1)

A cell is a source of e.m.f. When the cell is connected into a circuit the potential difference measured between its terminals, called the *terminal p.d.*, is less than its e.m.f.

(a) **(i)** Define the term *e.m.f.*

....

....

.... **[2]**

(ii) Explain why the terminal p.d. is less than the e.m.f.

....

....

.... **[2]**

(b) In the circuit of Fig. 3.1 the cell of e.m.f. 1.6V and internal resistance *r* is delivering a current of 0.20A to a resistor of resistance *R*. The voltmeter reads the terminal p.d. It is 1.2V.

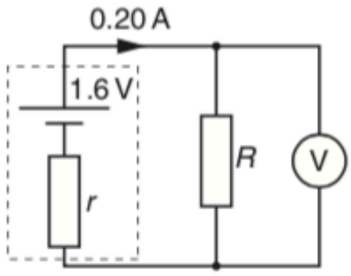

Fig. 3.1

Calculate the values of

(i) the resistance *R*

R = ... Ω **[2]**

(ii) the internal resistance *r*.

r = ... Ω **[2]**

(c) **(i)** The current in the resistor of Fig. 3.1 remains constant at 0.20 A for several hours. Calculate

1 the charge which passes through the resistor in 1.5 hours

charge = ... unit .... **[3]**

2 the energy dissipated by the resistor in 1.5 hours.

energy = ... J **[2]**

(ii) The cell is left connected to the resistor for 12 hours. The graph of Fig. 3.2 shows the variation of current I with time t.

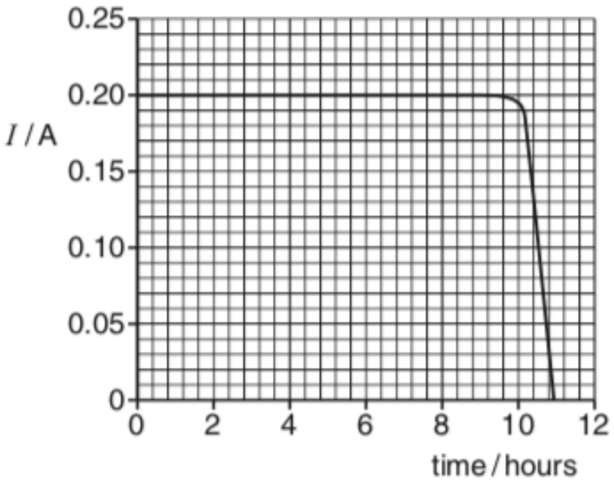

Fig. 3.2

Describe how the current varies with time. Suggest reasons why it varies in this way.

In your answer you should link each feature of the graph to the reason for it.

....

....

....

....

....

....

.... **[4]**

[Total: 17]

2)

Fig. 3.1 shows a circuit consisting of a battery of electromotive force 16.0V and negligible internal resistance, two resistors and a thermistor.

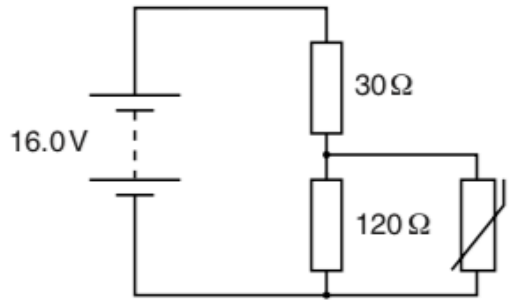

Fig. 3.1

(a) (i) Define the term *electromotive force* (*e.m.f.*).

....

....

.... **[2]**

(ii) Explain the meaning of the term *internal resistance*.

....

....

.... **[1]**

(b) The thermistor has a resistance of 360Ω at 20°C. Calculate

(i) the total resistance *R* of the thermistor and the resistor of resistance 120Ω at 20°C

R = ... Ω **[2]**

(ii) the potential difference *V* across the thermistor.

V = ... V **[3]**

(iii) It is suggested that the thermistor in the circuit of Fig. 3.1 is used to monitor temperatures between 20°C and 200°C. Describe how the potential difference across the thermistor and the current in it will vary as the temperature increases above 20°C.

In your answer you should explain why the potential difference and current vary as the temperature increases.

....

....

....

....

....

....

.... **[4]**

(c) The battery in Fig. 3.1 is rechargeable.

(i) Calculate the charge stored in the battery when it is charged for 8.0 hours at a constant current of 1.2 A.

charge = ... unit .... **[3]**

(ii) After charging, the battery loses energy at a constant rate of $1.4\,J\,s^{-1}$. The e.m.f. of the battery remains constant at 16.0 V. Calculate how many hours it takes for the battery to discharge.

discharge time = ... h **[3]**

[Total: 18]

3)

(a) A student wishes to determine the power dissipated in a variable resistor connected to a cell.

(i) Part of the circuit for this experiment is shown in Fig. 3.1. Complete the circuit of Fig. 3.1 showing how the variable resistor is connected and how the potential difference across it is measured. **[3]**

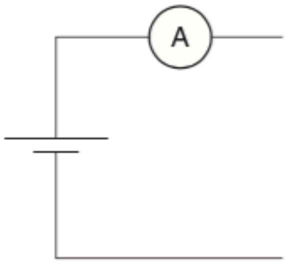

Fig. 3.1

(ii) Fig. 3.2 shows the variation of the potential difference V across the variable resistor with the current I in it.

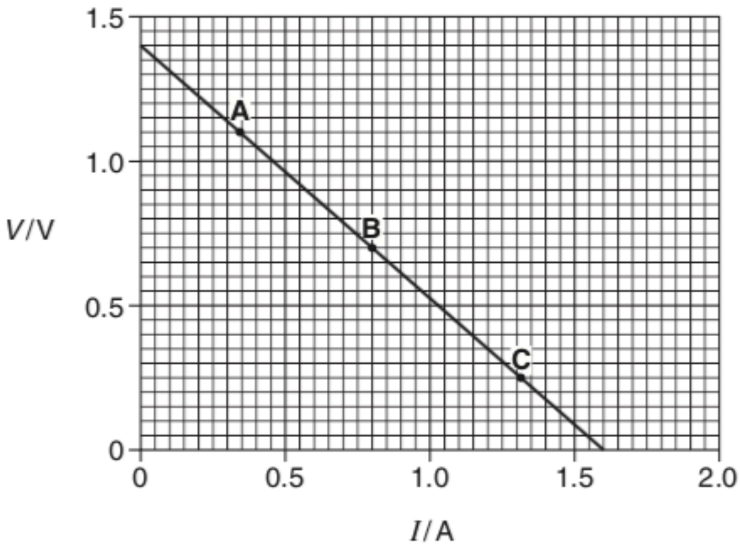

Fig. 3.2

1 The potential difference V across the variable resistor is also the terminal p.d. across the cell. Describe how the potential difference across the cell varies with the **resistance** R of the variable resistor. Suggest why the terminal p.d. varies in this way.

....

....

....

....

....

.... **[3]**

2 By referring to the points **A** and **C**, justify that the power dissipated in the variable resistor is a maximum at or near point **B**.

....

....

....

....

.... **[3]**

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

E = ... V **[1]**

4 Calculate the internal resistance r of the cell.

r = ... Ω **[2]**

(b) In Fig. 3.1, the cell is replaced by a solar cell as the source of e.m.f.
A solar cell transforms light energy into electrical energy. The maximum intensity of sunlight on the solar cell is $800\,W\,m^{-2}$. The surface area of the cell is $2.5 \times 10^{-3}\,m^2$.

(i) Define the term *intensity*.

....

.... **[1]**

(ii) The maximum power delivered by the solar cell to the variable resistor is 0.25 W. Determine the maximum efficiency of the solar cell.

maximum efficiency = ... **[3]**

[Total: 16]

4)

This question is about possible heating circuits used to demist the rear window of a car. The heater is made of 8 thin strips of a metal conductor fused onto the glass surface. Fig. 2.1 shows the 8 strips connected in parallel to the car battery of e.m.f. E and internal resistance r.

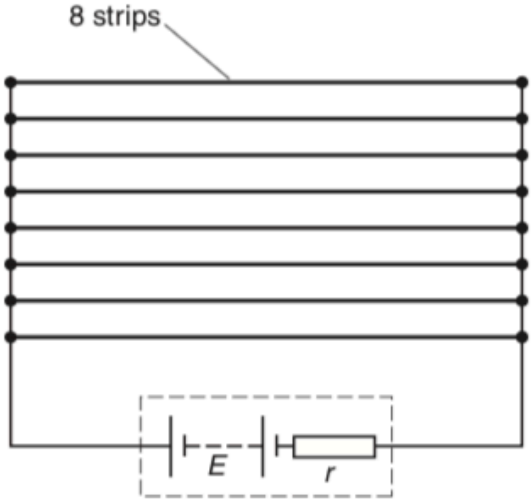

Fig. 2.1

(a) The potential difference across each strip is 12 V when a current of 2.0 A passes through it.

(i) Calculate the resistance r_p of one strip of the heater.

r_p = ... Ω **[1]**

(ii) Calculate the total resistance R_p of the heater.

R_p = ... Ω **[3]**

(iii) Show that the power P dissipated by the heater is about 200 W.

[2]

(b) Each strip is 0.90 m long, 2.4×10^{-4} m thick and 2.0×10^{-3} m wide.

Calculate the resistivity ρ of the metal of the strip. Give the unit with your answer.

ρ = ...unit .... **[4]**

(c) An alternative way of making the heater is to connect eight metal strips in **series**. The heater is to dissipate the same power as the parallel combination of **(a)** when the p.d. across it is 12V.

(i) Explain why the total resistance of the series heater must equal R_p calculated in **(a)(ii)**.

....

.... **[1]**

(ii) Calculate the resistance r_s of one strip of this series heater.

r_s = ... Ω **[1]**

(iii) Suggest, with a reason, whether you would choose the series or parallel circuit arrangement of the strips for a demister heater.

....

.... **[1]**

(d) Fig. 2.2 is a graph showing how the potential difference across the terminals of the battery varies with the current drawn from it.

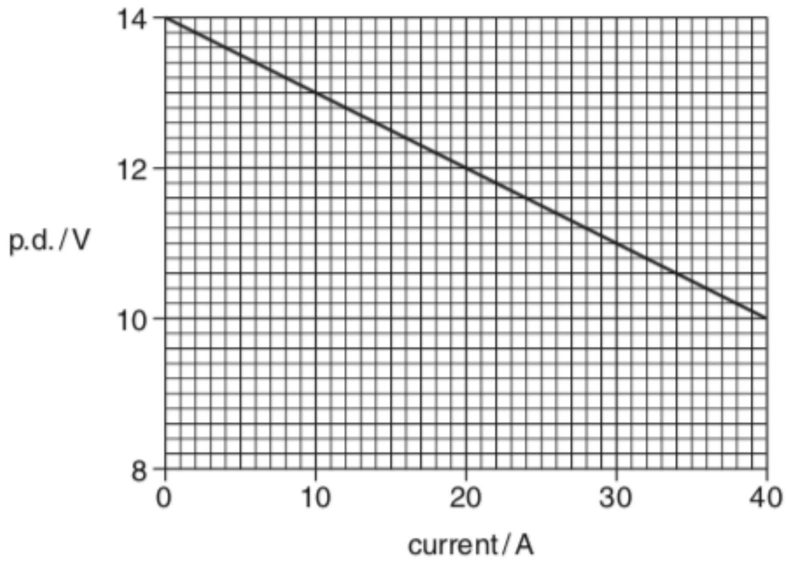

Fig. 2.2

(i) From the graph find the e.m.f. E of the battery.

E = ... V **[1]**

(ii) Use data from the graph to calculate the internal resistance r of the battery.

r = ... Ω **[3]**

[Total: 17]

5)

(a) The battery in an electric car has an e.m.f. of 24V. It can provide a current of 200A to the motor for a period of 4.0 hours.

(i) Define the term *electromotive force* (e.m.f.) for the battery.

....

....

.... **[2]**

(ii) Show that the total charge Q that can be delivered by the battery is about 3×10^6 C.

[2]

(iii) Calculate the total energy E that can be supplied by the battery at a constant e.m.f. of 24V.

E = ... J **[2]**

(b) The charger for the battery has a 30V output supplying a current I. The total resistance of the circuit is indicated by one resistor **R** in Fig. 2.1. The positive terminal of the battery is connected to **X**.

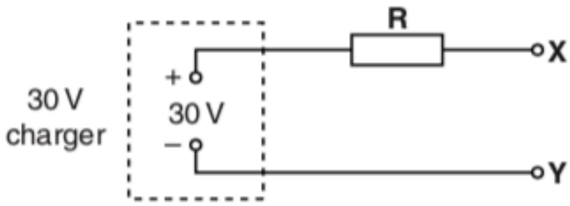

Fig. 2.1

(i) Complete the circuit by drawing the correct symbol for the battery between **X** and **Y** on Fig. 2.1. The battery has negligible internal resistance. **[1]**

(ii) The potential difference across the battery remains at 24V. The current I provided by the battery charger is constant at 120A. Show that the value of the resistance of **R** is 0.050 Ω.

[2]

(iii) Calculate the power lost in **R** as the battery is charging.

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

(iv) The efficiency of the charging process is given by the equation

$$\text{efficiency} = \frac{\text{input power from charger} - \text{power loss in } \mathbf{R}}{\text{input power from charger}}.$$

Calculate its value as a percentage.

efficiency = ... % **[3]**

(c) **(i)** Show that it takes about 7 hours to charge a completely flat battery.

[2]

(ii) Calculate the cost of charging the battery at 26p per kWh.

cost = ... p **[1]**

[Total: 17]

6)

(a) The following electrical quantities are often used when analysing circuits. The units given are alternatives to the units normally used for the quantities below. Draw a straight line from each quantity on the left to its correct unit on the right.

electromotive force	A s
resistance	V C
energy	$V A^{-1}$
charge	$J C^{-1}$

[2]

(b) The circuit in Fig. 2.1 consists of a cell and five resistors.

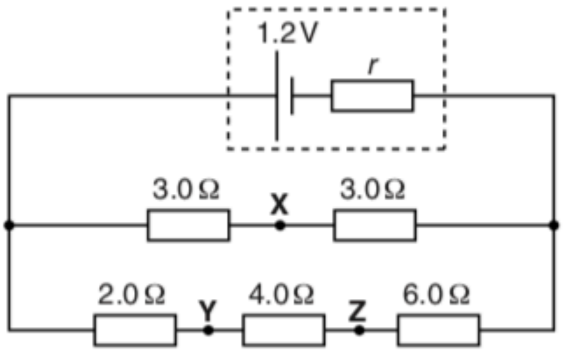

Fig. 2.1

The cell has e.m.f. 1.2 V and internal resistance *r*. The current at point **X** is 0.16 A.

(i) Define *potential difference*.

....

....

.... **[2]**

(ii) Explain what is meant by *internal resistance*.

....

.... **[1]**

(iii) Explain why the current at **X** must be twice the current at **Y** or **Z**.

....

....

....

....

.... **[2]**

(iv) Calculate the p.d. across the 6.0 Ω resistor.

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

(v) Suggest why the p.d. V_{XZ} between **X** and **Z** is zero.

....

....

....

....

.... **[2]**

(vi) Calculate the value of the internal resistance *r*.

r = ... Ω **[4]**

[Total: 15]

7)

(a) A battery charger contains a microprocessor circuit so that it can charge an AA rechargeable cell at a constant current of 450 mA. It takes 4 hours 40 minutes to charge a 1.5V cell from a fully discharged state.

(i) Calculate the charge Q passing through the cell during the charging process.

Q = ... unit .... **[3]**

(ii) Fig. 3.1 shows the cell of internal resistance 0.90 Ω connected to the battery charger. Assume that the e.m.f. of the cell is 1.5V.

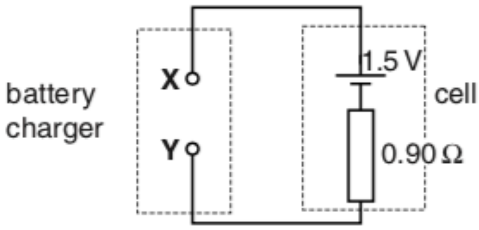

Fig. 3.1

1 State whether the terminal **X** of the battery charger is positive or negative.

....

2 Mark the direction of the current in the circuit on Fig. 3.1. Label your arrow I. Give a reason for your choice.

....

.... **[2]**

3 Calculate the terminal p.d. V_{XY} between **X** and **Y** during the charging process.

V_{XY} = ... V **[2]**

4 Show that the mean rate of increase of energy stored in the cell during the charging process is about 0.7 J s^{-1}.

[2]

(b) Explain how you would determine experimentally the e.m.f. *E* and internal resistance *r* of the charged cell. Include a circuit diagram with meters and a variable load resistor.

In your answer you should state how the data collected is used to determine the values of E and r.

....

....

....

....

....

....

.... **[5]**

(c) A 6.0 V 2.0 W filament lamp has a resistance of 18 Ω when lit to normal brightness. It is connected in series to four 1.5 V cells each of internal resistance 0.90 Ω.

(i) Explain, using calculations, why the lamp does not light to normal brightness.

[3]

(ii) It is found that by adding more cells in series it is possible to make the lamp light to normal brightness. Calculate the total number of cells needed in the circuit for this to occur. Show your working clearly.

number of cells = ... **[2]**

8)

(a) Circle the quantity, in the list below, that is conserved in Kirchhoff's second law.

charge **e.m.f.** **energy** **current** **[1]**

(b) Explain the meaning of the following terms which are often used when referring to a d.c. supply

(i) *terminal potential difference*

....

....

.... **[2]**

(ii) *internal resistance.*

....

....

.... **[1]**

(c) Fig. 3.1 shows a d.c. supply labelled 6.0V connected to a circuit containing an ammeter, a voltmeter, a fixed 3.0 Ω resistor and a 0 to 15 Ω variable resistor. You are to carry out an experiment to show that the internal resistance *r* of the d.c. supply is constant for a range of currents and to find the value of *r*.

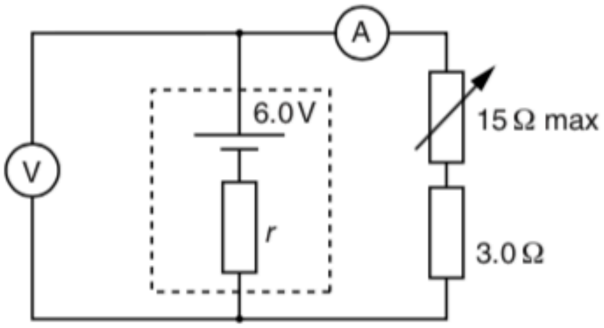

Fig. 3.1

(i) Describe how you would carry out the experiment. Explain how you would determine the value of the internal resistance of the d.c. supply and show that it is constant.

....

....

....

....

....

....

....

....

....

....

.... **[5]**

(ii) Suggest why the 3.0 Ω resistor is included in the circuit.

....

....

.... **[1]**

(d) Two cells **X** and **Y** each have an e.m.f. and internal resistance as shown in Fig. 3.2. They are connected in series to a resistor **R** of resistance 2.0 Ω.

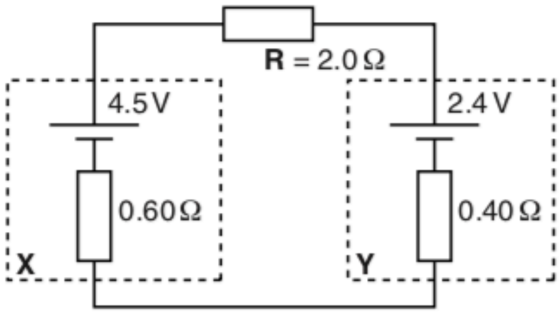

Fig. 3.2

(i) Note that the positive terminals of the cells are connected together. Draw a single arrow on Fig. 3.2 to show the direction of the current in **R**. **[1]**

(ii) Calculate the current in **R**.

current = ... A **[2]**

(iii) Calculate

1 the p.d. V_R across **R**

V_R = ... V **[1]**

2 the terminal p.d. V_X across **X**.

V_X = ... V **[2]**

9)

Fig. 4.1 shows part of a circuit where three resistors are connected together.

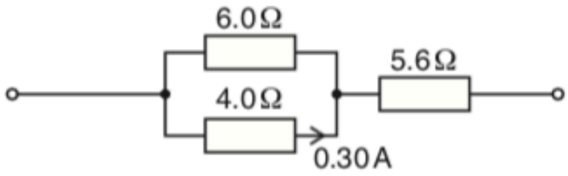

Fig. 4.1

The current in the 4.0 Ω resistor is 0.30 A.

(a) Explain why the current in the 6.0 Ω resistor is 0.20 A.

....

....

....

....

.... **[2]**

(b) **(i)** State the law which enables you to calculate the current in the 5.6 Ω resistor.

....

.... **[1]**

(ii) Calculate the current in the 5.6 Ω resistor.

current = ... A **[1]**

(c) Calculate the total resistance *R* of the combination of resistors.

R = ... Ω **[3]**

(d) To cause the current of 0.30 A in the 4.0 Ω resistor, the resistor combination is connected to a d.c. supply of electromotive force (e.m.f.) 5.0 V.

(i) Explain the term *e.m.f.*

....

....

.... **[2]**

(ii) Show that the terminal potential difference across the supply is 4.0 V.

[1]

(iii) Calculate the internal resistance of the supply.

internal resistance = ... Ω **[2]**

[Total: 12]

10)

(a) A battery of e.m.f. *E* and internal resistance *r* delivers a current *I* to a circuit of resistance *R*.

Write down an equation for *E* in terms of *r*, *I* and *R*.

.... **[1]**

(b) A 'flat' car battery of internal resistance 0.06 Ω is to be charged using a battery charger having an e.m.f. of 14 V and internal resistance of 0.74 Ω, as shown in Fig. 2.1.

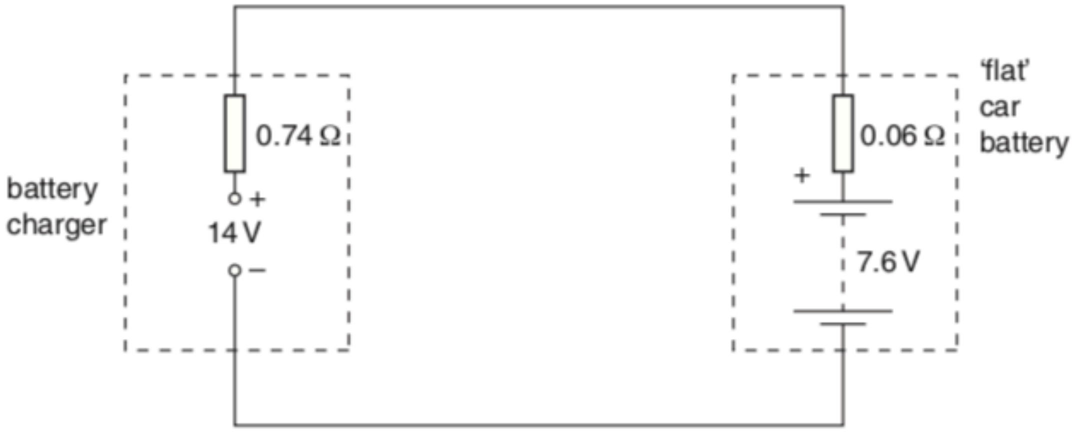

Fig. 2.1

You can see that the battery to be charged has its positive terminal connected to the positive terminal of the battery charger.

At the beginning of the charging process, the e.m.f. of the 'flat' car battery is 7.6 V.

(i) For the circuit of Fig. 2.1, determine

1 the total resistance

resistance = ... Ω **[1]**

2 the sum of the e.m.f.s in the circuit.

e.m.f. = ... V **[1]**

(ii) State Kirchhoff's second law.

....

.... **[1]**

(iii) Apply the law to this circuit to calculate the initial charging current.

current = ... A **[2]**

(c) For the majority of the charging time of the car battery in the circuit of Fig. 2.1, the e.m.f. of the car battery is 12V and the charging current is 2.5A. The battery is charged at this current for 6.0 hours. Calculate, for this charging time,

(i) the charge that passes through the battery

charge = ... C **[2]**

(ii) the energy supplied by the battery charger of e.m.f. 14V

energy = ... J **[2]**

(iii) the percentage of the energy supplied by the charger which is dissipated in the internal resistances of the battery charger and the car battery.

percentage of energy = ... % **[2]**

[Total: 12]

11)

(a) A 12V car battery contains an electrolyte. The battery is connected to an electric motor **M**. There is a current in the motor and the battery. See Fig. 2.1.

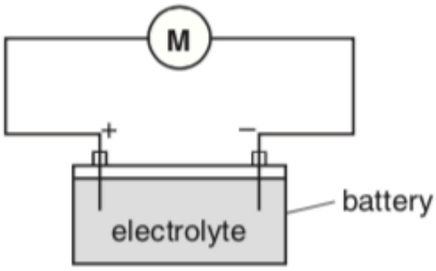

Fig. 2.1

State

(i) the charge carriers in the electrolyte

.... **[1]**

(ii) the charge carriers moving through the electrolyte to the positive terminal of the battery

.... **[1]**

(iii) the charge carriers moving through the wires to the positive terminal of the battery.

.... **[1]**

(b) When used to start the engine of the car, the electric motor draws 40A from the battery of e.m.f. 12V. The potential difference across the motor at this time is only 8.0V.

(i) Explain why the potential difference across the motor at this time is not the same as the e.m.f. of the car battery.

....

....

....

.... **[2]**

(ii) Show that the internal resistance of the battery is 0.10 Ω.

[3]

(iii) It takes 1.2 s for the electric motor to start the engine. Calculate the charge Q which passes through the electric motor in this time.

Q = ... C **[2]**

(c) The car has two 12V headlamps each rated at 54W, connected in parallel to the battery. In normal working conditions the current in each lamp is 4.5A.

(i) Explain how and why the resistance of the headlamp filament varies with the current passing through it.

....

....

....

....

.... **[2]**

(ii) Suggest a value for the current rating of a fuse for the headlamp circuit. Justify your choice.

....

....

.... **[2]**

(iii) A car contains a number of different fuses for its various electrical circuits. Suggest why this is necessary.

....

....

.... **[1]**

[Total: 15]