Marking Scheme

#1

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
4	(a)		**Indicative content:** **Description:** D1: At very low temperatures resistance of superconductor is zero ohms D2: Reference to transition temperature or critical temperature...... D3: .....where resistance suddenly drops to zero as temperature drops (or jumps up from zero as temperature rises) D4: Above transition temperature resistance increases with temperature D5: This increase in resistance with temperature is [approximately] linear **[Sketch graph can show some of these points]** **Explanation:** **No explanation required for superconducting state.** **Above transition temperature:** **E1:** As temperature increases, the ions in the metal lattice vibrate more quickly **E2:** Which makes it more likely that an electron will interact (accept collide) with the ion.... E3: So electrons lose kinetic energy and the drift velocity decreases **E4:** ......and collisions will cause ions to gain kinetic energy making further collisions more likely **5-6 marks** Comprehensive description and explanation provided. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description or explanation provided or limited attempt at both description and explanation. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited attempt at description or explanation. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** No attempt made or no response worthy of credit.	6			6		
	(b)		One benefit to society given for each application: **Particle accelerator 1 × (1) from:** • Improve understanding of the nature of particles, • Skilled workforce opportunities • Have led to more powerful computing • Particle discoveries used in everyday applications e.g. TV sets • Well-reasoned economic benefits **MRI scanner 1 × (1) from:** • Improved diagnoses and treatment of many ailments • Skilled workforce opportunities • Benefits more people Reasoned choice of application [1]			3	3		
			Question 4 total	6	0	3	9	0	0

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*		There are 6 J of energy/work done (converted from electrical to other forms) (1) Per coulomb of charge between X and Y (1)	2			2		
	(b)	(i)	Attempt to use equation to determine resistors in parallel (1) Resistance of parallel combination = 3.7[2] Ω (1) Total circuit resistance = 9.3 Ω ecf on parallel (1) Current = $\frac{V}{R}$ = 0.64 A [accept 0.65 A] answer to 2 d.p. (1)	1	1 1 1		4	3	
		(ii)	Apply ecf from part (b) (i) PD across parallel = 0.65 × 3.7 ecf OR pd across 5.6 Ω = 0.65 × 5.6 = 3.6 V (1) Answer = 2.4 V (1)		2		2	1	
		(iii)	Substitute values into $P = I^2R$ [P = 0.65^2× 3.7] (1) P = 1.54 W – ecf (1)	1	1		2	2	
			Question 2 total	**4**	**6**	**0**	**10**	**6**	**0**

#3

Question	Marking details	Marks available: AO1	AO2	AO3	Total	Maths	Prac
(a)	**Methodology** • Take readings of diameter at more than one point and determine mean diameter. • Tape the wire to the ruler (or move wire close to the ruler) • Ensure wire is taut (kink free) • Obtain values for R for at least 5 different values for l • Most/all of the length of the wire used to take readings from. • Obtain value for resistance of crocodile clips and subtract from each reading of R. **Analysis** • Calculate CSA from $\frac{\pi d_{mean}^2}{4}$ • Plot graph of R against l • Determine gradient of graph • ρ =gradient × A **Uncertainties** • Check zero error for micrometer (or state that 'any' zero error should be subtracted from each reading of diameter). Or close callipers and press 'zero' button. • Plot uncertainties on R-axis from repeat readings of R **Other possible answers** {Uncertainty in $\frac{R}{l}$ obtained from graph (no details)} {Total % uncertainty in ρ calculated from % unc in gradient + % unc in A.}	4		2	6		6
	5-6 marks At least 7 clear points made, but must include at least one statement from each of methodology, analysis and uncertainties *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** At least 5 clear points made and must include at least one statement from each of methodology and analysis. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** At least 3 clear points made. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
(b)	$R_{total} = \frac{V^2}{P} = \frac{14.3^2}{45}$ = 4.5[44 Ω] [1] R of each strip = 4 × 4.5[44] = 18[.176 Ω] [1] A calculated = $\frac{\rho l}{R} = \frac{6.0 \times 10^{-6} \times 1.2}{18}$ = 4.0 × 10^{-7} [m^2] [1] (**ecf** on R, even if total R used) A = 3.96 × 10^{-7} if 18.176 Ω used. Thickness = $\frac{4.0 \times 10^{-7}}{2.0 \times 10^{-3}}$ = 2.0 × 10^{-4} [m] (0.2 mm) and appropriate statement e.g. can be achieved [1] (Thickness = 0.198 mm if A = 3.96 × 10^{-7} used) **Alternative:** Find power used for thickness of 0.2 mm: A = 2 × 10^{-3} × 0.2 × 10^{-3} = 4.0 × 10^{-7} [m^2][1] $R = \frac{\rho l}{A}$ = 18 [Ω] [1] Total R = 4.5 [Ω] [1] $P = \frac{14.3^2}{4.5}$ = 45.4 [W] and appropriate statement [1] **Or alternative for final two marks above:** $P = \frac{14.3^2}{18}$ = 11.4 [W] for each strip [1] Total P = 11.4 × 4 = 45.4 [W] and appropriate statement [1]			4	4	4	
	Question total	4	0	6	10	4	6

#4

Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
10	(a)		Flux changes in ring as it approaches [or recedes from] magnet (1) Emf induced (1) [or by implication by next marking point] Current induced (complete circuit) (1) [Motor effect force] opposes motion or energy lost or Lenz's law stated(1)		4		4		
	(b)		Nothing [or equiv](1) Always opposes motion (Lenz) / field in opposite direction / current in opposite [not: the force opposite] (1)		2		2		
	(c)		Length = $2\pi r$ used (1) [0.157 m] $R = \frac{1.59\times10^{-8}\times2\pi\times0.025}{2.4\times10^{-5}}$ seen (or 1.04×10^{-4} [Ω] seen) (1)	1	1		2	1	
	(d)		Ohm's law used (1) Emf $=\frac{BNA}{t}$ i.e. Faraday's used (1) [= 0.55 mV] [NB c.s.a of wire used → no credit and no ecf] Answer, $\frac{B}{t}$ = 0.29 T s^{-1} (or 0.28 depending on rounding)(1)	1	1 1		3	2	
			Question 10 total	**2**	**9**	**0**	**11**	**3**	**0**

#5

Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
	(a)		Using $I = nAve$ (1) Area calculated correctly = 1.96 × 10^{-7} m^2 (1) n = 18 × 10^{28} [m^{-3}] (1) Drift velocity v = 0.000496 or 0.0005[0] m s^{-1} **unit mark** (1)	1	1 1 1		4	4	
	(b)		Current remains the same as do n and e (1) [Cross-sectional] area less in thinner portion (1) Correct conclusion needs to be qualified - drift velocity is <u>greater</u> in thinner portion (1)			3	3		
	(c)	(i)	Superconductor is when R = 0 accept negligible	1			1		
		(ii)	**Advantage** No power / energy loss [in the power lines] (1) power lines needs to be referenced if referring to 100% efficient As R = 0 [and $P = I^2R$] / no heat (1) **Or** Use in MRI scanners / particle accelerators (1) High currents / large magnetic fields (1) **Disadvantage** Operates at very low temperature (1) Extra energy/apparatus required to cool the wires (1) **Or** Due to cooling [the materials] (1) Cost is high (needs to be qualified) (1)		4		4		
			Question total	**2**	**7**	**3**	**12**	**4**	**0**

#6

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
	(a)		Electrical energy (or work) transferred [to other forms] per unit [accept coulomb] of charge [passing between the two points]	1			1		
	(b)		**Either:** I in circuit = $\frac{2.4}{160}$ (1) [= 15.0 mA] $R_{\text{Thermistor}} = \frac{(12.0-2.4)(1)}{15.0 \times 10^{-3}}$ **[ecf** on I**]** = 640 [Ω] (1) **Or:** $R_T = \frac{9.6(1)}{2.4} \times 160$ (1) **or** $2.4 = \frac{12 \times 160}{160 + R_T}$ (2) = 640 [Ω] (1)	1	1 1		3	3	
	(c)	(i)	[Resistance of thermistor decreases as temp increases] pd across thermistor decreases (1) So pd across fixed resistor increases **because**: **Either** - ratio of pds across potential divider changes **Or** - total pd must = 12.0 V (or equivalent) (1) **Alternative:** [Resistance of thermistor decreases as temp increases] so circuit current increases (1) So pd across fixed resistor increases **because** $V = IR$ and R is constant or $V \propto I$ (1)		2		2		
		(ii)	At 30 °C, $R_{\text{thermistor}}$ = 480 Ω from graph (1) $V_{\text{cooling system}} = \frac{160}{(480+160)} \times 12.0$ (1) **[ecf** on $R_{\text{Thermistor}}$**]** = 3.0 [V] (1) **Alternative:** $2.8 = \frac{160}{(R_{\text{Thermistor}} + 160)} \times 12.0$ (1) $R_{\text{Thermistor}}$ = 526 [Ω] (1) Corresponds to 25 °C from graph (1) **Alternative:** $I_R = \frac{2.8}{160}$ = 0.0175 [A] (1) $R_T = \frac{9.2}{0.0175}$ = 526 [Ω] (1) Corresponds to 25 °C from graph (1) **Alternative:** $I_R = \frac{2.8}{160}$ = 0.0175 [A] (1) At 30 °C, $R_{\text{thermistor}}$ = 480 Ω from graph (1) $I_T = \frac{9.2}{480}$ = 0.0192 [A] (1) **Alternative:** At 30 °C, $R_{\text{thermistor}}$ = 480 Ω from graph (1) $I = \frac{V}{R} = \frac{12}{(480+160)}$ =0.01875 [A] (1) $V = IR$ = 0.01875 × 160 = 3 [V] (1) **Final mark for all methods - Valid conclusion consistent with answer:** i.e. Claim incorrect - system activated at $\theta < 30$ °C (1)			4	4	3	
	(d)		More effective at 0 °C – 10 °C (no mark) Because: Steeper gradient / larger change in resistance (1) Greater sensitivity in this range / greater [fractional] change in R per °C change in temperature or over the same temperature range) (1)			2	2		2
			Question total	**2**	**4**	**6**	**12**	**6**	**2**

#7

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
	(a)		Method for obtaining N e.g. $\frac{4\,000}{0.25 \times 10^{-3}}$ (1) Use of πd or $2\pi r$ (1) 1 508 m or 16 000 × π × 0.03 seen or equivalent (1)	1	1 1		3	3	
	(b)		$R = \frac{\rho l}{A}$ used and $I = \frac{V}{R}$ used (1) 0.25 mm used as diameter for area or (0.125 mm as radius) (1) 24.6 mA seen or $\frac{12}{488}$ or $\frac{12}{486}$ seen or equivalent evidence (1)	1	1 1		3	3	
	(c)		$n = \frac{N}{\text{length}}$ (1) Answer = 1.23 × 10^{4} [T] (1) Award 1 mark only for answer of 3.35 × 10^{-7} [T]	1	1		2	2	
	(d)		$B = \mu_0 nI$ used to calculate I **ecf** (1) Correct conclusion stated and consistent with calculation (1) Wires would melt / damaged / burnt / become hot / use superconductor / use cooling (1)			3	3	1	
			Question total	**3**	**5**	**3**	**11**	**9**	**0**

#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		*V*- Energy (per coulomb or unit charge) used in external resistor/circuit [1] *E*- Energy (per coulomb/unit charge) transferred by source [or from chemical energy or from other forms] or used in whole circuit [1] *Ir* – energy (per coulomb/unit charge) wasted/lost in source or due to internal resistance [1] Use of 'per coulomb' or 'unit charge' at least once [1]	4			4		
	(b)	(i)	Circuit current = $\frac{1050\times10^{-3}}{2.5}$ = 0.42 [A] [1] Total internal resistance = $\frac{0.5}{0.42}$ = 1.2 [Ω] **ecf** on I [1] r_{cell} = 0.6 [Ω] [1]		3		3	2	
		(ii)	Substitution into I^2rt i.e. $(0.42)^2 \times 0.6 \times 60$ (**ecf** on I, r) [1] **Alternative:** Substitution into $\frac{V^2t}{r}$ i.e. $\frac{(0.25)^2\times60}{0.6}$ (**ecf** on V, r) **Alternative:** Substitution into IVt i.e. $0.42 \times 0.25 \times 60$ (**ecf** on I, V) Energy dissipated = 6.3 [J] [N.B. Alternative → 6.4 J] [1]	1	1		2	1	
	(c)		**Either**: Total resistance of coils in parallel = 2.975 [Ω] [1] and total circuit resistance = 4.175 [Ω] **ecf** [1] New current in circuit = $\frac{3}{4.175}$ = 0.72 [A] [1] **For the 4th mark:** Rate of energy dissipation in each cell = $(0.72)^2 \times 0.6$ = 0.31 [W] so Kiera correct (or ratio calculated to be approx. 3) **Or** Energy dissipated in each cell in one minute = $(0.72)^2 \times 0.6 \times 60$ = 18.6 [J] so Kiera correct (or ratio calculated to be approx. 3) [1] **Alternative:** Total resistance of coils in parallel = 2.975 [Ω] [1] and total circuit resistance = 4.175 [Ω] **ecf** [1] New current = 0.72 [A] and pd drop across internal resistance = 0.72×1.2 = 0.86 [V] [1] Rate of energy dissipation in each cell **For the 4th mark:** = $\frac{(0.43)^2}{0.6}$ = 0.31 [W] so Kiera correct (or ratio calculated to be approx. 3) **Or** Energy dissipated in each cell in one minute = $\frac{(0.43)^2\times60}{0.6}$ = 18.6 [J] so Kiera correct (or ratio calculated to be approx. 3) [1]			4	4		
			Question 1 total	**5**	**4**	**4**	**13**	**3**	**0**

#9

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)		Use of $s = \frac{1}{2}(u+v)t$ (1) t = 14.6 [s] (1)	1	1		2	2	
	(b)		Gain in KE = 4 020 – 962 = 3 058 [J] (1) Gain in PE = 95 × 9.8 × 4 = 3 728 [J] (1) Total = 3 058 + 3 728 = 6 786 [J] ecf (1)		3		3	3	
	(c)	(i)	Use of $E = VIt$ (1) 3 679 or 3 680 [J] ecf (1)	1	1		2	2	
		(ii)	Useful energy of motor = *(b)* – 6 500 = 1 286 [J] (1) Efficiency $= \frac{1286}{3679} \times 100 = 35$ [%] (1) ecf from (c)(i)		2		2	2	
		(iii)	Friction within motor / between front tyre and road (not just 'friction') (1) Air resistance on bike and Helen (1) Do not accept just heat / sound loss	2			2		
	(d)		Yes compared to petrol vehicles no [direct] emissions (1) ..and power station emissions [of CO_2, PM2s etc] much less than petrol vehicles			2	2		
			Question 3 total	**4**	**7**	**2**	**13**	**9**	**0**

#10

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Label axis with units and suitable scale (1) Plot all points correctly ± ½ small square division (1) Draw a smooth curve with maximum between 2.3 and 2.6 Ω **no** straight lines present (no requirement to extend back to the origin) (1)	1	1 1		3	3	3
	(b)	(i)	6.0 [J] of [chemical] energy transferred/converted/work done to electrical [potential] energy (1) Per unit charge [or coulomb] [flowing through the cell/battery] (1)	2			2		2
		(ii)	Using $P = I^2R$ (1) Data point from graph when R = 4.5 Ω, P = 3.64 W (1) Need 2 dp and within ± ½ small square Calculation of current correctly i.e. = 0.90 [A] (1)	1	1 1		3	3	3
		(iii)	Using $E = V + Ir$ (1) Substituting correct values 6 = 0.90 × 4.5 + 0.90r **ecf** (1) Internal resistance = 2.2 [Ω] (1)	1	1 1		3	3	3
	(c)		Power is <u>higher/greater/larger</u> (1) Total resistance of circuit is less for <u>all values of R</u> (1) Accept peak of graph shifts to left			2	2		2
			Question total	**5**	**6**	**2**	**13**	**9**	**13**

#11

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="4">Marks available</th><th></th><th></th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td></td><td>(a)</td><td>(i)</td><td>For Left Hand Combination:
$\frac{1}{R_{\text{parallel}}} = \frac{1}{2R} + \frac{1}{R} + \frac{1}{2R}$ (RHS seen in any correct form e.g. $\frac{4}{2R}$)(1)
$= \frac{R}{2}$ (1)
Total $R = \frac{R}{2} + R$ or $\frac{3R}{2}$ seen (1)
Alternative solutions possible e.g.
Sum of top and bottom branch = R (1)
Then parallel branch = $\frac{R}{2}$ (1)
Total $R = \frac{R}{2} + R$ (1)</td><td></td><td>3</td><td></td><td>3</td><td>3</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Right hand resistor circled (1)
Greatest current / greatest voltage (1)</td><td></td><td>2</td><td></td><td>2</td><td></td><td></td></tr>
<tr><td></td><td>(b)</td><td></td><td>Correct substitution into $l = \frac{RA}{\rho}$
i.e. $\frac{2.0 \times 10^3 \times 250 \times 10^{-9} \times 0.25 \times 10^{-3}}{1.20 \times 10^{-6}}$ (1)
$l = 0.10$ [m] (1) (ecf on slip in powers of 10)</td><td>1</td><td>1</td><td></td><td>2</td><td>2</td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>n- <u>free</u> electron density. Accept- number of <u>free</u> electrons per unit volume or per m^3 (or equivalent)</td><td>1</td><td></td><td></td><td>1</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td><table><tr><th>Ratio</th><th>Value</th><th>Explanation</th></tr><tr><td>$\frac{n_X}{n_Y}$</td><td>1</td><td>Wires made of the same material</td></tr><tr><td>$\frac{I_X}{I_Y}$</td><td>1</td><td>Wires in series</td></tr><tr><td>$\frac{v_X}{v_Y}$</td><td>0.25</td><td>Correct explanation based on $A_x v_x = A_y v_y$
e.g $(d)^2 v_x = \left(\frac{d}{2}\right)^2 v_y$</td></tr></table>Award 1 mark for each correct row</td><td>1
1</td><td>1</td><td></td><td>3</td><td></td><td></td></tr>
<tr><td></td><td></td><td>(iii)</td><td>$R = \frac{\rho l}{A}$ substituted into $P = I^2 R$ i.e. $P = \frac{I^2 \rho l}{A}$ (1)
$P_x = \frac{I^2 \rho_x l_x}{A_x}$ and $P_z = \frac{I^2 \rho_z l_z}{A_z}$ (or equivalent) - can award 1st mark from one of these expressions
$A_x = 4A_z$ and $l_x = \frac{l_z}{2}$ and $\rho_x = 2\rho_z$ to show: (1)
$\frac{P_z}{P_x} = 4$ (1)</td><td></td><td>3</td><td></td><td>3</td><td>3</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Question total</td><td>4</td><td>10</td><td>0</td><td>14</td><td>8</td><td>0</td></tr>
</table>

#12

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	Rate of charge flow Accept $I = \frac{\Delta Q}{\Delta t}$ only if ΔQ and Δt defined [accept Q and t]	1			1		
		(ii)	J C^{-1} and C s^{-1} as units of V and I respectively clearly shown (1) Correct division seen i.e. $\frac{\text{JC}^{-1}}{\text{Cs}^{-1}}$ seen (1) Or from alternative correct expression, e.g. $R = \frac{V^2}{P}$ Or equivalent in terms of quantities.	1	1		2	1	
	(b)	(i)	I through R_P = 1.2 A and I through R_T = 0.8 A (1) $\frac{V_P}{V_T} = \frac{1.2R_P}{0.8R_T}$ (=1.5) seen (1) Or Parallel combination calculated as $\frac{2}{3}R$ (1) Potential divider: $\frac{R}{R+\frac{2}{3}R} \times 9 = 1.5$ (1)		2		2	1	
		(ii)	$2.5V_T = 9.0$ or $\frac{5V_P}{3} = 9.0$ (1) V_T = 3.6 V or V_P = 5.4 V (1) Award 2 marks for either V_P or V_T calculated correctly. $R_T = \frac{3.6}{0.8} = 4.5\ \Omega$ or $R_P = \frac{5.4}{1.2} = 4.5\ \Omega$ or $\frac{1.8}{0.4} = 4.5\ \Omega$(1) **Alternative:** Total circuit $R = \frac{9.0}{1.2} = 7.5\ \Omega$ (1) Parallel and series combination shown to be = $\frac{5R}{3}$(1) $\frac{5R}{3} = 7.5$ and $R = 4.5\ \Omega$ (1) **Alternative:** Understanding that $V_P + V_T = 9$ (1) $1.2R_P + 0.8R_T = 9$ (1) (award 2 marks for this only) $R_P = R_T = R$ and $R = \frac{9}{2} = 4.5\ \Omega$ clearly shown (1) Accept reverse argument.		3		3	3	
	(c)		P (circuit) = 10.8 W (1) (either $\frac{81}{7.5}$ or $(1.2)^2 \times 7.5$ or 1.2×9) P in $R_Q = (0.4)^2 \times 4.5 = 0.72$ W (1) $\frac{10.8}{0.72} = 15$ seen (1) **Alternative:** $P_s = P_Q$ since $I_s = I_Q$ $P_T = 4 \times P_Q$ since $I_T = 2 \times I_Q$ $P_P = 9 \times P_Q$ since $I_P = 3 \times I_Q$ Hence total circuit power = $P_Q + P_Q + 4P_Q + 9P_Q$ $= 15P_Q$ Award (1) for correct individual power analysis Award (1) for correct reason linked to currents Award (1) for showing correct total P		3		3	2	
	(d)		Circuit resistance increases, leading to total current decreasing. Power dissipated in circuit decreases (1) V across R_Q has increased (from 1.8 V to 3.0 V), so P_Q increases / I through R_Q has increased (from 0.4 A to 0.67 A) so P_Q increases (1) Hence ratio decreases (1) [only award from correct explanation] Accept numerical explanation: e.g. Circuit resistance is now 13.5 Ω and circuit current = 0.67 A (1) circuit power shown to be 6 W and P_Q shown to be 2 W (1) Hence ratio decreases or is now 3 (1) **Alternative:** With T removed, I through all remaining resistors is the same or V across each is the same (1) Use of VI or I^2R or V^2/R or power / energy dissipated in all three resistors equal (1) So total $P = 3 \times P_Q$ or which is less than $15P_Q$ (1)		3		3		
			Question 2 total	**2**	**12**	**0**	**14**	**7**	**0**

#13

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)	All resistors connected in parallel (1) Using $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$ [or equiv] (1) R_{total} = 1.44 [Ω] (1)	1	1 1		3	2	3
	(b)	(i)	(A4/emf) is the energy generated in the cell (1) per coloumb (1) Loss of energy in circuit in the load resistor (E4) (1) $E-V$ is the energy is lost in internal resistance (1) Energy is conserved (1) Re-arrange gives $r=\frac{E-V}{I}$ (1)	1 1	1 1 1 1		6	1	
		(ii)	Substituting values in $\frac{\text{A7-E7}}{\text{D7}}$ (1) r = 0.15 [Ω] (1)	1	1		2	2	
		(iii)	Using $P=I^2R$ (1) P = 0.45 [W] (1) 0.50 W – has to be greater than the power dissipated (need reason) (1)	1	1 1		3	1	
			Question 5 total	**5**	**9**	**0**	**14**	**6**	**3**

#14

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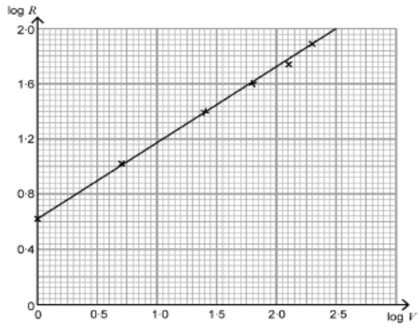
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>2</td><td>(a)</td><td></td><td>Varies value of variable resistor</td><td></td><td></td><td>1</td><td>1</td><td></td><td>1</td></tr>
<tr><td></td><td>(b)</td><td></td><td>Correct attempt e.g. $\ln R = \ln(kV^n)$ or $\ln R = \ln k + \ln V^n$ [or using $\log_e$ or using $\log_{10}$] [1]
Correct expression $\ln R = n \ln V + \ln k$ [or using $\log_e$ or using $\log_{10}$] [1]</td><td></td><td>2</td><td></td><td>2</td><td>2</td><td>2</td></tr>
<tr><td></td><td>(c)</td><td></td><td>
<table>
<tr><th>V / V</th><th>I / A</th><th>R / Ω</th><th>ln(V/V)</th><th>ln(R/Ω)</th></tr>
<tr><td>1.00</td><td>0.52</td><td>1.9(2)</td><td>0.00</td><td>0.65</td></tr>
<tr><td>2.00</td><td>0.72</td><td>2.78 or 2.8</td><td>0.69</td><td>1.02</td></tr>
<tr><td>4.00</td><td>0.98</td><td>4.08 or 4.1</td><td>1.39</td><td>1.41</td></tr>
<tr><td>6.00</td><td>1.20</td><td>5.00</td><td>1.79</td><td>1.61</td></tr>
<tr><td>8.00</td><td>1.40</td><td>5.7(1)</td><td>2.08</td><td>1.74</td></tr>
<tr><td>10.00</td><td>1.54</td><td>6.49 or 6.5</td><td>2.30</td><td>1.87</td></tr>
</table>
$\ln V$ values correct or accept $\log_{10} V$ values [1]
Use of $R = \frac{V}{I}$ and all R and $\ln R$ values correct or accept $\log_{10} R$ values [1]
<table>
<tr><th>Log₁₀(V/V)</th><th>Log₁₀(R/Ω)</th></tr>
<tr><td>0.00</td><td>0.28</td></tr>
<tr><td>0.30</td><td>0.45</td></tr>
<tr><td>0.60</td><td>0.61</td></tr>
<tr><td>0.78</td><td>0.70</td></tr>
<tr><td>0.90</td><td>0.76</td></tr>
<tr><td>1.00</td><td>0.81</td></tr>
</table>
Accept 2 or 3 sig figs in all cases. Accept 4 sig. Figs for $\ln V$ at 10.00 V (= 2.302) [1]</td><td></td><td>3</td><td></td><td>3</td><td>3</td><td>3</td></tr>
<tr><td></td><td>(d)</td><td></td><td>Axes labelled either with no units i.e. $\ln R$ (or $\log_{10}R$) on y-axis and $\ln V$ (or $\log_{10}V$) on x-axis, or with $\ln(R/\Omega)$ and $\ln(V/\text{V})$ respectively (or equivalent using) [1]
Suitable scale e.g. large block – 0.2 on y-axis and 0.4 on x-axis for ln values and 0.2 on x-axis and 0.1 on y-axis on both axes for $\log_{10}$ values. [Linear, scales, with points occupying ≥ half available space] [1]
All points plotted correctly within ±< small square division [2]
5 points plotted correctly within ±< small square division [1]
4 or less points plotted correctly within ±< small square division [0]
Straight line of best fit drawn [1]
e.g. for ln graph:

</td><td></td><td>5</td><td></td><td>5</td><td>4</td><td>5</td></tr>
<tr><td></td><td>(e)</td><td>(i)</td><td>Attempt at taking gradient [1]
$n = \frac{(2.0 - 0.65)}{2.5} = 0.5[4]$ [1] [answer gains both marks]
$\ln k = 0.65$ or $k = e^{0.65}$ [1]
k = 1.9[2] [1] [answer gains both marks]
N.B. ecf from graph for both values.
Mark scheme to be applied as above for candidates using $\log_{10}$ values.</td><td>1
1</td><td>1
1</td><td></td><td>4</td><td>3</td><td>4</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$R = 1.9\ V^{0.5}$ (ecf on n and k)</td><td>1</td><td></td><td></td><td>1</td><td>1</td><td>1</td></tr>
<tr><td></td><td>(f)</td><td></td><td>**Required statement:**
Results lie close to line of best fit suggests good quality
Accept: results fit with the expected theory
Don't accept it's a straight line or reference to measuring instruments</td><td></td><td></td><td>1</td><td>1</td><td></td><td>1</td></tr>
<tr><td></td><td></td><td></td><td>**Question 2 total**</td><td>3</td><td>12</td><td>2</td><td>17</td><td>13</td><td>17</td></tr>
</table>

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	Using $R = \frac{\rho l}{A}$ (1) Area = $\frac{\pi d^2}{4}$ = 6.16 × 10^{-8} m² (1) Resistivity = 1.62 × 10^{-8} Ω m **unit mark** (1)	1	1 1		3	2	
		(ii)	$p_l = \frac{0.1}{32.4} \times 100\%$ = 0.3% or statement – negligible (1) $p_A = 2 \times p_d$ = 7.1% (1) Total percentage uncertainty = 12% (**ecf**) (1) Abs unc (resistivity) = ± 0.2 × 10^{-8} [Ω m] to 1 sf maximum (**ecf**) (1)		4		4	4	4
		(iii)	Silver and copper lie within range of values (**ecf**) (1) Material cannot be determined exactly from table (1)			2	2		
	(b)	(i)	Current is flow of (free) electrons (1) Flow is obstructed by <u>collisions with ions</u> (1) Collisions increase as temperature increases (1) Because of increased vibrations of ions/lattice *or* random speed of electrons increases (1)	4			4		
		(ii)	Using $R = \frac{V}{I}$ or proportional to $\frac{1}{I}$ OR temperature is inversely proportional to current (V constant) (1) Determining constant for at least 3 values dependent on method $k = \frac{R}{\text{Temperature}}$ or Temperature x I (1) Conclusion – not constant (accept directly proportional if temperature in kelvin) (1)			3	3	2	3
			Question 4 total	5	6	5	16	8	7