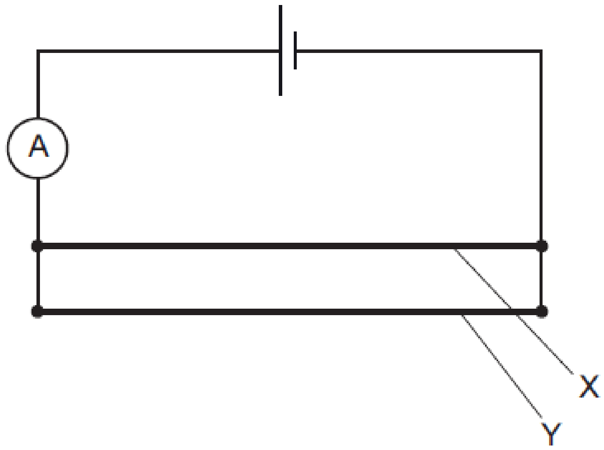

Fig. 6.2

State and explain the effect, if any, of this change on:

(i) the reading on the ammeter

....

....

.... [2]

(ii) the average drift speed of the charge carriers in X.

....

.... [1]

[Total: 9]

Question 33

(a) Define electric potential difference across a component.

....

.... [1]

(b) A circuit contains four resistors and a battery of electromotive force (e.m.f.) 8.0 V with negligible internal resistance. When the variable resistor has resistance *R*, the currents in the circuit are 0.030 A, I_1 and I_2, as shown in Fig. 6.1.

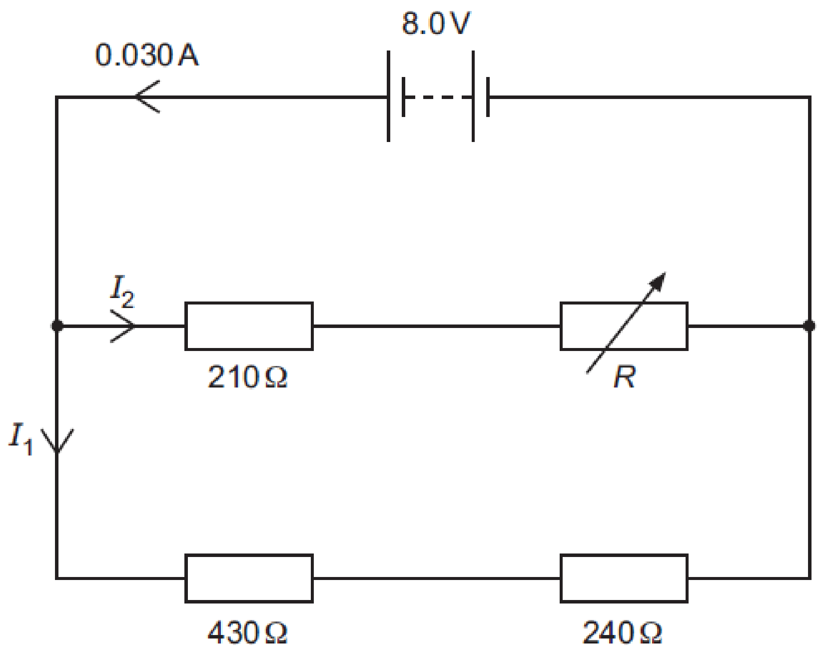

Fig. 6.1

(i) Determine the charge passing through the battery in a time of 4.0 minutes.

charge = ... C [2]

(ii) Calculate I_1.

I_1 = ... A [2]

(iii) Calculate I_2.

I_2 = ... A [1]

(iv) Determine R.

R = ... Ω [2]

(c) The variable resistor in **(b)** is fitted with a scale so that its resistance can be accurately determined.

The resistor of resistance 240 Ω is now replaced by a new resistor X of unknown resistance. A galvanometer is connected as shown in Fig. 6.2.

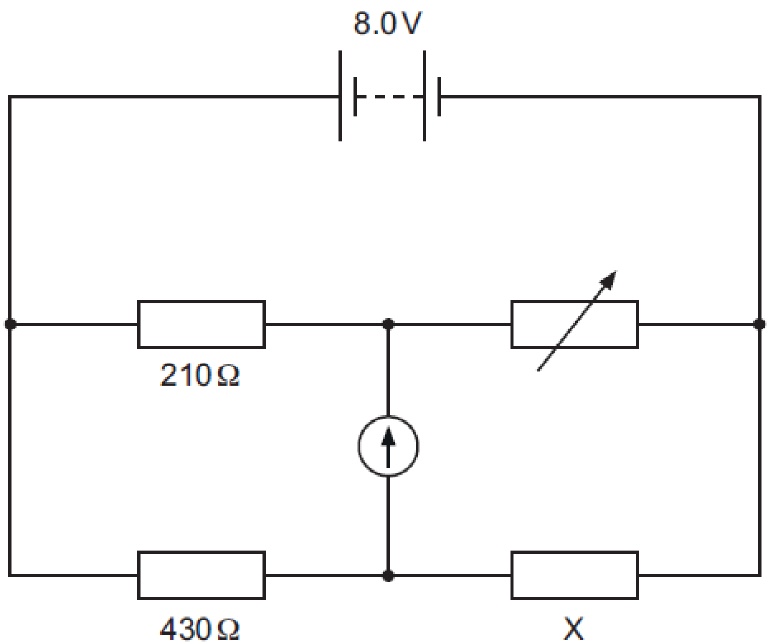

Fig. 6.2

With reference to ratios of resistances, explain how this circuit can be used to determine the resistance of X.

....

....

....

....

.... [2]

[Total: 10]

Question 34

A nichrome resistance wire has length 150 cm, cross-sectional area $2.45 \times 10^{-7}\,m^2$ and resistivity $1.12 \times 10^{-6}\,\Omega\,m$.

(a) Calculate, to three significant figures, the resistance of the wire.

resistance = ... Ω [3]

(b) The nichrome wire forms part of a potentiometer circuit together with a cell of electromotive force (e.m.f.) 1.2 V and negligible internal resistance, as shown in Fig. 7.1.

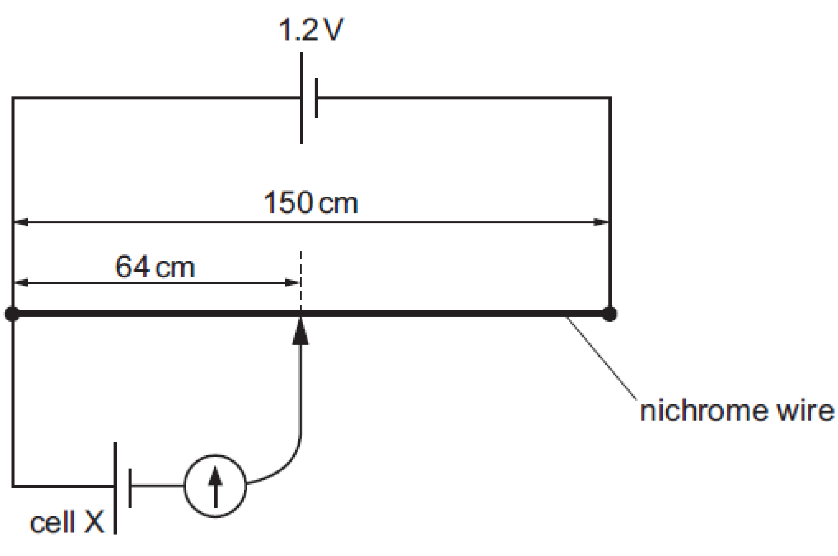

Fig. 7.1 (not to scale)

The circuit is used to determine the e.m.f. of cell X.

The galvanometer is used in a null method to find the null point 64 cm from the left-hand end of the nichrome wire.

(i) Explain what is meant by a null method.

....

.... [1]

(ii) Calculate the e.m.f. of cell X.

e.m.f. = ... V [2]

(iii) The cell of e.m.f. 1.2 V is replaced by a new cell with the same e.m.f. but with an internal resistance that is **not** negligible.

State and explain the effect, if any, of the internal resistance of the new cell on the position of the null point.

....

....

....

.... [2]

[Total: 8]

Question 35

(a) **(i)** State and explain the effect, if any, on the resistance of a filament wire in a lamp as the current in the wire decreases.

....

.... [1]

(ii) On Fig. 5.1, sketch the *I*–*V* characteristic of a filament lamp.

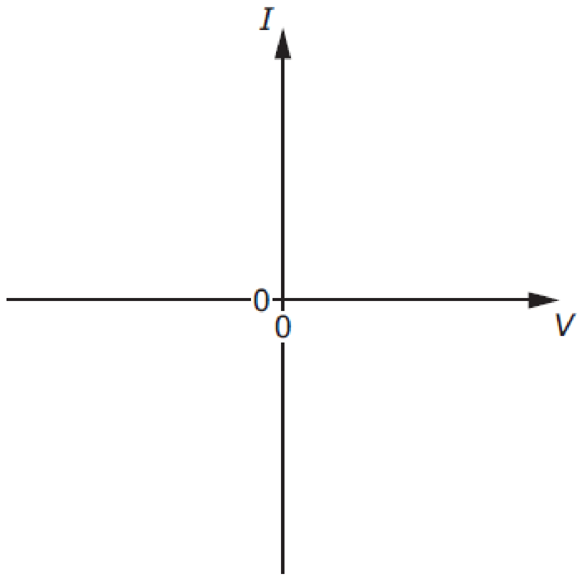

Fig. 5.1

[2]

(b) A battery of electromotive force (e.m.f.) *E* and negligible internal resistance is connected in parallel with two filament lamps A and B, as shown in Fig. 5.2.

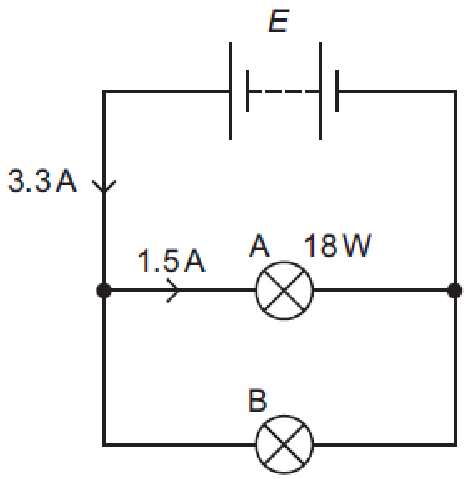

Fig. 5.2

The current in the battery is 3.3 A and the current in lamp A is 1.5 A. The power dissipated in lamp A is 18 W.

(i) Calculate the e.m.f. *E* of the battery.

E = ... V [2]

(ii) The filament wire of lamp B has a cross-sectional area of $1.4 \times 10^{-9}\,m^2$. The number of free (conduction) electrons per unit volume in the metal of the filament wire is $3.4 \times 10^{28}\,m^{-3}$.

Calculate the average drift speed of the free electrons in the filament wire of lamp B.

average drift speed = ... $m\,s^{-1}$ [3]

[Total: 8]

Question 36

A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected in series with a variable resistor and a uniform resistance wire XY, as shown in Fig. 6.1.

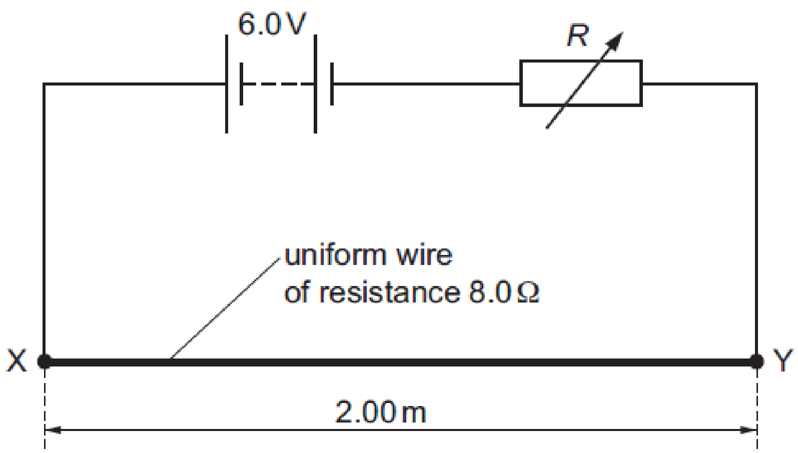

Fig. 6.1

Wire XY has length 2.00 m and resistance 8.0 Ω. The resistance *R* of the variable resistor is adjusted so that the potential difference across wire XY is 2.4 V.

(a) Determine *R*.

R = ... Ω [2]

(b) Explain why the potential difference *V* between any two points on wire XY is proportional to the distance *L* between those points.

....

....

....

.... [2]

(c) A cell of e.m.f. E and internal resistance r is connected to the circuit, as shown in Fig. 6.2.

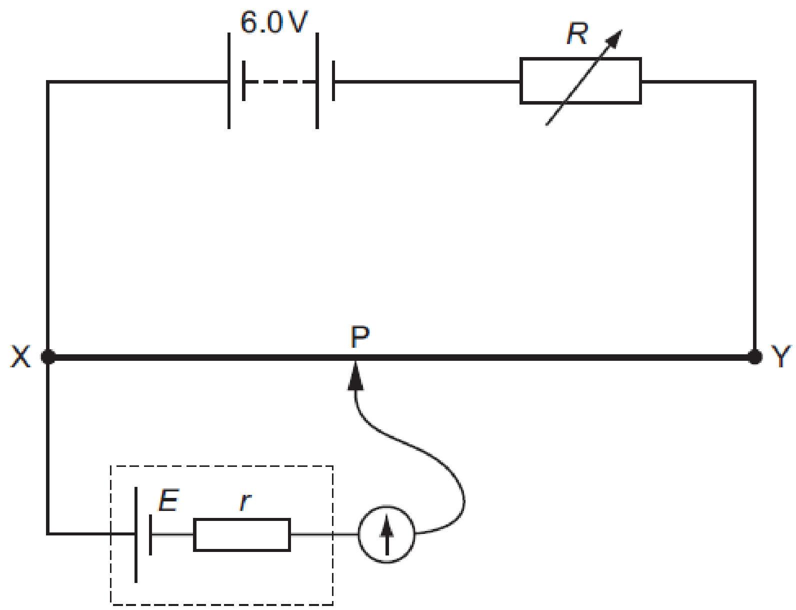

Fig. 6.2

Resistance R is unchanged.
The movable connection P is positioned on wire XY so that the galvanometer reading is zero.
Distance XP is 1.24 m.

(i) Calculate E.

E = ... V [2]

(ii) The value of R is now decreased.

State and explain the change that must be made to the position of P on wire XY so that the galvanometer reads zero again.

....

....

....

.... [2]

[Total: 8]

Question 37

(a) State Kirchhoff's first law.

....

.... [1]

(b) Fig. 5.1 shows a circuit containing a thermistor T that has a negative temperature coefficient.

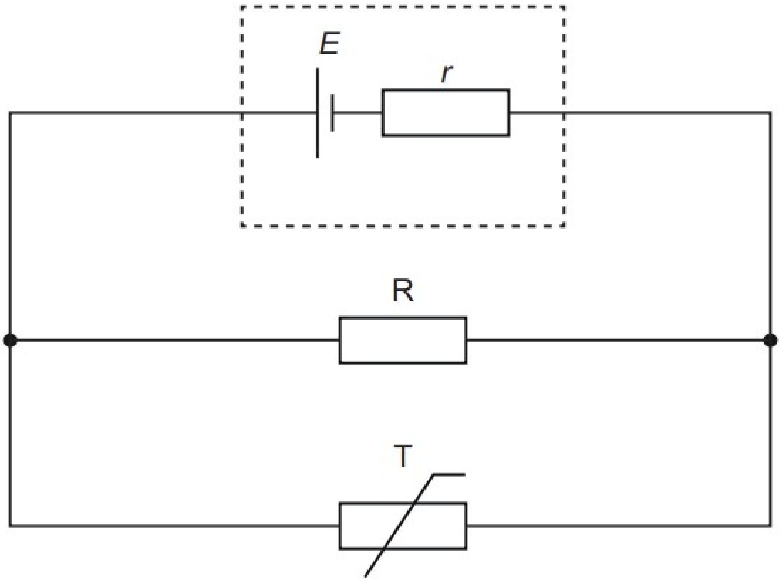

Fig. 5.1

(i) The thermistor has resistance R_0 at a temperature of 0 °C.

On Fig. 5.2, sketch a possible variation of the resistance of the thermistor with temperature between 0 °C and 100 °C.

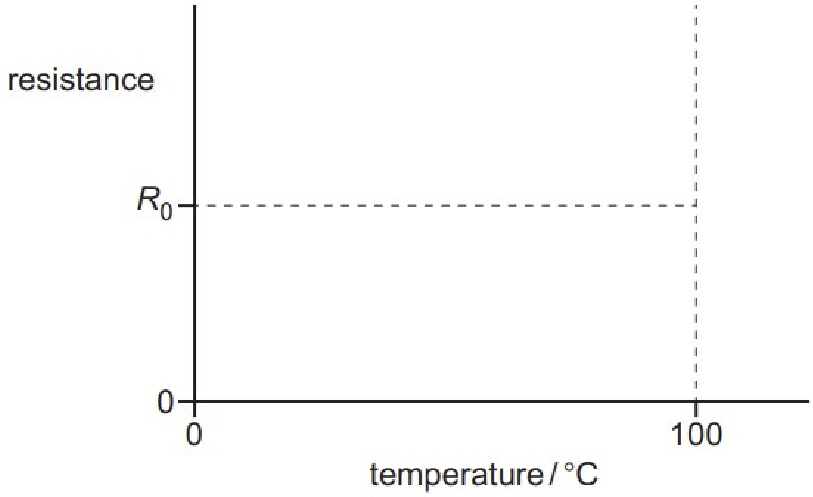

Fig. 5.2

[2]

(ii) With reference to the current in the cell, explain why the current in **resistor R** decreases with increasing temperature of the thermistor.

....

....

....

....

.... [3]

(c) The electromotive force (e.m.f.) E of the cell in Fig. 5.1 is 1.50 V. The internal resistance r of the cell is 0.12 Ω.

Resistor R has a resistance of 6.00 Ω.

At a particular temperature of the thermistor, the current in R is 0.200 A.

For this temperature of the thermistor, determine:

At a particular temperature of the thermistor, the current in R is 0.200A.

For this temperature of the thermistor, determine:

(i) the current in the cell

current = ... A [2]

(ii) the resistance of the thermistor.

resistance = ... Ω [2]

[Total: 10]

Question 38

Fig. 5.1 shows a circuit containing a battery, two fixed resistors X and Y, and a light-dependent resistor (LDR) Z.

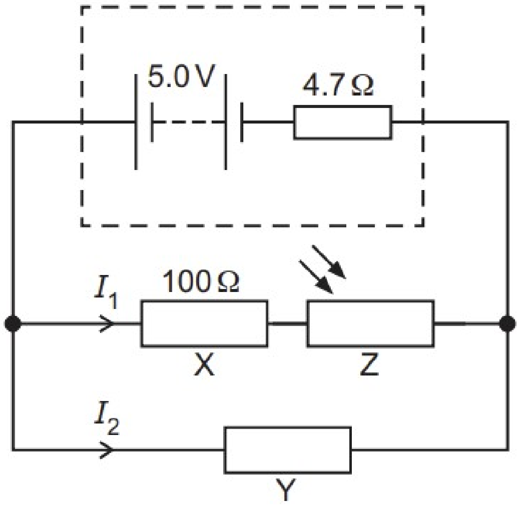

Fig. 5.1

The battery has electromotive force (e.m.f.) 5.0 V and internal resistance 4.7 Ω. The current in X is I_1 and the current in Y is I_2.

The resistance of X is 100 Ω. The resistance of Z varies with the intensity of light incident on it as shown in Fig. 5.2.

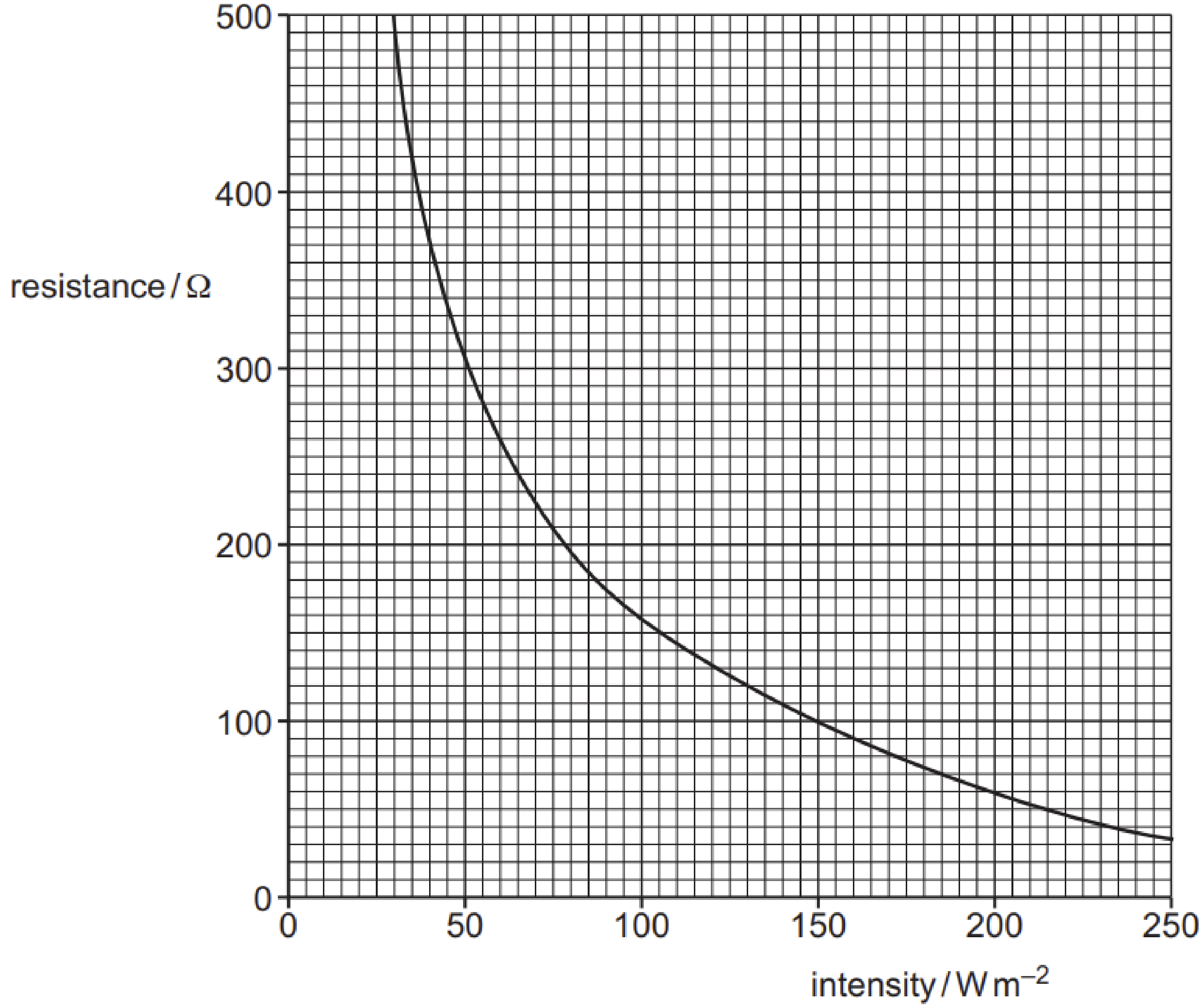

Fig. 5.2

(a) State Kirchhoff's first law.

....

.... [1]

(b) The intensity of light incident on Z is 130 $W\,m^{-2}$. The current in the battery is 38 mA.

(i) Show that the terminal potential difference of the battery is 4.8 V.

[2]

(ii) Calculate the current I_2 in Y.

I_2 = ... A [3]

(iii) Calculate the power dissipated in Y.

power = ... W [2]

(iv) The intensity of the light incident on Z decreases.

State and explain the effect on the terminal potential difference of the battery.

....

....

....

....

.... [3]

[Total: 11]

Question 39

(a) State Kirchhoff's first law.

....

.... [1]

(b) Fig. 5.1 shows a circuit containing a thermistor T that has a negative temperature coefficient.

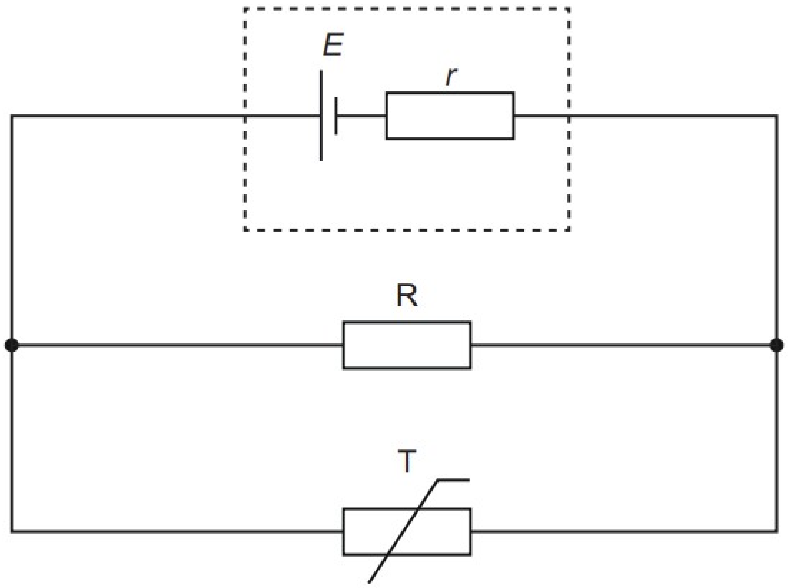

Fig. 5.1

(i) The thermistor has resistance R_0 at a temperature of 0 °C.

(i) The thermistor has resistance R_0 at a temperature of 0 °C.

On Fig. 5.2, sketch a possible variation of the resistance of the thermistor with temperature between 0 °C and 100 °C.

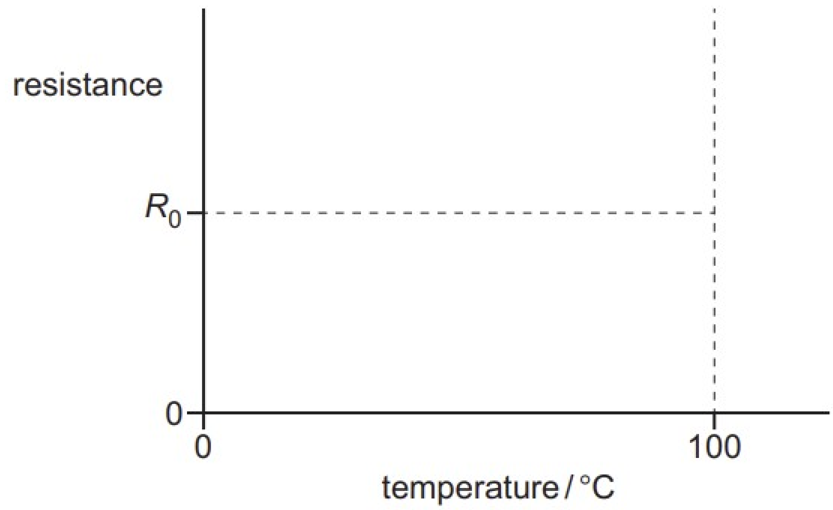

Fig. 5.2

[2]

(ii) With reference to the current in the cell, explain why the current in **resistor R** decreases with increasing temperature of the thermistor.

....

....

....

....

.... [3]

(c) The electromotive force (e.m.f.) E of the cell in Fig. 5.1 is 1.50 V. The internal resistance r of the cell is 0.12 Ω.

Resistor R has a resistance of 6.00 Ω.

At a particular temperature of the thermistor, the current in R is 0.200 A.

For this temperature of the thermistor, determine:

(i) the current in the cell

current = ... A [2]

(ii) the resistance of the thermistor.

resistance = ... Ω [2]

[Total: 10]

Question 40

A student uses a circuit containing an ammeter, a voltmeter and a cell to take measurements to determine the resistance of a length of nichrome wire.

(a) **(i)** Define resistance.

....

.... [1]

(ii) Draw a circuit diagram to show how the components should be connected. Use the symbol for a resistor to represent the nichrome wire.

[2]

(b) The student also measures the length and the diameter of the wire. Table 5.1 shows the measurements recorded for each quantity.

Table 5.1

quantity	measurement
length	(0.864 ± 0.001) m
diameter	(0.496 ± 0.002) mm
voltmeter reading	(1.38 ± 0.02) V
ammeter reading	(0.276 ± 0.001) A

(i) Show that the resistance of the wire is $5.00\,\Omega$.

[1]

(ii) Calculate, to three significant figures, the resistivity ρ of the nichrome.

ρ = ... Ωm [3]

(iii) Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... % [2]

(iv) Determine the absolute uncertainty in ρ.

absolute uncertainty = ... Ω m [1]

[Total: 10]

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