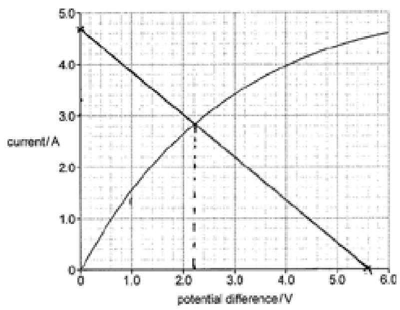
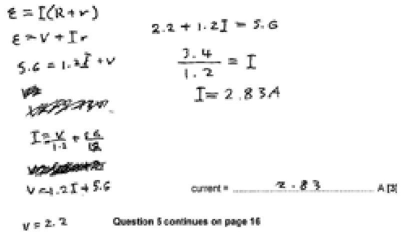
Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			ε = *I*(*R* + *r*) or ε = *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 

					 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}
			Total	**3**	

2			Circuit diagram Battery as power source **and** Voltmeter in parallel with thermistor **and** Ammeter in series with thermistor Record temperature (with a thermometer) and corresponding current and pd readings (as the temperature falls) Take at least 5 readings **or** take readings at regular intervals Calculates resistance using R=V/I	B1 B1 B1 B1	All circuit symbols correct **Ignore** other components drawn in the circuit diagram e.g. variable resistor **Allow** stated temperature intervals for recording temperature **Allow** voltage for potential difference Correct rearrangement required **<u>Examiner's Comments</u>** Overall, candidates performed well on this question with most achieving at least 1 mark and some achieving over 2 marks. Most candidates were given marks for a correctly drawn circuit diagram (including current circuit symbols for the components required for the investigation) and for a correct rearrangement of V=IR to be able calculate the resistance. Some candidates would describe that measurements would need to be read from the ammeter and voltmeter, which was insufficient as the measurements of current and potential difference needed to be specified to achieve the mark.
			Total	**4**	
3			**A**	1	**<u>Examiner's Comments</u>** This should have been a straightforward starting question for all the candidates in identifying the correct S.I. base unit but only some gave the correct response of A. The most common distractor was B.
			Total	**1**	
4			C	1	**<u>Examiner's Comments</u>** This question was relatively poorly answered with fewer than half of the candidates getting the correct response. **B** and **D** were the two common distractors with **B** treating the cells as if they were resistors, and D simply adding up the three voltages.
			Total	**1**	

5	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 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

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>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></tr>
<tr><td></td><td>c</td><td></td><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></table>
Allow 1sf for resistance values from calculations
Ignore POT error for M mark

<u>Examiner's Comments</u>

Candidates were asked to use both 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.</td></tr>
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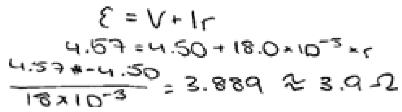
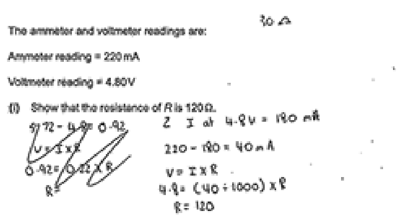
	d		In circuit 1, p.d. (across the thermistor) will remain (almost) constant (with varying temperature) In circuit 2, p.d. (across the thermistor) will vary (with varying temperature) Hence, circuit 2 will be best to choose / circuit 1 is not suitable Correct potential divider argument OR explanation 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 $V_{out} = V_{in}$ x (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 **<u>Examiner's Comments</u>** 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**	
6	a	i	Since the <u>current is zero</u>, the (terminal) p.d. / voltmeter reading is the e.m.f.	B1	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.
		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… **<u>Examiner's Comments</u>** 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 $\frac{4.5}{0.018} = 250\ \Omega$	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	($0.018 \times 0.07 \times 300 = 0.378$) **<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 $Q = \frac{0.38}{0.07} = 5.43$ $\left(N = \frac{5.43}{1.60 \times 10^{-19}} = \right) 3.4 \times 10^{19}$	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} **<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 **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**	
7	a		(filament) lamp	B1	**Examiner's Comments** 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 **Examiner's Comments** 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  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**	
8		i	f (= $1/T$) = 1 / (40 × 10^{-3}) f = 25 (Hz)	B1 B1	**Allow** $f = 1/T$ **and** $T = 40 \times 10^{-3}$ (s) **<u>Examiner's Comments</u>** It is important to show how the information from the graph has been used to calculate the frequency. The correct answer did not score full marks unless some working had been shown.
		ii	**EITHER** Calculation of Q_o / e time constant (read from graph) = 14 (ms) **OR** Use of $Q = Q_0 e^{-t/CR}$ time constant = 14 (ms)	C1 A1 (C1) (A1)	**Allow** any initial value of charge e.g. 8.0 / e = 2.9 (μC) **or** 37% × 8.0 = 3.0 (μC) **Allow** 14±1 (ms) e.g. $2.0 = 8.0e^{-0.02/CR}$ gives CR = 0.02 / ln4 Using the decay equation may incur two POT errors **<u>Examiner's Comments</u>** The question specifies using the discharging section of the graph. Some candidates tried to use the charging section, but this proved more difficult.

					Using the definition of the time constant, we need to find how long it takes for the charge to fall from any initial value to 37% (1/*e*) of that value. Many candidates chose 8μC for their initial value, but this is not vital. 37% of 8μC is 2.9μC. The charge is 8μC at 20ms and 2.9μC at 34ms, so the time taken is 34 − 20 = 14ms. A common alternative approach was to insert values from the graph into the equation $Q = Q_0 e^{-t/CR}$This gave the same result, but sometimes resulted in a POT error because of the need to give the answer in milliseconds.
		iii	tangent drawn to graph <u>at steepest part of curve</u> maximum current in range 5.0×10^{-4} to 7.0×10^{-4} (A)	M1 A1	Judge by eye, no daylight between curve and tangent **Allow** a negative answer **Allow** answer to 1sf **<u>Examiner's Comments</u>** Many candidates lost marks here because they did not realise that, to calculate the *maximum* current in the resistor, they had to draw the steepest possible tangent to the graph.
		iv	vertical axis labelled as current with the correct unit **and** at least one positive and one negative scale marking **and** scale should allow for their maximum current to be plotted exponential decay of current in each section sign of current alternates at 20, 40, 60 and 80 ms	B1 M1 A1	For example *I* / mA, *I* (mA), *I* /10^{-4} A, current in mA etc All scale markings shown must be correct **Allow** any curve with a decreasing gradient in each section **Ignore** value of minimum current but **not** zero **Ignore** sign of current for this marking point All curves should start at the correct maximum current value. However, If **B1** mark has not been scored, **allow** any value of maximum current as long as it remains consistent across all four sections

					<u>Examiner's Comments</u> Since $I = \Delta Q/\Delta t$, the graph of I against t can be found from the gradient of the graph of Q against t. The gradient is positive from 0 − 20 ms and negative from 20 − 40ms; this represents the current flowing one way around the circuit while the capacitor charges and then the opposite way while it discharges. Since the gradient is never zero, the value of the current is never zero either. **Tasks that caused problems in 6(b)(iv)** • drawing an exponential decay, particularly in the negative section of the graph (most drew a sinusoidal curve). • converting the maximum current into mA or μA. • labelling the vertical axis and drawing on a sensible scale. **Assessment for learning** Centres should consider providing more practice in drawing graphs without the aid of graph-plotting software.
			Total	**9**	
9			**A**	1	**<u>Examiner's Comments</u>** This question was correctly answered by a majority of candidates. Although many candidates wrote out $V = IR$ or some other version of Ohm's law, they seemed unable to relate this to the statements. There was evidently some uncertainty as to what Ohm's law exactly was, and the writing of the resistivity formula inevitably led several candidates to responses C and D.

			Total	**1**	
10			B	1	**Examiner's Comments** This question was generally answered well with candidates correctly using the *I–V* graph to determine that **R** and **L** had the same resistance when the two lines intersected at 1.5 V. The most common distractor was answer D.
			Total	**1**	
11	a		$A = \frac{48 \times 10^{-8} \times 11.8}{31}$ or 1.827×10^{-7} $d^2 = \frac{4 \times 1.827 \times 10^{-7}}{\pi}$ or 2.326×10^{-7} 4.8×10^{-4} (m)	C1 C1 A1	**Allow** 5.82×10^{-8} (determines r^2) for 1 mark **Allow** 2.4×10^{-4} (determines r) for 2 marks **Examiner's Comments** Many candidates scored all three marks on this question. High scoring candidates often determined the cross-sectional area of the wire before determining the diameter. Some candidates omitted to take a square root or determined the radius of the wire.
	b	i	Correct symbols circuit for components including <u>four</u> cells Circuit diagram: ammeter connected in series with battery and ring A and voltmeter in parallel with ring A / battery.	B1 B1	**Ignore** other circuit components (e.g. rheostat) **Note** if variable resistor added to circuit then voltmeter must be in parallel with ring A. **Examiner's Comments** It was expected that the correct circuit symbols would be used. A small number of candidates were unable to position the ammeter and voltmeter correctly.
		ii	$R\left(= \frac{6.2}{0.34}\right) = 18\ (\Omega)$	A1	**Allow** 18.2 (Ω) **Examiner's Comments** The majority of the candidates answered this question correctly. Although it is a simple question, candidates should be advised to show their working.

		iii	$\frac{0.02}{0.34}(\times 100)$ or $\frac{0.2}{6.2}(\times 100)$ Percentage uncertainty (= 5.9 + 3.2) = 9.1 %	C1 A1	**Allow** max/min methods, e.g. $\frac{6.4}{0.32}$ or $\frac{6.0}{0.36}$ **Allow** 9 (%) **Do not allow** bald 10(%) **Examiner's Comments** This question was answered well by the large majority of candidates. Many correctly worked out the percentage uncertainty in the current and added it to the percentage uncertainty in the potential difference. This was the simplest method. A few candidates used maximum/minimum methods. In this case it needed to be maximum potential difference divided by minimum current or minimum potential difference divided by maximum current.
		iv	When using the battery pack, current is lower than when connected to the mains ORA When using the battery pack the temperature of the wire / heating effect is lower ORA	B1 B1	**Examiner's Comments** Candidates found this question challenging. Few candidates realised that the current was smaller so the heating effect would be less.
		v	Any **two** from: Repeat experiment with a different number of cells / use a variable resistor Use more sensitive meter(s) or reading to greater precision Plot a graph of *V* against *I*	1 B1 × 2	**Allow** variable power supply **Do not allow** power supply greater than 12 V **Do not allow** more accurate meters / digital meters **Examiner's Comments** There were many vague answers to this question. Ideally there should be more measurements taken. Some candidates discussed using a variable resistor or potentiometer in the circuit and other suggested then plotting a graph. Some candidates discussed increasing the power supply. Some candidates also suggested using more sensitive meters or meters reading to a greater precision. Marks were not given for using more accurate meters or digital meters.
			Total	**12**	