

Mark Scheme

Q1.

Question Number	Answer	Mark
	D is the correct answer as $V = (-r)I + \mathcal{E}$ when in a $y=mx + c$ format. A is not the correct answer as the area beneath the graph does not represent energy dissipated in the cell B is not the correct answer as the gradient of the graph is $-r$ C is not the correct answer as the graph is not a straight line through the origin	(1)

Q2.

Question Number	Answer	Additional Guidance	Mark
	e.m.f. = 1.5 (V) (1) Reads two pairs of corresponding values of V and I (1) Internal resistance = 0.50 Ω (1)	Intercept can be read as one of the pairs <u>Example of calculation</u> Gradient = $\frac{1.20 - 0.00}{3.00 - 0.60} = -0.50$ $r = 0.50 \Omega$	3
	Total for question		3

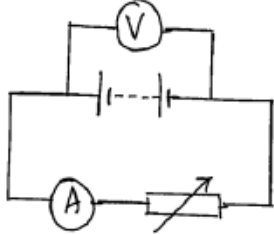
Q3.

Question Number	Answer	Mark
(a)	$\varepsilon = 1.50 \text{ V}$ (accept answers in the range 1.48 V to 1.52 V) (1)	3
	Attempt to calculate gradient of graph to find r (1)	
	$r = 0.75 \Omega$ (accept answers in the range 0.72 Ω to 0.78 Ω) (1)	
(b)	Gradient is doubled (1)	2
	y-intercept is doubled (1)	
	(If no other marks scored, allow “new graph has steeper gradient and y-intercept has a greater value” for 1 mark)	
	(If no other marks scored, allow new values for ε and r , consistent with their answers to (a))	
Total for question		5

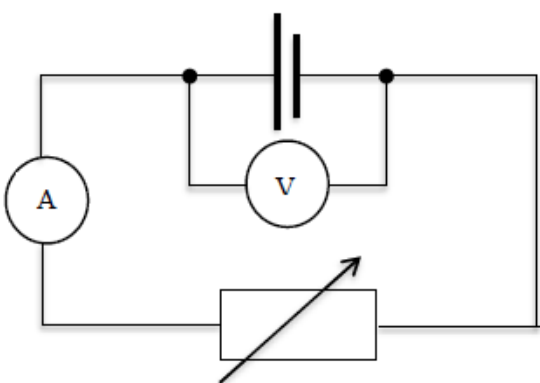
Q4.

Question Number	Answer	Mark
a	Ammeter in series with cell and an external component with resistance (1)	3
	Voltmeter parallel with cell (1)	
	Variable resistor included in circuit (1)	
b	(Uses conservation of energy to) obtain the equation $\varepsilon = V + Ir$ (1)	4
	Compares $\varepsilon = V + Ir$ with $y = mx + c$ (1)	
	e.m.f. is the y-intercept of the graph (1)	
	Internal resistance is the negative of the gradient (1)	
Total for question		7

Q5.

Question Number	Answer	Mark
(a)	There was no current (in the battery) (1) So there was no potential difference across the internal resistance (1)	2
(b)	Voltmeter connected across battery and ammeter in series with battery (1) Variable resistor in series with battery Or potential divider (1)	2
	<u>Example of circuit</u> 	
(c)(i)	e.m.f. = 8.8 V (1) Calculates gradient of graph (1) Internal resistance = 2.2 to 2.4 Ω (1) <u>Example of calculation</u> $r = \frac{(8.8-0) \text{ V}}{(3.8-0) \text{ A}} = 2.3 \Omega$	3
(c)(ii)	As the current (in the battery) increases, the potential difference across the internal resistance increases (1) Until the p.d. across the internal resistance equals the e.m.f. (and current can no longer increase) (1)	2
Total for question		9

Q6.

Question Number	Answer	Mark
a	Ammeter in series with cell, voltmeter in parallel with cell Variable resistor  (Voltmeter can be drawn in parallel with the (variable) resistor for MP1, as long as there are no other components with resistance in the circuit).	(1) (1) 2
b	Line of best fit drawn $\varepsilon = 0.28 - 0.29 \text{ V}$ (Magnitude of) gradient calculated using a best fit line $r = 400 - 430 \Omega$ (If no best fit line has been drawn, only MP2 and MP4 are available) <u>Example of calculation</u> Gradient = $\Delta V / \Delta I = -0.18 \text{ V} / (0.44 \times 10^{-3} \text{ A}) = -409 \Omega$ so $r = 409 \Omega$	(1) (1) (1) (1) 4

c	In series/A there is a greater (combined) resistance than in parallel/B Or Resistance in series/A is $2R$, resistance in parallel/B is $R/2$. (1) So greater current in parallel/B Or so less current in series/A (1) As ε and r the same Or since $\varepsilon = V + Ir$ Or more lost volts in parallel/B (1) Terminal potential difference is greater in series/A (1) OR In series/A there is a greater (combined) resistance than in parallel/B Or Resistance in series/A is $2R$, resistance in parallel/B is $R/2$. (1) as ε and r the same (1) $V = \frac{\varepsilon R}{R+r}$ (1) Terminal potential difference is greater in series/A (1)	4
Total for question		10

Question Number	Answer	Mark
a	Energy (supplied) to/per unit charge Or Work done (supplied) to/per unit charge Or The work done moving unit charge around the whole circuit (1)	(1)
bi	Use of sum of e.m.f. = sum of p.d. (1) Or see $\mathcal{E} = V + Ir$ with correct substitutions (1) $r = 1.9 \times 10^{-2} \Omega$ (1) <u>Example of calculation</u> $\mathcal{E} = V + Ir$, $12.0 \text{ V} = 11.81 \text{ V} + (9.83 \text{ A}) r$. so $r = 0.0193 \Omega$	(2)
bii	Plot V against I (1) Determine the gradient (1) Gradient is $-r$ (1) OR Plot I against V (1) Determine the gradient (1) Gradient is $-(1/r)$ (1) OR Plot $(\mathcal{E} - V)$ against I (1) Determine the gradient (1) Gradient is r (1)	(3)
c	Calculates circuit current using $I = \mathcal{E} / \text{Total } R$ Or Calculates p.d. across fixed resistor using potential divider equation (1) Use of a power equation (to calculate Power dissipated in fixed resistor) (1) Divides final power by initial power Or Divides difference in power by initial power Or Calculates 70% of initial power (1) Calculated value for final power/initial power is greater than 70% of initial power so student incorrect Or Calculated value for difference between initial and final power is less than 30% so student incorrect Or Calculated value for 70% of initial power is less than the final power so student incorrect (1) (Candidates who use incorrect values of I, V or R in either power calculation for MP2 cannot be awarded MP3 or MP4) <u>Example of calculation</u> Initially $I = \mathcal{E} / \text{Total } R = 9.0 \text{ V} / (5.0 + 0.10 \Omega) = 1.76 \text{ A}$ Power of external resistor = $I^2 R = (1.76 \text{ A})^2 (5.0 \Omega) = 15.5 \text{ W}$ When $r = 0.50 \Omega$, $I = \mathcal{E} / \text{Total } R = 9.0 \text{ V} / (5.0 + 0.50 \Omega) = 1.64 \text{ A}$ Power of external resistor = $I^2 R = (1.64 \text{ A})^2 (5.0 \Omega) = 13.4 \text{ W}$ Percentage of original value = $(13.4 \text{ W}) / (15.5 \text{ W}) = 0.86$ (or 86%)	(4)

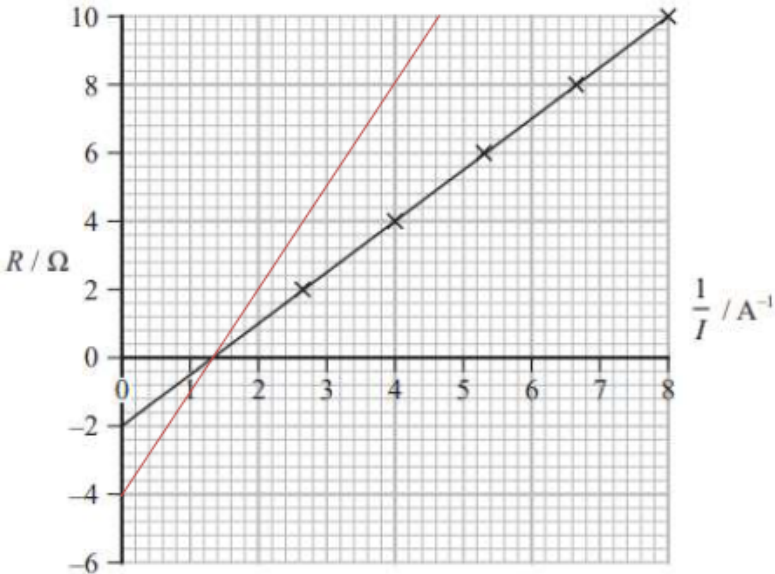
Q8.

Question Number	Answer	Mark
a	Use of $V = W / Q$ or $W = VIt$ (1) $\epsilon = 1.56$ (V) (1) Use of $V = IR$ (1) Sum of e.m.f.s = Sum of p.d.s Or see $\epsilon = V + Ir$ (1) $r = 2.6 \Omega$ (1) OR (1) Use of $W = Pt$ With $P = I^2 R$ (1) with $R = r + 12$ (1) All other data correctly substituted ($50 = (0.107)^2 (r + 12) 300$) (1) $r = 2.6 \Omega$ (1) <u>Example of calculation</u> (1) $\epsilon = W / Q = (50 \text{ J}) / (0.107 \text{ A})(300 \text{ s}) = 1.56 \text{ V}$ $\epsilon = IR + Ir, 1.56 \text{ V} = (0.107 \text{ A}) (12 \Omega) + (0.107 \text{ A}) r,$ $r = 2.56 \Omega$	5
b	(Increasing R) decreases I Or (Increasing R) gives R a greater share of the total resistance in the circuit (1) Less p.d. across internal resistance Or Ir becomes less (Accept decrease in 'lost volts') (1)	2
c	Take readings for p.d. and current (1) Change resistance / R (1) Plot a graph of V against I (1) Gradient is $-r$. (1) (MP4 conditional on MP3) (Allow MP3/4 for graph of I-V with gradient $-1/r$) (A sketch graph of V-I with the gradient labelled $-r$ can achieve MP3/4)	4
Total for question		11

Q9.

Question Number	Answer	Mark
a	Use of sum of e.m.f. = sum of p.d. (1)	2
	Correct rearrangement leading to given equation (1)	
	Or	
	Total resistance of circuit = $R + r$ (1)	
	Correct rearrangement with total resistance replaced by $\frac{\varepsilon}{I}$ (1)	
	<u>Example of rearrangement</u> $\varepsilon = I(R + r)$, so $\frac{\varepsilon}{I} = R + r$, so $R = \frac{\varepsilon}{I} - r$	
b	Gradient calculation (to calculate ε) (1)	3
	$\varepsilon = 1.5 \text{ V}$ (1)	
	$r = 2 \Omega$ (1)	
	OR	
	$r = 2 \Omega$ (read from y-intercept) (1)	
	Use of co-ordinates from the graph with the formula (1)	
	$\varepsilon = 1.5 \text{ V}$ (1)	

c	Current (in r/R /circuit) decreases (1)	3
	Reference to $P = I^2 r$ (Do not allow if R used instead of r) (1)	
	P decreases, so student is correct (1)	
	(MP3 dependent on MP2)	
	OR	
	V across r decreases (1)	
	Reference to $P = V^2/r$ (Do not allow if R used instead of r) (1)	
	P decreases, so student is correct (1)	
	(MP3 dependent on MP2)	
	OR	
	V across r decreases (1)	
	$P = VI$ and current (in r/R /circuit) decreases (1)	
	P decreases, so student is correct (1)	
	(MP3 dependent on MP2)	
	OR	
	Current (in r/R /circuit) decreases (1)	
	$P = VI$ and p.d. across r decreases (1)	
	P decreases, so student is correct (1)	
	(MP3 dependent on MP2)	

d	Graph is steeper than initial graph and is a straight line Exactly $2 \times$ original gradient y-intercept at -4Ω 	(1) (1) (1) 3
Total for question		11

Q10.

Question Number	Answer	Mark
(a)	Substitution into $hf = \phi$ (1) Use of $1\text{eV} = 1.6 \times 10^{-19} \text{ J}$ (1) Threshold frequency = $4.5 \times 10^{14} \text{ Hz}$ (1) <u>Example calculation</u> $E = 1.86 \text{ eV} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 2.98 \times 10^{-19} \text{ J}$ $f = \frac{2.98 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ J s}} = 4.49 \times 10^{14} \text{ Hz}$	3
(b)	The number of photons (arriving) each second on the cell is the same (1) (Initially) layer 1 absorbs photons with the greater frequency (of those emitted by the Sun) (1) Photons reaching layer 2 have an energy greater than the work function (of layer 2) Or Photons reaching layer 2 have a frequency greater than the threshold frequency (of layer 2) (1) One photon interacts with one electron (1) so, the rate at which electrons are released remains the same (1)	5

(c)	Use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ (1) $R_T = 0.40 \text{ } (\Omega)$ (1) Use of potential divider equation (to determine p.d. across resistor) Or Use of $\varepsilon = I(R+r)$ (to determine current in resistor) (1) Use of power equation to find power (dissipated in resistor) (1) $P = 5.2 \text{ (W)}$ which is less than half of 13 (W) so the suggestion is correct (1) <u>Example calculation</u> $R_{\text{internal}} = \frac{1}{\frac{1}{0.80 \text{ } \Omega} + \frac{1}{0.8 \text{ } \Omega}} = 0.40 \text{ } \Omega$ $V = \frac{5.0 \text{ V} \times 4.0 \text{ } \Omega}{4.0 \text{ } \Omega + 0.4 \text{ } \Omega} = 4.55 \text{ V}$ $I = \frac{5.0 \text{ V}}{4.0 \text{ } \Omega + 0.40 \text{ } \Omega} = 1.14 \text{ A}$ $P = 4.55 \text{ V} \times 1.14 \text{ A} = 5.19 \text{ W}$	5
Total for question		13