1)

Question			Expected Answers	M	Additional Guidance
1	a		use of $R = \rho l/A$ $= 2.4 \times 12 \times 10^{-3}/9.0 \times 10^{-6}$ $= 3.2 \times 10^{3}$ (Ω)	C1 M1 A0	
	b		$V^2 = PR$ $= 0.125 \times 3.2 \times 10^{3}$ $V = 20$(V)	C1 M1 A0	**allow** $V = \sqrt{(0.125 \times 3.2 \times 10^{3})}$ **allow** substituting V = 20 to prove P = 0.125 W
	c	i	adding resistors in series and then in parallel to show that total resistance is 3.2 kΩ	B1 B1	**do not allow** any reference to values of V or P, etc in answer
		ii	p.d across each resistor is 20 V so power dissipated is 0.125 W	B1 B1	**accept** $P = 40^2/3.2$ k = 0.50 W so P per resistor = 0.50/4 = 0.125 W **do not accept** P_{total} = 0.50 W without proof – scores zero
	d	i	using $R_X = \rho l/A$; $A \rightarrow 4A$ and $l \rightarrow 2l$ $R_Y = \rho 2l/4A = \rho l/2A = R_X/2$	M1 A1	**accept** figures 24×10^{-3} m and 36×10^{-6} m^2 to give 1.6×10^{3} Ω
		ii	same current in X and Y (as in series) power dissipated is I^2R **or** IV where $V_X = 2V_Y$ so X has larger P (dissipation)	B1 M1 A1	**allow** $P = V^2/R$; $V_X = 2V_Y$ etc. **allow** 1 mark only for using $P = V^2/R$ or IV and V is larger across X (i.e. not quantitative) so X has larger P
			Total question 1	**13**	

2)

(a)		resistivity = resistance x area (of cross-section)/length	B1	**accept** equation with *resistance* as subject **allow** *over* for divide by; do **NOT** allow formula with a word for each symbol
(b)	(i)	$R = \rho l/A = 1.7 \times 10^{-8}/ 6.4 \times 10^{-3}$ $= 2.7 \times 10^{-6}$ (Ω)	C1 A1	**accept** 2.66×10^{-6} (Ω)
	(ii)	$P = I^2R$ $= 8000^2 \times 2.7 \times 10^{-6}$ = 170 W	C1 C1 A1	select formula; can use P = VI & V = IR **ecf b(i)** 173 (2.7), 170 (2.66)
	(iii)	170 x 9.0 = 1530 W **or** 170 x 24 = 4080 W 1.5 x 24 = 36 (kW h) 4.08 x 9 = 36.7 (kWh)	B1 B1	**ecf b(ii)**; 1 mark for X 9 **or** 1 mark for X 24
	(iv)	36 x 15 = 540 p	B1	**ecf b(iii)** 551(36.7), 555 (37)
(c)		$I = nAev$ $8000 = 8.4 \times 10^{28} \times 6.4 \times 10^{-3} \times 1.6 \times 10^{-19} v$ $v = 9.3 \times 10^{-5}$ (m s^{-1})	C1 C1 A1	select formula correct substitution
		Total	**12**	

3)

Question			Expected Answers	Marks	Additional Guidance
	a		ρ = RA/l with terms defined	M1 A1	full word definition gains both marks **allow** *A is area* as adequate; no unit cubes
	b	i	**either** the cable consists of (38) strands in parallel; **or** the area of the cable is 38 times the area of a strand or vice versa; so the resistance of 1 strand is 38 times bigger, (i.e. 1.98 Ω km^{-1}) **or** the resistance is inversely proportional to the area	B1 B1	max 1 mark for 38 x 0.052 = 1.98 with no further explanation **allow** with **either** and **or** **allow only** with **or**
		ii	A = ρ l/R = 2.6 x 10^{-8} x 1000/2.0 = 1.3 x 10^{-5} (m^2)	C1 A1	**allow** 1 mark max. for R = 0.052 giving A = 5.0 x 10^{-4} (m^2) **give** 1 mark max. for 1.3 x 10^{-8} (m^2)
	c	i	P = VI = 400x 10^3 x 440 = 1.8 x 10^8 (W) or 180 M(W)	C1 A1	P = VI **not** adequate for first mark **expect** 176
		ii	2000/176 = 11.4 so 12 required	B1	**ecf(c)(i);** using 180 gives 11.1
		iii	P = I^2R = 440^2 x 0.052 = 1.0 x 10^4 W (km^{-1}) or 10 kW (km^{-1})	C1 C1 A1	**accept** power/cable = 2000/12 = 167 MW I = 167M/400k = 417 A P = 417^2 x 0.052 = 9.0(3) kW (km^{-1}) **N.B.** answer mark includes consistent unit
		iv	power lost per cable = 10 k x 100 x 12 = 12.0 MW fraction remaining = (2000 – 12)/2000 = 0.994 x 100 = 0.994 so 99.4% or power lost per strand = 10 k x100 = 1.0 MW fraction remaining = (176 – 1)/176 = 0.994 so 99.4%	C1 A1	**ecf(c)(ii)(iii)** **allow** second mark for 'correct' answer as fraction not percentage with BOD sign **allow** 1 mark max. if give correct % lost given rather than % remaining **allow** 1 mark max. for 100 x (2000 – 1)/2000 = 99.95%
			Total question 2	**14**	

4)

(a)	**(i)**	I = 230/(42.5 + 2.5) I = 5.11 (A)	C1 A1	 **accept** 5.1 A
	(ii)	P = I^2R = 5.11^2 x 45 = 1175.0 W **or** use P = VI or P = V^2/R answer given to 3 SF i.e. 1180 (W)	C1 A1 B1	**ecf(a)(i)** and **allow** 5.00^2 x 45 = 1125 W 5.1^2 x 45 = 1170 W **give** 1 mark for 65.3 W (wires only) or 1110 W (heater only) **any** follow through answer given to 3 SF gains third mark
	(iii)	6 to 10 A (integer values only)	B1	**ecf(a)(i)** ; **allow** 13 A
(b)		1180 x 21 x 4/1000 = 99 p	C1 A1	**ecf(a)(ii)** **allow** 99.1(2) **or** 100 p
(c)		R = ρl/A A = 1.70 x 10^{-8} x 9.50/2.50 A = 6.46 x 10^{-8} (m^2)	C1 C1 A1	select formula mark correct substitution **allow** correct answer to 2 SF, i.e. 6.5 x 10^{-8} (m^2) **special case** 2/3 marks for: l = 4.75 m; A = 3.23 x 10^{-8} (m^2)
(d)		resistance of wires increases so smaller current (in heater) power dissipation in heater less	B1 B1 B1	**N.B.** wires can be implied by e.g. A reduces so R increases **or** lower voltage across heater/greater voltage across wires **or** power dissipation in wires greater/wires get hotter/melt **N.B.** any statement implying constant or increased current invalidates second and third marking points
	•	**Total**	**14**	

5)

a		current moves from + to – (of battery in circuit) **and** electrons move from – to +	B1	
b		$C\ s^{-1}$ $V\ \Omega^{-1}$	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 series or current is the same (at every point) in a series 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 $I = nAev$ $v = 4.0 \times 10^{-5}$ ($m\ s^{-1}$)	B1 B1	**allow** v α 1/A **accept** 4×10^{-5} ($m\ s^{-1}$) **no** SF error
		Total question 1	**10**	

6)

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**	

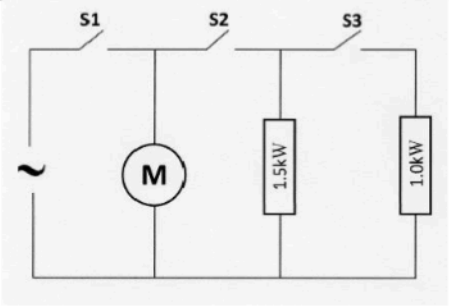
7)

(a)		Work done/energy transfer(red) per unit time	**B1**	**accept** per second **or** rate of energy transfer / rate of doing work **or** energy transfer / time taken
(b)	(i)	using P = VI I = 40/230 = 0.17(4) (A)	**C1** **A1**	 accept 4/23
(b)	(ii)	R = 230/0.17 = 1400 (Ω)	**B1**	**possible ecf b(i);** expect and **accept** 1322 or 1353 Ω **accept** $40 = 230^2/R$ giving R = 52900/40 = 1322 Ω
(c)		$I = RA/\rho$ $I = 1.3 \times 10^3 \times 3.0 \times 10^{-8} / 7.0 \times 10^{-5}$ I = 0.56 (m)	**C1** **C1** **A1**	Choosing $R = \rho l/A$ substitution; **ecf b(ii)** evaluation; **allow** 0.57 m (using R = 1322 Ω) and 0.58 m (using 1353 Ω) and 0.6 m (using 1400 Ω)
(d)		larger power needs larger I so smaller R (for same V) smaller R (but same length) so larger A / thicker	**B1** **B1** **B1**	**accept** $P = V^2/R$ **or** calculation I = 0.26 A giving R = 880 or 890 Ω NB if R calculated correctly here, give first 2 marks hence smaller R (but same length) so larger A / thicker
(e)	(i)	Q = It = 0.17 x 8 x 60 x 60 Q = 4900 (C)	**C1** **A1**	**ecf b(i)** **allow** 4896; or 5000 or 5011 if using I = 0.174 A give 1 mark for 1.36 or 81.6
	(ii)1	(a unit of) energy equal to 3.6 MJ **or** 1 kW for 1 h/AW	**B1**	**eg** 1000 W for 3600 s or similar
	(ii)2	40 x 8 = 320 Wh / 0.32 kWh 0.32 x 22 = 7.0(4) p	**C1** **A1**	 **accept** 7 p (no SF error); allow 7000p (7040) for 1 mark
		Total	**15**	

8)

(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
(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**	

9)

a	**i**	P = V^2/R = 230^2/R = 1500 R = 35.3 Ω	C1 A1	**accept** I = P/V = 6.52 A and R = 230/6.52 **allow** 52900/1500 = 35 Ω, i.e. some working shown
	ii	use of ρ = RA/l or R = ρl/A l = 35 x 7.8 x 10^{-8}/1.1 x 10^{-6} l = 2.5 (m)	C1 C1 A1	formula correct substitution answer (2.48)
b		resistors and motor wired in parallel to supply switches correctly placed (open or closed) any suitably labelled symbols; components <u>in correct order</u>	B1 M1 A1	 do not expect switches to be labelled
c	**i**	power is inversely proportional resistance (for same V) resistance of wire is inversely proportional to c-s area/diameter squared (as l and ρ are fixed/same)	B1 B1	**accept**: (same V so for) larger/smaller power need (larger/smaller I and so) smaller/larger resistance **accept** smaller c-s area/diameter (of wire) causes larger resistance or vice versa
	ii	P α A (because P = V^2/R = V^2A/ρl) **or** P α d^2 (because A = πd^2/4) 1.0/1.5 = $(d/D)^2$ = 2/3 so d = 0.82 D	B1 M1 A1	**accept** R_{1000} = 52.9 Ω and R α 1/A [where A_d = 5.2 x 10^{-8} & A_D = 7.8 x 10^{-8}] so 35.3 / 52.9 = $[(d/D)^2$ or A_d/A_D] = 2/3 [where d = 2.57 x 10^{-4} & D = 3.15 x 10^{-4}]

10)

a		resistivity = resistance x (cross-sectional) area / length	B1	**accept** equation with *resistance* as subject **allow** *over* for divide by; do **NOT** allow algebraic formula followed by a word definition of each symbol
b	**i**	$A = \pi d^2/4 = 3.14 \times 10^{-6}$ m^2 $\rho = RA/l = 8.0 \times 3.14 \times 10^{-6} / 0.15$ $\rho = 1.7 \times 10^{-4}$ unit Ω m	C1 C1 A1 B1	**apply** POT error as many times as occurs correct substitution with **ecf** for A **accept** 1.68×10^{-4} **accept** Ω mm or mΩ m, etc.
	ii 1	current below X in 'lead' equals current in 4 Ω same V across 'lead' below X and 4 Ω **or** they are in parallel (so) X is the mid point of the 'lead'/ 4 Ω is half of 8 Ω	B1 B1 B1	**allow** reverse argument starting from 4 Ω as resistance of half of 'lead' **allow** references to A_1 & A_2 possibly to indicate branches of circuit rather than meters
	ii 2	sum of R's in parallel = 2 Ω total R = 6 Ω so I = 0.50 A	C1 A1	incorrect working with correct answer cannot score second mark **allow** 0.5 A;
c		select I = nAev = 0.40 A $v = 0.40/3.6 \times 10^{26} \times 3.14 \times 10^{-6} \times 1.6 \times 10^{-19}$ $= 2.2 \times 10^{-3}$ (m s^{-1})	C1 C1 A1	 correct substitutions into formula with **ecf** for A answer to be given to 2 or more SF
d	**i**	reference to differences in <u>number density</u> of (free) electrons/charge carriers conductors have n a (few) powers of 10 <u>greater</u> than semiconductors/AW	 B1 B1	allow n, number per m^3 or unit volume **allow** <u>much</u> greater than
	ii	 *conductor*: R or ρ rises because of (increase in) electron ion collisions/ v falls *semiconductor*: R or ρ falls because of (large) increase in n/free electrons	 B1 B1	**allow** R or resistivity rises for conductors and falls for semiconductors for 1 mark **allow** current decreases for same p.d. /AW **allow** current increases for same p.d. /AW
		Total question 1	**17**	