

Mark Scheme

Q1.

Question Number	Answer	Mark
	The only correct answer is C - $\frac{2\varepsilon}{3}$ A is not correct because the two resistors in parallel have half the resistance of the resistor connected across the voltmeter B is not correct because the resistors do not share the potential difference equally D is not correct because the p.d. cannot be greater than the emf	1

Q2.

Question Number	Answer	Mark
	C is the correct answer as inverting $(1/Y + 1/Z)$ leads to $YZ / (Y + Z)$ A is not the correct answer as the section $(1/Y + 1/Z)$ has not been inverted B is not the correct answer as this considers resistor X as a parallel resistor D is not the correct answer as this considers resistor X as a parallel resistor	(1)

Q3.

Question Number	Answer	Mark
	D is the correct answer A is not correct because $6\ \Omega$ is not connected in parallel B is not correct because the resistance of the parallel section is inverted C is not correct because the $2\ \Omega$ and $3\ \Omega$ resistors are in series	1

Q4.

Question Number	Answer	Mark
	D is the correct answer (Total resistance in series is 10Ω and 2.5Ω in parallel) A is not the correct answer as the two resistances are the wrong way around B is not the correct answer as this assumes the formulae for series and parallel resistors are the same C is not the correct answer as this assumes the formulae for series and parallel resistors are the same	(1)

Q5.

Question Number	Answer	Mark
	C is the correct answer A is not correct because the resistance of the 7Ω and 18Ω resistors in parallel is not correct. B is not correct because the resistance of the 7Ω and 18Ω resistors in parallel is not correct and there is a short circuit around the 4Ω resistor. D is not correct because there is a short circuit around the 4Ω resistor.	1

Q6.

Question Number	Answer	Mark
	D is the correct answer A is not correct because the potential difference should not be halved and 3.3 V should be subtracted from 10 V B is not correct because the potential difference across R_1 is not the same as that across the voltmeter C is not correct because the potential difference should not be halved	1

Q7.

Question Number	Answer	Mark
	Use of conservation of charge (1)	3
	Use of conservation of energy (1)	
	Algebra leading to given expression (1)	
	<u>Example of derivation</u> (conservation of charge) $I = I_1 + I_2$ $\frac{V_{tot}}{R_{tot}} = \frac{V_1}{R_1} + \frac{V_2}{R_2}$ (conservation of energy) $V_{tot} = V_1 = V_2$ $\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2}$ $\frac{1}{R_{tot}} = \frac{R_1 + R_2}{R_1 R_2}$ $R_{tot} = \frac{R_1 R_2}{R_1 + R_2}$	
	Total for question	3

Q8.

Question Number	Answer	Mark
a	See $I_T = I_1 + I_2$ (1) See $V/R_T = V/R_1 + V/R_2$ (1) Divides both sides by V to give $1/R_T = 1/R_1 + 1/R_2$ Or V is the same in parallel, so $1/R_T = 1/R_1 + 1/R_2$ (1) (MP3 cannot be awarded for just seeing the equation as this is given on the formula sheet).	3
bi	Use of resistors in parallel formula for N, P and Q (or see 3.3Ω from relevant working) (1) Adds total to resistance of O (or see 8.3Ω) (1) Total resistance = 3.1Ω (1) (No unit penalty as is a "show that") (Each step in calculation could be achieved with product/sum calculations, but need to see bracketed values for MP1 and MP2) <u>Example of calculation</u> Resistor N = 5.0Ω, $P + Q = 5.0 \Omega + 5.0 \Omega = 10.0 \Omega$ $1/R_T$ for N parallel with (P+Q) = $(1/5.0 \Omega) + (1/10.0 \Omega)$. $R_T = 10/3 = 3.3 \Omega$. O in series with this 3.3Ω, so total for N,O,P,Q section = $25/3 = 8.3 \Omega$. $1/R_T$ (for whole combination) = $(1 / 8.3 \Omega) + (1 / 5.0 \Omega)$ $R_T = 3.1 \Omega$	3
bii	Replace resistor M (1) The resistance of a parallel combination is always less than a single resistor in parallel with the others. (1) (MP2 dependent on MP1)_	2
Total for question		8

Q9.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	Calculate cross-sectional area (1) Use of $R = \frac{\rho l}{A}$ (1) $R = 4.9 \text{ } (\Omega)$ (1)	<u>Example of calculation</u> $A = 1.64 \times 10^{-3} \text{ m} \times 2 \times 10^{-4} \text{ m} = 3.3 \times 10^{-7} \text{ m}^2$ $R = \frac{1.70 \times 10^{-6} \text{ } \Omega \text{ m} \times 0.95 \text{ m}}{3.3 \times 10^{-7} \text{ m}^2} = 4.92 \text{ } \Omega$	3
(a)(ii)	Use of $\frac{1}{R_{\text{tot}}} = \frac{1}{R_1} + \frac{1}{R_2}$ (1) $R = 0.45 \text{ } \Omega$ (ecf from (a)(i)) (1)	<u>Example of calculation</u> $\frac{1}{R_{\text{tot}}} = 11 \times \left(\frac{1}{5 \text{ } \Omega} \right)$ $R_{\text{tot}} = \frac{5 \text{ } \Omega}{11} = 0.45 \text{ } \Omega$	2
(a)(iii)	Use of $RR = \frac{V}{I}$ (1) $I = 26.7 \text{ A}$ (ecf from (a)(ii)) (1) Show that value gives 26.4 A	<u>Example of calculation</u> $I = \frac{12 \text{ V}}{0.45 \text{ } \Omega} = 26.67 \text{ A}$	2
(b)	Resistance of wire in series would be greater (1) Or p.d. from power supply shared across each strip (1) So power dissipated would be lower (MP2 dependent on MP1)		2
Total for question			9

Q10.

Question Number	Answer	Mark
ai	Use of $\frac{1}{R} = \frac{1}{500\ \Omega} + \frac{1}{600\ \Omega}$ (1) Use of $V = IR$ (1) Voltmeter reading = 6.3 (V) (1) <u>Example of calculation</u> $\frac{1}{R_{\text{parallel}}} = \frac{1}{500\ \Omega} + \frac{1}{600\ \Omega}$, so $R_{\text{parallel}} = 273\ \Omega$ $V = IR = 23.0 \times 10^{-3}\ \text{A} \times 273\ \Omega = 6.28\ \text{V}$	3
aii	p.d. across thermistor = 12 V – 6.3 V (allow ecf from ai) (1) Use of $P = VI$ (allow use of $P = I^2R$ or $P = V^2 / R$) (1) $P = 0.13\ \text{W}$ (1) <u>Example of calculation</u> p.d. across thermistor = 12.0 V – 6.3 V = 5.7 V $P = VI = 5.7\ \text{V} \times 23 \times 10^{-3}\ \text{A}$ $P = 0.13\ \text{W}$	3
b	Resistance (of circuit/thermistor) increases (1) Ammeter reading decreases (dependent on MP1) Or Current decreases (dependent on MP1) (1) p.d. across thermistor increases Or $V=IR$ for fixed/parallel resistors, and I decreases (1) Reading on voltmeter decreases (dependent on MP3) Or p.d. across fixed/parallel resistors decreases (dependent on MP3) (1) (Allow 1 mark maximum if stated that both ammeter and voltmeter readings decrease, and no other marks have been awarded)	4
Total for question		10

Q11.

Question Number	Answer	Mark
a	Either Uses resistors in parallel formula correctly (1) Adds series resistance (1) Use of $V = IR$ to find whole circuit current (1) Current in the 6.0Ω resistor = $0.67(A)$ (1) Use of $Q = It$ (1) 4.2×10^{18} (electrons) (1) Or Uses resistors in parallel formula correctly (1) Uses potential divider to calculate V across parallel section (1) Use of $V = IR$ to find current in 6.0Ω resistor (1) Current in the 6.0Ω resistor = $0.67(A)$ (1) Use of $Q = It$ (1) 4.2×10^{18} (electrons) (1) <u>Example of calculation</u> $\frac{1}{R_p} = \frac{1}{3.0\Omega} + \frac{1}{6.0\Omega}$, so $R_{\text{parallel}} = 2.0 \Omega$ Total circuit resistance = $4.0 \Omega + 2.0 \Omega = 6.0 \Omega$ $I = V / R = 12 \text{ V} / 6.0 \Omega = 2.0 \text{ A}$ Current in 6.0Ω resistor is $1/3$ of $2.0\text{A} = 0.67 \text{ A}$ No. of electrons per second = $\frac{\text{current}}{\text{charge per electron}} = \frac{0.67 \text{ A}}{1.60 \times 10^{-19} \text{ C}}$ $= 4.2 \times 10^{18}$ electrons per second	6

b	(Student is correct that) resistance in circuit/parallel is greater (1) V is the same (1) So if student uses $P = V^2/R$ (1) Power in whole circuit would be less, so student incorrect (1) Or (Student is correct that) resistance in circuit/parallel is greater (1) This leads to current being lower (1) So if student used $P = VI$ with same V (1) Power in whole circuit would be less, so student incorrect (1) Or (Student is correct that) resistance in circuit/parallel is greater (1) This leads to current being lower (1) Effect of decreasing current > the effect of increasing resistance (1) Power in whole circuit would be less, so student incorrect (1) (MP4 via any method is dependent on awarding MP2 & MP3)	4
Total for question		10

Question Number	Answer	Mark
a	Use of resistors in parallel formula (1) Resistance of parallel section of circuit calculated as 1.33Ω (1) Total circuit resistance = 2Ω + their parallel resistance Or Use of ratio of resistance:p.d. (1) Use of $I = V/R$ to calculate total circuit current (3A) Or Use of $I = V/R$ to calculate p.d. across resistor A (6V) (1) Use of $P = VI$, $P = V^2/R$ or $P = I^2R$ (1) A = 18W, B = 2W, C = 2W, D = 8W (1) Example of calculation $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ (for parallel combination) $\frac{1}{R_p} = \frac{1}{2} + \frac{1}{4}$ $R_p = 1.33\Omega$ Total resistance in circuit = $(1.33 + 2.00) = 3.33\Omega$ $I = V/R$ (for whole circuit) = $10.0\text{ V} / 3.33\Omega = 3.00\text{ A}$ For resistor A, $P = I^2R = (3.00\text{ A})^2 \times 2.00\Omega = 18\text{ W}$ Current through D = $\frac{2}{3} (3.00\text{ A}) = 2.00\text{ A}$ For D, $P = I^2R = (2.00\text{ A})^2 \times 2.00\Omega = 8\text{ W}$ For B and C, $P = I^2R = (1.00\text{ A})^2 \times 2.00\Omega = 2\text{ W}$	6
b	(With resistor D removed there is) lower circuit current Or (with resistor D removed there is) lower p.d. across A (1) Seeing an appropriate power equation to support the conclusion that power would be less in A (1)	2
c	As p.d increases, current increases (1) (As current increases,) temperature increases (allow "heats up") (1) Atoms/ions/lattice have greater vibrations/KE (1) Increased rate of collisions between electrons and atoms/ions (1)	4
Total for question		12

Question Number	Answer	Mark
a	See $V_T = V_1 + V_2$ (1) See $IR_T = IR_1 + IR_2$ (1) (Divides by I to give) $R_T = R_1 + R_2$ (1)	3
b	Use of $V = IR$ with 7.0V and 0.5A (1) Use of $\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2}$ (1) $R = 12\Omega$ (1) Or Use of $V = IR$ with 6Ω and 0.5A (to get 3V across 6Ω resistor) (1) Second use of $V = IR$ with $V = 4V$ (1) $R = 12\Omega$ (1) <u>Example of calculation</u> R for whole circuit = $(7.0V/0.5A) = 14\Omega$ So R for parallel section = $14 - 6 = 8\Omega$ $1/8 = 1/24 + 1/R_2$ $R_2 = 12\Omega$	3

ci	Use of $V = IR$ to determine circuit current (1) Use of $P = I^2R$ or $P = V^2/R$ or $P = VI$ (1) $P = 1.5 \times 10^{-2} \text{ W}$ (1) Or Ratio of resistances used to calculate p.d. across R (1) Use of $P = V^2/R$ (1) $P = 1.5 \times 10^{-2} \text{ W}$ (1) <u>Example of calculation</u> $I = 12.0 \text{ V} / (8000 + 670 \Omega) = 1.38 \times 10^{-3} \text{ A}$ $P = (1.38 \times 10^{-3} \text{ A})^2 \times 8000 = 0.015 \text{ W}$	3
cii	Decrease in the number of conduction/ free electrons (1) Greater resistance of LDR (1) Less p.d. across the fixed resistor (allow "voltage" for "p.d.") (1) Use of a suitable power equation to conclude that less power dissipated in the fixed resistor. (1) (Converse argument not allowed for MP1 & MP2) (For MP4, do not accept an answer that includes an incorrect statement about one of the variables)	4
Total for question		13

Question Number	Answer	Mark
(a)(i)	Use of $P = VI$ and $V = IR$ Or Use of $P = I^2 R$ and $V = IR$ (1) Appropriate algebra to derive $P = \frac{V^2}{R}$ (1)	2
(a)(ii)	EITHER Their resistance from graph divided by 4 (1) Use of $P = \frac{V^2}{R}$ (1) Use of p.d. across battery = $5 \times$ p.d. across R (1) p.d. across battery = $9.0 - 9.2$ V (1) OR Their resistance from graph divided by 4 (1) Use of $P = I^2 R$ (1) Use of $V = I(R + R_t)$ (1) p.d. across battery = $9.0 - 9.2$ V (1) <u>Example calculation</u> Resistance of $R = \frac{35 \Omega}{4} = 8.75 \Omega$ $0.38 \text{ W} = \frac{V_R^2}{8.75 \Omega}$ $V_R = \sqrt{0.38 \text{ W} \times 8.75 \Omega} = 1.82 \text{ V}$ $V_B = 5 \times 1.82 \text{ V} = 9.1 \text{ V}$	4

(b)(i)	Number of conduction electrons (per unit volume) increases (1) So current increases (for the same potential difference and $R = V/I$) (1)	2
(b)(ii)	(Increased temperature caused) increased lattice/atom/ion vibrations (in the thermistor and the wire resistor) (1) This caused an increase in collisions between electrons and the lattice/ions/atoms (in the thermistor and the wire resistor) (1) So the resistance of the wire resistor increased (1) (Because current decreases) total resistance of the circuit must increase (1) So the increase in the resistance of the wire resistor must be greater than the decrease in the resistance of the thermistor (1)	5
Total for question		13

Q15.

Question Number	Answer	Mark
(a)(i)	The resistance of a sample of the material of unit <u>cross sectional area</u> and unit length Or $\rho = \frac{RA}{l}$ with terms defined (1)	1
(a)(ii)	Measure the L using a metre rule (1) Measure the thickness of the material using a micrometer Or Measure the thickness of the material using vernier callipers (1) Use an ammeter and voltmeter to determine the resistance using $R = \frac{V}{I}$ Or Use an ohmmeter to measure the resistance of the sample (1) Use $\rho = \frac{RA}{l}$ to determine the resistivity (1) Or valid description of a graph and gradient calculation to determine the resistivity (1)	4
(b)	Copper has a high concentration of charge carriers (1) $I = nAqv$ so (for a given current) drift velocity is small (1)	2
(c)	The same potential difference is applied across each additional panel (1) So each panel dissipates the same power, and power output of the system increases (1) OR As more panels are connected, the resistance (of the system) decreases (and potential difference remains the same) (1) And $P = \frac{V^2}{R}$ so power output of the system increases (1) OR As more panels are connected, the current in the power supply increases (and potential difference across each panel is the same) (1) And $P = VI$ so power output of the system increases (1) OR As more panels are connected, the current in the power supply increases and the resistance of the system decreases by the same factor (1) And $P = I^2R$ so power output of the system increases (1)	2

(d)	Use of $A = \text{length} \times \text{thickness}$	(1)	5
	Use of $\rho = \frac{RA}{l}$	(1)	
	Use of $R_{\text{total}} = \frac{R_{1 \text{ panel}}}{5}$	(1)	
	Use of $P = \frac{V^2}{R}$	(1)	
	680 W is greater than 350 W so the system is not safe	(1)	
	OR		
	Use of $A = \text{length} \times \text{thickness}$	(1)	
	Use of $\rho = \frac{RA}{l}$	(1)	
	Use of $P = \frac{V^2}{R}$	(1)	
	Use of $P_{\text{total}} = 5 \times P_{1 \text{ panel}}$	(1)	
	680 W is greater than 350 W so the system is not safe	(1)	
	<u>Example of calculation</u>		
	$A = 1.60 \text{ m} \times 0.48 \times 10^{-3} \text{ m} = 7.68 \times 10^{-4} \text{ m}^2$		
	$R = \frac{6.4 \times 10^{-3} \Omega \text{ m} \times 0.51 \text{ m}}{7.68 \times 10^{-4} \text{ m}^2} = 4.25 \Omega$		
	$R_{\text{total}} = \frac{4.25 \Omega}{5} = 0.85 \Omega$		
	$P = \frac{(24 \text{ V})^2}{0.85 \Omega} = 678 \text{ W}$		
Total for question			14

Q16.

Question Number	Answer	Mark																																								
* a	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr><tr><td>6</td><td>4</td><td>2</td><td>6</td></tr><tr><td>5</td><td>3</td><td>2</td><td>5</td></tr><tr><td>4</td><td>3</td><td>1</td><td>4</td></tr><tr><td>3</td><td>2</td><td>1</td><td>3</td></tr><tr><td>2</td><td>2</td><td>0</td><td>2</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table> Indicative content • Current is the rate of flow of charge • Current is the same at all points in a series circuit Or current in C = current in cell. • total current going into a junction = total current out of junction Or current in C/cell = current in A + current in B Or current splits (equally) between A and B • p.d. is energy transferred per unit charge • p.d. is shared between components in series Or p.d. across C + p.d. across A = e.m.f. of cell Or p.d. across C + p.d. across B = e.m.f. of cell Or p.d. across C + p.d. across A/B combination = e.m.f. of cell • p.d. is the same across components in parallel Or p.d. across A is the same as that across B	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	
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bi	Use of resistors in parallel formula (1) Use of resistors in series formula (1) Total resistance = 18.8Ω (1) (Allow MP1 for use of $R^2 / 2R$) <u>Example of calculation</u> For parallel section, $\frac{1}{R_p} = \frac{1}{12.5\Omega} + \frac{1}{12.5\Omega}$ so $R_p = 6.25\Omega$ $R_{total} = 6.25\Omega + 12.5\Omega = 18.75\Omega$.	3
bii	Equation for sum of p.d. = sum of e.m.f. seen e.g. $\mathcal{E} = IR + Ir$ (1) Rearranged to make r the subject of the formula e.g. $r = \frac{\mathcal{E}}{I} - R$ (1) Ammeter labelled anywhere on series part of circuit (1) Or Terminal p.d. calculated using IR (1) Subtract from $\mathcal{E}$ and divide by ammeter reading (1) Ammeter labelled anywhere on series part of circuit (1) Or $\mathcal{E}$ divided by ammeter reading (1) Subtract answer for (b)(i) from this value (1) Ammeter labelled anywhere on series part of circuit (1)	3
	Total for question	12

Q17.

Question Number	Answer	Mark
(a)	Use of $A = \pi r^2$ (1) Use of $R = \rho l / A$ (1) $R = 23.5 \text{ } (\Omega)$ (1) (Units are in brackets, as this is a “show that” question, where the units have already been given in the question) (For a “show that” question, the answer needs to be given to at least one more significant figure than that given in the question, so an answer of $24 \text{ } \Omega$ would not score MP3 unless it is shown to a greater number of significant figures beforehand) (If a candidate uses diameter instead of radius, MP2 can still be awarded if the substituted value for A is dimensionally-correct) <u>Example of calculation</u> $A = \pi r^2 = \pi \times (0.0905 \times 10^{-3} \text{ m})^2 = 2.57 \times 10^{-8} \text{ m}^2$ $R = \rho l / A = (1.10 \times 10^{-6} \text{ } \Omega\text{m}) \times (0.550 \text{ m}) / (2.57 \times 10^{-8} \text{ m}^2)$ $= 23.5 \text{ } \Omega$	3
(b)	Maximum power when total resistance of circuit is the lowest (1) Calculation of total resistance when X and Y are closed (1) Use of $P = V^2/R$ (1) Maximum power = 9W, which is less than 12 W, so student incorrect (1) (allow full e.c.f. from (a), including situations where power is calculated to be more than 12W so student is correct) (MP1 and MP2 can be awarded if candidate clearly calculates the power when switches X and Y are closed with no explanation). (MP3 can be awarded when candidate has only switch X or switch Y closed) (For MP4 there needs to be a clear conclusion of whether the student is correct or incorrect) (Some students might calculate the power of each individual resistor when both switches X and Y are closed – this is an acceptable method that can gain full credit – look for 6W, 1.5W and 1.5W added to give 9W) <u>Example of calculation</u> When X is closed, $R_{\text{tot}} = 23.5 \text{ } \Omega + 23.5 \text{ } \Omega = 47 \text{ } \Omega$ When Y is closed, $R_{\text{tot}} = 23.5 \text{ } \Omega$ When X and Y are closed, $R_{\text{tot}} = \left(\frac{1}{47 \text{ } \Omega} + \frac{1}{23.5 \text{ } \Omega} \right)^{-1} = 15.7 \text{ } \Omega$ $P = V^2 / R$, so greatest power when resistance is lowest, $= (12.0 \text{ V})^2 / (15.7 \text{ } \Omega) = 9.2 \text{ W}$ (If using the “show that” value from (a), power = 9W)	4

(c)(i)	Use of $R = V / I$ to calculate I (1) Use of $I = Q / t$ and number of electrons = Q / e (1) Number of electrons = 3.2×10^{18} (no units) (1) (allow full e.c.f. from (a)) <u>Example of calculation</u> $I = V / R = 12.0 \text{ V} / 23.5 \Omega = 0.511 \text{ A}$. $Q = It$ (for 1 second) = $0.511 \text{ A} \times 1.0 \text{ s} = 0.511 \text{ C}$ Number of electrons = $0.511 \text{ C} / (1.60 \times 10^{-19} \text{ C}) = 3.2 \times 10^{18}$ electrons (if using the “show that” value from (a), answer = 3.1×10^{18})	3
(c)(ii)	Temperature of resistor increases (1) Resistance of resistor increases (1) Use of $P = V^2 / R$ to explain that power output falls (1) (For MP3, allow use of $P = VI$ as long as it is clear that I decreases)	3
	Total for question	13