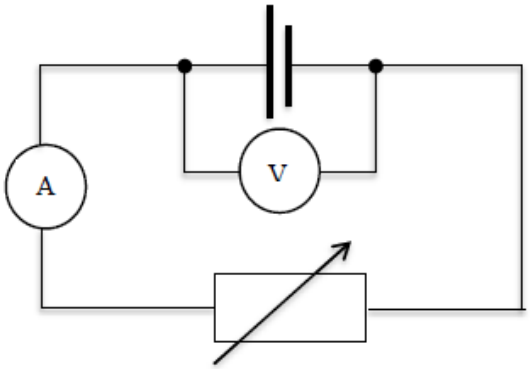
Mark Scheme

Q1.

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 $\varepsilon = 0.28 - 0.29$ 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 = $\Delta V / \Delta I = -0.18$ V / (0.44 x 10^{-3} 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. So greater current in parallel/B **Or** so less current in series/A As ε and r the same **Or** since $\varepsilon = V + Ir$ **Or** more lost volts in parallel/B Terminal potential difference is greater in series/A **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. as ε and r the same $V = \frac{\varepsilon R}{R+r}$ Terminal potential difference is greater in series/A	(1) (1) (1) (1) (1) (1) (1) (1)	4
	Total for question		10

Q2.

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. **Or** see $\mathcal{E} = V + Ir$ with correct substitutions (1) $r = 1.9 \times 10^{-2}\ \Omega$ (1) Example of calculation $\mathcal{E} = V + Ir$, 12.0 V = 11.81 V + (9.83 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 $I = \mathcal{E}$ / 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) Example of calculation Initially $I = \mathcal{E}$ / Total R = 9.0 V / (5.0 + 0.10 Ω) = 1.76 A Power of external resistor = $I^2 R$ = (1.76 A)^2 (5.0 Ω) = 15.5 W When r = 0.50 Ω, $I = \mathcal{E}$ / Total R = 9.0 V / (5.0 + 0.50 Ω) = 1.64 A Power of external resistor = $I^2 R$ = (1.64 A)^2 (5.0 Ω) = 13.4 W Percentage of original value = (13.4 W) / (15.5 W) = 0.86 (or 86%)	**(4)**

Q3.

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

QQ.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Means of varying the current **(1)** • Ammeter, voltmeter and variable resistor correctly connected **(1)**	Accept a circuit that will allow correct measurements to be taken.	**2**
(b)	An explanation that makes reference to: • Vary the current using the variable resistor **(1)** • Record corresponding values for I and V **(1)** • Graph of V against I is a straight line with negative gradient **(1)** • The e.m.f. is given by the intercept on the V axis **(1)** • The internal resistance is given by the gradient **(1)**		**5**

This question must be marked holistically in the context of the candidate's answer, and marks awarded wherever they appear.

Question Number	Answer		Mark
5(a)	(a) Correct *circuit diagram* Cell, ammeter, voltmeter and a resistive component variable resistor in working circuit [correct circuit symbol only]	**(1)** **(1)**	**2**
	(b) *State the quantities to be measured* potential difference, current	**(1)**	**1**
	(c) *for **two** of these quantities explain your choice of measuring instrument*, 1st instrument reason 2nd instrument reason	**(1)** **(1)** **(1)** **(1)**	**4**
	<u>Examples of answer</u> P.d.: voltmeter or multimeter on voltage scale (stated or implied) 0.1 V interval or better because 1.5 V cell Or measures up to 2V because 1.5 V cell Current: ammeter or multimeter on current scale (stated or implied) 0.1 A interval or better because 1.5 V cell Or measures up to 2A because 1.5 V cell		
	(d) *Explain how the data will be used* graph drawn of p.d. against current intercept is emf gradient is (-) *r*	**(1)**	
	(e) *identify the main sources of uncertainty and/or systematic error*: **Max 2** Systematic/zero error on meter parallax errors if analogue meter accuracy of meters fluctuating reading on digital meter	**(1)** **(1)** **(1)** **(1)**	**3**
	(f) *appropriate comment on safety* <u>Examples of answer</u> Avoid touching hot wires Low voltage so no risk of electrocution Ensure cell is not short-circuited otherwise cell will get hot	**(1)** **(1)**	**2** **1**
	Total for question 7		**13**

Question	Answer	Marks
6(a)	gradient = $\frac{R}{E}$ y-intercept = $\frac{r}{E}$	**1**
6(b)	29 or 29.4 22 or 21.7 18 or 17.9 15 or 15.2 13 or 13.2 12 or 11.9	**1**
	absolute uncertainties in $1/I$ from ±2 (or ±1) to ±0.2, ±0.3 or ±0.4. Allow a mixture of significant figures.	**1**
6(c)(i)	Six points plotted correctly. Must be within half a small square. Diameter of points must be less than half a small square.	**1**
	Error bars in $1/I$ plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	**1**
6(c)(ii)	Line of best fit drawn. Points must be balanced. Line should pass to the left of (0.50, 29.6) **and** line should pass between (0.210, 16) and (0.225, 16).	**1**
	Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars). All error bars must be plotted.	**1**

Question	Answer	Marks
6(c)(iii)	Gradient determined with clear substitution of points from line of best fit into $\Delta y/\Delta x$. Distance between points must be at least half the length of the drawn line.	**1**
	uncertainty = gradient of line of best fit – gradient of worst acceptable line **or** uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)	**1**
6(c)(iv)	*y*-intercept determined by substitution into $y = mx + c$.	**1**
	y-intercept of worst acceptable line determined by substitution into $y = mx + c$. uncertainty = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line **or** uncertainty = ½ (steepest worst line *y*-intercept – shallowest worst line *y*-intercept) Do not allow if false origin used.	**1**
6(d)(i)	*E* calculated using gradient. Correct substitution of numbers required. $E = \frac{470}{\text{gradient}} = \frac{470}{\textbf{(c)(iii)}}$	**1**
	r calculated using *y*-intercept. Correct substitution of numbers required. $r = E \times y\text{-intercept}$	**1**
	E and *r* determined using correct method with: • Unit of *E* with correct power of ten – e.g. V, AΩ • Unit of *r* with correct power of ten – e.g. Ω, V A^{-1} • *E* and *r* given to 2 or 3 significant figures.	**1**

Question	Answer	Marks
6(d)(ii)	Percentage uncertainty in r determined. Correct substitution of numbers required. %uncertainty in gradient + %uncertainty in R (1.06%) + %uncertainty in y-intercept **or** %uncertainty in E + %uncertainty in y-intercept Maximum/minimum methods: $\max r = \max y\text{-intercept} \times \max E$ $\max r = \max y\text{-intercept} \times \frac{\max R(475)}{\min \text{gradient}}$ $\min r = \min y\text{-intercept} \times \min E$ $\min r = \min y\text{-intercept} \times \frac{\min R(465)}{\max \text{gradient}}$	**1**

	Mark	Expected Answer	Additional Guidance
7 (a)	A1	gradient = $\frac{4\rho}{\pi E d^2}$ *y*-intercept = $\frac{r}{E}$	
(b)	T1	$\frac{1}{I}$ / A^{-1}	Allow $\frac{1}{I}$ (A^{-1}) or $\frac{1}{I}\left(\frac{1}{A}\right)$.
	T2	4.2 or 4.17 5.0 or 5.00 5.9 or 5.88 6.7 or 6.67 7.7 or 7.69 8.3 or 8.33	Allow a mixture of significant figures. Must be table values.
	U1	± 0.2 to ± 0.6 or ± 0.7 or ± 0.8	Allow more than one significant figure.
(c) (i)	G1	Six points plotted correctly	Must be within half a small square. Do not allow "blobs". ECF allowed from table.
	U2	Error bars in $1/I$ plotted correctly	All error bars to be plotted. Must be accurate to less than half a small square. Length of bar must be accurate to less than half a small square. Do not allow less than 0.05.
(ii)	G2	Line of best fit	If points are plotted correctly then lower end of line should pass between (41, 4.5) and (44, 4.5) **and** upper end of line should pass between (83, 8.0) and (88, 8.0). Line should not go from bottom to top points.
	G3	Worst acceptable straight line. Steepest or shallowest possible line that passes through <u>all</u> the error bars.	Line should be clearly labelled or dashed. Examiner judgement on worst acceptable line. Lines must cross. Mark scored only if error bars are plotted.
(iii)	C1	Gradient of line of best fit	The triangle used should be at least half the length of the drawn line. Check the read-offs. Work to half a small square. Do not penalise POT. (Should be about 8.)
	U3	Absolute uncertainty in gradient	Method of determining absolute uncertainty: difference in worst gradient and gradient.
(iv)	C2	*y*-intercept	Check substitution into $y = mx + c$. Allow ECF from **(c)(iii)**. (Should be about 0.7–1.5.)

	U4	Absolute uncertainty in *y*-intercept	Uses worst gradient and point on WAL. Do not check calculation.
(d) (i)	C3	$\rho = 2.415 \times 10^{-7} \times$ gradient Must be in the range 1.80×10^{-6} to 2.10×10^{-6} and given to 2 or 3 s.f.	Must use gradient. $\rho = \frac{\pi E d^2}{4} \times$ gradient [$2 \times 10^{-6}\ \Omega$m = $2 \times 10^{-4}\ \Omega$cm = $2 \times 10^{-3}\ \Omega$mm]
	C4	$r = E \times y$-intercept $= 3.2 \times y$-intercept and Ωm and Ω given	Must include units for ρ and r. Allow $V A^{-1}$ or $kg\,m^2 A^{-2} s^{-3}$ for Ω.
(ii)	U5	Percentage uncertainty in ρ	Must be greater than 9.6%.

Uncertainties in Question 2

(c) (iii) Gradient [U3]

uncertainty = gradient of line of best fit – gradient of worst acceptable line

uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)

(iv) [U4]

uncertainty = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line

uncertainty = ½ (steepest worst line *y*-intercept – shallowest worst line *y*-intercept)

(d) (ii) [U5]

$$\text{percentage uncertainty} = \left(\frac{\Delta m}{m} + \frac{0.1}{3.2} + 2 \times \frac{0.01}{0.31}\right) \times 100$$

$$= \left(\frac{\Delta m}{m} \times 100\right) + 3.125 + 2 \times 3.226$$

$$\text{max. } p = \frac{\pi \times 3.3 \times \left(0.32 \times 10^{-3}\right)^2}{4} \times \text{max. gradient}$$

$$\text{min. } p = \frac{\pi \times 3.1 \times \left(0.30 \times 10^{-3}\right)^2}{4} \times \text{min. gradient}$$