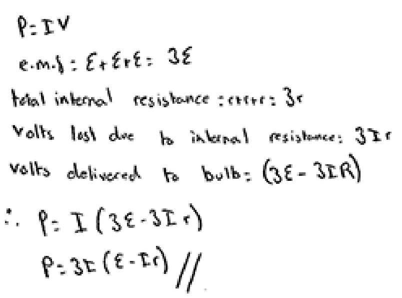
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			**C**	1	**Examiner's Comments** Candidates performed well on this question to correctly calculate the percentage uncertainty in the calculated value of W as answer C, by calculating the sum of each individual percentage uncertainty in each measurement.
			Total	**1**	
2			$\varepsilon = Ir + IR$ Or $\varepsilon = Ir + V$ or $V = \varepsilon - Ir$ Total internal resistance in circuit = 3r and Total emf in circuit = 3ε Clear steps leading to given equation	B1 M1 A1	Any correct rearrangement **Not** reference to 3I **Allow** $3\varepsilon = 3Ir + IR$ Or $3\varepsilon = 3Ir + V$ ***Use of $P=I^2R$*** $\varepsilon I = I^2r + I^2R$ $\varepsilon I = I^2r + P$ $P = I(\varepsilon - Ir)$ $P = I(3\varepsilon - 3Ir)$ ***Use of $P = IV$*** Total pd = $3(\varepsilon - Ir)$ $P = IV_T = 3I(\varepsilon - Ir)$ **Examiner's Comments** Most candidates achieved 1 mark for this question, for stating the correct expression for e.m.f, ε, e.g. ε = Ir + V with some candidates showing clearly that the power, P delivered to the bulb is given by the expression P = 3I(ε - Ir). Responses that were given 1 mark did not give clear working to express their understanding that the e.m.f. ε and internal resistance, r, were increased by 3. Often, candidates would just give an unqualified expression for P, e.g. P = 3 x I(ε - Ir), but from this expression it was not clear whether the factor of 3 was for current I or ε and r despite the correct application of P=IV. The responses that achieved 3 marks showed a clear rationale in their

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>working and that for the 3 cells in series the total e.m.f. was 3ε, and the total internal resistance was 3r. These candidates then showed clear steps in finding an expression for the potential difference across the bulb using ε = Ir + V to be, e.g. V = 3ε - 3Ir. By showing clear working, it was evident that candidates understood that the potential difference across the bulb was equal to the total terminal potential difference across the three cells in series. These candidates then correctly substituted their expression for the potential difference into an equation for power, e.g. P=IV to show the power P delivered to the bulb given in the stem of the question.

Exemplar 1



Exemplar 1 demonstrates clear working and rationale to show the given expression for the power P delivered to the bulb. The response is given 3 marks.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
<tr><td>3</td><td>a</td><td>i</td><td>Since the <u>current is zero</u>, the (terminal) p.d. / voltmeter reading is the e.m.f.</td><td>B1</td><td>no p.d. across r as I = 0

<u>Examiner's Comments</u>

There were many vague answers given. Candidates needed to state the reading of 4.57 V occurs when the current was zero. An open switch was not good enough.</td></tr>
<tr><td></td><td></td><td>ii</td><td>$\frac{1}{R} = \frac{1}{300} + \frac{1}{300}$ and $\frac{1}{R} = \frac{1}{300} + \frac{1}{300} + \frac{1}{300}$

(3.9 Ω)</td><td>M1
A0</td><td>Allow $4.57 = 4.50 + 18 \times 10^{-3} \times r$ and 3.88…
Allow $4.57 = 18 \times 10^{-3} \times 250 + 18 \times 10^{-3} \times r$ and 3.88…

<u>Examiner's Comments</u></td></tr>
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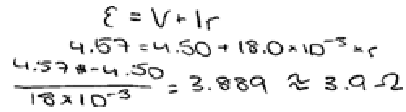
					This was another show question where the method needed to be clearly stated. High scoring candidates stated the circuit equation, substituted the data and evaluated answer before rounding it to 3.9 Ω. The majority of the candidates gained credit. **Exemplar 3**  The candidate has stated an equation, substituted in the data and evaluated the answer (3.889) which has then clearly been rounded to 3.9 Ω.
		iii	$\frac{1}{R}=\frac{1}{300}+\frac{1}{300}$ and $\frac{1}{R}=\frac{1}{300}+\frac{1}{300}+\frac{1}{300}$ 150 + 100 = 250 Ω OR $R=\frac{4.5(\text{V})}{18(\text{mA})}$ or $\frac{4.5}{0.018}$ = 250 Ω	M1	$R=\frac{300}{2}+\frac{300}{3}$ **Allow** $R=\frac{4.57(\text{V})}{18(\text{mA})}-3.9$ **<u>Examiner's Comments</u>** This question was well answered. There were two different routes for gaining credit. Candidates could either use the formulae for resistors in series and parallel or use the data given and use *R*=*V*/*I*.
	b	i	($0.018^2 \times 3.9 \times 300 = 0.379$) 0.38 (J)	A1	(0.018 × 0.07 × 300 = 0.378) **<u>Examiner's Comments</u>** Many candidates incorrectly calculated the total energy dissipated in the five 300 Ω resistors rather than *r*.
		ii	0.018 × 300 OR 5.4 (C) OR $Q=\frac{0.38}{0.07}=5.43$ $\left(N=\frac{5.43}{1.60\times10^{-19}}=\right)3.4\times10^{19}$	C1 A1	**Allow ecf** from (b)(i) For use of 24 J (calculating energy in circuit) $Q=\frac{24}{4.5}=$ 5.33 which gives 3.3×10^{19} **<u>Examiner's Comments</u>** This question required candidates to determine the total charge flow and

					then divide this by the change on one electron.
		iii	I_X = 0.009 A **and** I_Y = 0.006 A 1.5	C1 A1	**Allow** use of total current through 1st parallel combination = total current through second parallel combination and $I_X = I / 2$ **and** $I_Y = I / 3$ **Allow** $\frac{3}{2}$, 3:2 **<u>Examiner's Comments</u>** Candidates needed to understand how the current in X and Y would be different and relate this to the *I=Anev* equation.
	c	i	decreases	B1	**<u>Examiner's Comments</u>** Candidates generally found this question challenging. They needed to understand that removing a resistor from a parallel combination, increased the total resistance of the circuit so that the current decreased.
		ii	increases	B1	**<u>Examiner's Comments</u>** This question was very challenging. Since the current has decreased, there would be less 'lost volts' across r so the voltmeter reading would increase. May candidates thought incorrectly that the voltmeter reading would remain the same.
			Total	**10**	
4			$P = V^2 / R$ $R = 12^2 \div 40 =$ **3.6** (Ω)	C1 A1	**Allow** $I = P/V$ (= 3.3A**) and** $R = V/I$ Correct to at least 2sf **<u>Examiner's Comments</u>** The most common mistakes here were in rearranging the formula and/or forgetting to square the voltage in $P = V^2/R$.
			Total	**2**	
5			C	1	**<u>Examiner's Comments</u>** This is a relatively simple calculation

					and was answered correctly by the vast majority of candidates. Although it is quite possible to do this in one calculation on a calculator, it is always good practice to show working as it is less likely to result in a 'power of ten' or 'transcription' error.
			Total	**1**	
6			A	1	**Examiner's Comments** This relatively simple calculation was done correctly by a large majority of the candidates. It is good to see candidate's workings on the question, as there are potential pitfalls in this. A number of candidates answered with response **D,** which showed a lack of appreciation of their calculation with actual costings.
			Total	**1**	
7	a		e.m.f → (chemical) to electrical and p.d. → from electrical (to thermal / heat) **or** e.m.f → charges/electrons gain energy and p.d. → charges/electrons lose energy	B1	**Allow** e.m.f. is work done on charges and pd is work by charges **Allow** battery for e.m.f and resistor for p.d. **Allow** less p.d. (than e.m.f.) due to energy transferred in <u>internal</u> resistance (must be clear that it is internal or cell resistance and not any other circuit resistance). **AW** **Examiner's Comments** The important word in this question is energy and so any response needs to be framed with this in mind. This is directly from the specification point 4.2.2 (e). Many candidates stated differences between the magnitudes of the e.m.f. and p.d. without referring to energy and so could not be given a mark. There were many good responses, and the simplest was to state how the electrical energy is transferred in each case.

	b		length (of wire)	B1	**Examiner's Comments** This was correctly answered by the majority of candidates; it was clear that some had not read the question and answered along the lines of changing the number of turns/coils, presumably thinking about a rheostat. Another common incorrect answer was temperature.
	c	i	*E* = *V* + *Ir* / *E* = *IR* + *Ir* / *E* = *I* (*R* + *r*) Clear manipulation leading to $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$	M1 A1	**Allow** ε for E throughout **Expect** at least one line of intermediate correct algebra leading to correct expression, explicitly shown. **Examiner's Comments** Many candidates were able to do this relatively simple manipulation. The circuit diagram should alert the candidates that this question is based on internal resistance and allow them to select one of the appropriate starting points. Some less successful responses chose other routes, such as $I = I_1 + I_2$, but then quickly found themselves unable to go further, unless by using incorrect algebra.
		ii	**1** I^{-1} = 0.8 (A^{-1}) / *I* = 1.25 (A) P (= 1.25^2 × 3.0) = 4.7 (W) **2** (Intercept =) 0.20 (A^{-1}) *r* = (0.20 × 5.0) = 1.0 (Ω)	C1 A1 M1 A1	**Allow** *I* = 1.3 (A). **Expect** at least 2sf. **No ecf** from graph misread. **Allow** 5.1 (W) from use of 1.3 (A) Value of 0.2 anywhere in calculation implies correct reading of intercept. **Allow** ± 0.02. **Allow** current = 5 (A) implies intercept correctly read **Do not allow** substitutions into *E* = *IR* + *Ir* other than using the intercept. **Allow** 1 SF answer **Alternative** r = (*E* / *I* = 5 / 5) = 1.0 (Ω) **Examiner's Comments** The vast majority of candidates were able to complete 1 correctly – there were few misreads from the graph,

					although some candidates took the reading of 0.8 as the current rather than the inverse of the current. There were also a few arithmetic slips with some candidates correctly setting out their calculation, such as $P = 1.25^2 \times 3.0$, but then not squaring the current. 2 was answered slightly less successfully and although the reading of the intercept was taken, some candidates could go no further.
			Total	**8**	
8		i	$I = \frac{1100 + 1700}{230}$ or $\frac{1100}{230}$ or 4.78 or $\frac{1700}{230}$ or 7.39 12(.2) (A)	C1 A1	**Examiner's Comments** This question was generally well answered with candidates often demonstrating that current was power divided by potential difference. Some candidates simply worked out the current in each ring but did not state the total current. Some candidates attempted to work out the maximum power using 13 A – this did not answer the question since the question required candidates to show that the maximum current in the cooker was less than 13 A **Assessment for learning** When answering "show" questions, it is essential to demonstrate that the answer matches the question. In this question high scoring candidates often stated that 12.2 A is less than 13 A.
		ii	Cost (= 2.8 × 0.5 × 18) = 25 (p)	A1	**Allow** 25.2 (p) **Examiner's Comments** This question was generally answered well. Where errors were made it was usually in the conversion of minutes to hours or not converting the power in watt to kilowatt.
			Total	**3**	