

Mark Scheme

Q1.

Question Number	Answer	Mark
	B is the correct answer as $v \propto 1/A$ when I, n and q are the same. A is not the correct answer as both wires have the same charge carrier density as they are both made from copper. C is not the correct answer as both wires have the same current as they are in series D is not the correct answer as the length of the wire is not related to drift velocity	(1)

Q2.

Question Number	Answer	Mark
	D is the correct answer A is not the correct answer as a larger charge would decrease drift velocity B is not the correct answer as a larger diameter would decrease drift velocity C is not the correct answer as a larger current would increase drift velocity	1

Q3.

Question Number	Answer	Mark
	C is the correct answer as v represents the drift velocity of the charge carriers. A is not the correct answer as n is the number of charge carriers per m^3 B is not the correct answer as q is the charge per charge carrier D is not the correct answer as A is the cross-sectional area	(1)

Q4.

Question Number	Answer	Mark
	The only correct answer is D (4 v) A because this would be 16 times less than the actual value B is not correct because this would be 8 times less than the actual value C is not correct because this would half the actual value	1

Q5.

Question Number	Answer	Mark
	The only correct answer is B - total number of conduction electrons in 1 m³ of a material A is not correct because n refers to the number of charge carriers per unit volume, not per unit length. C is not correct because the total number of electrons is not the same as the number of charge carriers, and n refers to the number of charge carriers per unit volume, not per unit length. D is not correct because the total number of electrons is not the same as the number of charge carriers.	1

Q6.

Question Number	Answer	Mark
	A is the correct answer $v = I/nAq$ – doubling d quadruples A, and with n doubling also, the denominator is 8 times larger B is not the correct answer as A is quadrupled and n is doubled (factor of 8 overall) C is not the correct answer as A is quadrupled and n is doubled (factor of 8 overall) D is not the correct answer as A is quadrupled and n is doubled (factor of 8 overall)	(1)

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Use of $I = nqvA$ (1) $v = 6.6 \times 10^{-5} \text{ m s}^{-1}$ (1)	<u>Example of calculation</u> $v = \frac{2.5 \text{ A}}{8.5 \times 10^{28} \text{ m}^{-2} \times 1.6 \times 10^{-19} \text{ C} \times 2.8 \times 10^{-6} \text{ m}^2}$ $= 6.57 \times 10^{-5} \text{ m s}^{-1}$	2
	Total for question		2

Q8.

Question Number	Answer	Mark
	Use of $I = nqvA$ (using dimensionally-correct A) (1) $v = 7.5 \times 10^{-4} \text{ m s}^{-1}$ (1)	2
	<u>Example of calculation</u> $A = \pi r^2 = \pi (0.40 \times 10^{-3} \text{ m})^2 = 5.0 \times 10^{-7} \text{ m}^2$ $v = \frac{I}{nqA} = \frac{5.1 \text{ A}}{(8.5 \times 10^{28} \text{ m}^{-2})(1.6 \times 10^{-19} \text{ C})(5.0 \times 10^{-7} \text{ m}^2)}$ $v = 7.5 \times 10^{-4} \text{ m s}^{-1}$	
	Total for Question	2

Q9.

Question Number	Answer	Additional Guidance	Mark
	Use of $I = nqvA$ (1) $v = 3.2 \times 10^{-4} \text{ m s}^{-1}$ (1)	<u>Example of calculation</u> $v = \frac{1.25 \text{ A}}{9.0 \times 10^{28} \text{ m}^{-3} \times 1.6 \times 10^{-19} \text{ C} \times 2.7 \times 10^{-7} \text{ m}^2}$ $v = 3.22 \times 10^{-4} \text{ m s}^{-1}$	2
	Total for question		2

Q10.

Question Number	Answer	Mark
a	The average/mean velocity of the (free) electrons (1) (allow “speed” for “velocity”, and “charge carriers” for “electrons”).	1
b	Use of $I = nqvA$ with $e = (-)1.60 \times 10^{-19} \text{ (C)}$ (1) $v = (-) 3.65 \times 10^{-4} \text{ m s}^{-1}$ (1) <u>Example of calculation</u> $v = I/nqA = \frac{1.31 \text{ A}}{(8.49 \times 10^{28} \text{ m}^{-3})(1.60 \times 10^{-19} \text{ C})(2.64 \times 10^{-7} \text{ m}^2)}$ $v = 3.65 \times 10^{-4} \text{ m s}^{-1}$	2
	Total for question	3

Q11.

Question Number	Answer	Mark
(a)	To limit the current (in the circuit) Or To avoid overheating/melting (in the circuit) (1)	1
(b)	$\frac{I_W}{I_Z} = 1$ (1) as current is the same around a series circuit. (1) $\frac{v_W}{v_Z} = 0.25$ (or 1:4) (1) as the (cross-sectional) area / A is 4 times less for Z Or as the (cross-sectional) area / A is 4 times greater for W (1) (for MP3, allow an answer "<1") (Do not award MP2 if value for MP1 is incorrect) (Do not award MP4 if value for MP3 is incorrect)	4
Total for question		5

Q12.

Question Number	Answer	Mark																				
a	Z has greater (cross sectional) area than W (1) So Z has smaller resistance than W (1) Z has greater current than W (1) Since $I = nAve$, with both A and I $4 \times$ greater in Z, (drift velocity is the same) (1)	4																				
b	<table><tr><th>Quantity</th><th>Same value for W and Z</th><th>Larger value in W</th><th>Larger value in Z</th></tr><tr><td>Current in the wires</td><td>$\times$</td><td></td><td></td></tr><tr><td>Resistance of the wires</td><td></td><td>$\times$</td><td></td></tr><tr><td>Potential difference across the wires</td><td></td><td>$\times$</td><td></td></tr><tr><td>Drift velocity of the charge carriers in the wires</td><td></td><td>$\times$</td><td></td></tr></table>	Quantity	Same value for W and Z	Larger value in W	Larger value in Z	Current in the wires	$\times$			Resistance of the wires		$\times$		Potential difference across the wires		$\times$		Drift velocity of the charge carriers in the wires		$\times$		(1) (1) (1) (1) 4
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Total for question		8																				

Q13.

Question Number	Answer	Mark
a	Use of $R = \rho l/A$ (1) $\rho = 1.1 \times 10^{-6} \Omega \text{ m}$ (1) <u>Example of calculation</u> $\rho = \frac{RA}{l} = \frac{(2.0 \Omega)(2.5 \times 10^{-7} \text{ m}^2)}{0.45 \text{ m}} = 1.11 \times 10^{-6} \Omega \text{ m}$	2
b	Use of $R = V/I$ (1) Use of $I = nqvA$ (1) $v = 4.2 \times 10^{-4} \text{ m s}^{-1}$ (1) <u>Example of calculation</u> $I = V/R = (3.0 \text{ V}) / 2.0 \Omega = 1.5 \text{ A}$ $v = \frac{I}{nqA} = \frac{1.5 \text{ A}}{(9.0 \times 10^{28} \text{ m}^{-3})(1.60 \times 10^{-19} \text{ C})(2.5 \times 10^{-7} \text{ m}^2)}$ $= 4.17 \times 10^{-4} \text{ m s}^{-1}$	3
c	Halving length halves resistance (1) Which doubles the current (1) $I = nqvA$ related to drift velocity doubling (so suggestion is correct) (1)	3
Total for question		8

Q14.

Question Number	Answer	Mark
a	Use of $R = V/I$ (to find resistance of whole circuit) (1) Subtracts $9\ \Omega$ from $11\ \Omega$ (to get $2\ \Omega$) (1) Use of resistors in parallel formula (1) $R = 6.0\ \Omega$ (1) (MP3 - Allow $2 = \frac{3R}{3+R}$) OR Use of $R = V/I$ (to find V across $9.0\ \Omega$ resistor) (1) Subtracts 1.26V from 1.54V (to get 0.28V) (1) Conservation of charge used to establish current in R (0.467 A) (1) $R = 6.0\ \Omega$ (1) <u>Example of calculation</u> $R = V/I$ for whole circuit $= 1.54\text{ V} / 0.14\text{ A} = 11\ \Omega$ Resistance of parallel section $= 11\ \Omega - 9\ \Omega = 2\ \Omega$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$, so $\frac{1}{R} = \frac{1}{2} + \frac{1}{3} = \frac{5}{6}$ So $R = 6\ \Omega$ OR $V = IR$ for $9.0\ \Omega$ resistor $= 0.14\text{ A} \times 9.0\ \Omega = 1.26\text{ V}$ p.d. across $3.0\ \Omega$ resistor and resistor $R = 1.54\text{ V} - 1.26\text{ V} = 0.28\text{ V}$ (for $3.0\ \Omega$ resistor) $I = V/R = 0.28\text{ V} / 3.0\ \Omega = 0.0933\text{ A}$ Current in resistor $R = 0.14\text{ A} - 0.0933\text{ A} = 0.0467\text{ A}$ $R = V/I = 0.28\text{ V} / 0.0467\text{ A} = 6.0\ \Omega$	4

bi	Use of cross-sectional area = πr^2 (1) Cross-sectional area = $1.8 \times 10^{-8} \text{ (m}^2\text{)}$ (1) (“Show that” so units not required) (MP1 – not awarded if diameter is used) <u>Example of calculation</u> cross-sectional area = $\pi r^2 = \pi \left(\frac{0.15 \times 10^{-2} \text{ m}}{2}\right)^2 = 1.77 \times 10^{-8} \text{ m}^2$	2
bii	Use of $R = \rho l / A$ (1) Length of copper wire = 9.5 m (1) (e.c.f. from (b)(i)) (Answer using “show that” value = 10.7 m) <u>Example of calculation</u> $l = \frac{RA}{\rho} = \frac{(9.0 \Omega)(1.77 \times 10^{-8} \text{ m}^2)}{(1.68 \times 10^{-8} \Omega \text{ m})} = 9.48 \text{ m}$	2
biii	Use of $I = nqvA$ (1) $v = 5.8 \times 10^{-4} \text{ m s}^{-1}$ (1) (e.c.f. from b(i)) (Answer using “show that” value = $5.2 \times 10^{-4} \text{ m s}^{-1}$) (ignore minus sign on answer) <u>Example of calculation</u> $v = \frac{I}{nqA} = \frac{(0.14 \text{ A})}{(8.49 \times 10^{28} \text{ m}^{-3})(1.60 \times 10^{-19} \text{ C})(1.77 \times 10^{-8} \text{ m}^2)} = 5.8 \times 10^{-4} \text{ m s}^{-1}$	2
Total for question		10

Q15.

Question Number	Answer	Mark
(a)	Corresponding values from best fit line (1) Use of $P = VI$ (1) Minimum potential difference = 9.0 V (1) <u>Example of calculation</u> $P = VI$ At 9.0 V, $P = 9.0 \text{ V} \times 3.9 \text{ A} = 35.1 \text{ W}$	3
(b)(i)	In parallel, each headlight receives 12 V Or In series, each headlight receives 6 V (1) In parallel, headlights will have higher power/brightness Or In series, headlights will have lower power/brightness (1) In parallel, if one headlight breaks/fails, the other one remains on Or In series, if one headlight breaks/fails, the other one goes out (1)	3
(b)(ii)	Use of $R = V/I$ (1) Use of resistors in parallel formula to calculate R_T in parallel (1) R_{series} is not $4 \times R_{\text{parallel}}$, so student not correct (1) <u>Example of calculation</u> (Using data from the graph): R of single headlight in parallel = $\frac{V}{I} = \frac{12.0 \text{ V}}{4.6 \text{ A}} = 2.61 \Omega$ (for parallel headlights), $\frac{1}{R_T} = \frac{1}{2.61 \Omega} + \frac{1}{2.61 \Omega}$, so $R_T = 1.30 \Omega$ R of single headlight in series = $\frac{V}{I} = \frac{6.0 \text{ V}}{3.2 \text{ A}} = 1.88 \Omega$ (for series headlights), $R_T = 1.88 \Omega + 1.88 \Omega = 3.76 \Omega$ $3.76 / 1.30 = 2.9$, so is $2.9 \times$ less in parallel, not $4 \times$ less	3
(c)	Use of $R = \rho l/A$ (1) Use of $I = nqvA$ (1) Drift velocity = $3.4 \times 10^{-4} \text{ m s}^{-1}$ (1) <u>Example of calculation</u> $R = \rho l/A$, so $A = \frac{\rho l}{R} = \frac{1.72 \times 10^{-8} \Omega \text{ m}}{0.0175 \Omega \text{ m}^{-1}} = 9.83 \times 10^{-7} \text{ m}^2$ $v = \frac{4.60 \text{ A}}{8.49 \times 10^{28} \text{ m}^{-3} \times 1.60 \times 10^{-19} \text{ C} \times 9.83 \times 10^{-7} \text{ m}^2} = 3.4 \times 10^{-4} \text{ m s}^{-1}$	3
Total for question		12