PRESTON MANOR

Physics Exam Pack

Circuits

Name:

Date:

Question / Paper	Mark

3 **(a)** State **one** similarity between *potential difference* and *electromotive force*.

....

....[1]

(b) Define the *volt*.

....

....[1]

(c) **(i)** Define the *kilowatt-hour* (kW h).

....

....[1]

(ii) Determine the value of the kilowatt-hour in joules.

1 kW h = ... J [1]

(d) A d.c. supply is connected across a variable resistor. The resistance of the variable resistor is changed. Fig. 3.1 shows the variation of the power P dissipated in the resistance R of the variable resistor.

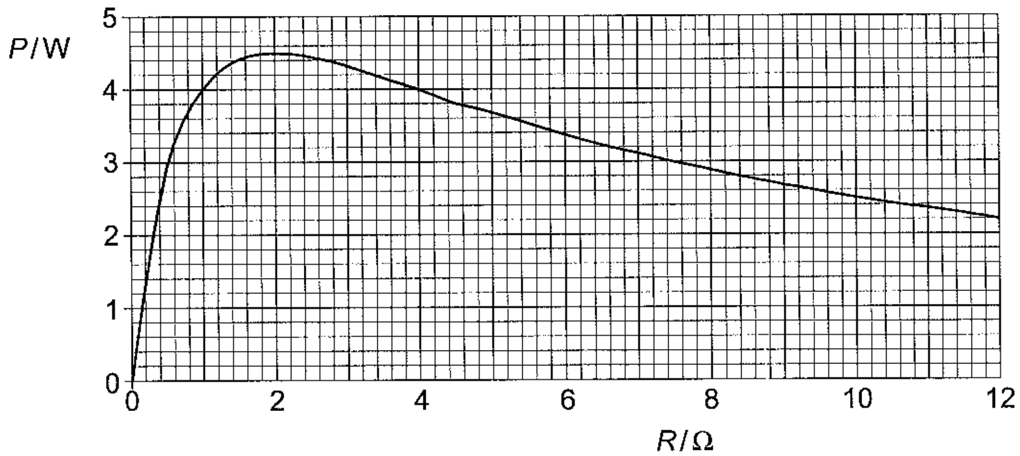

Fig. 3.1

(i) Use Fig. 3.1 to determine the potential difference across the variable resistor when it dissipates maximum power.

potential difference = ... V [3]

(ii) Explain why your answer to **(i)** is not equal to the e.m.f. of the supply.

....

....

....[2]

[Total: 9]

3

(a) Same unit / measured in volts / (both defined as) energy per (unit) charge / (both to do with) transfer of energy — B1

(b) 1 J (of energy transfer) per coulomb (of charge) (Allow 1 V = 1 JC^{-1}) — B1

(c)(i) It is the <u>energy</u> transferred by a 1 kW device working for 1 hour — B1

(c)(ii) 1 kWh = 1000 × 3600
1 kWh = 3.6×10^6 (J) — B1

(d)(i) $P = \frac{V^2}{R}$ / $P = I^2R$ / I = 1.5 (A) — C1

$4.5 = \frac{V^2}{2.0}$ / $V = 1.5 \times 2.0$ / $4.5 = 1.5 \times V$ — C1

potential difference = 3.0 (V) (Allow 1 sf) — A1

(Allow R in range 1.8 Ω to 2.2 Ω. This gives p.d. in the range 2.85 V to 3.15 V)

(d)(ii) The supply has internal resistance — B1
There is also a p.d. across the internal resistance / 'lost volts' / energy wasted within the supply or internal resistance — B1

[Total: 9]

4

(a) Correct arrow(s) between the north and south poles — B1

(b) $F = BIL$ — C1

current = $\frac{1.5}{8.0} = 0.1875$ (A) (Allow 0.19 A)

$F = 1.2 \times 10^{-2} \times 0.1875 \times 24$ — C1

force = 0.054 (Current of 0.19 A gives 0.055 (N)) — A1

unit: N / newton / TAm — B1

(c) The resistance of the wire *increases* by a factor of four (because $R \propto \frac{1}{A}$) / the current *decreases* by a factor of four — B1

Hence, the force decreases by a factor of four — B1

(Allow 1 mark for: Resistance is larger / current smaller <u>and</u> force smaller)

[Total: 7]

3 **(a)** In terms of energy transfers, state one major difference between electromotive force (e.m.f.) and potential difference (p.d.).

....

.... **[1]**

(b) State one similarity between potential difference and electromotive force.

....

.... **[1]**

(c) Fig. 3.1 shows two resistance wires **X** and **Y** connected in series to a battery.

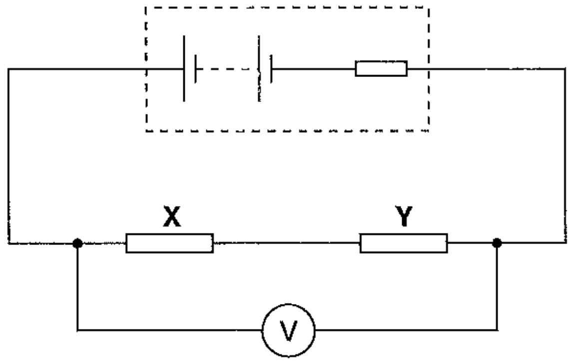

Fig. 3.1

(i) The voltmeter has an infinite resistance. Explain why the voltmeter reading is not equal to the e.m.f. of the battery.

....

.... **[1]**

(ii) The resistance of wire **X** is four times greater than the resistance of wire **Y**. The voltmeter reading is 6.0 V. Use your knowledge of potential divider circuits to calculate the potential difference across the wire **Y**.

potential difference = ... V **[3]**

(iii) The wires **X** and **Y** are connected in **parallel** to the battery. Explain which of the two wires will dissipate greater power.

....

....

.... [2]

[Total: 8]

Question			Expected Answers	Marks	Additional Guidance
3	a		For p.d: Charge(s) / electron(s) lose energy / change electrical energy to another form Or For e.m.f: Charge(s) / electron(s) gain energy / change energy to electrical energy	B1	
	b		Both (have the same unit) volts / V / J C^{-1}	B1	**Allow** Both 'energy/charge' (1) **Do not allow** the word "voltage(s)"
	c	i	There is p.d. across the internal resistor / resistance.	B1	**Allow** 'Energy / power lost in internal resistor / resistance' (1) **Allow** p.d./ voltage is *used* across the internal resistance.
		ii	$V_{out} = (\frac{R_2}{R_1 + R_2})V_{in}$ / $\frac{V_1}{V_2} = \frac{R_1}{R_2}$	C1	**Allow** 'Voltage splits in the ratio 4:1 (for **X** and **Y**)' for the first mark
			$(V_{out}) = \frac{R}{R+4R} \times 6.0$ / $(V_{out}) = \frac{1}{5} \times 6.0$	C1	**Allow** 2 marks if second equation is written
			p.d. = 1.2 (V)	A1	**Bald** 1.2 V scores 3 marks **Special case** Allow 2/3 marks if the p.d. of 4.8 V is determined for **X**
		iii	Wire **Y**	M1	
			Justified in terms of $P = \frac{V^2}{R}$ or $P \propto 1/R$	A1	**Note** This second mark is dependent on getting the first (M1) mark
			Total	**8**	

5 **(a)** State Ohm's law.

....

....

....[2]

(b) From the list below, circle the quantity that is conserved in Kirchhoff's second law.

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

(c) Fig. 5.1 shows an electrical circuit.

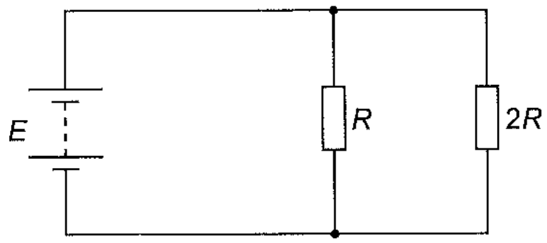

Fig. 5.1

The battery has e.m.f. E and negligible internal resistance. The resistances of the resistors are R and $2R$. Calculate

(i) the total resistance of the circuit in terms of R

resistance = ...[2]

(ii) the current from the battery in terms of E and R.

current = ...[1]

(d) Fig. 5.2 shows a circuit.

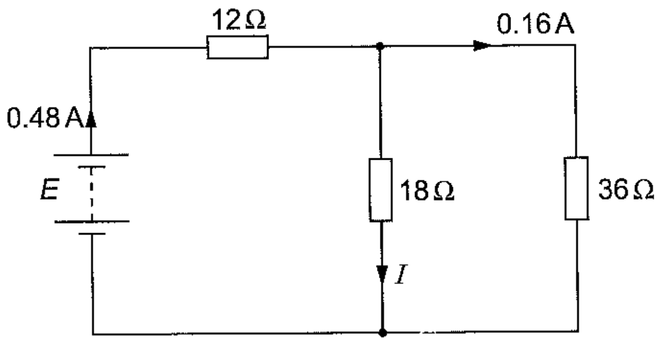

Fig. 5.2

The battery has negligible internal resistance.

Determine

(i) the charge passing through the battery in a time of 150 s

charge = ... C [2]

(ii) the number of electrons responsible for the charge in **(i)**

number = ...[1]

(iii) the current I in the 18 Ω resistor

current = ... A [1]

(iv) the e.m.f. *E* of the battery.

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

[Total: 12]

Please turn over for question 6.

5

(a) The current is (directly) proportional to the p.d. / voltage — B1
as long as the temperature remains constant (Allow 'physical conditions') — B1

(b) Only 'energy' is circled — B1

(c)(i) $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ — C1

$\frac{1}{R_{(t)}} = \frac{1+2}{2R}$

$R_{(t)} = \frac{2R}{3}$ / resistance = 0.67 R — A1

(c)(ii) current = $= \frac{3E}{2R}$ / current = $\frac{1.5E}{R}$ / current = $\frac{E}{2/3R}$ (Possible ecf) — B1

(d)(i) $Q = It$ — C1

$Q = 0.48 \times 150$

charge = 72 (C) — A1

(d)(ii) number (= $\frac{72}{1.6 \times 10^{-19}}$) = 4.5×10^{20} (Possible ecf) — B1

(d)(iii) current = 0.32 (A) — B1

(d)(iv) total resistance of 18 Ω and 36 Ω in parallel = 12 Ω

total resistance of circuit = 12 + 12 = (24 Ω) — C1

$E = 0.48 \times 24$

e.m.f. = 11.52 (V) ≈ 12 (V) — A1

Or

$V_{12} = 0.48 \times 12 (= 5.76)$ / $V_{18} = 18 \times 0.32 (= 5.76)$ / $V_{36} = 36 \times 0.16 (= 5.76)$ — C1

$E = 5.76 + 5.76$

e.m.f = 11.52 (V) ≈ 12 (V) — A1

[Total: 12]

3 A negative temperature coefficient (NTC) thermistor is connected across the terminals of a battery of e.m.f. 6.0 V and of negligible internal resistance. Fig. 3.1 shows the variation of current I with time t from the moment the thermistor is connected to the battery.

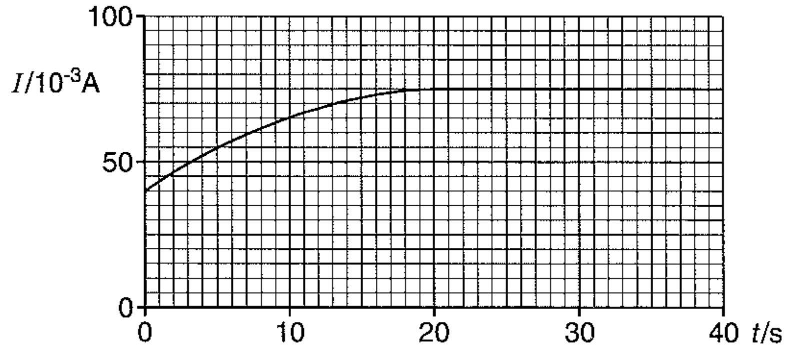

Fig. 3.1

(a) Calculate the power dissipated by the thermistor at time $t = 0$.

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

(b) In this question two marks are available for the quality of written communication.

Explain the shape of the graph of Fig. 3.1.

....

....

....

....

....

....

....

.... **[4]**

Quality of Written Communication [2]

[Total: 8]

Question			Expected Answers	Marks	Additional Guidance
3	a		$P = VI$	C1	
			$P = 6.0 \times 40 \times 10^{-3}$		
			power = 0.24 (W)	A1	**Bald** 0.24 (W) scores 2/2
	b		Any <u>four</u> from: 1. The <u>thermistor</u> 'heats up' / temperature increases 2. The resistance (of thermistor / circuit) decreases 3. Correct linking of rise in current to fall in resistance 4. Eventually the temperature/resistance is constant 5. Eventually 'heat / power generated = heat / power lost'	B1×4	**Show** ticks on scoris
			QWC The answer must involve physics, which attempts to answer the question.		
			Structure and organisation.	B1	Award this mark if the whole answer is well structured.
			Spelling and grammar.	B1	More than two spelling mistakes or more than two grammatical errors means the SPAG mark is lost.
			Total	**8**	

Answer **all** the questions.

1 A cell, a resistor of resistance 120 Ω and a negative temperature coefficient (NTC) thermistor are connected in **series**.

(a) In the space below, sketch a circuit diagram of this arrangement.

[2]

(b) The cell has e.m.f. 1.4 V and negligible internal resistance. At a particular temperature, the current in the resistor is 5.0×10^{-3} A.

(i) Calculate the potential difference across the resistor.

potential difference = ... V [2]

(ii) Calculate the resistance of the thermistor at this temperature.

resistance = ... Ω [2]

(c) State and explain how the potential difference across the resistor changes when the temperature of the thermistor is lower.

....

....

....[2]

[Total: 8]

1

(a) Correct symbols for the cell (<u>not</u> battery), resistor and thermistor — B1
Correctly drawn circuit — B1

(b)(i) $V = IR$ / $V = 0.005 \times 120$ — C1
potential difference = 0.60 (V) (Allow 1 sf) — A1

(b)(ii) V = 1.4 – 0.6 (= 0.8 V) (Possible ecf) — C1

$$R = \frac{0.8}{0.005}$$

resistance = 160 (Ω) — A1
[Allow 1 mark for total resistance calculation: $R = 1.4/0.005 = 280$ (Ω)]

(c) The resistance of the <u>thermistor</u> increases / the current decreases — B1
Hence, the p.d across the resistor decreases. — B1

[Total: 8]

2

(a) All I/V graphs identified correctly — B1

(b)(i) The resistance / R remains constant — B1
$I \propto V$ / Graph has a constant slope / gradient / Obeys Ohm's law — B1

(b)(ii) R is infinite / large when: I = 0 / no conduction / 'reverse' direction / 'up to a point' / negative V / negatively biased — B1
R is small / decreases / low(er) when: I is not zero / there is conduction / 'positive' direction / 'beyond a point' / positive V / positively biased — B1
(No credit for 'conducts in one direction only')

(b)(iii) The resistance increases as <u>I (or V)</u> increases — B1
The temperature increases (as I increases) / more electrons collisions (with the vibrating atoms / ions) — B1

QWC
The answer must involve physics, which attempts to answer the question.

Structure and organisation -
Award this mark if the whole answer is well structured. — B1

Spelling and Grammar mark -
More than two spelling mistakes or more than two grammatical errors means the SPAG mark is lost. — B1

[Total: 9]

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

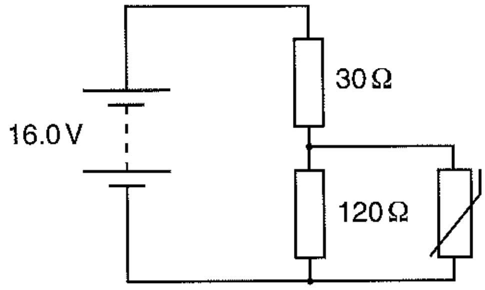

Fig. 3.1

(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 360 Ω at 20 °C. Calculate

(i) the total resistance R of the thermistor and the resistor of resistance 120 Ω 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 $1.4\,\mathrm{J\,s^{-1}}$. 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]

Question			Answer	Marks	Guidance
3	(a)	(i)	energy transferred from source/changed from some form to electrical energy; per unit charge (to drive charge round a complete circuit)	M1 A1	**allow** chemical
		(ii)	(some) energy is transferred into thermal energy /lost as heat in (driving charge through) the battery. It behaves as if it has an (internal) resistance/AW **or** there is a voltage drop across/decrease in voltage from the battery when a current is drawn from it/AW	B1	**allow** any description which uses E = V + Ir with symbols defined but **not** just the formula alone **or** e.g. statement about 'lost volts'/current
	(b)	(i)	correct substitution into resistors in parallel formula R = 90 Ω	C1 A1	1/R = 1/90 or 0.011 correct answer
		(ii)	using $V_{out} = R_2/(R_1 + R_2)\ V_{in}$: **alt:** 16 = I x 120 V_{out} = 90/(30 + 90) 16 so I = 0.133 A V_{out} = 12 V V_{out} = 0.13 x 90 = 12 V	C1 C1 A1	**ecf (b)(i)** **accept** V_{out} = (90/120) x 16 = 12 V for full marks **N.B.** beware of false ratios, e.g. 360/(120 + 360) giving correct answer; give first marking point only
A A A		(iii)	resistance (of thermistor) decreases (with temperature increase) current <u>in circuit</u> increases **or** as <u>total</u> resistance is less so current in thermistor increases voltage ratio between 30 Ω and combination changes so voltage across thermistor falls	B1 M1 A1 M1 A1	**max** 4 marks QWC mark is either of the M marks
	(c)	(i)	Q = It = 1.2 x 8 x 60 x 60 Q = 34560 (C) correct unit,	C1 A1 B1	 **accept** 3.5 or 3.46 x 10^4 **allow** 1 mark for answer of 9.6 or 576 **allow** C, kC, A s; **N.B.** 9.6 A h or 576 A min score 3/3
		(ii)	energy = 34560 x 16 = 552960 J **or** I = 1.4/16 = 00875 A time = 552960/1.4 = 394970 s **then** t = 34560/I time = 394970/3600 = (109.7 h) = 110 h	C1 C1 A1	**ecf (c)(i)** **allow** full marks for 1.2 x 8 x 16/1.4 = 110 h **allow** 111 h when using 3.5 x 10^4 C
			Total	**18**	

2 **(a)** The battery in an electric car has an e.m.f. of 24 V. It can provide a current of 200 A 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 24 V.

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

(b) The charger for the battery has a 30 V 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**.

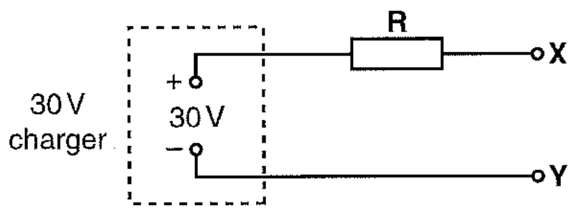

Fig. 2.1

(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 24 V. The current I provided by the battery charger is constant at 120 A. 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]

Question			Answer	Marks	Guidance
2	(a)	(i)	energy transfer per unit charge from chemical/other to electrical form	B1 B1	**allow** energy per unit charge
		(ii)	(Q = It =) 200 x 4 x 60 x 60 = 2.9 x 10^6 (C)	M1 A1	**accept** 200 x 14400 **accept** 2.88 x 10^6
		(iii)	E = QV = 2.88 x 10^6 x 24 = 6.9 x 10^7 (J)	C1 A1	**accept** 72 MJ if using 3 MC or 69.6 or 70 if using 2.9 MC
	(b)	(i)	correct symbol and polarity connected to X and Y	B1	**allow** one cell or more or two cells with dotted lines between
A A A		(ii)	V = 30 – 24 = 6 V R = V/I = 6/120 = 0.05 (Ω)	M1 M1 A0	evidence of the V subtraction needed **do not allow** use of E = V + Ir; it must be IR
		(iii)	P = VI = 6 x 120 = 720 (J s^{-1})	C1 A1	**or** $I^2R = 120^2 \times 0.05$ **or** $V^2/R = 6^2/0.05$
		(iv)	(3600 – 720)/3600 = 2880/3600 = 0.8 = 80 (%)	C1 C1 A1	**ecf b(iii)**; using 2880 instead of 3600 gives 75%; scores zero **allow** (30 – 6)*I*/30*I* = 24/30 = 0.8 = 80 (%)
	(c)	(i)	t = Q/I = 2.88 x 10^6/120 **or** E/VI = 69 x 10^6/(24 x 120) t = 2.4 x 10^4/3600 = 6.7 h	M1 A1	**ecf (a)(iii); accept** 3 x 10^6 giving 2.5 x 10^4 s and 6.9 h **allow ora** using 7.0 h giving E = 72.5 MJ
		(ii)	power supplied = 30 x 120/1000 = 3.6 kW cost = 3.6 x 7 x 26 = 655 (p)	A1	**ecf c(i) accept** any consistent answer **do not allow** 2.88 kW giving 524 p **unless** repeated error from **b(iv)**
			Total	**17**	

Answer **all** the questions.

1 Fig. 1.1 shows the I–V characteristic of a slice of semiconducting material.

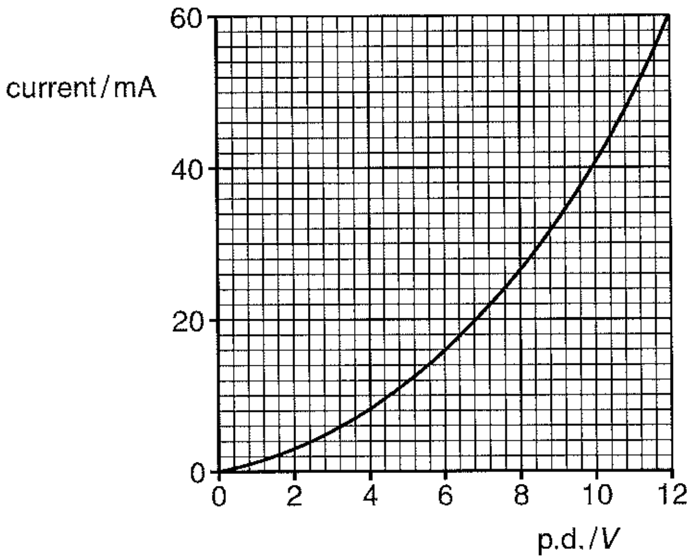

Fig. 1.1

(a) (i) Define *resistance.*

....

.... **[1]**

(ii) Show that the resistance of the slice is about 250 Ω when there is a current of 40 mA in it.

[2]

(b) The dimensions of the slice are shown in Fig. 1.2.

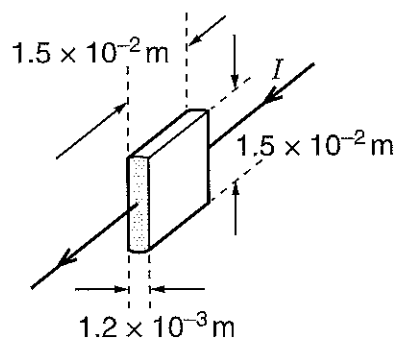

Fig. 1.2

Calculate the resistivity ρ of the semiconducting material when there is a current I of 40 mA in the slice.

ρ = ... Ωm **[3]**

(c) Explain how the I–V characteristic shows that the resistivity of the semiconducting material decreases with increasing temperature.

In your answer you should explain how you are aware that the temperature of the slice changes.

....

....

....

....

....

....

....

....

....

....

....

.... **[4]**

[Total: 10]

Question			Answer	Marks	Guidance
1	(a)	(i)	potential difference (across a component)/current (in it)	B1	**allow** symbols if symbols defined; voltage or p.d.; **allow** per **not** over
		(ii)	read 10 V from graph (R = V/I =) 10/ 0.04 = 250 (Ω)	C1 M1 A0	**allow** 9.8 or 9.9 **ecf** reading from graph
	(b)		R = ρl/A **or** ρ =RA/l ρ = 250 x 1.2 x 10^{-3} ρ = 0.30 (Ω m)	C1 C1 A1	select formula mark **ecf(a)(ii)**; a correct substitution correct answer **allow** 0.3
A A A	(c)		(graph curves so) R changes qualification: I increases faster than V **increased temperature is caused by (larger) <u>current</u> in slice** qualification: P = I^2R as R decreases ρ decreases	B1 B1 B1 B1 B1	**allow** R increases or decreases **allow**: by calculating two values of R **do not allow** either of the first two marking points if reference made linking gradient and R value **QWC mark; allow** heating effect is caused by.... **allow** 'R decreases' already stated earlier in answer **max** 3 out of 4 + QWC mark
			Total	**10**	

3 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. 1.6 V and internal resistance r is delivering a current of 0.20 A to a resistor of resistance R. The voltmeter reads the terminal p.d. It is 1.2 V.

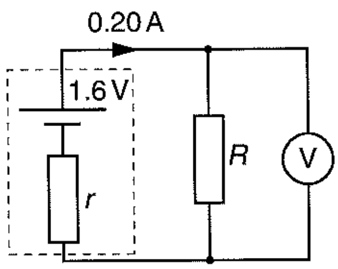

Fig. 3.1

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.

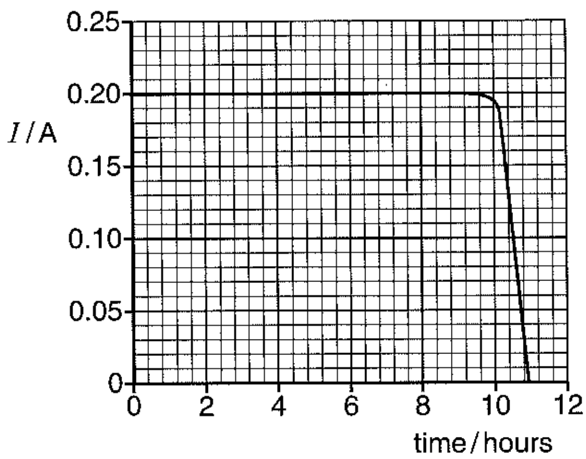

Fig. 3.2

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]

Question			Answer	Marks	Guidance
3	(a)	(i)	**energy transferred from source/changed from some form to electrical energy;** per unit charge (to drive charge round a complete circuit)	M1 A1	 allow energy divided by charge
		(ii)	any source has an internal resistance where energy is transferred into thermal energy /lost as heat	B1 B1	there will be 'lost' volts (across the cell when a current is drawn) **or** $V = E - Ir$ explained
	(b)	(i)	$V = IR$ $1.2 = 0.2\ R$ $R = 6.0\ \Omega$	C1 A1	substitution needed to score mark **allow** 6 Ω
		(ii)	$1.6 - 1.2 = 0.4 = 0.2\ r$ $r = 2.0\ \Omega$	C1 A1	 **allow** 2 Ω
	(c)	(i)1	$Q = It = 0.20 \times 3600 \times 1.5$ =1100 correct unit,	C1 A1 B1	substitution needed to score mark 1080 **allow** 1 mark max for 0.3 or 18 **allow** C, kC, A s **exception** 0.3 A h or 18 A min scores 3 marks
		(i)2	energy = $QV = 1100 \times 1.2$ **or** $I^2Rt = 0.2^2 \times 6 \times 5400$ = 1320 (J)	C1 A1	**ecf (c)(i)1** substitution needed to score mark 1296(1080) **allow** 1 mark for 1728 (using 1.6)
		(ii)	I is constant for about 9 to 10 hours because internal resistance remains constant/cell operates at constant emf I falls rapidly/towards zero over last hour or so because cell's/chemical energy is used up (so E falls)	B1 B1 B1 B1	QWC must have link between observation and reason to score full marks **accept** r of cell increases causing fall in V or I
			Total	**17**	

2 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.

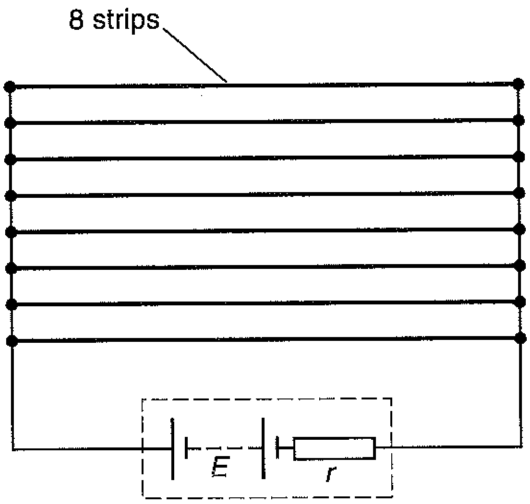

Fig. 2.1

(a) The potential difference across each strip is 12V when a current of 2.0A 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 200W.

[2]

(b) Each strip is 0.90m 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.

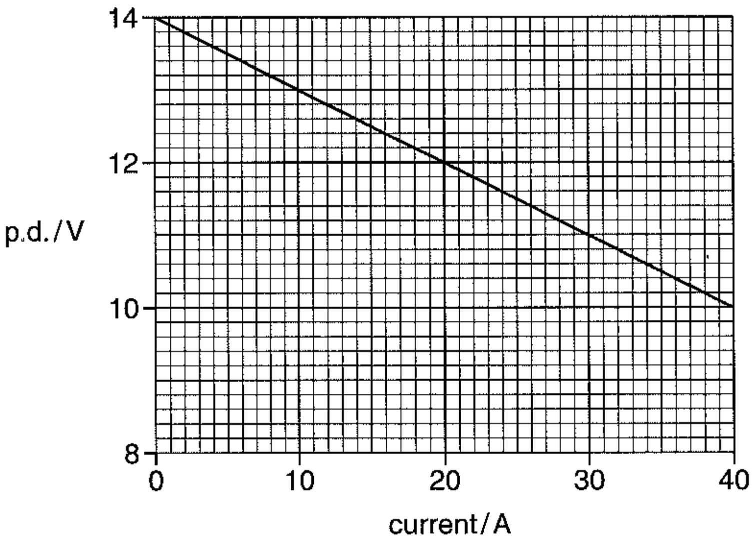

Fig. 2.2

(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]

Question			Expected Answers	M	Additional Guidance
2					
	a	i	12/2.0 = 6.0 (Ω)	B1	**allow** 6; do not apply the SF penalty (N.B. applied only once per paper) for any answer where the second SF is 0
		ii	attempt to <u>use</u> resistors in parallel formula 1/R = 8/6 R = 0.75 (Ω)	C1 C1 A1	no mark for just quoting formula **ecf (a)(i)** **allow** ¾ (Ω)
		iii	$P = V^2/R = 12^2/0.75$ **or** 8VI = 8 x 12 x 2 **or** $I^2R = 16^2 \times 0.75$ = 192 W	C1 A1	**ecf (a)(ii)**
	b		ρ = RA/l $= 6.0 \times 0.24 \times 2.0 \times 10^{-6}/0.9$ $= 3.2 \times 10^{-6}$ Ω m	C1 C1 A1 B1	correct rearrangement of formula **ecf (a)(i);** substitution into a correct formula 2/3 marks for one or more POT errors **accept** 3.2 Ω μm; 4×10^{-7} scores 2/3
	c	i	(As V is the same) then R must be the same to give <u>same P</u>	B1	**accept** alternative wording producing same argument, e.g. same I, same V so same R
		ii	0.75/8 = 0.094 (Ω)	B1	**ecf (a)(ii)/8; accept** 3/32 but NOT 0.09
		iii	for parallel circuit with break in one wire rest still work **or** series strips very wide (if use material of same resistivity as such low resistance/ giving poor visibility))	B1	any sensible statement
	d	i	14 V	B1	
		ii	e.g. V = 12 V; I = 20 A substitution into E = V + Ir, e.g. 14 = 12 + 20 r r = 0.1 Ω	C1 C1 A1	**or** any suitable pair of readings from graph **ecf(d)(i); accept** r = gradient; = (14 – 10)/40 or similar ; = 0.1 Ω
			Total question 2	**17**	

2 **(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.

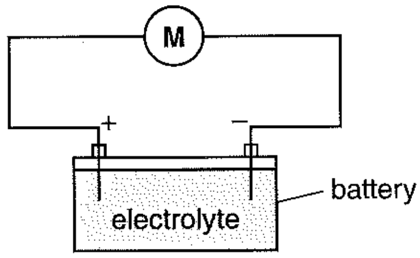

Fig. 2.1

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 40 A from the battery of e.m.f. 12 V. The potential difference across the motor at this time is only 8.0 V.

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

(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]

Question			Expected Answers	M	Additional Guidance
2	a	i	ions	B1	
		ii	positive ions	B1	**allow** positive charges / cations
		iii	electrons	B1	
	b	i	the battery has an internal resistance/AW some of the emf is across the (internal) resistance (leaving a smaller p.d. across motor)	B1 B1	**accept** connecting leads have resistance **accept** V = E - Ir or 'lost volts'/p.d. across r
		ii	use E = V + Ir giving 12 = 8 + 40r r = (12 – 8)/40 **or** 4/40 = 0.10 Ω	C1 M1 M1 A0	**accept** reverse solution, 0.10 Ω → 8 V→ 12 V substitution and or solution showing working
		iii	Q = It = 40 x 1.2 I= 48 (C)	C1 A1	
	c	i	The current heats the filament The resistance/resistivity (of the metal filament) increases (with temperature). .	B1 B1	no mention of temperature increase or heating scores zero
		ii	4.5 to 8 A in each (parallel) arm **or** 9 to 16 A for both together needs to be great enough to cover initial surge/current **or** use antisurge fuses	B1 B1	no mark if fuse value outside range
		iii	e.g. the starter motor draws 40 A so would need a bigger fuse than headlamp circuit so need different fuses for different situations **or** if battery used for starter motor with lights on will need too large a fuse – damage occurs before fuse blows/AW	B1	**accept** headlamp circuit damaged before fuse blows if 40 A fuse only used **or** fuse blows in starter circuit if 10 A used, etc.
			Total question 2	**15**	

3 (a) The following electrical quantities are often used when analysing circuits. Draw a straight line from each quantity on the left-hand side to its correct units on the right-hand side.

potential difference	$C\,s^{-1}$
resistance	$J\,C^{-1}$
power	$V\,A^{-1}$
current	$J\,s^{-1}$

[3]

(b) Fig. 3.1 shows a battery of e.m.f. 6.0V and negligible internal resistance connected in series with a thermistor and a 560 Ω resistor.

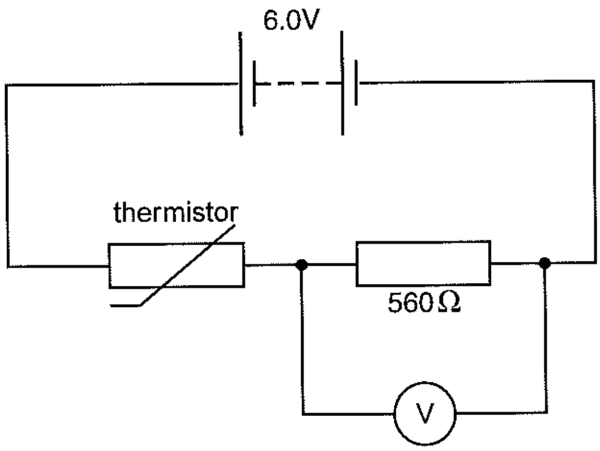

Fig. 3.1

The voltmeter across the resistor has infinite resistance.

(i) The reading on the voltmeter is 2.4V. Calculate the resistance R_T of the thermistor.

R_T = ... Ω [3]

(ii) Calculate the current in the circuit.

current = ... A [1]

(c) The variation of resistance with temperature for this thermistor is shown in the graph of Fig. 3.2.

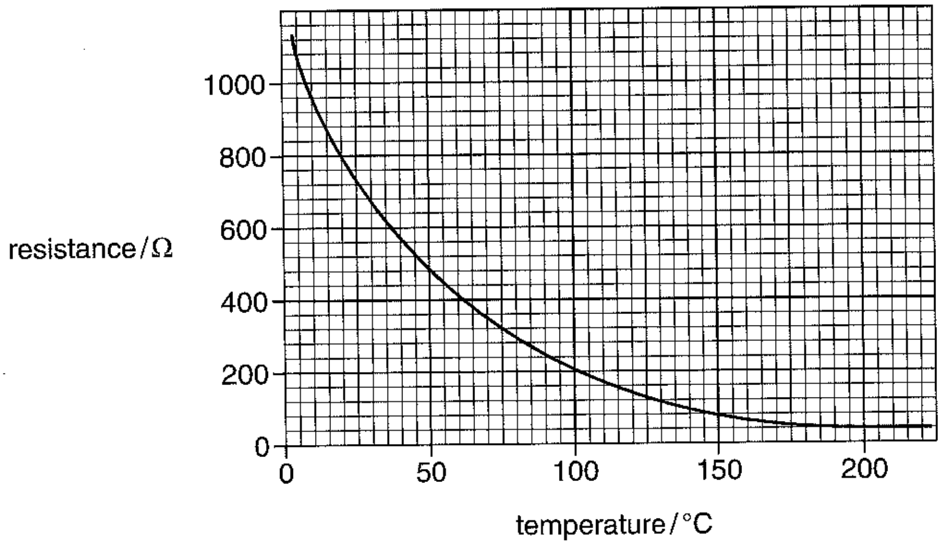

Fig. 3.2

(i) Use the graph to determine the temperature of the thermistor when its resistance is 800 Ω.

temperature = ... °C **[1]**

(ii) State and explain, without calculation, how the reading of the voltmeter in Fig. 3.1 will change as the temperature of the thermistor increases to 80 °C.

....

....

....

....

.... **[3]**

(iii) The circuit of Fig. 3.1 can be used as a temperature sensor. Temperature sensors are used in the kitchen to control the internal temperatures of ovens (typically 200 °C) and refrigerators (typically 4 °C). Use the graph of Fig. 3.2 to suggest in which device this sensor would be more suitable.

In your answer you should link the information from the graph to the working of the sensor.

....

....

....

....

.... **[3]**

[Total: 14]

Question			Expected Answers	M	Additional Guidance
3					
	a	i	V $J\ C^{-1}$ R $V\ A^{-1}$ P $J\ s^{-1}$ I $C\ s^{-1}$.	B1 B1 B1	4 correct 3 marks; 2 correct 2 marks 1 correct 1 mark
	b	i	using $V_{out} = R_2/(R_1 + R_2)\ V_{in}$: **alt:** 2.4 = I x 560 V_{out} = 3.6 V so I = 4.3 mA 3.6 = R_2/(560 + R_2) 6 3.6 = I R_2 R_2 = 840 (Ω)	C1 C1 A1	**accept** R_2 = (3.6/2.4) x 560 or .2.4 = 560/(560 + R_2) 6
		ii	I = 4.3 x 10^{-3} (A)	B1	**accept** 4.3 m(A) or 3/700 (A) **ecf (b)(i)** i.e. I = 6/(560 + R_2)
	c	i	20 ± 2 (°C)	B1	
		ii	R_{Th} will fall/ resistance will fall giving greater share of supply V across fixed R/AW causing the voltage across (fixed) R/voltmeter reading to rise	B1 B1 B1	**accept** explanation in terms of potential divider equation **or** current increases **or** current same in both resistors/resistors in series
		iii	ΔR is large for small ΔT at low temperatures/AW in terms of gradient so thermistor is better in circuit to control low temp, refrigerator	M2 A1	**accept** sensitivity greater at low temperature **or** vice versa **or** ΔR is small for small ΔT at high temperatures scores 1 out of 2
			Total question 3	**14**	

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

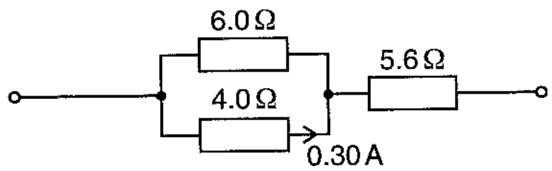

Fig. 4.1

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]

Question			Answer	Marks	Guidance
4	(a)		R's in parallel have same V/AW so 4.0 x 0.30 = 6.0 x 0.20	M1 A1	**allow** I splits in inverse ratio to R **or** AW; hence I in 6 ohm = 4 / 6 x 0.3 = 0.2 A
	(b)	(i)	sum of/total current into a junction equals the sum of/total current out **or** total algebraic sum of currents is zero	B1	**allow** Kirchhoff's first law
		(ii)	0.50 (A)	A1	**accept** 0.5 (A) (no SF error)
	(c)		correct formula for R_p and substitution R_p = 2.4 Ω R_s = 8.0 (Ω)	C1 C1 A1	 **apply ecf** to R_p for second mark **accept** 8 (Ω) (no SF error)
	(d)	(i)	energy transferred from source/changed from some form to electrical energy; <u>per</u> unit charge (to drive charge round a complete circuit)	M1 A1	**allow** form as e.g. light/chemical/heat **allow** energy <u>divided by</u> charge
		(ii)	V = IR = 0.50 x 8.0 =4.0 (V)	A1	**ecf b(ii),c** i.e. answer = b(ii) x c **accept** 4 (V) (no SF error)
		(iii)	E – V = Ir giving 5.0 – 4.0 = 0.50 r r = 2.0 (Ω)	C1 A1	**ecf b(ii)** **accept** 2 (Ω) (no SF error); give max of 1 mark for r = 3.3 Ω , i.e. using I = 0.3 A
			Total	12	

3 **(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 1.5 V 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 1.5 V.

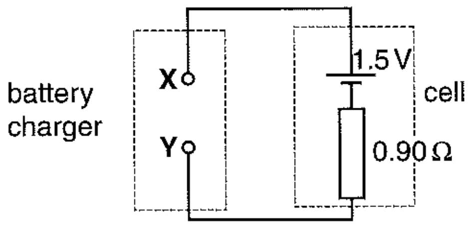

Fig. 3.1

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 6.0V 2.0W filament lamp has a resistance of 18 Ω when lit to normal brightness. It is connected in series to four 1.5V 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]**

Question			Answer	M	Guidance
3					
	a	i	Q = It= 0.45 x 4.67 x 60 x 60 = 7600 C or As	C1 A1 B1	 **accept** 7560 or 7570
		ii 1,2	**1** positive; **2** clockwise energy must be transferred to the cell **or** current in opposite direction transfers energy from the cell to the circuit/AW	M1 A1	positive plus correct direction of arrow for first mark; do not penalise if arrow not labelled I. **allow** (conventional) current is from positive to negative ; **or** electron flow from – to + [but current must be clockwise in **1**]
		3	V_{XY} = 1.5 + 0.45 x 0.90 V_{XY} = 1.9 (V)	C1 A1	 **accept** 1.905 or 1.91
		4	P = VI = 0.45 x 1.5 P = 0.675 (J s^{-1})	C1 A1	**allow** QV/t with **ecf a(i)** if necessary (11340/16800) **allow** 0.7 as final line if 0.675 appears above
	b		**1.**cell across variable resistor R ammeter in series and voltmeter in parallel across R or cell **2.**Take (set of) readings of V and I for different positions/values of the variable resistor **3.**plot a graph of V against I **4.**(find) y-intercept = E **5.**(find) the gradient of the V against I graph which equals the internal resistance in magnitude **or 4 or 5** take one pair of values of V,I and substitute into equation E = V + Ir to find r or E	 B1 B1 B1 B1 B1	QWC last marking point needed for full marks **allow** use (digital) voltmeter across <u>unloaded</u> cell to find E; add R and find one value of V and I; then use equation to find r (points 2 to 5) **ignore** sign of gradient in determining r **allow** for no graph plot, using 2 pairs of values of V and I substituted into equation allows r and E to be found.(points 2 to 5)
	c	i	4 x 1.5 V cells gives 6.0 V with r of 3.6 Ω so current is 6.0/(3.6 + 18) = 0.28 A requires (2 W/6 V =) 0.33 A to light normally or power delivered = (0.28^2 x 18 or 5.0 x 0.28)= 1.4 W **alt**: use 0.33 A & 6 V to show need emf of 7.2 V (1.8 V per cell)	B1 B1 B1	**allow** AW such as: 6 V but total R now 21.6 Ω; 6 V across 21.6 Ω gives 5 V across 18 Ω; requires 6 V to light normally **allow** P = 1.(6)7 W for 2 marks; only give the third mark if P labelled as power delivered by cell
		ii	1.5 n = 0.33 (18 + 0.9 n) **or** 1.5n = 6 + 0.3n so 3.6 n = 18 **or** 1.2n = 6 giving n = 5	M1 A1	**alt:** lamp needs V = 6V and I = 0.33 A terminal p.d per cell is 1.5 = V + 0.9 x 0.33 giving V = 1.2 V so n = 6/1.2 = 5 **allow** trial and error method but working must be shown to score any marks
			Total question 3	**19**	

2 **(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.

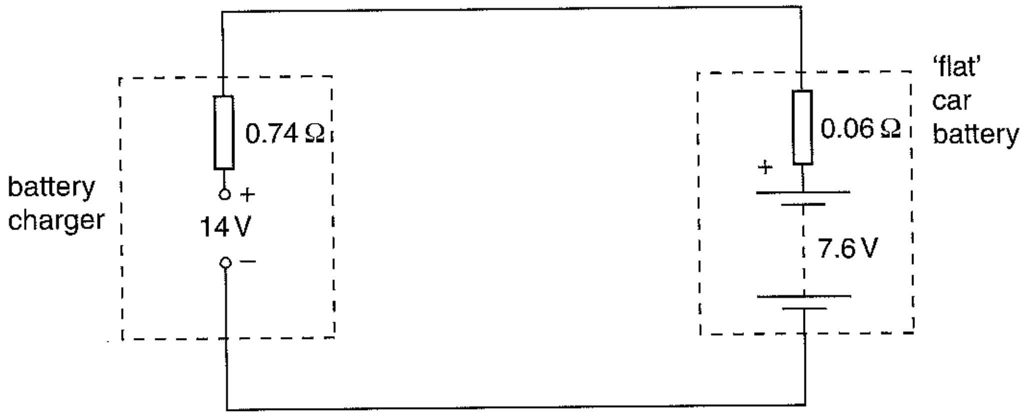

Fig. 2.1

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 12 V and the charging current is 2.5 A. 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. 14 V

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]

Question			Expected Answers	Marks	Additional Guidance
2	(a)		E = I(R + r)	B1	
	(b)	(i) 1 2	0.80 Ω 6.4 V	B1 B1	
		(ii)	(sum of) e.m.f.s = sum /total of p.d.s/sum of voltages (in a loop)	B1	
		(iii)	6.4 = 0.80I I = 8.0 A	C1 A1	**can be 2 ecf** from **(b)(i)**, eg 21.6/0.8 = 27 A (1 ecf) or 21.8/0.68 = 31.8 A (2 ecf)
	(c)	(i)	Q = It = 2.5 x 6 x 60 x 60 = 54000 (C)	C1 A1	**allow** 1 mark if forgets one or two 60's giving 900 C or 15 C
		(ii)	energy = QE = 54000 x 14 = 756000 (J)	C1 A1	**allow** (use of 12 V gives) 648000 J for 1 mark
		(iii)	energy loss = I2Rt = VIt = 2 x 2.5 x 6.0 x 60 x 60= 108000 J percentage = (108000/756000) x 100 = 14%	C1 A1	**accept** QΔV = 54000 x 2.0 = 108000 J **accept** QΔV/QE = 2.0/14.0 = 14% **not** 756000/54000 = 14%
			Total question 2	**12**	