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	$R = \rho l/A$ $= 1.7 \times 10^{-8} \times 20 \times d/4d^2 = 1.7 \times 10^{-8} \times 5/3.8 \times 10^{-10}$ $=220\ (\Omega)$	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			Answer	Marks	Guidance
2	**(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)	**(**	correct substitution into resistors in parallel formula R = 90 Ω	C1 A1	1/R = 1/90 or 0.011 correct answer
		(ii)	using $V_{out} = R_2/(R_1 + R_2)\ V_{in}$: $V_{out} = 90/(30 + 90)\ 16$ $V_{out} = 12$ V **alt:** 16 = I x 120 so I = 0.133 A $V_{out} = 0.13 \times 90 = 12$ V	C1 C1 A1	**ecf (b)(i)** **accept** $V_{out} = (90/120) \times 16 = 12$ 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)	**(**	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**	

Question			Expected Answers	Marks	Additional Guidance
3					
	a	**i**	E = (Pt =) 36 x 3600 = 1.3 x 10^5 (J)	C1 A1	**allow** I = 3 A and E = VIt, etc. **accept** 129600 (J)
		ii	Q = E/V = 1.3 x 10^5/12 **or** Q =It =3 x 3600 = 1.1 x 10^4 unit: C	C1 A1 B1	**ecf (a)(i)** **accept** 1.08 x 10^4 **allow** A s **not** J V^{-1}
		iii	Q/e = 1.1 x 10^4/1.6 x 10^{-19} = 6.9 x 10^{22}	C1 A1	**ecf (a)(ii)** **accept** 6.75 or 6.8 x 10^{22} using 10800
	b	**i**	the average displacement/distance travelled of the electrons <u>along the wire</u> per second; (over time/on average) they move slowly in one direction through the metal/Cu lattice (when there is a p.d. across the wire); (because) they collide constantly/in a short distance with the lattice/AW	 B1 B1 B1	no mark for quoting formula **allow** in one second **max 2 marks** from 3 marking points
		ii	select I = nAev (= 3.0 A) v = 3.0/8.0 x 10^{28} x 1.1 x 10^{-7} x 1.6 x 10^{-19} = 2.1 x 10^{-3} (m s^{-1})	C1 C1 A1	1 mark for correct formula 1 mark for correct substitutions into formula 1 mark for correct answer to 2 or more SF
			Total question 1	**12**	