For Examiner's Use

1 **(a)** A student has been asked to make an electric heater. The heater is to be rated as 12 V 60 W, and is to be constructed of wire of diameter 0.54 mm. The material of the wire has resistivity $4.9 \times 10^{-7}\,\Omega\,m$.

(i) Show that the resistance of the heater will be 2.4 Ω.

[2]

(ii) Calculate the length of wire required for the heater.

length = ... m [3]

(b) Two cells of e.m.f. E_1 and E_2 are connected to resistors of resistance R_1, R_2 and R_3 as shown in Fig. 7.1.

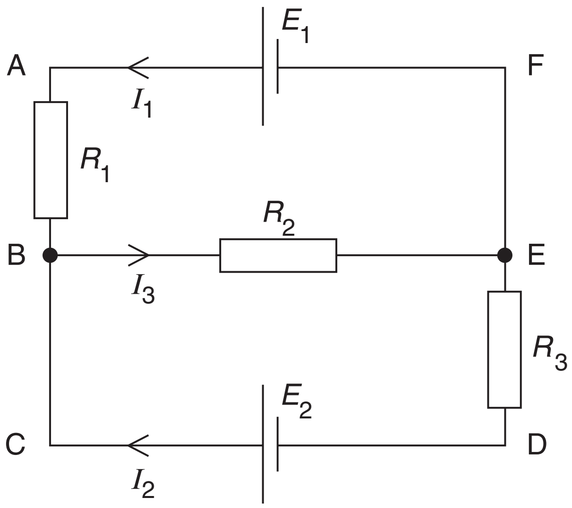

Fig. 7.1

The currents I_1, I_2 and I_3 in the various parts of the circuit are as shown.

(i) Write down an expression relating I_1, I_2 and I_3.

....[1]

(ii) Use Kirchhoff's second law to write down a relation between

1. E_1, R_1, R_2, I_1 and I_3 for loop ABEFA,

....

2. E_1, E_2, R_1, R_3, I_1 and I_2 for loop ABCDEFA.

....

[2]

2 A student has available some resistors, each of resistance 100 Ω.

(a) Draw circuit diagrams, one in each case, to show how a number of these resistors may be connected to produce a combined resistance of

(i) 200 Ω,

(ii) 50 Ω,

(iii) 40 Ω.

[4]

(b) The arrangement of resistors shown in Fig. 8.1 is connected to a battery.

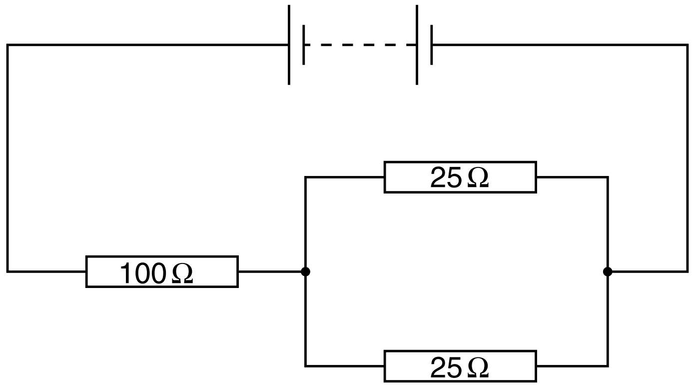

Fig. 8.1

The power dissipation in the 100 Ω resistor is 0.81 W. Calculate

(i) the current in the circuit,

current = ... A

(ii) the power dissipation in each of the 25 Ω resistors.

power = ... W

[4]

3 A student set up the circuit shown in Fig. 7.1.

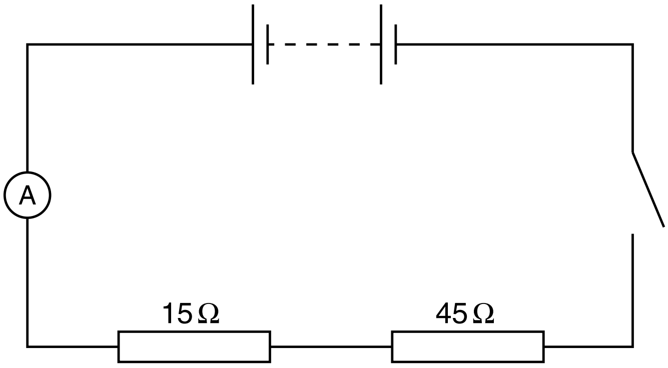

Fig. 7.1

The resistors are of resistance 15 Ω and 45 Ω. The battery is found to provide 1.6×10^5 J of electrical energy when a charge of 1.8×10^4 C passes through the ammeter in a time of 1.3×10^5 s.

(a) Determine

(i) the electromotive force (e.m.f.) of the battery,

e.m.f. = ... V

(ii) the average current in the circuit.

current = ... A
[4]

(b) During the time for which the charge is moving, 1.1×10^5 J of energy is dissipated in the 45 Ω resistor.

(i) Determine the energy dissipated in the 15 Ω resistor during the same time.

energy = ………………………………… J

(ii) Suggest why the total energy provided is greater than that dissipated in the two resistors.

....

....

[4]

4 A household electric lamp is rated as 240 V, 60 W. The filament of the lamp is made from tungsten and is a wire of constant radius 6.0×10^{-6} m. The resistivity of tungsten at the normal operating temperature of the lamp is $7.9 \times 10^{-7}\ \Omega$ m.

(a) For the lamp at its normal operating temperature,

(i) calculate the current in the lamp,

current = ... A

(ii) show that the resistance of the filament is 960 Ω.

[3]

(b) Calculate the length of the filament.

length = ... m [3]

(c) Comment on your answer to **(b)**.

....

.... [1]

5 A filament lamp operates normally at a potential difference (p.d.) of 6.0 V. The variation with p.d. V of the current I in the lamp is shown in Fig. 5.1.

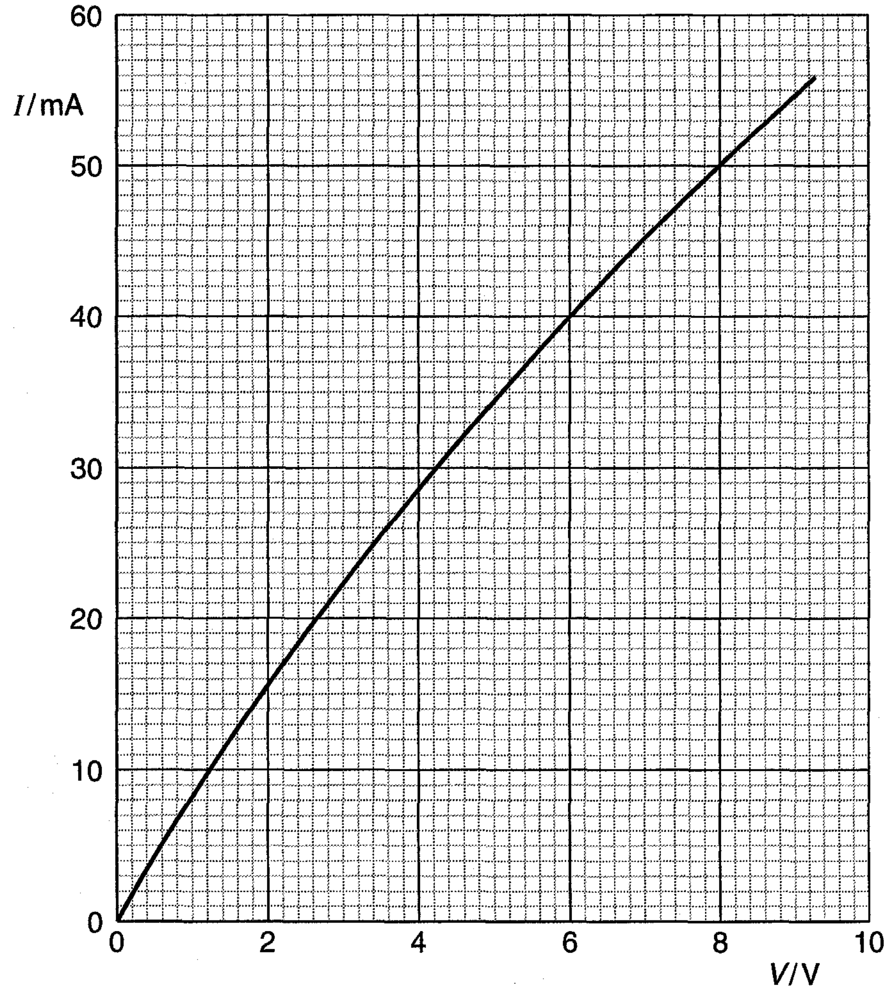

Fig. 5.1

(a) Use Fig. 5.1 to determine, for this lamp,

(i) the resistance when it is operating at a p.d. of 6.0 V,

resistance = ... Ω

(ii) the change in resistance when the p.d. increases from 6.0 V to 8.0 V.

change in resistance = ... Ω
[4]

(b) The lamp is connected into the circuit of Fig. 5.2.

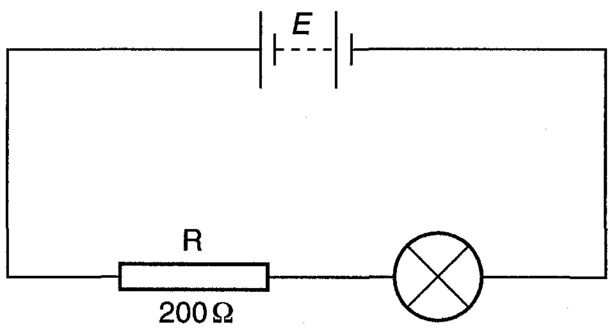

Fig. 5.2

R is a fixed resistor of resistance 200 Ω. The battery has e.m.f. *E* and negligible internal resistance.

(i) On Fig. 5.1, draw a line to show the variation with p.d. *V* of the current *I* in the resistor R.

(ii) Determine the e.m.f. of the battery for the lamp to operate normally.

e.m.f. = ... V
[4]

6 Fig. 6.1 shows the variation with applied potential difference V of the current I in an electrical component C.

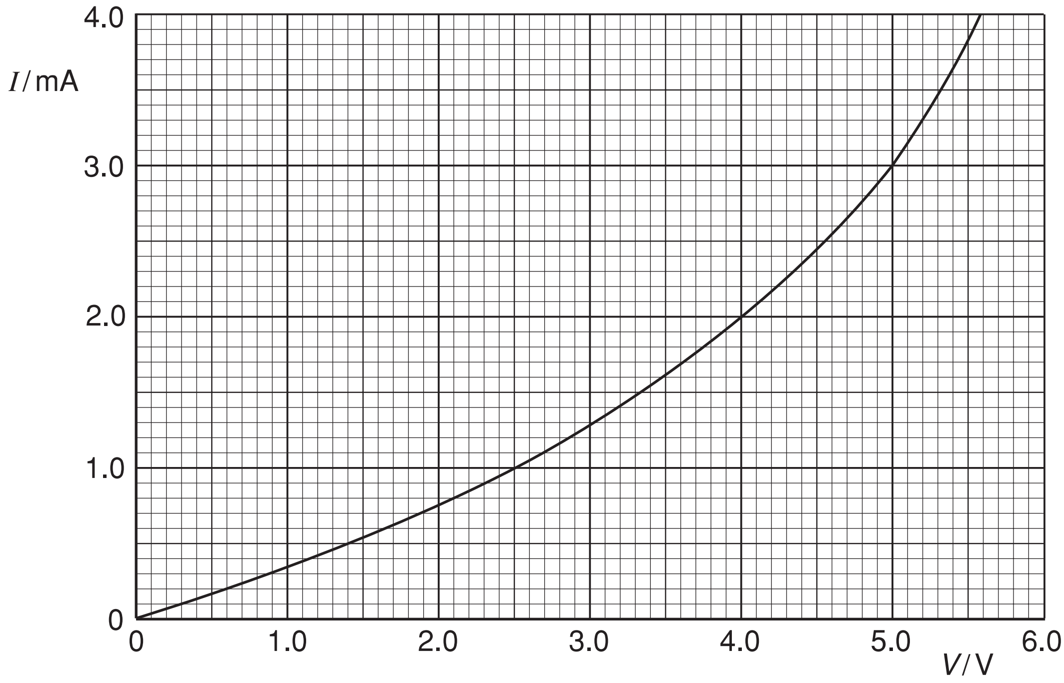

Fig. 6.1

(a) **(i)** State, with a reason, whether the resistance of component C increases or decreases with increasing potential difference.

....

.... [2]

(ii) Determine the resistance of component C at a potential difference of 4.0 V.

resistance = ……………………….. Ω [2]

(b) Component C is connected in parallel with a resistor R of resistance 1500 Ω and a battery of e.m.f. *E* and negligible internal resistance, as shown in Fig. 6.2.

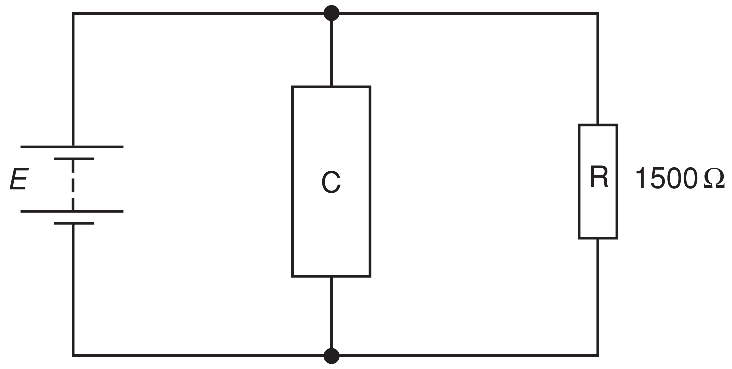

Fig. 6.2

(i) On Fig. 6.1, draw a line to show the variation with potential difference *V* of the current *I* in resistor R. [2]

(ii) Hence, or otherwise, use Fig. 6.1 to determine the current in the battery for an e.m.f. of 2.0 V.

current = ... A [2]

(c) The resistor R of resistance 1500 Ω and the component C are now connected in series across a supply of e.m.f. 7.0 V and negligible internal resistance.

Using information from Fig. 6.1, state and explain which component, R or C, will dissipate thermal energy at a greater rate.

....

....

....

.... [3]

7 **(a)** Define the *resistance* of a resistor.

....

....[1]

(b) In the circuit of Fig. 7.1, the battery has an e.m.f. of 3.00 V and an internal resistance *r*. R is a variable resistor. The resistance of the ammeter is negligible and the voltmeter has an infinite resistance.

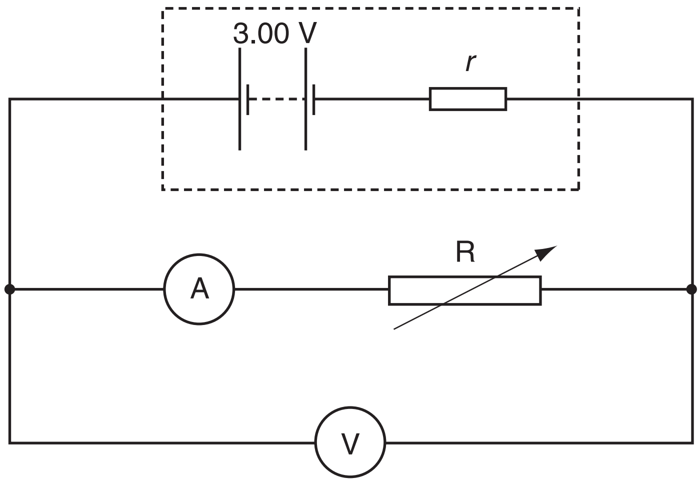

Fig. 7.1

The resistance of R is varied. Fig. 7.2 shows the variation of the power *P* dissipated in R with the potential difference *V* across R.

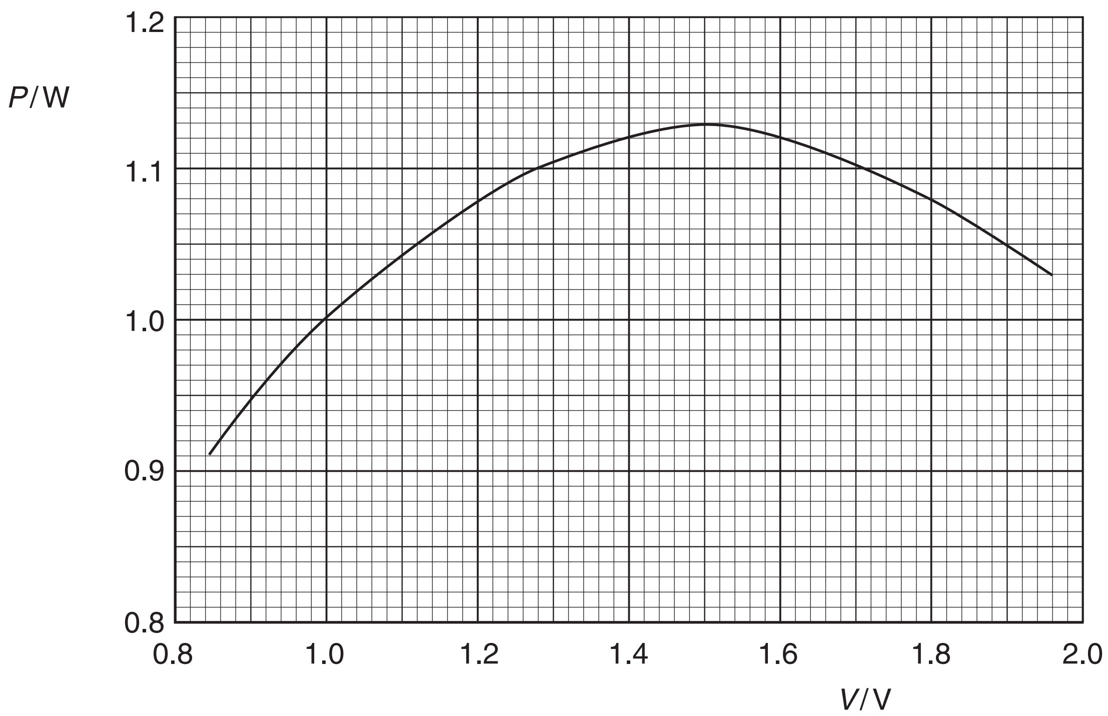

Fig. 7.2

(i) Use Fig. 7.2 to determine

1. the maximum power dissipation in R,

maximum power = ... W

2. the potential difference across R when the maximum power is dissipated.

potential difference = ... V
[1]

(ii) Hence calculate the resistance of R when the maximum power is dissipated.

resistance = ... Ω [2]

(iii) Use your answers in **(i)** and **(ii)** to determine the internal resistance *r* of the battery.

r = ... Ω [3]

(c) By reference to Fig. 7.2, it can be seen that there are two values of potential difference *V* for which the power dissipation is 1.05 W.
State, with a reason, which value of *V* will result in less power being dissipated in the internal resistance.

....

....

....

....[3]

For Examiner's Use

8 A battery of e.m.f. 4.50 V and negligible internal resistance is connected in series with a fixed resistor of resistance 1200 Ω and a thermistor, as shown in Fig. 7.1.

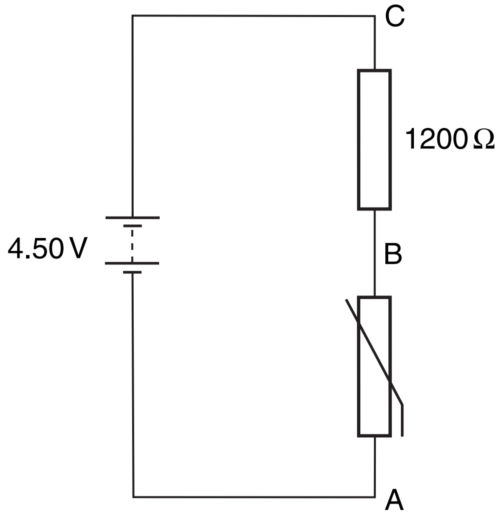

Fig. 7.1

(a) At room temperature, the thermistor has a resistance of 1800 Ω. Deduce that the potential difference across the thermistor (across AB) is 2.70 V.

[2]

(b) A uniform resistance wire PQ of length 1.00 m is now connected in parallel with the resistor and the thermistor, as shown in Fig. 7.2.

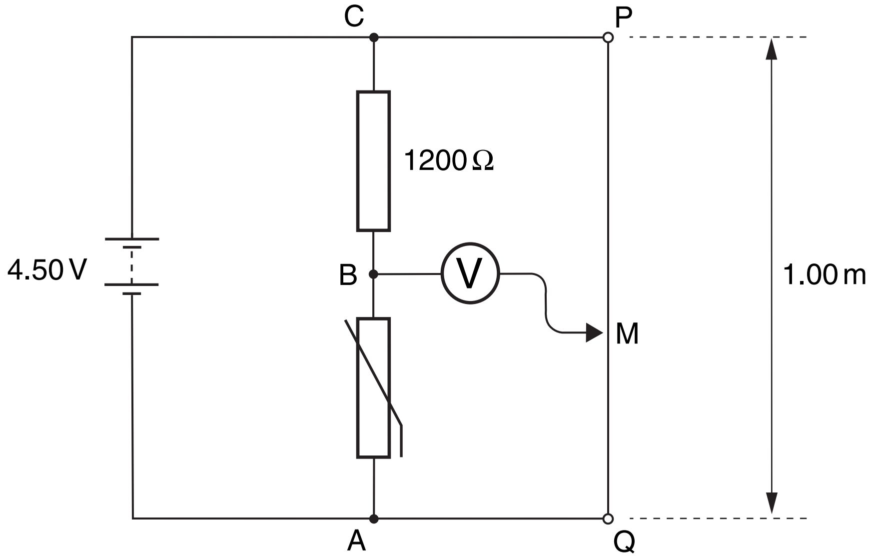

Fig. 7.2

A sensitive voltmeter is connected between point B and a moveable contact M on the wire.

For Examiner's Use

(i) Explain why, for constant current in the wire, the potential difference between any two points on the wire is proportional to the distance between the points.

....

....

....[2]

(ii) The contact M is moved along PQ until the voltmeter shows zero reading.

1. State the potential difference between the contact at M and the point Q.

potential difference = ………………………… V [1]

2. Calculate the length of wire between M and Q.

length = ………………………….. cm [2]

(iii) The thermistor is warmed slightly. State and explain the effect on the length of wire between M and Q for the voltmeter to remain at zero deflection.

....

....

....[2]

9 A circuit contains three similar lamps A, B and C. The circuit also contains three switches, S_1, S_2 and S_3, as shown in Fig. 7.1.

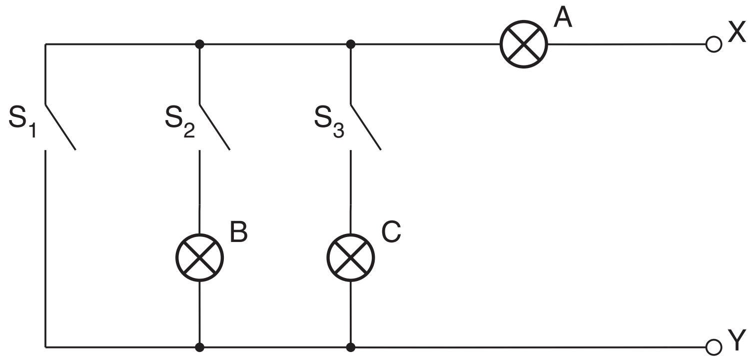

Fig. 7.1

One of the lamps is faulty. In order to detect the fault, an ohm-meter (a meter that measures resistance) is connected between terminals X and Y. When measuring resistance, the ohm-meter causes negligible current in the circuit.

Fig. 7.2 shows the readings of the ohm-meter for different switch positions.

switch S_1	switch S_2	switch S_3	meter reading / Ω
open	open	open	∞
closed	open	open	15 Ω
open	closed	open	30 Ω
open	closed	closed	15 Ω

Fig. 7.2

(a) Identify the faulty lamp, and the nature of the fault.

faulty lamp: ....

nature of fault: .... [2]

(b) Suggest why it is advisable to test the circuit using an ohm-meter that causes negligible current rather than with a power supply.

....

.... [1]

(c) Determine the resistance of one of the non-faulty lamps, as measured using the ohm-meter.

resistance = ... Ω [1]

(d) Each lamp is marked 6.0 V, 0.20 A.

Calculate, for one of the lamps operating at normal brightness,

(i) its resistance,

resistance = ... Ω [2]

(ii) its power dissipation.

power = ... W [2]

(e) Comment on your answers to **(c)** and **(d)(i)**.

....

....

....[2]

For Examiner's Use

10 A straight wire of unstretched length L has an electrical resistance R. When it is stretched by a force F, the wire extends by an amount ΔL and the resistance increases by ΔR. The area of cross-section A of the wire may be assumed to remain constant.

(a) **(i)** State the relation between R, L, A and the resistivity ρ of the material of the wire.

....

.... [1]

(ii) Show that the fractional change in resistance $\frac{\Delta R}{R}$ is equal to the strain in the wire.

[2]

(b) A steel wire has area of cross-section $1.20 \times 10^{-7}\,m^2$ and a resistance of $4.17\,\Omega$.

The Young modulus of steel is $2.10 \times 10^{11}\,Pa$.

The tension in the wire is increased from zero to 72.0 N. The wire obeys Hooke's law at these values of tension.

Determine the strain in the wire and hence its change in resistance. Express your answer to an appropriate number of significant figures.

change = ... Ω [5]

11 **(a)** Distinguish between the electromotive force (e.m.f.) of a cell and the potential difference (p.d.) across a resistor.

....

....

....

.... [3]

(b) Fig. 7.1. is an electrical circuit containing two cells of e.m.f. E_1 and E_2.

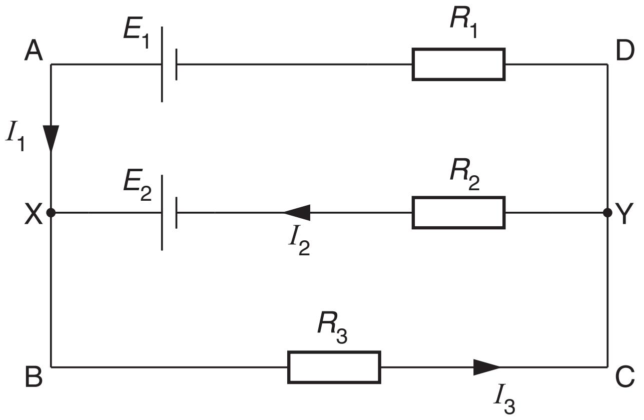

Fig. 7.1

The cells are connected to resistors of resistance R_1, R_2 and R_3 and the currents in the branches of the circuit are I_1, I_2 and I_3, as shown.

(i) Use Kirchhoff's first law to write down an expression relating I_1, I_2 and I_3.

.... [1]

(ii) Use Kirchhoff's second law to write down an expression relating

1. E_2, R_2, R_3, I_2 and I_3 in the loop XBCYX,

.... [1]

2. E_1, E_2, R_1, R_2, I_1 and I_2 in the loop AXYDA.

.... [1]

12 A car battery has an internal resistance of 0.060 Ω. It is re-charged using a battery charger having an e.m.f. of 14 V and an internal resistance of 0.10 Ω, as shown in Fig. 6.1.

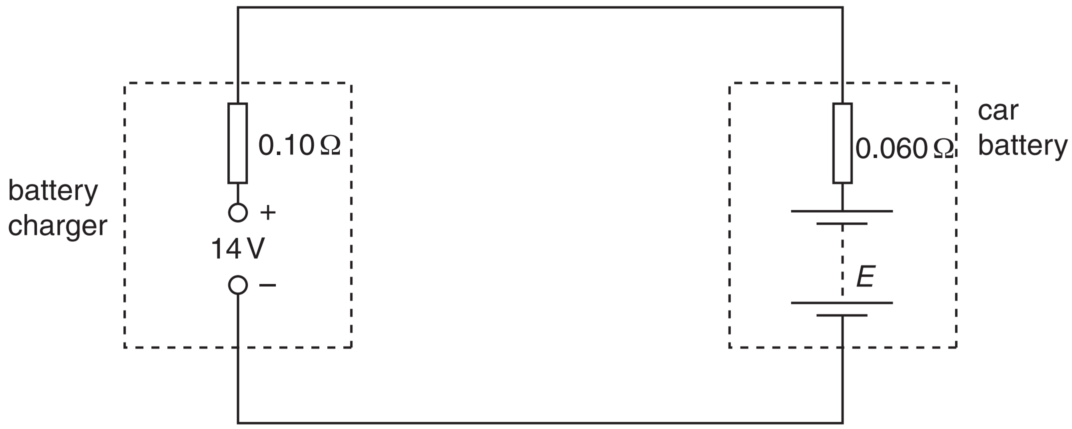

Fig. 6.1

(a) At the beginning of the re-charging process, the current in the circuit is 42 A and the e.m.f. of the battery is *E* (measured in volts).

(i) For the circuit of Fig. 6.1, state

1. the magnitude of the total resistance,

resistance = ... Ω

2. the total e.m.f. in the circuit. Give your answer in terms of *E*.

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

(ii) Use your answers to **(i)** and data from the question to determine the e.m.f. of the car battery at the beginning of the re-charging process.

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

(b) For the majority of the charging time of the car battery, the e.m.f. of the car battery is 12 V and the charging current is 12.5 A. The battery is charged at this current for 4.0 hours. Calculate, for this charging time,

(i) the charge that passes through the battery,

charge = ... C [2]

(ii) the energy supplied from the battery charger,

energy = ... J [2]

(iii) the total energy dissipated in the internal resistance of the battery charger and the car battery.

energy = ... J [2]

(c) Use your answers in **(b)** to calculate the percentage efficiency of transfer of energy from the battery charger to stored energy in the car battery.

efficiency = ...% [2]

13 An electric shower unit is to be fitted in a house. The shower is rated as 10.5 kW, 230 V. The shower unit is connected to the 230 V mains supply by a cable of length 16 m, as shown in Fig. 6.1.

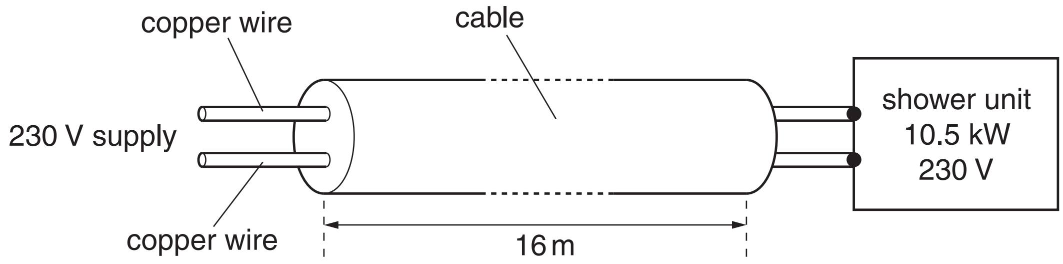

Fig. 6.1

(a) Show that, for normal operation of the shower unit, the current is approximately 46 A.

[2]

(b) The resistance of the two wires in the cable causes the potential difference across the shower unit to be reduced. The potential difference across the shower unit must not be less than 225 V.
The wires in the cable are made of copper of resistivity $1.8 \times 10^{-8}\,\Omega\,\text{m}$.
Assuming that the current in the wires is 46 A, calculate

(i) the maximum resistance of the cable,

resistance = ... Ω [3]

(ii) the minimum area of cross-section of each wire in the cable.

area = ... m^2 [3]

(c) Connecting the shower unit to the mains supply by means of a cable having wires with too small a cross-sectional area would significantly reduce the power output of the shower unit.

(i) Assuming that the shower is operating at 210 V, rather than 230 V, and that its resistance is unchanged, determine the ratio

$$\frac{\text{power dissipated by shower unit at 210 V}}{\text{power dissipated by shower unit at 230 V}}.$$

ratio = ... [2]

(ii) Suggest and explain one further disadvantage of using wires of small cross-sectional area in the cable.

....

....

.... [2]

14 An electric heater consists of three similar heating elements A, B and C, connected as shown in Fig. 6.1.

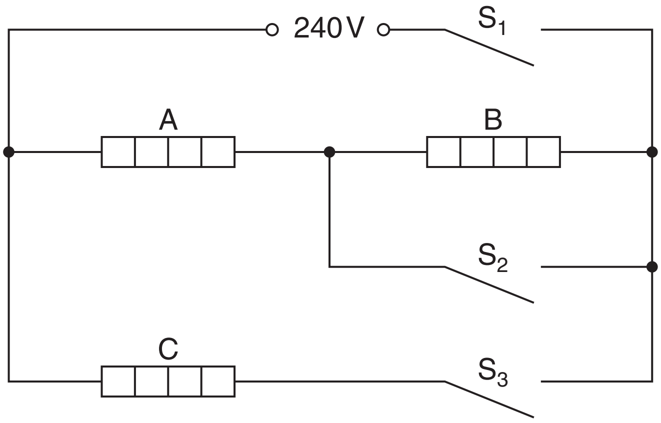

Fig. 6.1

Each heating element is rated as 1.5 kW, 240 V and may be assumed to have constant resistance.
The circuit is connected to a 240 V supply.

(a) Calculate the resistance of one heating element.

resistance = ……………………………….. Ω [2]

(b) The switches S_1, S_2 and S_3 may be either open or closed.

For Examiner's Use

Complete Fig. 6.2 to show the total power dissipation of the heater for the switches in the positions indicated.

S_1	S_2	S_3	total power / kW
open	closed	closed	....
closed	closed	open	....
closed	closed	closed	....
closed	open	open	....
closed	open	closed	....

[5]

Fig. 6.2

For Examiner's Use

15 A potential divider circuit consists of two resistors of resistances P and Q, as shown in Fig. 7.1.

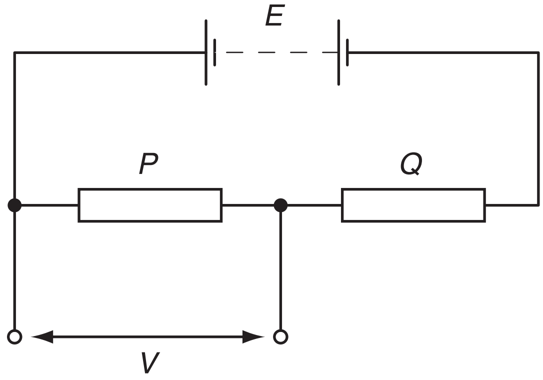

Fig. 7.1

The battery has e.m.f. E and negligible internal resistance.

(a) Deduce that the potential difference V across the resistor of resistance P is given by the expression

$$V = \frac{P}{P + Q} E.$$

[2]

(b) The resistances P and Q are 2000 Ω and 5000 Ω respectively.
A voltmeter is connected in parallel with the 2000 Ω resistor and a thermistor is connected in parallel with the 5000 Ω resistor, as shown in Fig. 7.2.

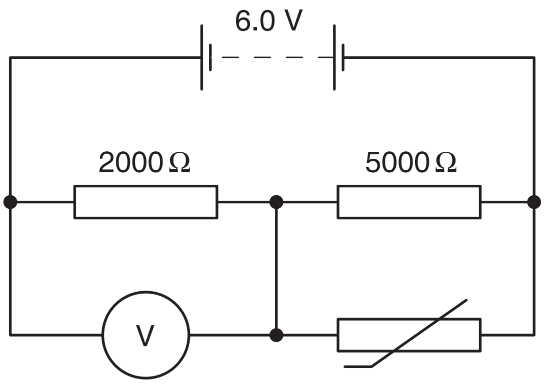

Fig. 7.2

The battery has e.m.f. 6.0 V. The voltmeter has infinite resistance.

(i) State and explain qualitatively the change in the reading of the voltmeter as the temperature of the thermistor is raised.

....

....

....

.... [3]

(ii) The voltmeter reads 3.6 V when the temperature of the thermistor is 19 °C.
Calculate the resistance of the thermistor at 19 °C.

resistance = ... Ω [4]