Question			Answer	Marks	Guidance
1	**a**		p.d./voltage (across component) divided by current (in it)	**B1**	**accept** V/I with V and I defined; per (unit) current, etc
	b	**i**	$R = \rho l/A$ $= 1.7 \times 10^{-8} \times 20 \times d/4d^2 = 1.7 \times 10^{-8} \times 5/3.8 \times 10^{-10}$ $=220$ (Ω)	**C1** **C1** **A1**	 **allow** $A = 4\pi r^2 = 4.5 \times 10^{-19}$ giving 285 Ω **accept** 220 to 230 Ω
		ii	$n = 1/d^3 =(1.8 \times 10^{28})$	**A1**	**accept** alternatives, e.g. 80/volume
		iii	$I = nAev$ $= 1.8 \times 10^{28} \times 4 \times (3.8 \times 10^{-10})^2 \times 1.6 \times 10^{-19} \times 1.9 \times 10^{-5}$ $= 3.2 \times 10^{-14}$ (A)	 **C1** **A1**	 1 mark for substitution into formula, **ecf** n, A values accept 3.16 and 3.5 (using $n = 2 \times 10^{28}$) accept 2.48 and 2.76 (for 285 Ω)
		iv	$P = I^2R$ $= (3.2 \times 10^{-14})^2 \times 200 \times 10^9$ $= 2.0 \times 10^{-16}$ (W)	**C1** **C1** **A1**	**ecf b(i) & (iii)** **accept** 1 SF as estimate; can obtain 1.2 to 2.8 using all values possible in **(iii)**
	c		electron moves at drift velocity signal travels at/close to the speed of light	**B1** **B1**	**accept** answers explaining idea of drift velocity
			Total	**12**	

Question			Expected Answers	M	Additional Guidance
2					
	a		current moves from + to – (of battery in circuit) **and** electrons move from – to +	B1	
	b		C s^{-1} V Ω^{-1}	B1 B1	2 correct 2 marks; 1 correct 1 mark, withhold a mark for each additional answer given
	c	**i**	statement of Kirchhoff's first law or conservation of charge	B1	**accept** wires are in <u>series</u> or current is the same (at every point) in a <u>series</u> circuit/AW **not** current in = current out
		ii1	$R = \rho l/A$ calculation to justify R = 72 Ω	B1 A1	accept R α l and R α 1/A **or** similar method/argument must be convincing **accept** 3/½ x12 but **not** 3 x 2 x 12
		ii2	R = sum of Rs R = 84 Ω	C1 A1	**accept** Rs in series **ecf (c)(ii)1**
		iii	select I = nAev v = 4.0 x 10^{-5} (m s^{-1})	B1 B1	**allow** v α 1/A **accept** 4 x 10^{-5} (m s^{-1}) **no** SF error
			Total question 1	**10**	

Question			Expected Answers	Marks	Additional Guidance
3	**(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)**	$Q = It = 2.5 \times 6 \times 60 \times 60$ $= 54000$ (C)	C1 A1	**allow** 1 mark if forgets one or two 60's giving 900 C or 15 C
		(ii)	energy = $QE = 54000 \times 14$ $= 756000$ (J)	C1 A1	**allow** (use of 12 V gives) 648000 J for 1 mark
		(iii)	energy loss = $I2Rt = VIt = 2 \times 2.5 \times 6.0 \times 60 \times 60 = 108000$ J percentage = $(108000/756000) \times 100 = 14\%$	C1 A1	**accept** $Q\Delta V = 54000 \times 2.0 = 108000$ J **accept** $Q\Delta V/QE = 2.0/14.0 = 14\%$ **not** $756000/54000 = 14\%$
			Total question 2	**12**	

Question			Expected Answers	M	Additional Guidance
4	**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** $4/40$ $= 0.10\ \Omega$	C1 M1 M1 A0	**accept** reverse solution, $0.10\ \Omega \rightarrow 8\ V \rightarrow 12\ V$ substitution and or solution showing working
		iii	$Q = It = 40 \times 1.2$ $I = 48$ (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**	