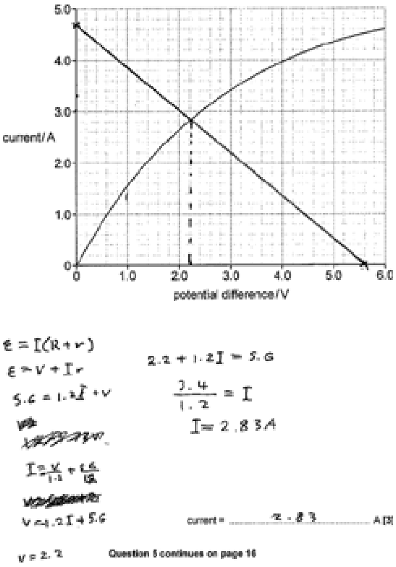
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	Resistance (which causes a loss of energy) as charges pass through the cell	B1	**Allow** current passes for charges pass **Allow** resistance inside the cell or resistance produced by materials or chemicals in the cell **Allow** lost volts per (unit) current **Allow** resistance which leads to a drop in terminal p.d. when current is drawn from the cell **Ignore** resistance *of* the cell
		ii	energy transferred <u>per (unit) charge</u> (from chemical energy / some other form of energy) into <u>electrical</u> energy	B1	**Allow** work (done) for energy **Allow** energy transferred <u>per (unit) charge</u> to charge carriers **Allow** (maximum) p.d./voltage across a cell when no current is drawn
	b		$\varepsilon = I(R + r)$ or $\varepsilon = V + Ir$ Rearranging V = 5.6 - 1.2*I* gives *I* = 4.7 − 0.83 *V* drawn as a line on the graph *I* = 2.8 (A)	C1 C1 A1	**Allow** V = 5.6 - 1.2*I* **Allow** evidence of a trial and improvement method (could be inferred from graph) **Allow** answer in the range 2.70 − 2.90 (A) **<u>Examiner's Comments</u>** 5 (b) (ii) was a question aimed at stretch and challenge level candidates with good problem-solving abilities.. Voltage V and current I are related through the formula ε = V + Ir so, given the values in the question, 5.6 = V + 1.2I. The relationship between V and I is also shown graphically. The problem is to find a pair of corresponding values for V and I which match both relationships. One way of solving this problem is to draw the relationship 5.6 = V + 1.2I onto the graph. This can be done by arranging it into a y = mx + c form i.e. *I* = 4.7 − 0.83V. The solution to the problem can then be found where the two lines cross, which is the point (2.2,

2.8). So, the values I = 2.8A (and V = 2.2V) fit both relationships. This method of solution is shown in Exemplar 2.

Exemplar 2



$\varepsilon = I(R + r)$

$\varepsilon = V + Ir$

$5.6 = 1.2I + V$

$I = \frac{V}{1.2} + \frac{5.6}{1.2}$

$V = -1.2I + 5.6$

$V = 2.2$

$2.2 + 1.2I = 5.6$

$\frac{3.4}{1.2} = I$

$I = 2.83A$

current = 2.83 A [3]

Question 5 continues on page 16

An alternative method of solution is trial and improvement.

Pick a point on the V-I graph; say (1.2, 1.8). Calculate ε = V + 1.2I = 1.2 + 2.16 = 3.36V. This is lower than the 5.6V we need for the emf.

So, try a point higher on the graph: say (3.0, 3.4). Calculate ε = = 3.0 + 4.08 = 7.08V. This value is too high.

In this way we can eventually reach the correct point at (2.2, 2.8).

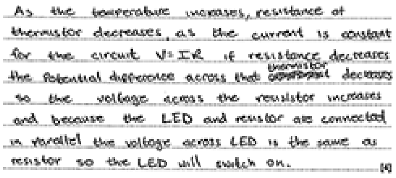
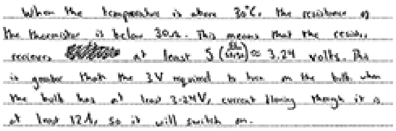
There are, of course, other methods of solving this problem.

The majority of candidates attempted to work out the resistance of an arbitrary point on the graph (often by finding the gradient, or 1/gradient, at a tangent) and then evaluated a current using 5.6 = I(R + 1.2). If they ended up with I = 2.8A, it was usually by luck rather than by good judgment.

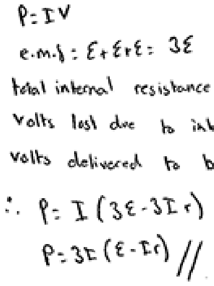
? **Misconception**

					If you are given the I-V characteristic of a non-Ohmic device, you should never try to evaluate the resistance of the device using 1/gradient; this is incorrect physics. The gradient of the graph gives ΔI/ΔV, which is not the same as I/V. For example, for the graph in this question, when V = 4.0V, the gradient of the graph is approximately 0.5 Ω^{-1}, but I/V = 4.0/4.0 = 1.0 Ω^{-1}
	c		**Level 3 (5–6 marks)** Clear description **and** clear uncertainties *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear description (eg correct circuit, valid method for varying temperature, r found from graph) **or** clear uncertainties (eg adds error bars to graph and uses a wfl to find uncertainties) **or** Some description **and** limited uncertainties *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description (eg thermistor symbol correct, range of temperatures used, *V* and *I* measured) **or** Limited uncertainties (eg uncertainties not related to graph, uncertainty in *r* found from Δintercepts rather than Δgradients)	B1 × 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description** • correct circuit symbols and diagram • vary resistance of thermistor, record *V* and *I* • method to vary resistance of thermistor, e.g. water bath and thermometer, start from 0°C • Plot V (y-axis) against *I* (x-axis) • e.m.f. = y-intercept; r = - gradient • alternatively, $P = IV$, $R = V/I$ • plot *P* (y-axis) against *R* (x-axis) • maximum power occurs when $r = R$ • e.m.f. found from $\varepsilon = V + Ir$ **Uncertainties** • Gather repeat readings of *V* and *I* at each temperature if possible and estimate uncertainty in *V* and *I* from half the range of the repeated values • If no repeats, use accuracy (or (half) resolution) of ammeter and voltmeter for uncertainty in *V* and *I* • Add error bars to graph and draw a wfl

			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. **0 mark** *No response or no response worthy of credit.*		• Find gradient and y-intercept of wfl • Uncertainty in r / e.m.f. is difference between gradients / y-intercepts of best and worst line • For alternative method, estimate width of peak to find uncertainty in *r* and find uncertainty in e.m.f. using $\varepsilon = V + Ir$ **Examiner's Comments** Although it was clear that many candidates had performed an experiment to determine *r* and ε for a cell, they were sometimes thrown by the need to use a thermistor rather than a variable resistor. Many candidates drew the symbol for a variable resistor anyway instead of a thermistor, and others put the variable resistor into the circuit alongside the thermistor. Some suggestions for varying the temperature of the thermistor were impractical. Although it would be practically difficult to take several values of V and I at exactly the same temperature, candidates were allowed to use error bars found from half the range of repeated values, rather than by using the resolution of the ammeter and voltmeter. Often candidates were rather vague when trying to describe how to determine the uncertainties; 'Use the worst fit line' was often all the instruction that was given.
			Total	**11**	
2			LED switches on at/above 3.0 V (Use graph to find) $R_{thermistor}$ =30 Ω at θ=30°C Calculate $V_{LED} = \frac{55}{55+30} \times 5$ / $V_{LED} = 0.647 \times 5$ V_{LED} = 3.2 V > 3.0 V	C1 C1 C1 A1	**Allow** $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ and $V_s = V_1 + V_2$ $V_{LED} = \frac{R_2}{R_1+R_2} \times V_{IN}$ **ECF** for incorrect resistance reading from the graph **Allow** correct alternative method pd across thermistor 2V to give resistance = 37 Ω and temperature 26°C when it switches on **Examiner's Comments**

					Candidate performance on this question was variable as some were given 0 marks because they did not reference and interpret the data from the two graphs given in the question. Exemplar 2 As the temperature increases, resistance of thermistor decreases, as the current is constant for the circuit V=IR if resistance decreases the potential difference across that ~~component~~ thermistor decreases so the voltage across the resistor increases and because the LED and resistor are connected in parallel the voltage across LED is the same as resistor so the LED will switch on. [4] Exemplar 2 demonstrates a typical response from a candidate. They describe the relationship between temperature and resistance of the thermistor, and then they relate this to the potential difference across the LED but without any reference to the data given in the two graphs. Exemplar 3 When the temperature is above 30°C, the resistance of the thermistor is below 30Ω. This means that the resistor receives ~~[illegible]~~ at least 5 ([illegible]) ≈ 3.24 volts. This is greater than the 3V required to turn on the bulb. when the bulb has at least 3.24V, current flowing through it is at least 12A, so it will switch on. Exemplar 3 is a correct response that uses the data from the graph of resistance R/Ω against temperature θ/°C to find the resistance at 30°C and then applies the equation for a potential divider to calculate the potential difference across the LED. They then clearly compare their calculated value of potential difference to the I-V characteristic for the LED to explain why the LED switches on above a threshold potential difference of 3V.
			Total	**4**	
3	a		$\varepsilon = Ir + IR$ 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. $\varepsilon = Ir + V$ with some candidates showing clearly that the power, P delivered to the bulb is given by the expression $P = 3I(\varepsilon - Ir)$. 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. $P = 3 \times I(\varepsilon - Ir)$, 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 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 $\varepsilon = Ir + V$ to be, e.g. $V = 3\varepsilon - 3Ir$. 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

					 $P = IV$ e.m.f $= \varepsilon + \varepsilon + \varepsilon = 3\varepsilon$ total internal resistance $= r + r + r = 3r$ volts lost due to internal resistance $= 3Ir$ volts delivered to bulb $= (3\varepsilon - 3IR)$ $\therefore P = I(3\varepsilon - 3Ir)$ $P = 3I(\varepsilon - Ir)$ // 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.
	b		More energy is dissipated as heat (in a larger *r*) (So) less energy transferred to the bulb **Or** Larger p.d. across *r* /Ir will be larger / More "lost volts"/ Reduces the pd across the bulb/ (ε - Ir) will be smaller **Or** (For larger r) more power is dissipated (as $P=I^2r$) (So) P (power) delivered to the bulb is less	B1 B1 B1 B1 B1 B1	**Ignore** ref. to less current/dimmer bulbs/more cells/batteries required to power the bulb/batteries need replacing more often **<u>Examiner's Comments</u>** Some candidates achieved 1 mark for this question for suggesting the most common response that the potential difference across the bulb would decrease or that there would be more lost volts across the cells but only a few linked these suggestions to achieve 2 marks. Most candidates mixed suggestions by referencing energy transfer and potential difference which meant that they only achieved 1 mark. Some candidates gave suggestions in terms of current and efficiency, which did not link to the undesirability of a large internal resistance and so were not given any marks.
			Total	**5**	
4			**D**	1	**<u>Examiner's Comments</u>** Candidates performed well on this question by correctly applying Kirchoff's current law that the current flowing into a junction must be equal to the current flowing out of it to give the correct answer D.
			Total	**1**	
5			**B**	1	**<u>Examiner's Comments</u>** Overall, candidates performed well on

					this question as many correctly applied their understanding of resistance in series and parallel to give a total resistance between **P** and **Q** as 133 Ω. The most common distractor was D, where candidates incorrectly calculated the total resistance as the sum of each individual resistance as they did not apply understanding that each pair of resistors where in a parallel arrangement around points **P** and **Q**.
			Total	**1**	
6	a		Connect the voltmeter in parallel with the thermistor	B1	**Allow** correctly drawn on diagram **Allow** "across" for "in parallel with" **Allow** voltmeter in parallel with cell **Examiner's Comments** This relatively simple first question was correctly answered by the significant majority of candidates. In general, it was lack of detail, such as 'place it in parallel' which meant that the mark would not be scored. A small number of candidates mentioned placing the ammeter in parallel.
	b	i	Points plotted correctly, within 1/2 small square	B1	**Examiner's Comments** Point plotting is always likely to form part of a question in this paper. The general rule is that each point should be plotted within ½ a small square of the correct position. Candidates are encouraged to plot points as 'crosses' and use a sharp pencil. The vast majority of candidates plotted these three points correctly with the second point most commonly being plotted incorrectly.
		ii	Smooth curve passing within 1 vertical small square of plotted points	C1	**No credit** for straight line If thick line drawn, all width of line must lie within 1 vertical small square **Examiner's Comments** The suitable line is a curve of increasing gradient and well over half of the candidates were able to draw this carefully. There were very few

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<td>lines which simply joined the points as ‘dot-to-dot’ straight lines although a considerable number drew a single straight line often through the (false) origin which should have looked clearly unsuitable. When drawing the curve it needs to pass within a single small square of each data point; several candidates drew careless lines missing data points by some distance. Candidates are also encouraged to use a sharp pencil for this line. There were a reasonable number who attempted to correct a line drawn in pencil, often making it difficult to award a mark.

OCR support

The Practical skills handbook: Physics has support for drawing tables and graphs in Appendix 5, including examples of acceptable and unacceptable graph drawing.</td>
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<td>c</td>
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<td>Current increases as temperature increases (and voltage is constant)

Use of at least two sets of data to calculate resistance

The resistance decreases, therefore it is ntc thermistor</td>
<td>B1
M1
A1</td>
<td>**Accept** standard symbols (*T*, *I*, *θ* etc) for variables in explanation

<table>
<tr><th>Temp / °C</th><th>Resistance / kΩ</th></tr>
<tr><td>30</td><td>4.0</td></tr>
<tr><td>40</td><td>2.7</td></tr>
<tr><td>50</td><td>2.0</td></tr>
<tr><td>60</td><td>1.4</td></tr>
<tr><td>70</td><td>1.1</td></tr>
<tr><td>80</td><td>0.82</td></tr>
<tr><td>90</td><td>0.63</td></tr>
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Allow 1sf for resistance values from calculations
Ignore POT error for M mark

Examiner’s Comments

Candidates were asked to use both</td>
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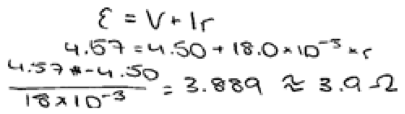
					the graph and table to draw their conclusion and for full credit both of these needed to be done. A simple description of the variance of current with temperature was all that was needed for the graph mark but calculations of resistance needed to be carried out from the table. Most candidates were able to score at least 1 mark on this question although some incorrectly identified the type of thermistor (as PTC) despite having the rest of the response correct.
	d		In circuit 1, p.d. (across the thermistor) will remain (almost) constant (with varying temperature) In circuit 2, p.d. (across the thermistor) will vary (with varying temperature) Hence, circuit 2 will be best to choose / circuit 1 is not suitable Correct potential divider argument OR explanation of operation of circuit	M1 M1 A1 B1	**Allow** voltage for p.d. **Allow** variation of pd to be increase or decrease Both M marks required for A mark e.g. Use of $V_{out} = V_{in} \times (R / R + 10\ 000)$ / the ratio of the resistances will vary (with temperature) e.g. as the milk gets hotter, the rate of heating reduces B mark is for qualifying statement **Examiner's Comments** A significant number of candidates did not score on this question despite giving a response, indicating a lack of understanding of voltage in circuits. In particular, those who did not appreciate that the full voltage was across the thermistor in circuit 1 generally struggled to obtain any marks. However, there were many good descriptions of a potential divider in circuit 2 and these often went into detail about the operation of the circuit and its suitability.
			Total	**10**	
7			D	1	**Examiner's Comments** This was correctly answered by most candidates. They were able to identify how to obtain the emf correctly but less certain on the internal resistance,

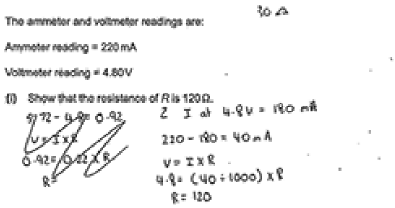
					which led to **C** being my far the most common incorrect response
			Total	**1**	
8	a	i	Since the current is zero, the (terminal) p.d. / voltmeter reading is the e.m.f.	B1	no p.d. across *r* as *I* = 0 **Examiner's Comments** There were many vague answers given. Candidates needed to state the reading of 4.57 V occurs when the current was zero. An open switch was not good enough.
		ii	$\frac{1}{R}=\frac{1}{300}+\frac{1}{300}$ and $\frac{1}{R}=\frac{1}{300}+\frac{1}{300}+\frac{1}{300}$ (3.9 Ω)	M1 A0	**Allow** 4.57 = 4.50 + 18 × 10^{-3} × *r* and 3.88… **Allow** 4.57 = 18 × 10^{-3} × 250+ 18 × 10^{-3} × *r* and 3.88… **Examiner's Comments** 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**  $\varepsilon = V + Ir$ $4.57 = 4.50 + 18.0\times10^{-3}\times r$ $\frac{4.57-4.50}{18\times10^{-3}} = 3.889 \approx 3.9\,\Omega$ 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 $R=\frac{4.5(\mathrm{V})}{18(\mathrm{mA})}$ or $\frac{4.5}{0.018}$ = 250 Ω	M1	$R=\frac{300}{2}+\frac{300}{3}$ **Allow** $R=\frac{4.57(\mathrm{V})}{18(\mathrm{mA})}-3.9$ **Examiner's Comments** 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 × 3.9 × 300 = 0.379) 0.38 (J)	A1	(0.018 × 0.07 × 300 = 0.378) **Examiner's Comments** 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 $Q = \frac{0.38}{0.07} = 5.43$ $\left(N = \frac{5.43}{1.60 \times 10^{-19}} = \right) 3.4 \times 10^{19}$	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} **Examiner's Comments** 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 **Examiner's Comments** 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	**Examiner's Comments** 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	**Examiner's Comments** 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**	
9		i	$\varepsilon = I(R + r)$ $R = \rho L/A$ **and** $A = \pi d^2/4$ clear steps leading to given equation	M1 M1 A1	**Allow** $\varepsilon = V + Ir$ **and** $V = IR$ **Allow** $A = \pi r^2$ **and** $r = d/2$ **Allow** area formula by inference, if clear **Examiner's Comments** Almost all candidates showed excellent ability in substituting and rearranging equations. The starting point was $\varepsilon = I(R + r)$ where $R = \rho L/A$. Some candidates rearranged $\varepsilon = I(R + r)$ before writing it down, starting with $R = \varepsilon / I - r$ or similar. Centres should encourage starting a proof with the standard form of the equations. The main difficulty was in substituting $A = \pi r^2 = \pi(d/2)^2$ into the formula for R. Poor presentation occasionally made responses difficult to mark.
		ii	(gradient = Δy/Δx where Δx ≥ 0.35) gradient = **5.0 (A^{-1} m^{-1})** $\rho = \frac{\pi \times (0.455 \times 10^{-3})^2 \times 1.45 \times gradient}{4}$ ρ = **1.2×10^{-6} (Ω m)**	C1 A1	**Allow** answer to 1sf Mark is **either** for the correct gradient **or** for working which would lead to 5.00 ± 0.10, seen anywhere in the question Correct to at least 2sf **Allow** the correct answer with no working shown for if the gradient (or working for the gradient) is correct **Allow ECF** for gradient ($\rho = 2.358 \times 10^{-7} \times$ gradient) **Examiner's Comments** A gradient of 5 was chosen here deliberately to make the question as accessible as possible. Most candidates were able to see from the equation that the gradient would be equal to $4\rho/\pi\varepsilon d^2$. However, a significant number did not remember that d was measured in mm and so they had a power of ten error in their

					value for ρ. The question asks, 'Calculate the gradient ... and use this to determine ... the resistivity *ρ'.* It was helpful when candidates wrote down 'gradient = ...' to make their working clear.
		iii	r = y-intercept × ε = 0.40 × 1.45 r = **0.58(Ω)** y-intercept$_{MAX}$ = 0.73 (A^{-1}) **EITHER** Fractional uncertainty in r = 0.05/1.45 + 0.33/0.40 = 0.034 + 0.825 = 0.86 0.86 x 0.58 = 0.5(Ω) to 1sf so **r = 0.6 ± 0.5** (Ω) **OR** r_{MAX} = y-intercept$_{MAX}$ × ε_{MAX} = 0.73 x 1.5 = 1.1(Ω) 1.1 − 0.58 = 0.5(Ω) to 1sf so **r = 0.6 ± 0.5** (Ω)	B1 M1 A1 A1 (A1) (A1)	Mark is for working leading to the correct value of *r*. *r* = 0.58(Ω) seen either in working or on answer line implies B1 **Allow** answers in the range 0.70 to 0.75 **Ignore** any attempt to calculate uncertainty in gradient Expect answers in the range 0.78 − 0.91 (or 78% to 91%) **Ignore** units if given Expect answers for absolute uncertainty in the range 0.45 − 0.53 Value and uncertainty <u>must</u> be given to same number of dp Expect answers in the range 1.05 − 1.13 Expect answers for absolute uncertainty in the range 0.45 − 0.55 Value and uncertainty <u>must</u> be given to same number of dp Special case: **allow** abs unc of 0.55 giving *r* = 0.6 ± 0.6 (Ω) **<u>Examiner's Comments</u>** From the equation, y-intercept = r/ε and so r = y-intercept × ε. This was a relatively simple calculation. From the question stem, ε = 1.45 ± 0.05 V and, from the graph, y-intercept = 0.40 ± 0.33. Since *r* is found by multiplying y-intercept and ε, we can apply the rule: % uncertainty in *r* = % uncertainty in y-intercept + % uncertainty in ε.

					An alternative approach is to find the upper bound for *r*, which is the greatest value of y-intercept (0.73 from graph) × greatest value of *ε* (1.45 + 0.05 = 1.5V). Candidates should be reminded to quote the uncertainty to the same number of decimal places as their value for the internal resistance. Once again, poor presentation often made responses difficult to mark. For example, it is much easier to award a mark for the statement ‘intercept of worst line = 0.7’ or ‘intercept = 0.4 ± 0.3’ than to try and spot it mid-calculation.
			Total	**9**	
10	a		(filament) lamp	B1	**<u>Examiner’s Comments</u>** A significant minority of candidates did not score this mark. An array of answers were given. The specification is specific about the *I-V* characteristics that are expected to be understood by candidates.
	b		**E**	B1	**ALLOW** 0 – 20 V, ± 0.01 V **<u>Examiner’s Comments</u>** The majority of candidates correctly identified E as the correct voltmeter. The common mistake was either choosing B for the correct number of decimal places or D or F for the correct range but not considering the number of decimal places.
	c	i	Current in Z = 180 mA $\frac{4.8}{0.220-0.180} = \frac{4.8}{0.040}$ 120 (Ω)	C1 M1 A0	May be on graph **ALLOW** calculation of resistance of parallel network (21.8 Ω) **and resistance of lamp (26.7 Ω) substituted into parallel resistors formula 119 Ω** **<u>Examiner’s Comments</u>** For this ‘show question’ it was

					expected that candidates would begin by stating that the current in component Z was 180 mA for the given potential difference. More able candidates then stated that the current in *R* was 220 mA - 180 mA = 0.040 A before stating the final division. A common alternative method which also gained full marks was again to identify 180 mA as the current in Z which gave the resistance of Z as 26.7 Ω. The resistance of the parallel network was then calculated to be 21.8 Ω. Candidates then needed to show correct working for the use of the parallel network of resistances formula. Many candidates did not know the current of 180 mA and so did not score marks. Some candidates attempted to working backwards by stating the current in *R* was 0.040 A – without explanation this did not score marks. Exemplar 2  30 Ω The ammeter and voltmeter readings are: Ammeter reading = 220 mA Voltmeter reading = 4.80V (i) Show that the resistance of *R* is 120 Ω. ~~5.72 - 4.8 = 0.92~~ ~~V = I x R~~ ~~0.92 = 0.22 x R~~ ~~R =~~ Z I at 4.8V = 180 mA 220 - 180 = 40 mA V = I x R 4.8 = (40 ÷ 1000) x R R = 120 In this exemplar, the candidate clearly stated the current in Z for a p.d. of 4.8 V which gains the first mark. The subtraction of 220 mA – 180 mA is then shown and the then the final line demonstrates the equation used by the substitution of correct numbers, including the conversion of 40 mA to 0.04 A, and the response of 120 Ω.
		ii	(*E* =) 5.72 (V) $\frac{5.72 - 4.80}{0.220}$ (r =) 4.2 (Ω)	B1 C1 A1	4.18 **<u>Examiner's Comments</u>** Candidates struggled with this question. Few candidates realised

					that when the switch was open, the voltmeter reading of 5.72 V was the terminal p.d. and equal to the e.m.f. of the battery. Some candidates did manage to determine the internal resistance without specifically stating the e.m.f.
	d		Current / ammeter reading increases (since) <u>total</u> / <u>overall</u> resistance of the circuit decreases (Larger current means) *Ir* or lost volts is greater / greater proportion of V across the *r* So voltmeter reading decreases	B1 B1 M1 A1	**IGNORE** *R* decreases (repeats question) **<u>Examiner's Comments</u>** This question allowed candidates the opportunity of structuring their answer. The majority of candidates stated that the current in the circuit and thus the ammeter reading would increase. Fewer candidates were able to state that the <u>total</u> resistance of the circuit decreased – many just referred to *R*. Fewer candidates were able to explain the change in the voltmeter. Many stated it would stay the same since it was a parallel circuit. Other candidates stated that the p.d. would increase since p.d. is proportional to current. Ideally candidates would explain their answer by relating the increase in current to a greater p.d. across the internal resistance ('lost volts') and then stating that the p.d. across the parallel network decreases so the voltmeter reading decreases. Some candidates gave a good explanation by applying potential divider arguments. **Misconception** Since current increases, the p.d. increases in a circuit containing a battery with internal resistance. **Assessment for learning** The variation of current and potential difference in a circuit containing a

					battery with internal resistance when the value of the external resistance changes. It would be useful for candidates to see the effect on the ammeter and voltmeter practically and to practise writing explanations.
			Total	**11**	
11			C	1	**Examiner's Comments** This question was answered well as most candidates applied Kirchhoff's Law and that the sum of the currents entering a junction is equal to the sum of the currents out of the junction to give the correct answer of C.
			Total	**1**	
12			D	1	**Examiner's Comments** This question was generally answered well with most candidates correctly determining that as the temperature of the filament lamp increased so did the resistance of the filament lamp. By applying *V* = *IR* they then determined that the potential difference would also increase due to increased resistance. The most common distractor was C.
			Total	**1**	
13			C	1	**Examiner's Comments** Most of the candidates gave the answer C by correctly applying the equation £ = *I (R + r).*
			Total	**1**	
14		i	(100 / 5100) x 5 (= 0.098) (V) OR (8000 / 13000) x 5 (= 3.077) (V) **0.098 to 3.077** OR **2.98** (V)	C1 A1	**ALLOW** rounding of either or both of these values to 2sf **ALLOW** final answer of range of 0.1 to 3 OR 3 (1sf answer) if more than 1sf seen previously

					Examiner's Comments This was correctly done by around three quarters of the candidates. Most used a version of the potential divider formula twice and then either gave these two values as the extremities or the difference between them. There were some clear calculational errors despite the equation being used correctly. Some candidates had a value of the maximum voltage above the supply voltage which should have alerted them to a problem.
		ii	Any two from: Increase the input voltage Decrease (the resistance of) R_1 / (fixed) resistor Extend range of thickness of jelly used	2 x B1	**ALLOW** emf for input voltage but not just potential difference **IGNORE** current **NOT** decrease the resistance alone **NOT** just make jelly thinner/thicker. Must be clear that values below 1mm or above 5mm are to be used. **Examiner's Comments** Candidates should make sure that they only give the required number of responses when prompted, as any incorrect responses may invalidate correct ones. It is important to make sure that the sense of change of any quantity is given, rather than simply a change. Over three quarters of candidates were able to achieve at least 1 mark on this question.
		iii	As the light intensity increases the resistance of the LDR/ R_2 decreases the PD measured (across R_2) decreases OR As the light intensity increases the total resistance of the circuit decreases the current increases	B1	**ALLOW** reverse argument Must be clear that the resistance is that of the LDR **ALLOW** output voltage/voltmeter reading for PD across R2 **Examiner's Comments** Although many candidates had a good understanding of this response, only around a third were able to give a complete and structured response. Three points needed to be made: how the light intensity varies, its effect on

					the resistance of the LDR and the effect on the output p.d.. Many candidates mentioned just changes rather than the sense of change, and also missed out some detail making the explanation incomplete.
			Total	**5**	
15	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** **<u>Examiner's Comments</u>** 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	**<u>Examiner's Comments</u>** 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 (= $1.25^2 \times 3.0$) = 4.7 (W) **2** (Intercept =) 0.20 (A^{-1}) $r = (0.20 \times 5.0) = 1.0$ (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**	
16			**B**	1	**Examiner's Comments**

					This proved to be a challenging question with only around a quarter of the candidates able to obtain the correct response. It was likely that written working was helpful here and many candidates set out some form of a potential divider calculation. Some did this in ratios and others made up a value for the two resistances (e.g. 10 Ω) which they then decreased to 8.0 Ω for the thermistor. The incorrect responses were spread fairly evenly across the distractors, which is maybe surprising as it would be expected that candidates should have appreciated that the p.d. across the thermistor would now be less than the initial 4.5 V.
			Total	**1**	
17		i	Graph from 1.5 V at **0/A** to 0 V at **L/B** Curve of decreasing gradient	M1 A1	**Allow** curve of increasing gradient/straight line **<u>Examiner's Comments</u>** Many candidates were given no marks for this question and there was a significant number of candidates who omitted the question. Typical incorrect responses were to draw a line showing a directly proportional relationship between *V* and *L*. Very few candidates were given 2 marks for correctly showing a decreasing gradient.
		ii	At **A** / *x* = 0, *V* = 1.5 V and at **B** / x = *L*, *V* = 0.75 V/p.d is shared/halved Total resistance increases so current decreases (as length of wire **L** and resistor of **R** are in series)	B1 B1	**Allow** *V* (across **R**) decreases as *x* increases (as **S** moves from **A** to **B**) **Allow** Explanation of potential divider e.g. At **B** resistance of length of wire = resistance of **R** **<u>Examiner's Comments</u>** Over half of candidates were given no marks for this question as they would often confuse the potential difference *V* across the fixed resistor with the potential difference across the resistance wire and because they had not determined that when the connecting wire BC was removed the resistance wire and fixed resistor were

					in series. If candidates were given 1 mark it was for correctly describing the relationship between *V* and *x* but with little or confused understanding of a potential divider.
			Total	**4**	
18			C	1	**Examiner's Comments** Most candidates performed well and correctly selected the equation; $\mathcal{E} = V + Ir$ and applied Ohm's Law to give the answer C. The most common distractor was answer D where candidates had correctly calculated the current but carried out the calculation for the internal resistance $r = 1.2\ \text{V} / 0.15\ \text{A} = 8\ \Omega$.
			Total	**1**	
19			B	1	**Examiner's Comments** Candidates performed well on this question by correctly calculating the resistance *R* using the formula: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$ To give the correct answer B.
			Total	**1**	
20			A	1	**Examiner's Comments** This question assessed candidates understanding of Kirchhoff's two laws with most candidates applying their knowledge that current and potential difference were used in the laws. This meant that most candidates answered A correctly but C was a common distractor.
			Total	**1**	