1. **(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.

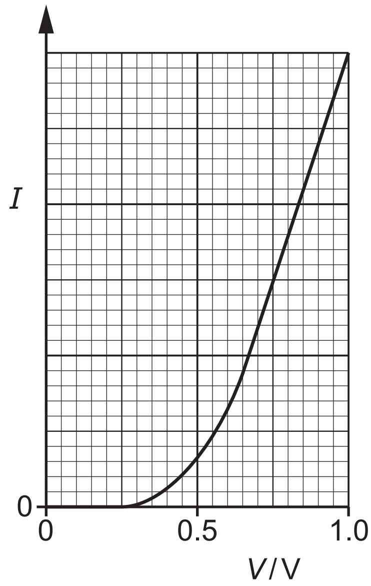

Fig. 6.1

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.

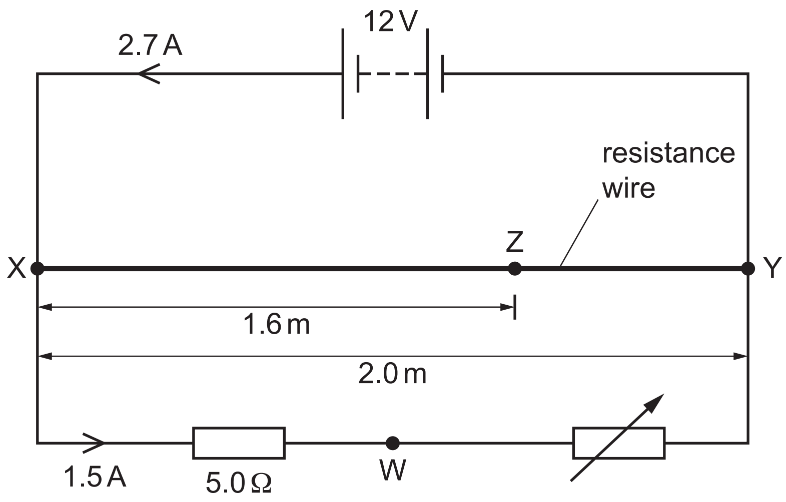

Fig. 6.2 (not to scale)

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.

(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]

2. **(a)** Define electric potential difference.

....

.... [1]

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

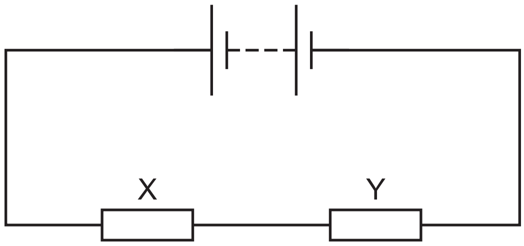

Fig. 6.1

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.

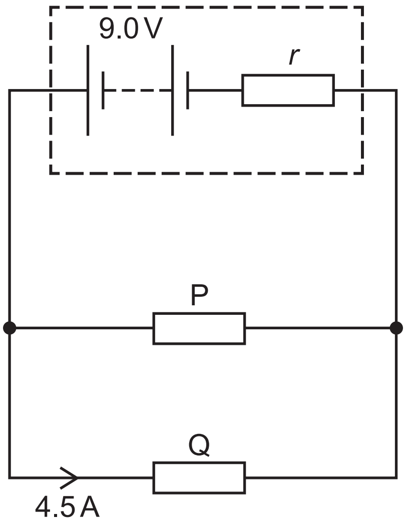

Fig. 6.2

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]

3. (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.

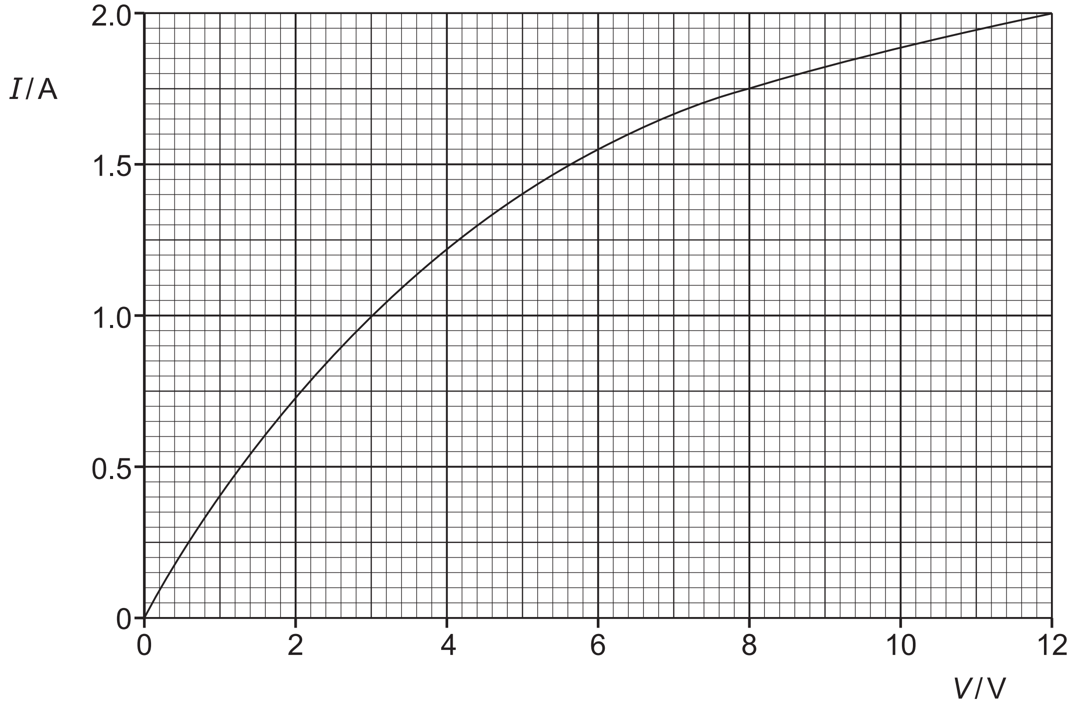

Fig. 5.1

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.

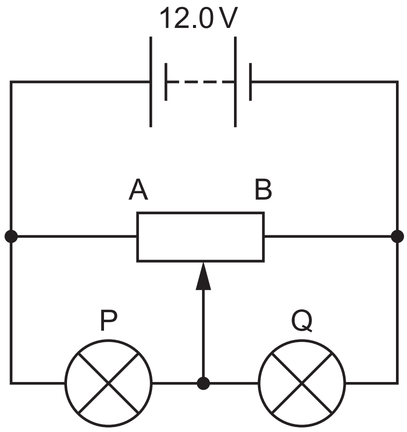

Fig. 5.2

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 1.78 A.

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]

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

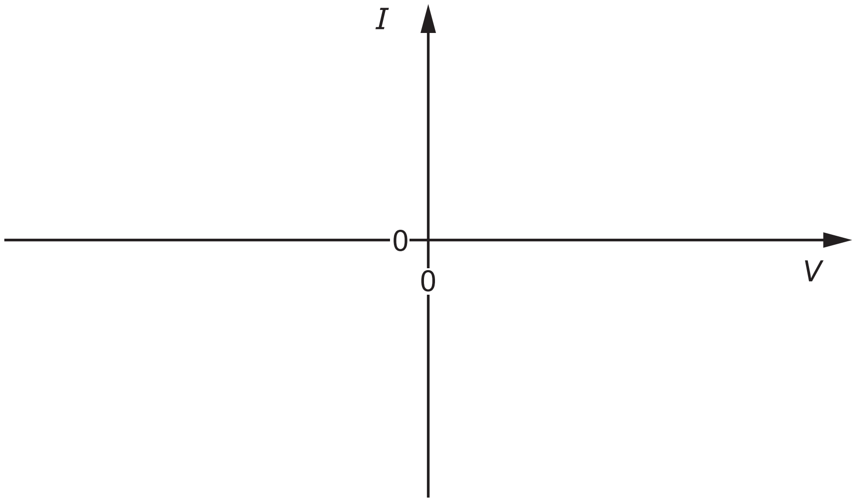

Fig. 6.1

[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 $3.4 \times 10^{-8}\,\text{m}^2$. The resistivity of the metal of the wire is $5.6 \times 10^{-8}\,\Omega\,\text{m}$.

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 2*R* and three ammeters X, Y and Z. The circuit is shown in Fig. 6.2.

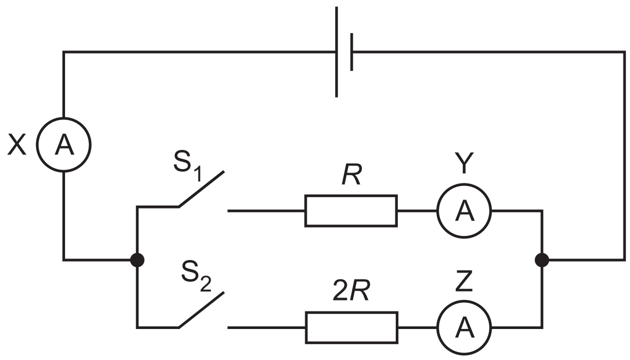

Fig. 6.2

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

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]

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

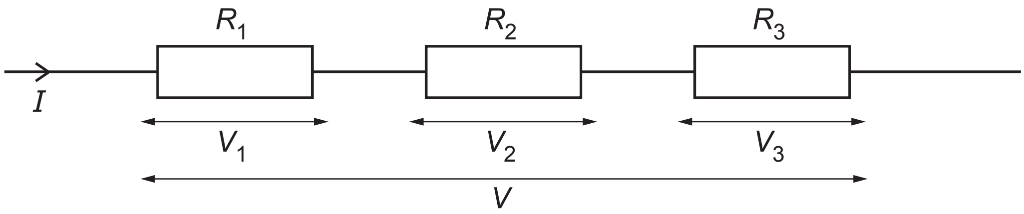

Fig. 6.1

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.

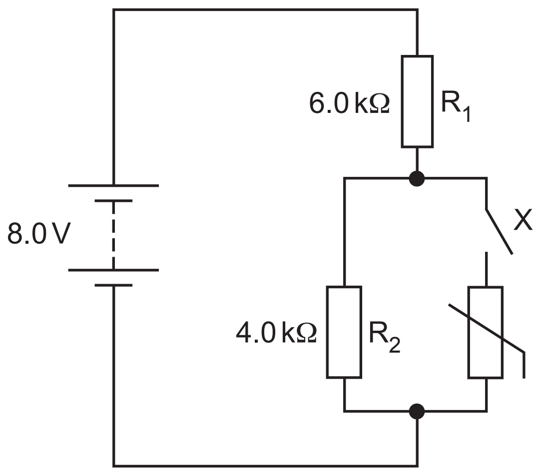

Fig. 6.2

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]

6. **(a)** State Kirchhoff's first law.

....

.... [1]

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

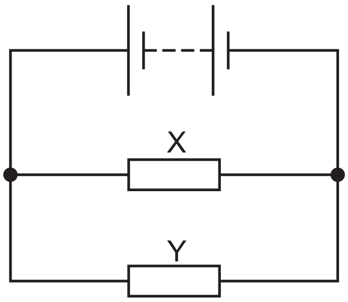

Fig. 6.1

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.

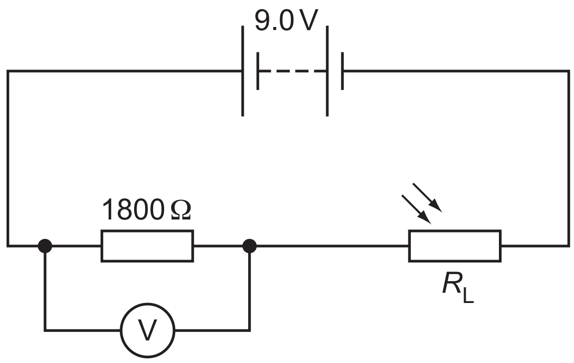

Fig. 6.2

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]

7. 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.

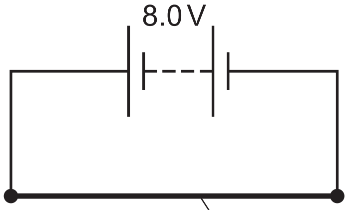

Fig. 6.1

The power dissipated by the resistance wire is 36 W.

(a) Calculate:

(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 $1.4 \times 10^{-6}\,\Omega\,\text{m}$. The cross-sectional area of the wire is $0.25\,\text{mm}^2$.

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.

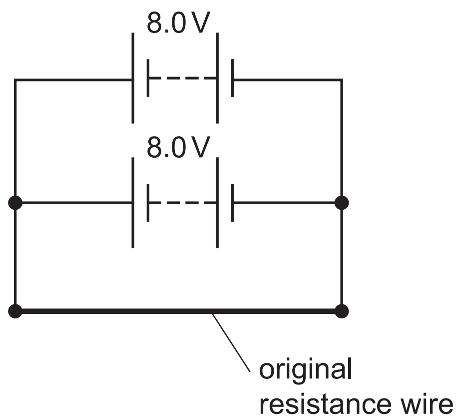

Fig. 6.2

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]

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

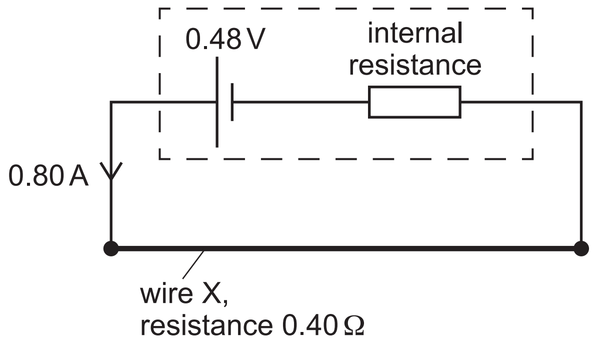

Fig. 6.1

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

Wire X has length 3.0 m, cross-sectional area $1.3 \times 10^{-7}\,\text{m}^2$ 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]

9. **(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*.

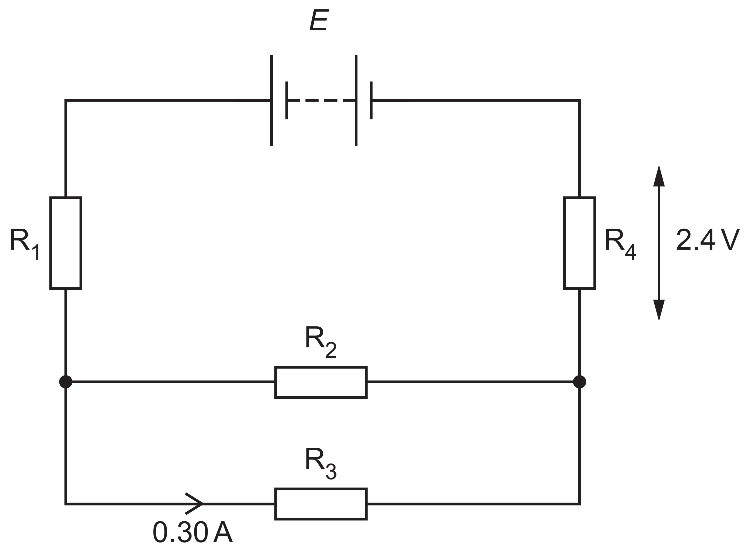

Fig. 5.1

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]

10. (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.

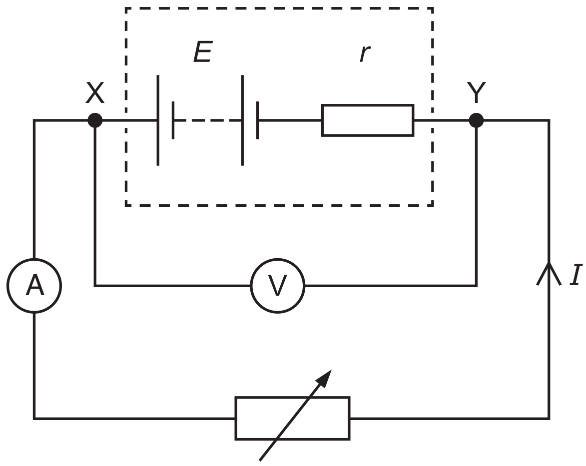

Fig. 5.1

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.

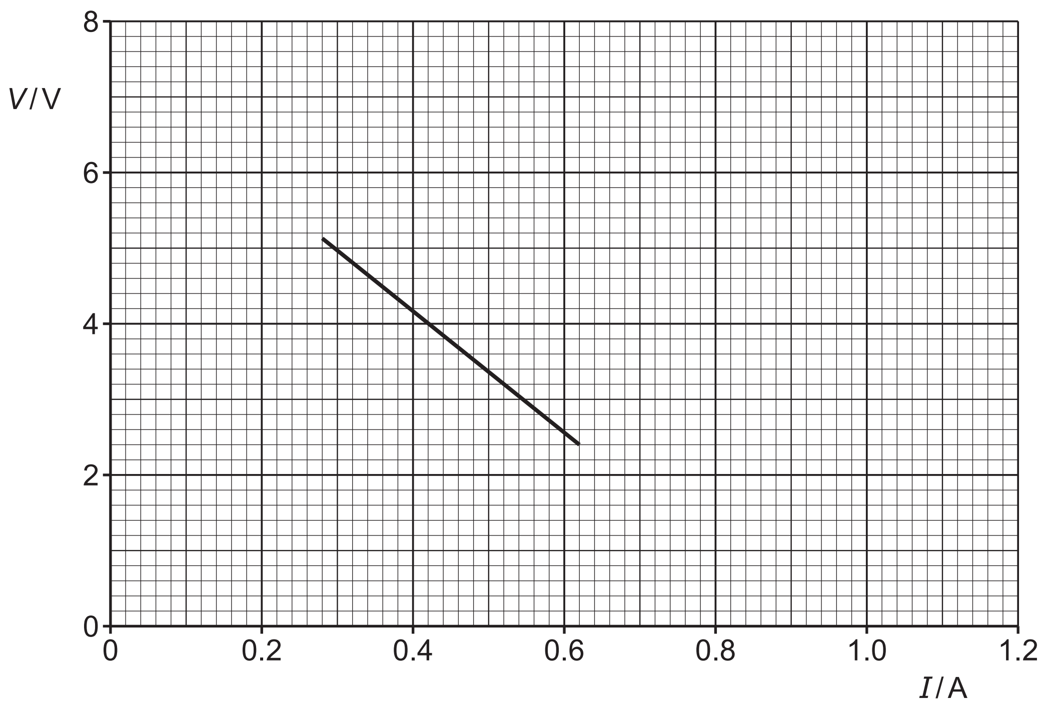

Fig. 5.2

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]

(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]

11. **(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.

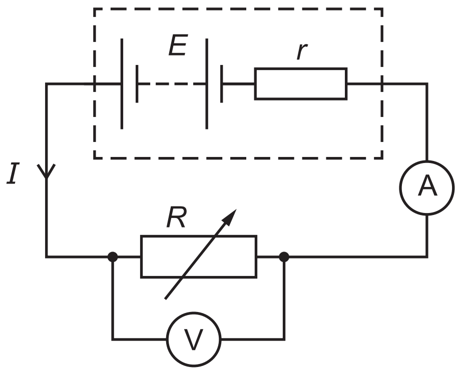

Fig. 5.1

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.

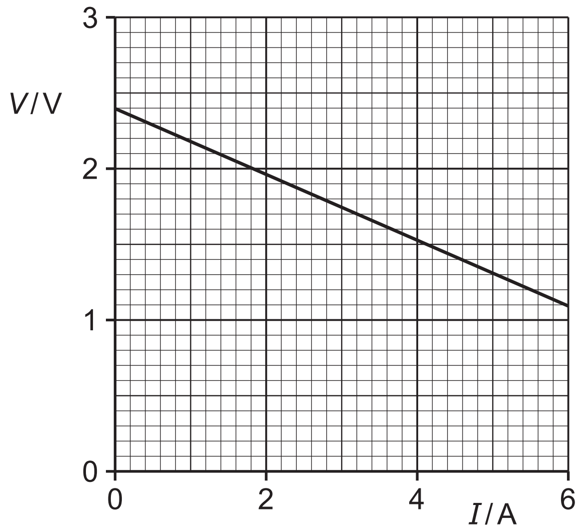

Fig. 5.2

(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]

12. (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.

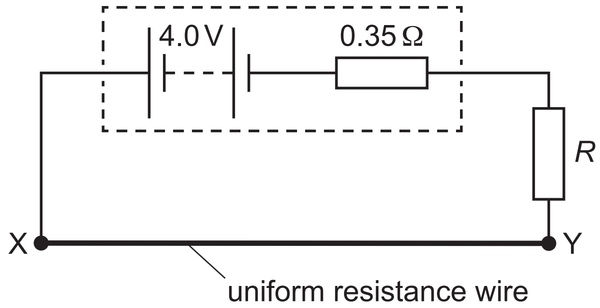

Fig. 5.1

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.

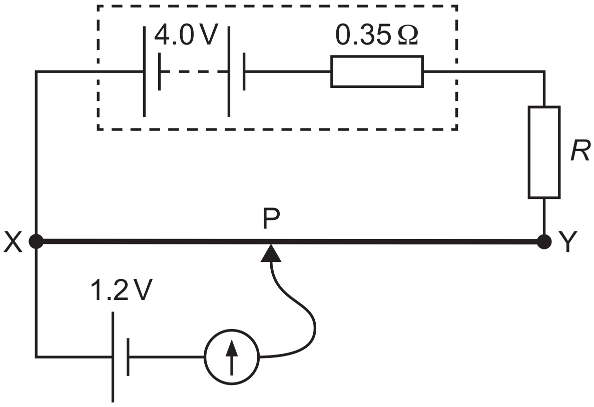

Fig. 5.2

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]

13. **(a)** State Kirchhoff's first law.

....

.... [1]

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

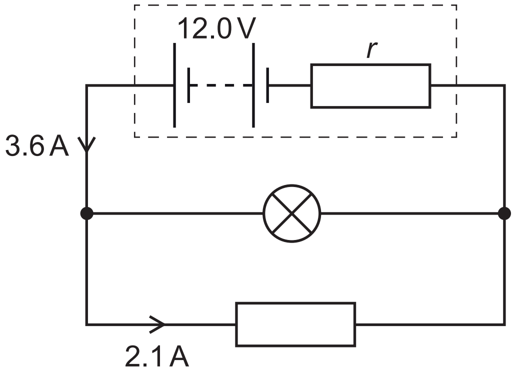

Fig. 6.1

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.

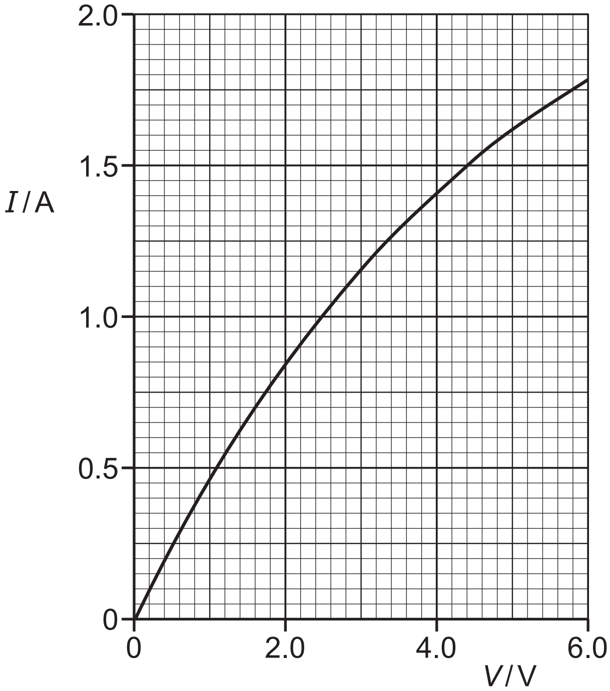

Fig. 6.2

(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.

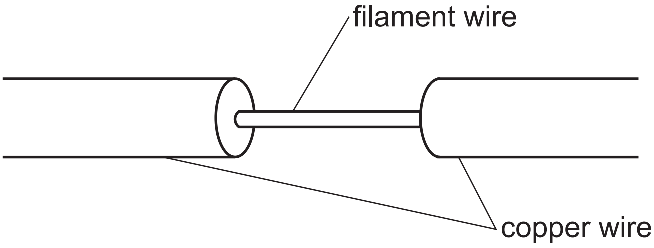

Fig. 6.3 (not to scale)

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	$360A$
number density of free electrons	n	$2.5n$

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]

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

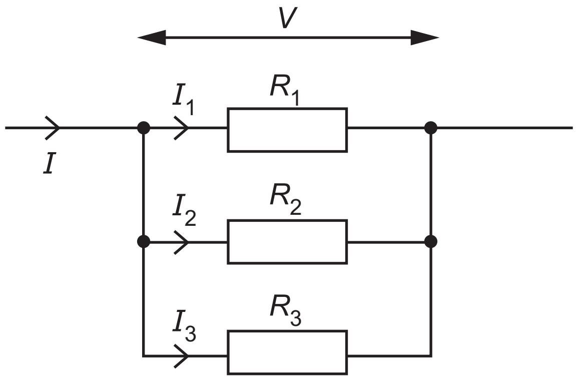

Fig. 6.1

The individual currents in the resistors are I_1, I_2 and I_3. The total current in the combination of resistors is I and the potential difference across the combination is V.

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

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance r is connected to three resistors X, Y and Z, as shown in Fig. 6.2.

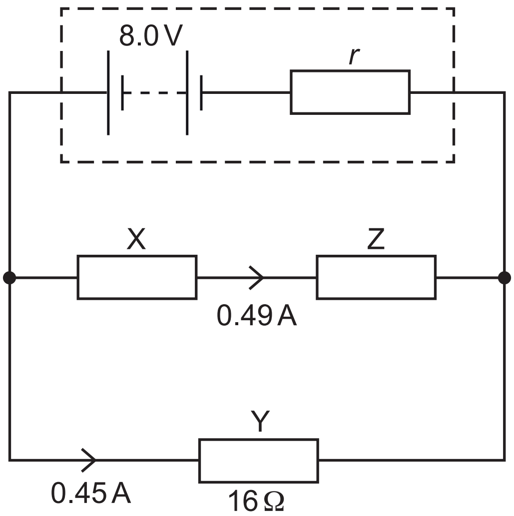

Fig. 6.2

Resistor Y has a resistance of 16 Ω. The current in resistor X is 0.49 A and the current in resistor Y is 0.45 A.

Calculate:

(i) the current in the battery

current = ... A [1]

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

r = ... Ω [2]

(c) Resistors X and Y in Fig. 6.2 are made from wires of the same material and cross-sectional area. The average drift speed of the free electrons in X is $2.1 \times 10^{-4}\,\mathrm{m\,s^{-1}}$.

Calculate the average drift speed *v* of the free electrons in Y.

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

(d) Resistor Z in Fig. 6.2 is replaced by a new resistor of smaller resistance.

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

....

....

.... [2]

[Total: 9]

15. **(a)** Define the *ohm*.

....

.... [1]

(b) A uniform wire has resistance 3.2 Ω. The wire has length 2.5 m and is made from metal of resistivity 460 nΩ m.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

(c) A cell of electromotive force (e.m.f.) *E* and internal resistance *r* is connected to a variable resistor of resistance *R*, as shown in Fig. 7.1.

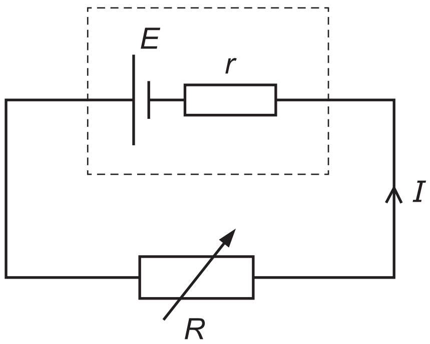

Fig. 7.1

The current in the circuit is I.

(i) State, in terms of energy, why the potential difference across the variable resistor is less than the e.m.f. of the cell.

....

.... [1]

(ii) State an expression for E in terms of I, R and r.

E = ... [1]

(iii) The resistance R of the variable resistor is changed so that it is equal to r.

Determine an expression, in terms of only E and r, for the power P dissipated in the variable resistor.

P = ... [2]

[Total: 8]

16. (a) Define the *volt*.

....

.... [1]

(b) Fig. 5.1 shows a network of three resistors.

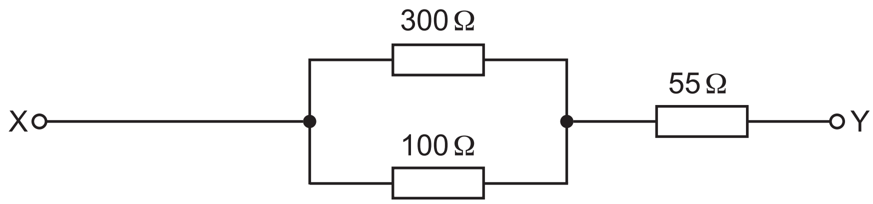

Fig. 5.1

Calculate:

(i) the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [1]

(ii) the total resistance between terminals X and Y.

total resistance = ... Ω [1]

(c) The network in **(b)** is connected to a power supply so that there is a potential difference between terminals X and Y. The power dissipated in the resistor of resistance 55 Ω is 0.20 W.

(i) Calculate the current in the resistor of resistance:

1. 55 Ω

current = ... A

2. 300 Ω.

current = ... A
[3]

(ii) Calculate the potential difference between X and Y.

potential difference = ... V [1]

[Total: 7]

17. The current I in a metal wire is given by the expression

$$I = Anve$$

where v is the average drift speed of the free electrons in the wire and e is the elementary charge.

(a) State what is meant by the symbols A and n.

A: ....

n: ....
[2]

(b) Use the above expression to determine the SI base units of e.
Show your working.

base units .... [2]

(c) Two lamps P and Q are connected in series to a battery, as shown in Fig. 6.1.

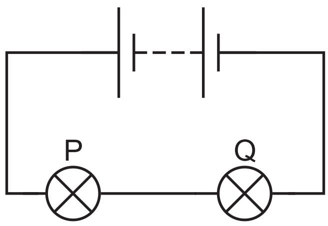

Fig. 6.1

The radius of the filament wire of lamp P is twice the radius of the filament wire of lamp Q. The filament wires are made of metals with the same value of n.

Calculate the ratio

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

ratio = ... [2]

[Total: 6]

18. (a) A battery of electromotive force (e.m.f.) 7.8 V and internal resistance *r* is connected to a filament lamp, as shown in Fig. 6.1.

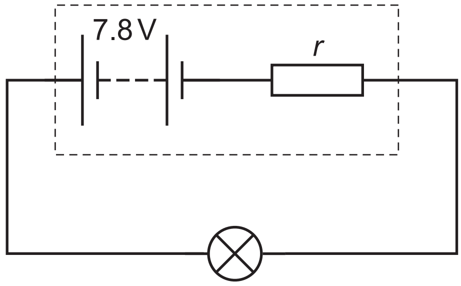

Fig. 6.1

A total charge of 750 C moves through the battery in a time interval of 1500 s. During this time the filament lamp dissipates 5.7 kJ of energy. The e.m.f. of the battery remains constant.

(i) Explain, in terms of energy and without a calculation, why the potential difference across the lamp must be less than the e.m.f. of the battery.

....

.... [1]

(ii) Calculate:

1. the current in the circuit

current = ... A [2]

2. the potential difference across the lamp

potential difference = ... V [2]

3. the internal resistance of the battery.

internal resistance = ... Ω [2]

(b) A student is provided with three resistors of resistances 90 Ω, 45 Ω and 20 Ω.

(i) Sketch a circuit diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 30 Ω between the terminals shown. Label the values of the resistances on your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of e.m.f. 9.0 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 3.6 V. The circuit diagram is shown in Fig. 6.2.

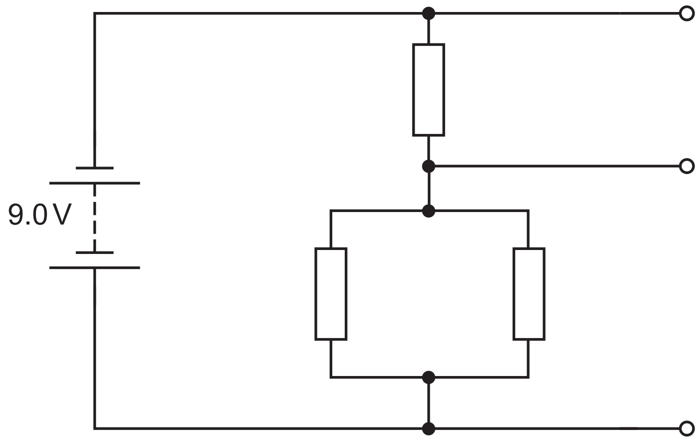

Fig. 6.2

On Fig. 6.2, label the resistances of all three resistors and the potential difference V_{OUT}. [2]

[Total: 10]

19. **(a)** Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of 3.4 Ω and the metal has a resistivity of 2.6×10^{-8} Ωm. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of 4.5×10^{-7} m^2.

[2]

(ii) The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

(iii) The number density of the free electrons in the wire is 6.1×10^{28} m^{-3}.

Calculate the average drift speed of the free electrons in the wire.

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

(b) A different wire carries a current. This wire has a part that is thinner than the rest of the wire, as shown in Fig. 5.1.

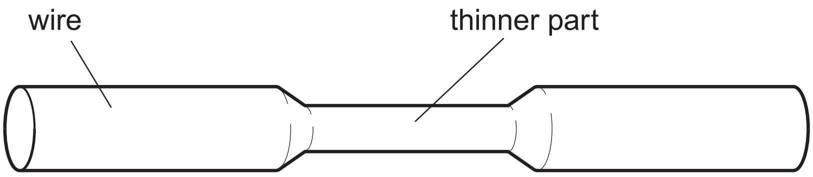

Fig. 5.1

(i) State and explain qualitatively how the average drift speed of the free electrons in the thinner part compares with that in the rest of the wire.

....

....

.... [2]

(ii) State and explain whether the power dissipated in the thinner part is the same, less or more than the power dissipated in an equal length of the rest of the wire.

....

....

.... [2]

(c) Three resistors have resistances of 180 Ω, 90 Ω and 30 Ω.

(i) Sketch a diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 60 Ω between the terminals shown.
Ensure you label the values of the resistances in your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 8.0 V.
Fig. 5.2 shows the circuit diagram.

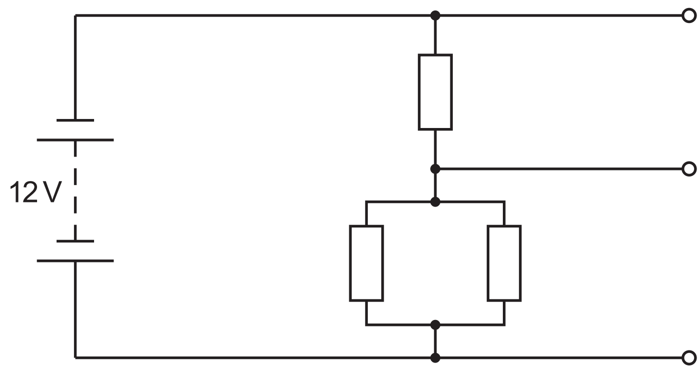

Fig. 5.2

On Fig. 5.2, label the resistances of all three resistors and the potential difference V_{OUT}. [2]

[Total: 12]

20. **(a)** Define the *ohm*.

....

....

.... [1]

(b) A wire has a resistance of 1.8 Ω. The wire has a uniform cross-sectional area of 0.38 mm^2 and is made of metal of resistivity 9.6×10^{-7} Ω m.

Calculate the length of the wire.

length = ... m [3]

(c) A resistor X of resistance 1.8 Ω is connected to a resistor Y of resistance 0.60 Ω and a battery P, as shown in Fig. 5.1.

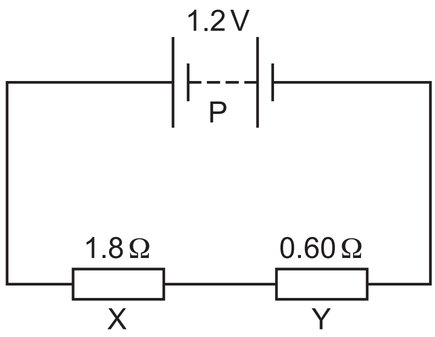

Fig. 5.1

The battery P has an electromotive force (e.m.f.) of 1.2 V and negligible internal resistance.

(i) Explain, in terms of energy, why the potential difference (p.d.) across resistor X is less than the e.m.f. of the battery.

....

....

.... [1]

(ii) Calculate the potential difference across resistor X.

potential difference = ... V [2]

(d) Another battery Q of e.m.f. 1.2 V and negligible internal resistance is now connected into the circuit of Fig. 5.1 to produce the new circuit shown in Fig. 5.2.

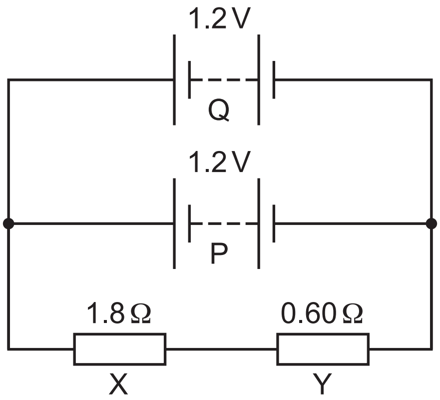

Fig. 5.2

State whether the addition of battery Q causes the current to decrease, increase or remain the same in:

(i) resistor X .... [1]

(ii) battery P. .... [1]

(e) The circuit shown in Fig. 5.2 is modified to produce the new circuit shown in Fig. 5.3.

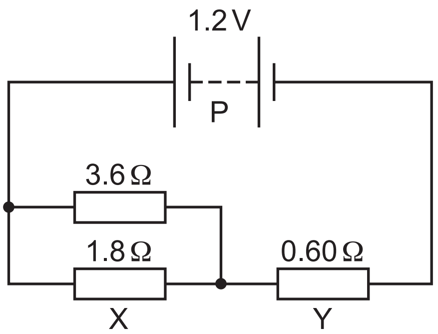

Fig. 5.3

Calculate:

(i) the total resistance of the two resistors connected in parallel

resistance = ... Ω [1]

(ii) the current in resistor Y.

current = ... A [2]

[Total: 12]

21. A uniform electric field is produced between two parallel metal plates. The electric field strength is $1.4 \times 10^4\,\mathrm{N\,C^{-1}}$. The potential difference between the plates is 350 V.

(a) Calculate the separation of the plates.

separation = ... m [2]

(b) A nucleus of mass 8.3×10^{-27} kg is now placed in the electric field. The electric force acting on the nucleus is 6.7×10^{-15} N.

(i) Calculate the charge on the nucleus in terms of *e*, where *e* is the elementary charge.

charge = ... *e* [3]

(ii) Calculate the mass, in u, of the nucleus.

mass = ... u [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the number of neutrons in the nucleus.

number = ... [1]

[Total: 7]

22. (a) State Kirchhoff's first law.

....

.... [1]

(b) The variations with potential difference V of the current I for a resistor X and for a semiconductor diode are shown in Fig. 6.1.

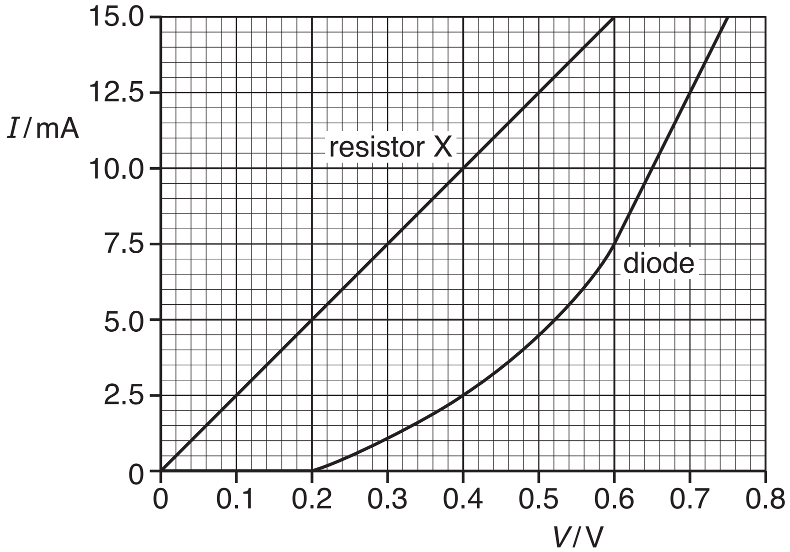

Fig. 6.1

(i) Determine the resistance of the diode for a potential difference V of 0.60 V.

resistance = ... Ω [3]

(ii) Describe, qualitatively, the variation of the resistance of the diode as V increases from 0.60 V to 0.75 V.

.... [1]

(c) The diode and the resistor X in **(b)** are connected into the circuit shown in Fig. 6.2.

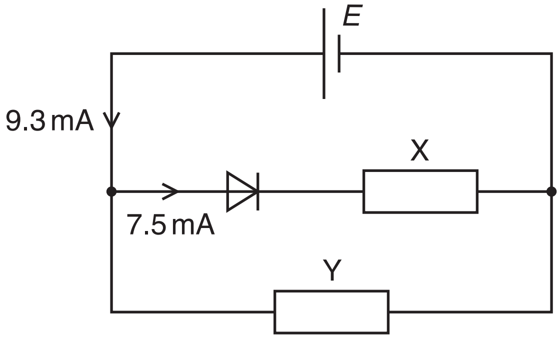

Fig. 6.2

The cell has electromotive force (e.m.f.) *E* and negligible internal resistance. Resistor Y is connected in parallel with resistor X and the diode. The current in the cell is 9.3 mA and the current in the diode is 7.5 mA.

(i) Use Fig. 6.1 to determine *E*.

E = ... V [1]

(ii) Determine the resistance of resistor Y.

resistance = ... Ω [2]

(iii) Calculate the power dissipated in the diode.

power = ... W [2]

(iv) The cell is now replaced by a new cell of e.m.f. 0.50 V and negligible internal resistance. Use Fig. 6.1 to determine the new current in the diode.

current = ... mA [1]

[Total: 11]

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

....

.... [1]

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

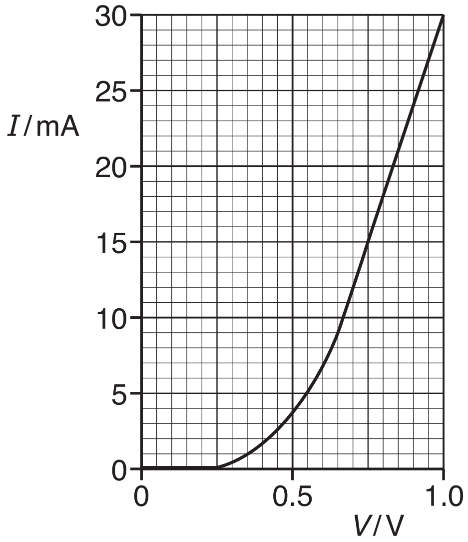

Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

....

....

....

.... [2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.

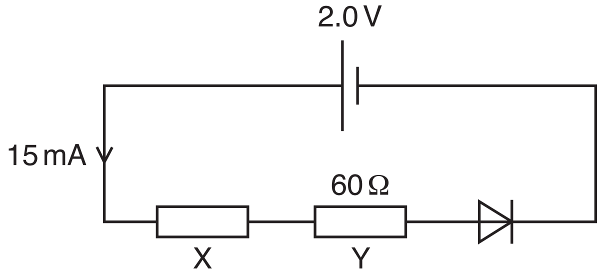

Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

(ii) Calculate:

1. the resistance of X

resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}.$$

ratio = ... [2]

[Total: 11]

24. **(a)** Define the *ohm*.

....[1]

(b) A battery of electromotive force (e.m.f.) E and internal resistance 1.5 Ω is connected to a network of resistors, as shown in Fig. 6.1.

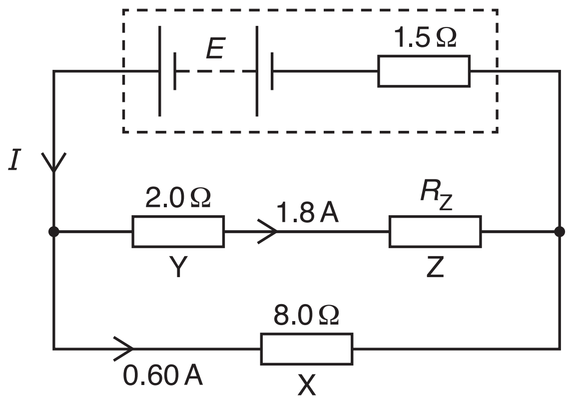

Fig. 6.1

Resistor X has a resistance of 8.0 Ω. Resistor Y has a resistance of 2.0 Ω. Resistor Z has a resistance of R_Z. The current in X is 0.60 A and the current in Y is 1.8 A.

(i) Calculate:

1. the current I in the battery

I = ... A [1]

2. resistance R_Z

R_Z = ... Ω [2]

3. e.m.f. E.

E = ... V [2]

(ii) Resistors X and Y are each made of wire. The two wires have the same length and are made of the same metal.

Determine the ratio:

1. $\dfrac{\text{cross-sectional area of wire X}}{\text{cross-sectional area of wire Y}}$

ratio = ... [2]

2. $\dfrac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}$.

ratio = ... [2]

[Total: 10]

25. (a) State Kirchhoff's second law.

....

....[2]

(b) A battery of electromotive force (e.m.f.) 5.6 V and internal resistance *r* is connected to two external resistors, as shown in Fig. 5.1.

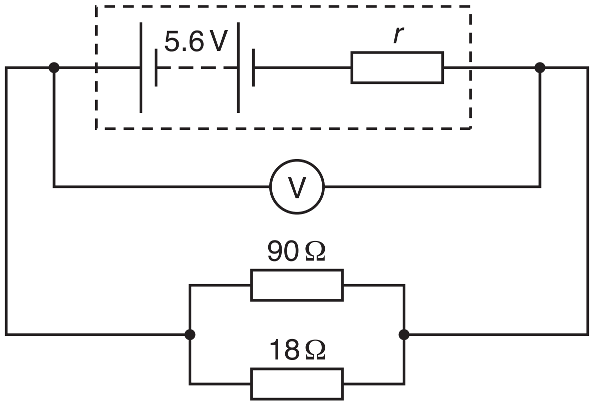

Fig. 5.1

The reading on the voltmeter is 4.8 V.

(i) Calculate:

1. the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [2]

2. the current in the battery.

current = ... A [2]

(ii) Show that the internal resistance *r* is 2.5 Ω.

[2]

(iii) Determine the ratio

$$\frac{\text{power dissipated by internal resistance } r}{\text{total power produced by battery}}.$$

ratio = ... [3]

(c) The battery in **(b)** is now connected to a battery of e.m.f. 7.2 V and internal resistance 3.5 Ω. The new circuit is shown in Fig. 5.2.

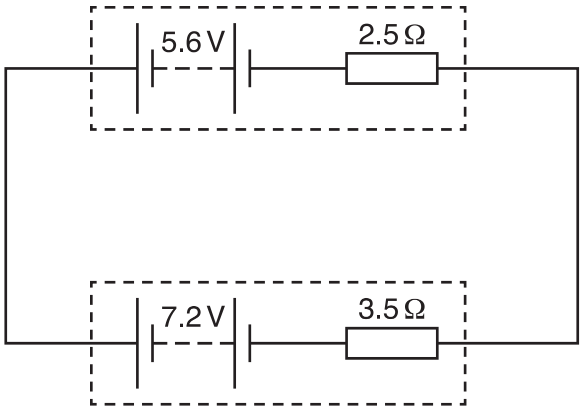

Fig. 5.2

Determine the current in the circuit.

current = ... A [2]

[Total: 13]

26. 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. 6.1.

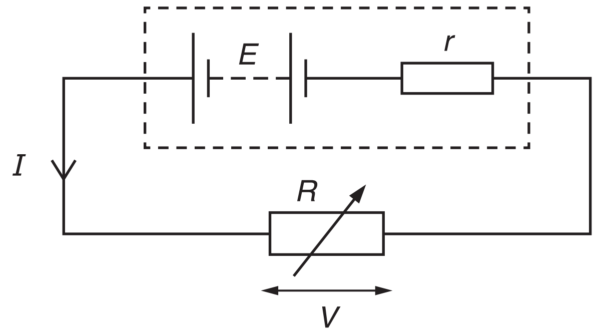

Fig. 6.1

The current in the circuit is I and the potential difference across the variable resistor is V.

(a) Explain, in terms of energy, why V is less than E.

....

....[1]

(b) State an equation relating E, I, r and V.

....[1]

(c) The resistance R of the variable resistor is varied. The variation with I of V is shown in Fig. 6.2.

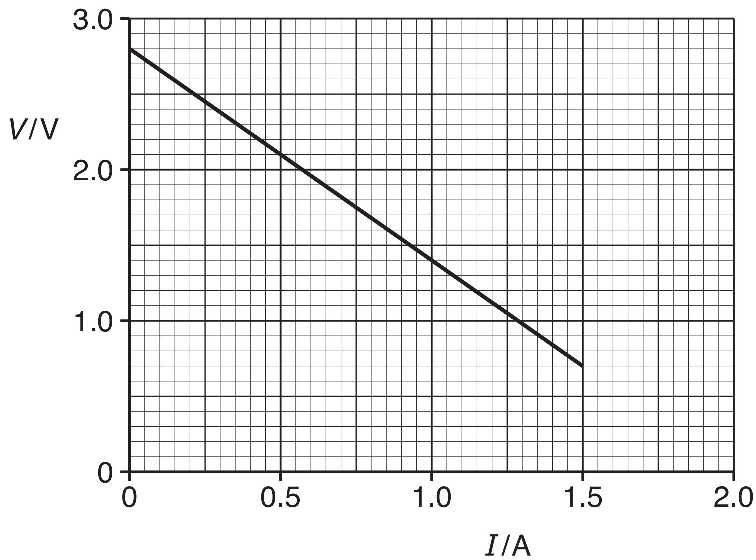

Fig. 6.2

Use Fig. 6.2 to:

(i) explain how it may be deduced that the e.m.f. of the battery is 2.8 V

....

....[1]

(ii) calculate the internal resistance *r*.

r = ... Ω [2]

(d) The battery stores 9.2 kJ of energy. The variable resistor is adjusted so that *V* = 2.1 V. Use Fig. 6.2 to:

(i) calculate resistance *R*

R = ... Ω [1]

(ii) calculate the number of conduction electrons moving through the battery in a time of 1.0 s

number = ... [1]

(iii) determine the time taken for the energy in the battery to become equal to 1.6 kJ.
(Assume that the e.m.f. of the battery and the current in the battery remain constant.)

time taken = ... s [3]

[Total: 10]

27. **(a)** Using energy transformations, describe the *electromotive force* (*e.m.f.*) of a battery and the *potential difference* (*p.d.*) across a resistor.

e.m.f.: ....

....

p.d.: ....

....[2]

(b) A battery of e.m.f. 6.0 V and negligible internal resistance is connected to a network of resistors and a voltmeter, as shown in Fig. 6.1.

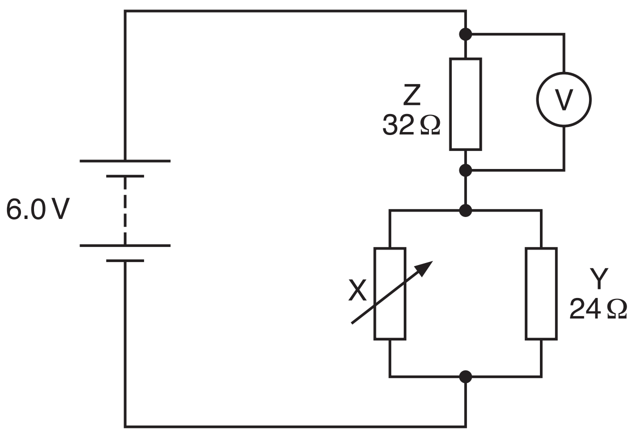

Fig. 6.1

Resistor Y has a resistance of 24 Ω and resistor Z has a resistance of 32 Ω.

(i) The resistance R_X of the variable resistor X is adjusted until the voltmeter reads 4.8 V.

Calculate:

1. the current in resistor Z

current = ... A [1]

2. the total power provided by the battery

power = ... W [2]

3. the number of conduction electrons that move through the battery in a time interval of 25 s

number = ... [2]

4. the total resistance of X and Y connected in parallel

total resistance = ... Ω [2]

5. the resistance R_X.

R_X = ... Ω [2]

(ii) The resistance R_X is now decreased.

State and explain the change, if any, to the reading on the voltmeter.

....

....

....[2]

[Total: 13]

28. **(a)** Define the *volt*.

....

....[1]

(b) A battery of electromotive force (e.m.f.) 7.0 V and negligible internal resistance is connected in series with three components, as shown in Fig. 6.1.

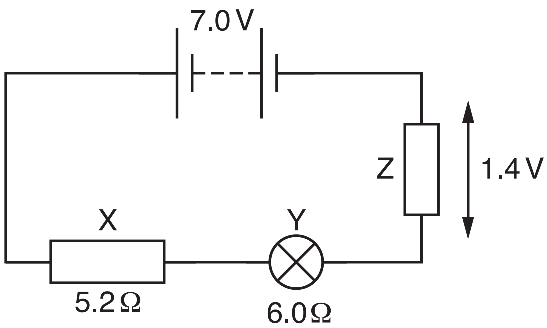

Fig. 6.1

Resistor X has a resistance of 5.2 Ω. The resistance of the filament wire of lamp Y is 6.0 Ω. The potential difference across resistor Z is 1.4 V.

(i) Calculate the current in the circuit.

current = ... A [2]

(ii) Determine the resistance of resistor Z.

resistance = ... Ω [1]

(iii) Calculate the percentage efficiency with which the battery supplies power to the lamp.

efficiency = ... % [3]

(iv) The filament wire of the lamp is made of metal of resistivity $3.7 \times 10^{-7}\,\Omega\,\mathrm{m}$ at its operating temperature in the circuit.

Determine, for the filament wire, the value of α where

$$\alpha = \frac{\text{cross-sectional area}}{\text{length}}.$$

α = ... m [2]

[Total: 9]

29. (a) The current I in a metal wire is given by the expression

$$I = Anve.$$

State what is meant by the symbols A and n.

A: ....

n: ....
[2]

(b) The diameter of a wire XY varies linearly with distance along the wire as shown in Fig. 7.1.

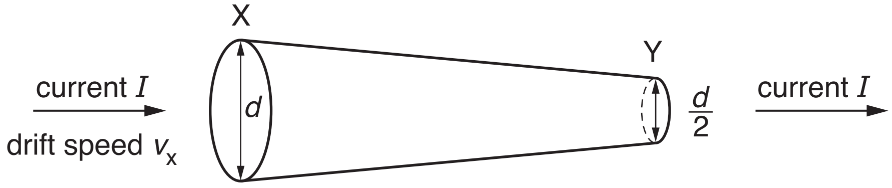

Fig. 7.1

There is a current I in the wire. At end X of the wire, the diameter is d and the average drift speed of the free electrons is v_x. At end Y of the wire, the diameter is $\frac{d}{2}$.

On Fig. 7.2, sketch a graph to show the variation of the average drift speed with position along the wire between X and Y.

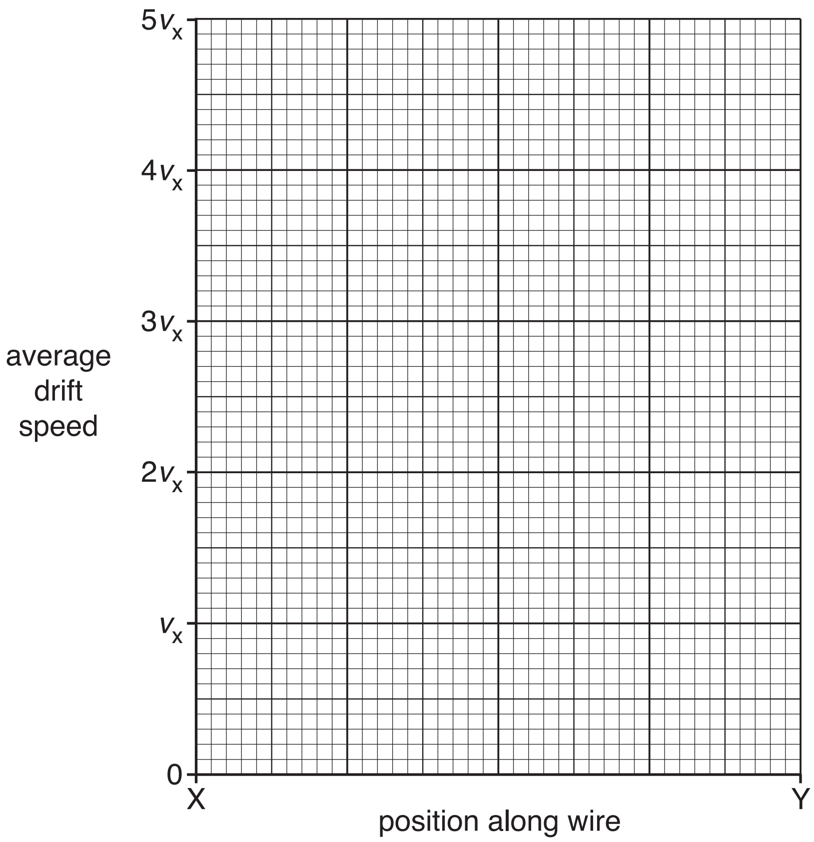

Fig. 7.2

[2]

[Total: 4]

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

....

....

.... [2]

(b) An electric heater containing two heating wires X and Y is connected to a power supply of electromotive force (e.m.f.) 9.0 V and negligible internal resistance, as shown in Fig. 6.1.

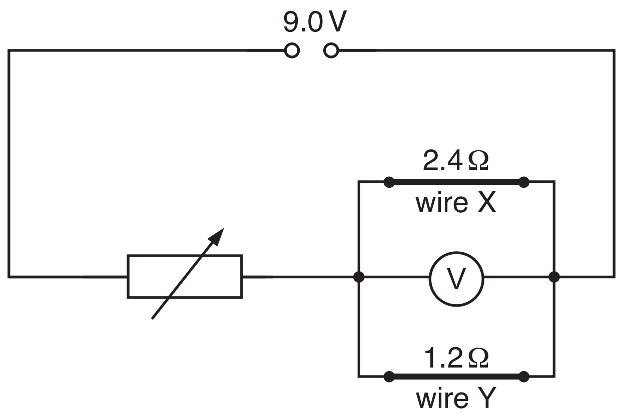

Fig. 6.1

Wire X has a resistance of 2.4 Ω and wire Y has a resistance of 1.2 Ω. A voltmeter is connected in parallel with the wires. A variable resistor is used to adjust the power dissipated in wires X and Y.

The variable resistor is adjusted so that the voltmeter reads 6.0 V.

(i) Calculate the resistance of the variable resistor.

resistance = ... Ω [3]

(ii) Calculate the power dissipated in wire X.

power = ... W [2]

(iii) The cross-sectional area of wire X is three times the cross-sectional area of wire Y. Assume that the resistivity and the number density of free electrons for the metal of both wires are the same.

Determine the ratio

1. $\dfrac{\text{length of wire X}}{\text{length of wire Y}}$,

ratio = ... [2]

2. $\dfrac{\text{average drift velocity of free electrons in wire X}}{\text{average drift velocity of free electrons in wire Y}}$.

ratio = ... [2]

[Total: 11]

31. A wire X has a constant resistance per unit length of $3.0\,\Omega\,m^{-1}$ and a diameter of 0.48 mm.

(a) Calculate the resistivity of the metal of wire X.

resistivity = ... Ω m [3]

(b) The wire X is connected into the circuit shown in Fig. 6.1.

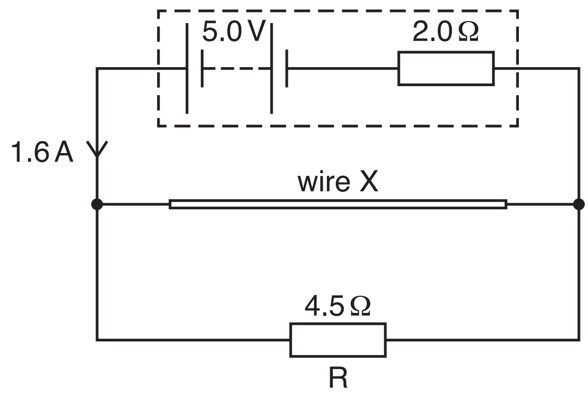

Fig. 6.1

The battery has an electromotive force (e.m.f.) of 5.0 V and an internal resistance of 2.0 Ω. The wire X and a resistor R of resistance 4.5 Ω are connected in parallel. The current in the battery is 1.6 A.

(i) Calculate the potential difference across resistor R.

potential difference = ... V [1]

(ii) Determine, for wire X,

1. its resistance,

resistance = ... Ω [3]

2. its length.

length = ... m [1]

[Total: 8]

32. (a) (i) State Kirchhoff's first law.

....

....[1]

(ii) Kirchhoff's first law is linked to the conservation of a certain quantity. State this quantity.

....[1]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 6.1.

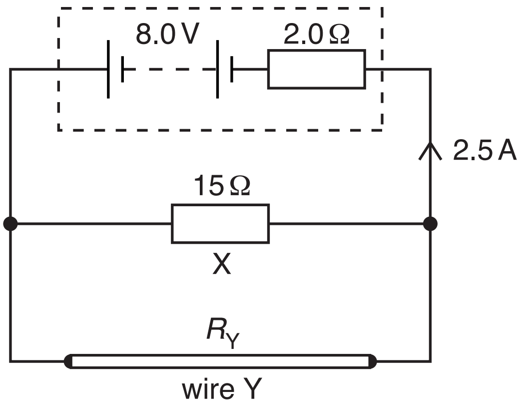

Fig. 6.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(i) Calculate

1. the thermal energy dissipated in the battery in a time of 5.0 minutes,

energy = ... J [2]

2. the terminal potential difference of the battery.

terminal potential difference = ... V [1]

(ii) Determine the resistance R_Y.

R_Y = ... Ω [3]

(iii) A new wire Z has the same length but less resistance than wire Y.

1. State two possible differences between wire Z and wire Y that would separately cause wire Z to have less resistance than wire Y.

first difference: ....

....

second difference: ....

....
[2]

2. Wire Y is replaced in the circuit by wire Z. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

....

....

....[2]

[Total: 12]

33. **(a)** Define the *volt*.

....[1]

(b) A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 6.1.

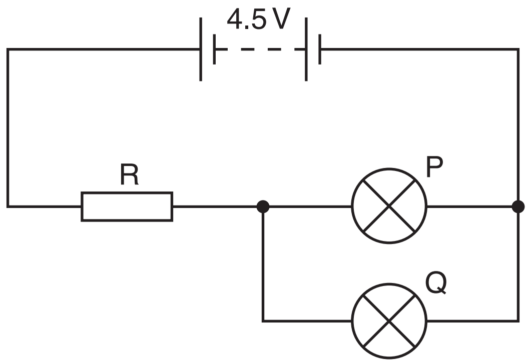

Fig. 6.1

The current in lamp P is 0.15 A.
The I–V characteristics of the filament lamps are shown in Fig. 6.2.

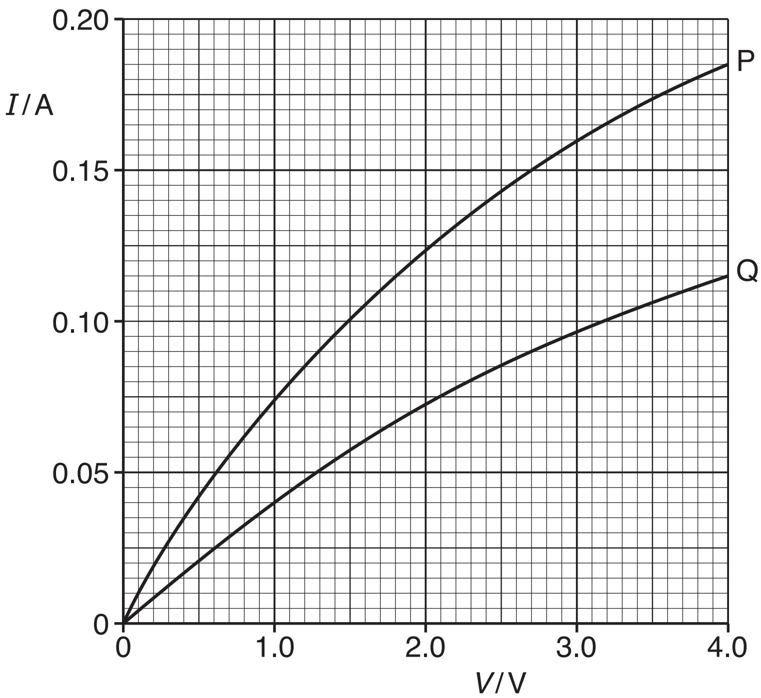

Fig. 6.2

(i) Use Fig. 6.2 to determine the current in the battery. Explain your working.

current = ... A [2]

(ii) Calculate the resistance of resistor R.

resistance = ... Ω [2]

(iii) The filament wires of the two lamps are made from material with the same resistivity at their operating temperature in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}.$$

ratio = ... [3]

(iv) The filament wire of lamp Q breaks and stops conducting.

State and explain, qualitatively, the effect on the resistance of lamp P.

....

....

....

....[2]

[Total: 10]

34. (a) State Kirchhoff's second law.

....

....[2]

(b) Two batteries, each of electromotive force (e.m.f.) 6.0 V and negligible internal resistance, are connected in series with three resistors, as shown in Fig. 5.1.

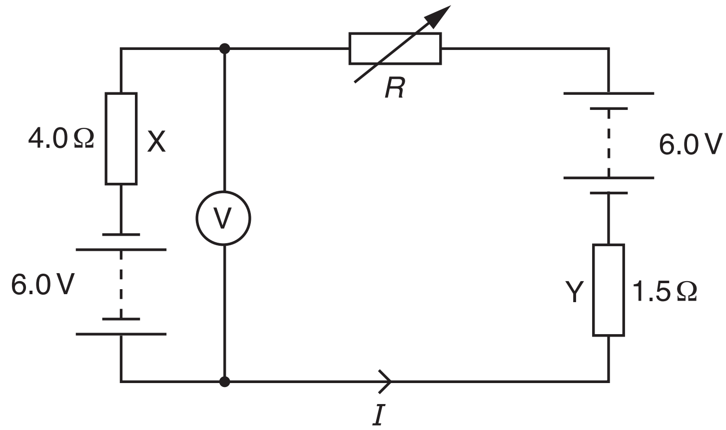

Fig. 5.1

Resistor X has resistance 4.0 Ω and resistor Y has resistance 1.5 Ω.

(i) The resistance *R* of the variable resistor is changed until the voltmeter in the circuit reads zero.

Calculate

1. the current *I* in the circuit,

I = ... A [1]

2. the resistance *R*.

R = ... Ω [2]

(ii) Resistors X and Y are wires made from the same material. The diameter of the wire of X is twice the diameter of the wire of Y.

Determine the ratio

$$\frac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}.$$

ratio = ... [2]

(iii) The resistance *R* of the variable resistor is now increased.

State and explain the effect of the increase in *R* on the power transformed by each of the batteries.

....

....

....

....[3]

[Total: 10]

35. **(a)** Define the *coulomb*.

....[1]

(b) Two vertical metal plates in a vacuum have a separation of 4.0 cm. A potential difference of 2.0×10^2 V is applied between the plates. Fig. 5.1 shows a side view of this arrangement.

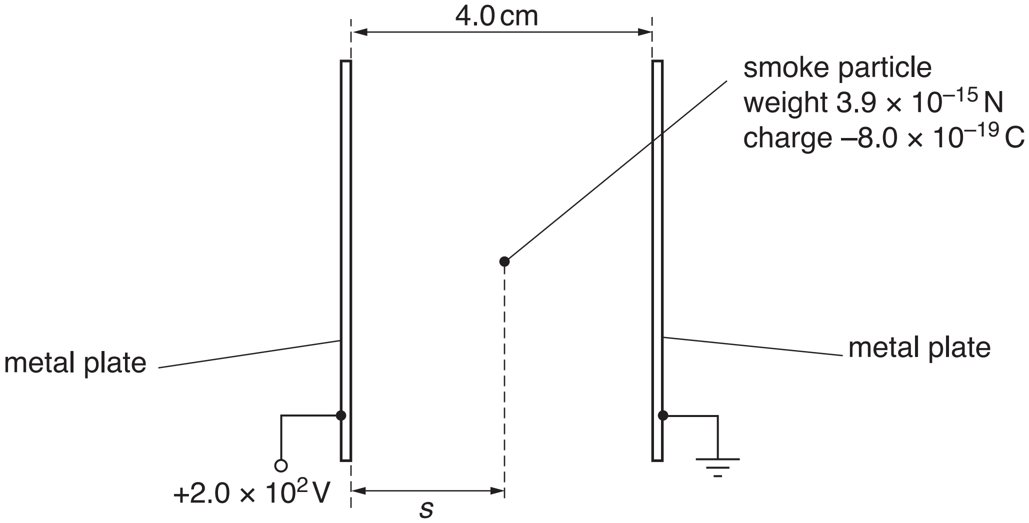

Fig. 5.1

A smoke particle is in the uniform electric field between the plates. The particle has weight 3.9×10^{-15} N and charge -8.0×10^{-19} C.

(i) Show that the electric force acting on the particle is 4.0×10^{-15} N.

[2]

(ii) On Fig. 5.1, draw labelled arrows to show the directions of the two forces acting on the smoke particle. [1]

(iii) The resultant force acting on the particle is F.

Determine

1. the magnitude of F,

magnitude = ... N

2. the angle of F to the horizontal.

angle = ... °
[3]

(c) The electric field in **(b)** is switched on at time $t = 0$ when the particle is at a horizontal displacement $s = 2.0\,\text{cm}$ from the left-hand plate. At time $t = 0$ the horizontal velocity of the particle is zero. The particle is then moved by the electric field until it hits a plate at time $t = T$.

On Fig. 5.2, sketch the variation with time t of the horizontal displacement s of the particle from the left-hand plate.

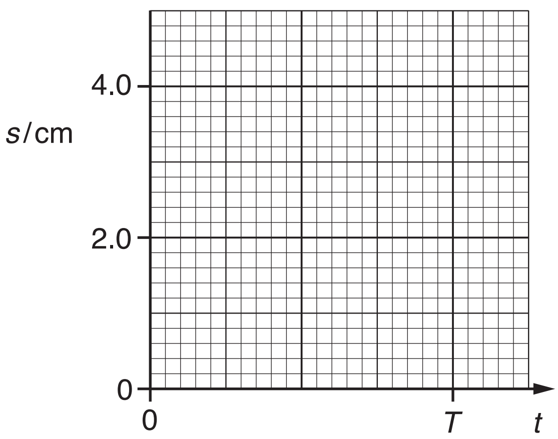

Fig. 5.2

[2]

[Total: 9]

36. **(a)** State what is meant by an *electric current*.

....[1]

(b) A metal wire has length L and cross-sectional area A, as shown in Fig. 6.1.

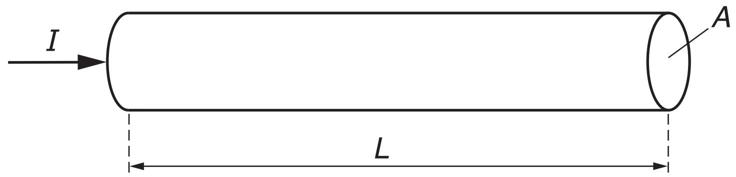

Fig. 6.1

I is the current in the wire,
n is the number of free electrons per unit volume in the wire,
v is the average drift speed of a free electron and
e is the charge on an electron.

(i) State, in terms of A, e, L and n, an expression for the total charge of the free electrons in the wire.

....[1]

(ii) Use your answer in **(i)** to show that the current I is given by the equation

$$I = nAve.$$

[2]

(c) A metal wire in a circuit is damaged. The resistivity of the metal is unchanged but the cross-sectional area of the wire is reduced over a length of 3.0 mm, as shown in Fig. 6.2.

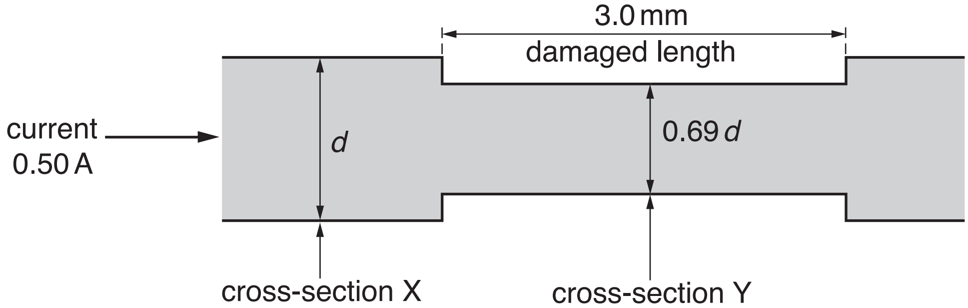

Fig. 6.2

The wire has diameter d at cross-section X and diameter $0.69d$ at cross-section Y.
The current in the wire is 0.50 A.

(i) Determine the ratio

$$\frac{\text{average drift speed of free electrons at cross-section Y}}{\text{average drift speed of free electrons at cross-section X}}.$$

ratio = ...[2]

(ii) The main part of the wire with cross-section X has a resistance per unit length of $1.7 \times 10^{-2}\,\Omega\,m^{-1}$.

For the damaged length of the wire, calculate

1. the resistance per unit length,

resistance per unit length = ... $\Omega\,m^{-1}$ [2]

2. the power dissipated.

power = ... W [2]

(iii) The diameter of the damaged length of the wire is further decreased. Assume that the current in the wire remains constant.

State and explain qualitatively the change, if any, to the power dissipated in the damaged length of the wire.

....

....

....[2]

[Total: 12]

37. Three cells of electromotive forces (e.m.f.) E_1, E_2 and E_3 are connected into a circuit, as shown in Fig. 5.1.

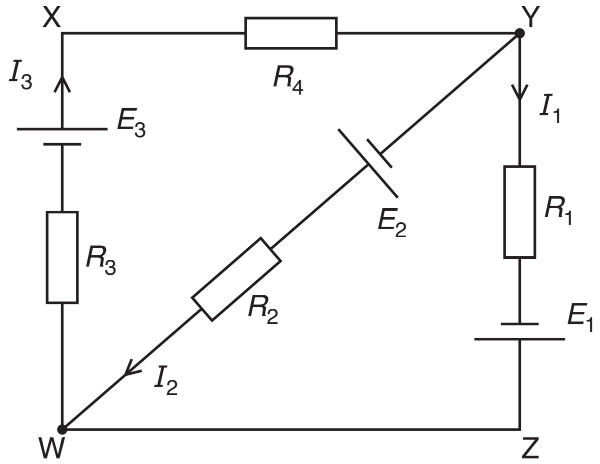

Fig. 5.1

The circuit contains resistors of resistances R_1, R_2, R_3 and R_4.
The currents in the different parts of the circuit are I_1, I_2 and I_3.
The cells have negligible internal resistance.

Use Kirchhoff's laws to state an equation relating

(a) I_1, I_2 and I_3,

....[1]

(b) E_1, E_3, R_1, R_3, R_4, I_1 and I_3 in loop WXYZW,

....

....[1]

(c) E_1, E_2, R_1, R_2, I_1 and I_2 in loop YZWY.

....

....[1]

[Total: 3]

38. **(a)** Define the *ohm*.

....[1]

(b) Wires are used to connect a battery of negligible internal resistance to a lamp, as shown in Fig. 7.1.

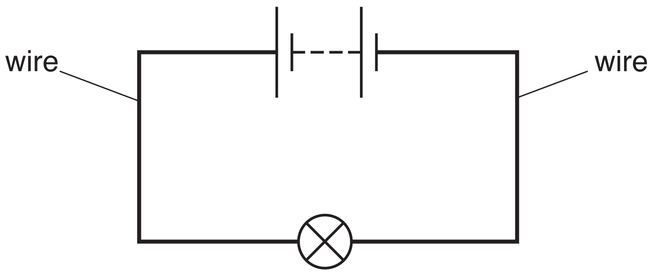

Fig. 7.1

The lamp is at its normal operating temperature. Some data for the filament wire of the lamp and for the connecting wires of the circuit are shown in Fig. 7.2.

	filament wire	connecting wires
diameter	d	$14\,d$
total length	L	$7.0\,L$
resistivity of metal (at normal operating temperature)	ρ	$0.028\,\rho$

Fig. 7.2

(i) Show that

$$\frac{\text{resistance of filament wire}}{\text{total resistance of connecting wires}} = 1000.$$

[2]

(ii) Use the information in **(i)** to explain qualitatively why the power dissipated in the filament wire of the lamp is greater than the total power dissipated in the connecting wires.

....

....

....[1]

(iii) The lamp is rated as 12 V, 6.0 W. Use the information in **(i)** to determine the total resistance of the connecting wires.

total resistance of connecting wires = ... Ω [3]

(iv) The diameter of the connecting wires is decreased. The total length of the connecting wires and the resistivity of the metal of the connecting wires remain the same.

State and explain the change, if any, that occurs to the resistance of the filament wire of the lamp.

....

....

....

....

....[3]

[Total: 10]

39. **(a)** Describe the I–V characteristic of

(i) a metallic conductor at constant temperature,

....

....[1]

(ii) a semiconductor diode.

....

....

....[2]

(b) Two identical filament lamps are connected in series and then in parallel to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance, as shown in Fig. 6.1a and Fig. 6.1b.

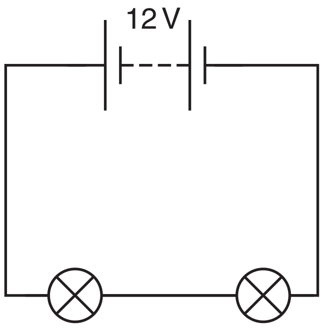

Fig. 6.1a

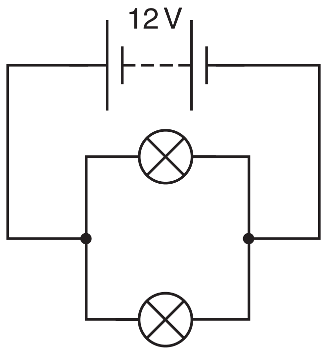

Fig. 6.1b

The I–V characteristic of each lamp is shown in Fig. 6.2.

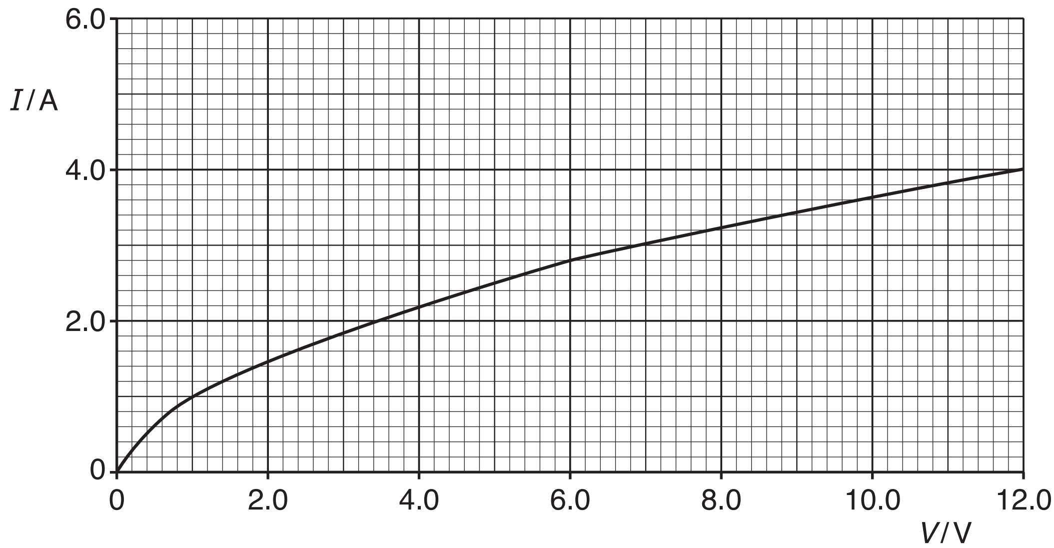

Fig. 6.2

(i) Use the information shown in Fig. 6.2 to determine the current through the battery in

1. the circuit of Fig. 6.1a,

current = ...A

2. the circuit of Fig. 6.1b.

current = ...A
[3]

(ii) Calculate the total resistance in

1. the circuit of Fig. 6.1a,

resistance = ...Ω

2. the circuit of Fig. 6.1b.

resistance = ...Ω
[3]

(iii) Calculate the ratio

$$\frac{\text{power dissipated in a lamp in the circuit of Fig. 6.1a}}{\text{power dissipated in a lamp in the circuit of Fig. 6.1b}}.$$

ratio = ...[2]

[Total: 11]

40. (a) Define *electromotive force* (e.m.f.) of a cell.

....

....[1]

(b) A cell C of e.m.f. 1.50 V and internal resistance 0.200 Ω is connected in series with resistors X and Y, as shown in Fig. 7.1.

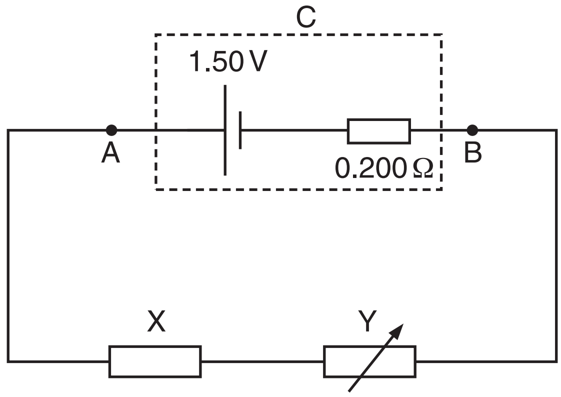

Fig. 7.1

The resistance of X is constant and the resistance of Y can be varied.

(i) The resistance of Y is varied from 0 to 8.00 Ω.

State and explain the variation in the potential difference (p.d.) between points A and B (terminal p.d. across C). Numerical values are not required.

....

....

....

....[3]

(ii) The resistance of Y is set at 6.00 Ω. The current in the circuit is 0.180 A.

Calculate

1. the resistance of X,

resistance = ... Ω [2]

2. the p.d. between points A and B,

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

3. the efficiency of the cell.

efficiency = ...[2]

[Total: 10]

41. **(a)** Define the *ohm*.

....

....[1]

(b) A cell X of electromotive force (e.m.f.) 1.5 V and negligible internal resistance is connected in series to three resistors A, B and C, as shown in Fig. 6.1.

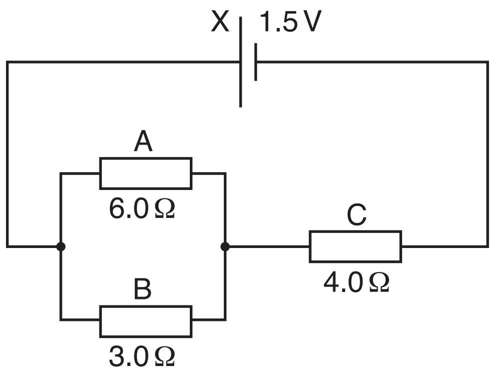

Fig. 6.1

Resistors A and B have resistances 6.0 Ω and 3.0 Ω respectively and are connected in parallel. Resistor C has resistance 4.0 Ω and is connected in series with the parallel combination.

Calculate

(i) the current in the circuit,

current = ...A [3]

(ii) the current in resistor B,

current = ...A [1]

(iii) the ratio

$$\frac{\text{power dissipated in resistor B}}{\text{power dissipated in resistor C}}.$$

ratio = ...[2]

(c) The resistors A, B and C in **(b)** are wires of the same material and have the same length.

(i) Explain how the resistors may be made with different resistance values.

....[1]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of the charge carriers in resistor B}}{\text{average drift speed of the charge carriers in resistor C}}.$$

ratio = ...[2]

(d) A cell of e.m.f. 1.5 V and negligible internal resistance is connected in parallel with cell X in Fig. 6.1 with their positive terminals together.

State the change, if any, to the current in

(i) cell X,

....[1]

(ii) resistor C.

....[1]

[Total: 12]

42. (a) Three resistors of resistances R_1, R_2 and R_3 are connected as shown in Fig. 6.1.

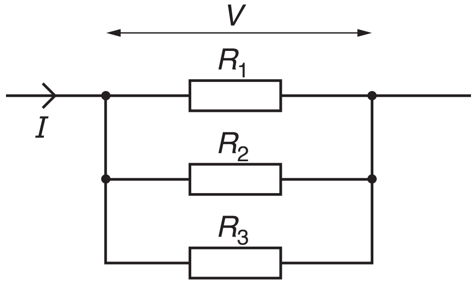

Fig. 6.1

The total current in the combination of resistors is I and the potential difference across the combination is V.

Show that the total resistance R of the combination is given by the equation

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

(b) A battery of electromotive force (e.m.f.) 6.0 V and internal resistance r is connected to a resistor of resistance 12 Ω and a variable resistor X, as shown in Fig. 6.2.

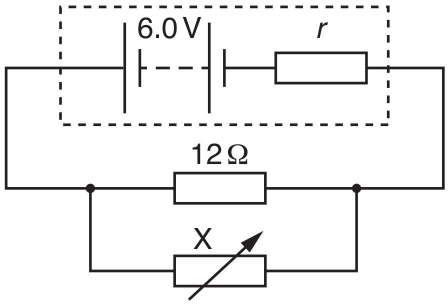

Fig. 6.2

(i) By considering energy, explain why the potential difference across the battery's terminals is less than the e.m.f. of the battery.

....

....

....

....[2]

(ii) A charge of 2.5 kC passes through the battery.

Calculate

1. the total energy transformed by the battery,

energy = ... J [2]

2. the number of electrons that pass through the battery.

number = ... [1]

(iii) The combined resistance of the two resistors connected in parallel is 4.8 Ω.

Calculate the resistance of X.

resistance of X = ... Ω [1]

(iv) Use your answer in **(b)(iii)** to determine the ratio

$$\frac{\text{power dissipated in X}}{\text{power dissipated in } 12\,\Omega \text{ resistor}}.$$

ratio = ... [2]

(v) The resistance of X is now decreased. Explain why the power produced by the battery is increased.

....

....

.... [1]

[Total: 11]

43. (a) State Kirchhoff's second law.

....

....

....

....[2]

(b) A battery is connected in parallel with two lamps A and B, as shown in Fig. 5.1.

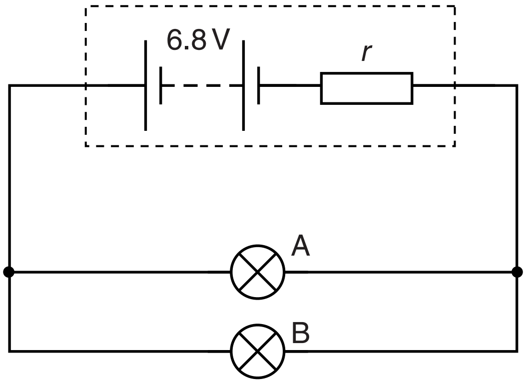

Fig. 5.1

The battery has electromotive force (e.m.f.) 6.8 V and internal resistance *r*.

The *I*–*V* characteristics of lamps A and B are shown in Fig. 5.2.

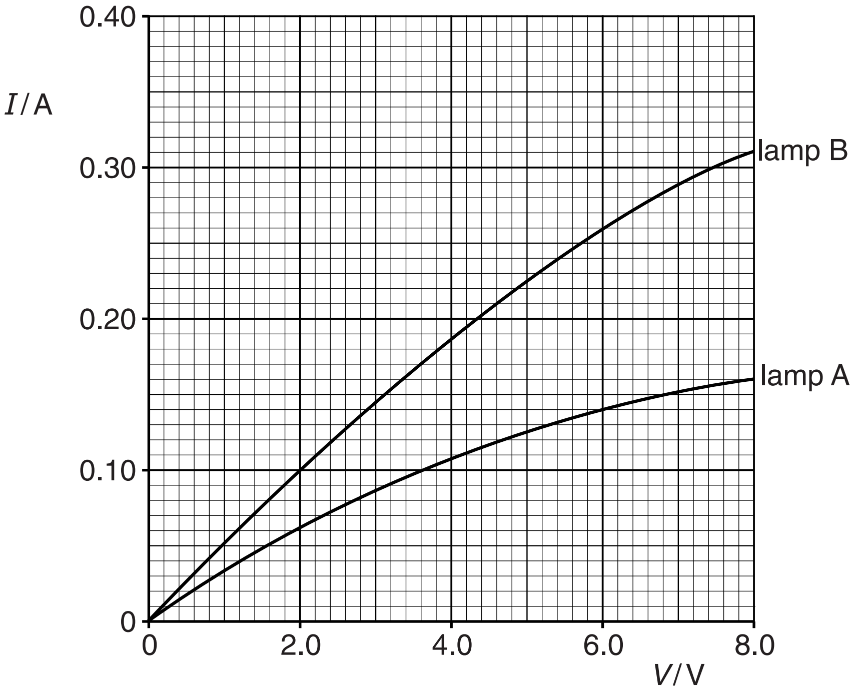

Fig. 5.2

The potential difference across the battery terminals is 6.0 V.

(i) Use Fig. 5.2 to show that the current in the battery is 0.40 A.

[2]

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

r = ... Ω [2]

(iii) Determine the ratio

$$\frac{\text{resistance of lamp A}}{\text{resistance of lamp B}}.$$

ratio = ... [2]

(iv) Determine

1. the total power produced by the battery,

power = ... W [2]

2. the efficiency of the battery in the circuit.

efficiency = ... [2]

[Total: 12]

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

....

....[1]

(b) A battery of electromotive force (e.m.f.) 14 V and negligible internal resistance is connected to a resistor network, as shown in Fig. 6.1.

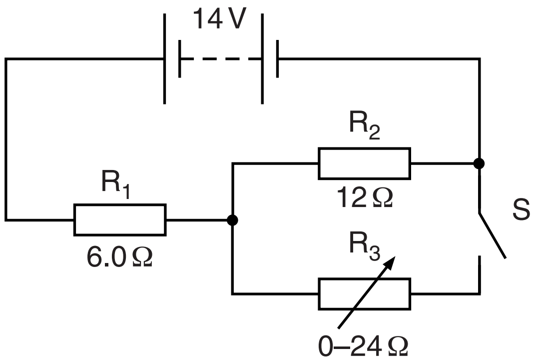

Fig. 6.1

R_1 and R_2 are fixed resistors of resistances 6.0 Ω and 12 Ω respectively. R_3 is a variable resistor.

Switch S is **closed**.

(i) Calculate the current in the battery when the resistance of R_3 is set

1. at zero,

current = ... A [2]

2. at 24 Ω.

current = ... A [2]

(ii) Use your answers in **(b)(i)** to calculate the change in the total power produced by the battery when the resistance of R_3 is changed from zero to 24 Ω.

change in power = ... W [2]

(c) Switch S in Fig. 6.1 is now **opened**.

Resistors R_1 and R_2 are made from metal wires. Some data for these resistors are shown in Fig. 6.2.

	R_1	R_2
cross-sectional area of wire	A	$1.8A$
number of free electrons per unit volume in metal	n	$0.50n$

Fig. 6.2

Determine the ratio

$$\frac{\text{average drift speed of free electrons in } R_1}{\text{average drift speed of free electrons in } R_2}.$$

ratio = ... [2]

[Total: 9]

45. **(a)** Define the *ohm*.

.... [1]

(b) A 15V battery with negligible internal resistance is connected to two resistors P and Q, as shown in Fig. 6.1.

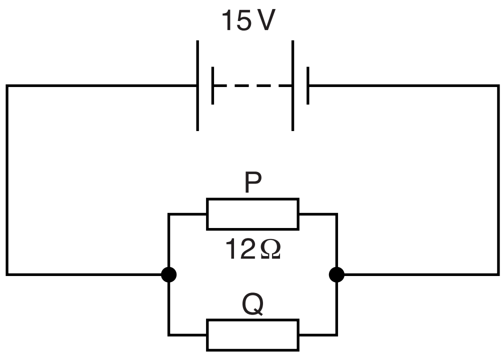

Fig. 6.1

The resistors are made of wires of the same material. The wire of P has diameter *d* and length 2*l*. The wire of Q has diameter 2*d* and length *l*.

The resistance of P is 12Ω.

(i) Show that the resistance of Q is 1.5Ω.

[3]

(ii) Calculate the total power dissipated in the resistors P and Q.

power = ... W [3]

(iii) Determine the ratio

$$\frac{\text{average drift speed of the charge carriers in P}}{\text{average drift speed of the charge carriers in Q}}.$$

ratio = ... [3]

[Total: 10]

46. **(a)** Electric current is a flow of charge carriers. The charge on the carriers is quantised. Explain what is meant by *quantised*.

....[1]

(b) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance 0.25 Ω is connected in series with two identical resistors X and a resistor Y, as shown in Fig. 7.1.

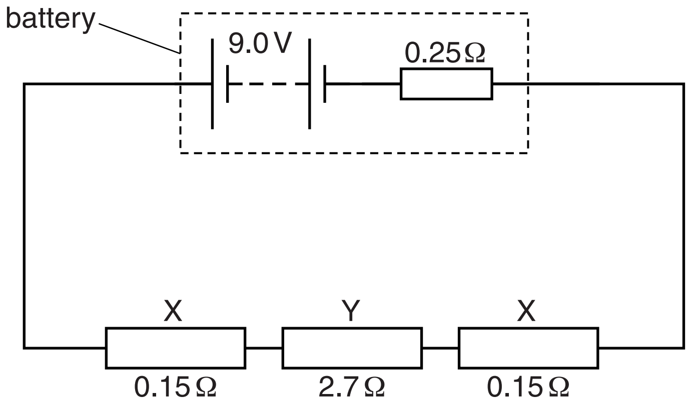

Fig. 7.1

The resistance of each resistor X is 0.15 Ω and the resistance of resistor Y is 2.7 Ω.

(i) Show that the current in the circuit is 2.8 A.

[3]

(ii) Calculate the potential difference across the battery.

potential difference = ... V [2]

(c) Each resistor X connected in the circuit in **(b)** is made from a wire with a cross-sectional area of 2.5 mm^2. The number of free electrons per unit volume in the wire is 8.5×10^{29} m^{-3}.

(i) Calculate the average drift speed of the electrons in X.

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

(ii) The two resistors X are replaced by two resistors Z made of the same material and length but with half the diameter.

Describe and explain the difference between the average drift speed in Z and that in X.

....

....

....

....[2]

[Total: 10]

47. (a) Define the *coulomb*.

....[1]

(b) A resistor X is connected to a cell as shown in Fig. 6.1.

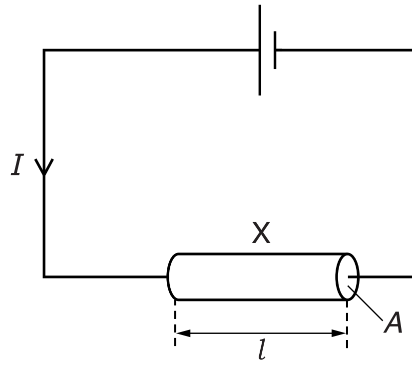

Fig. 6.1

The resistor is a wire of cross-sectional area A and length l. The current in the wire is I.

Show that the average drift speed v of the charge carriers in X is given by the equation

$$v = \frac{I}{nAe}$$

where e is the charge on a charge carrier and n is the number of charge carriers per unit volume in X.

[3]

(c) A 12V battery with negligible internal resistance is connected to two resistors Y and Z, as shown in Fig. 6.2.

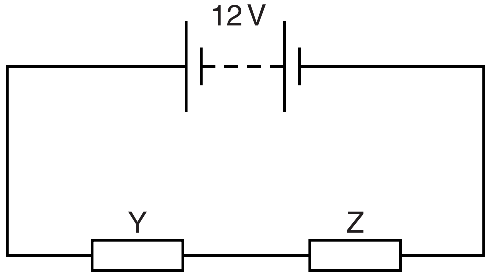

Fig. 6.2

The resistors are made from wires of the same material. The wire of Y has a diameter d and length l. The wire of Z has a diameter $2d$ and length $2l$.

(i) Determine the ratio

$$\frac{\text{average drift speed of the charge carriers in Y}}{\text{average drift speed of the charge carriers in Z}}\ .$$

ratio = ... [3]

(ii) Show that

$$\frac{\text{resistance of Y}}{\text{resistance of Z}} = 2.$$

[2]

(iii) Determine the potential difference across Y.

potential difference = ... V [2]

(iv) Determine the ratio

$$\frac{\text{power dissipated in Y}}{\text{power dissipated in Z}}\ .$$

ratio = ... [1]

[Total: 12]

48. **(a)** **(i)** State what is meant by an *electric current*.

....

.... [1]

(ii) Define electric *potential difference* (*p.d.*).

....

.... [1]

(b) A power supply of electromotive force (e.m.f.) 8.7 V and negligible internal resistance is connected by two identical wires to three filament lamps, as shown in Fig. 5.1.

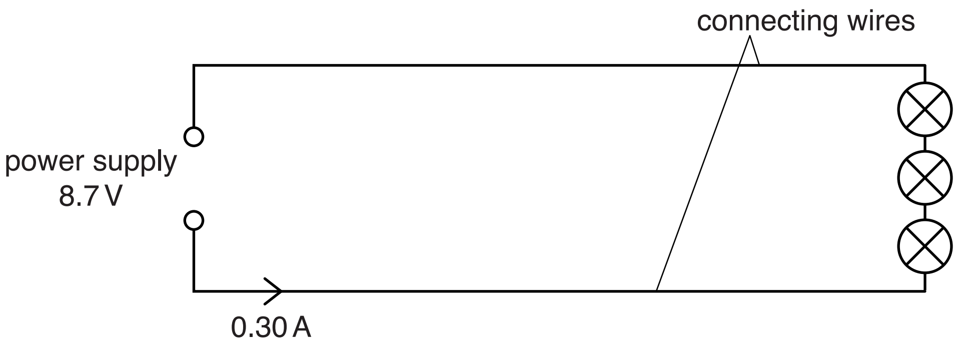

Fig. 5.1 (not to scale)

The power supply provides a current of 0.30 A to the circuit.
The filament lamps are identical. The I–V characteristic for **one** of the lamps is shown in Fig. 5.2.

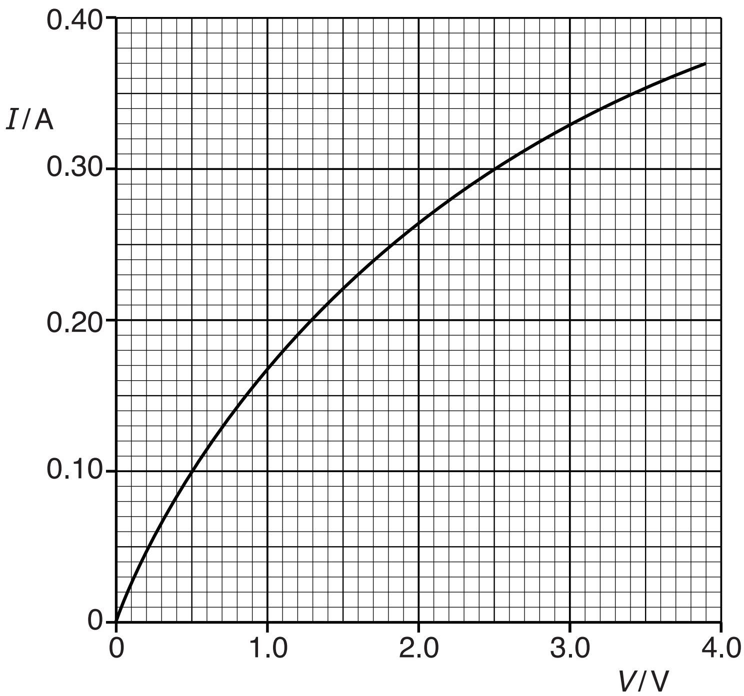

Fig. 5.2

(i) Show that the resistance of each connecting wire is $2.0\,\Omega$.

[2]

(ii) The resistivity of the metal of the connecting wires does not vary with temperature.
On Fig. 5.2, sketch the I–V characteristic for **one** of the connecting wires. [2]

(iii) Calculate the power loss in one of the connecting wires.

power = ... W [2]

(iv) Some data for the connecting wires are given below.

cross-sectional area = $0.40\,mm^2$
resistivity = $1.7 \times 10^{-8}\,\Omega\,m$
number density of free electrons = $8.5 \times 10^{28}\,m^{-3}$

Calculate

1. the length of one of the connecting wires,

length = ... m [2]

2. the drift speed of a free electron in the connecting wires.

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

[Total: 12]