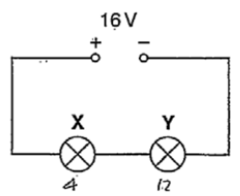
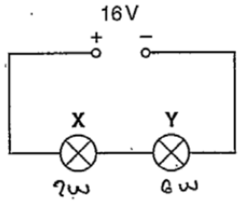
Mark scheme – Electrical Circuits

Question			Answer/Indicative content	Marks	Guidance
1			A	1	
			Total	**1**	
2			**B**	**1**	
			Total	**1**	
3			A	1	**<u>Examiner's Comments</u>** This is a question on a potential divider circuit and a sketch of the correct *V*-*R* graph. Unfortunately, the distractor **B** was a bit too strong. **A** is the correct sketch. When *R* = 0, *V* had to be zero too. Most candidates did write down the correct potential divider expression for *V*, but then did not acknowledge that *V* cannot be directly proportional to *R* – the straight-line graph through the origin could not be the correct answer. It was a choice between **A** or **B**, and by the brief reasoning above, the answer had to be **A**.
			Total	**1**	
4			**A**	**1**	
			Total	**1**	
5			**D**	**1**	
			Total	**1**	
6			**A**	**1**	
			Total	**1**	
7			C	1	
			Total	**1**	
8			**C**	**1**	**<u>Examiner's Comments</u>** This was a well-answered question with most candidates demonstrating excellent knowledge of resistors in series and parallel combination. On many scripts, there was hardly any working shown. The two 10.0 Ω resistors in parallel gave a combined resistance of 5.0 Ω. This added to the series resistor of 20.0 Ω gives the correct answer of 25.0 Ω. The most popular distractor was **D** – where all the resistance values were simply added together.
			Total	**1**	
9			D	1	

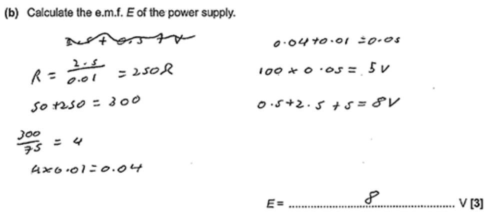
			Total	**1**	
10			C	1	
			Total	**1**	
11			**A**	**1**	
			Total	**1**	
12			A	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.
			Total	**1**	
13			**D**	1	
			Total	**1**	
14			D	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.
			Total	**1**	
15			B	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions. The candidates to demonstrate their knowledge and understanding of physics.
			Total	**1**	
16			D	1	
			Total	**1**	
17			C	1	

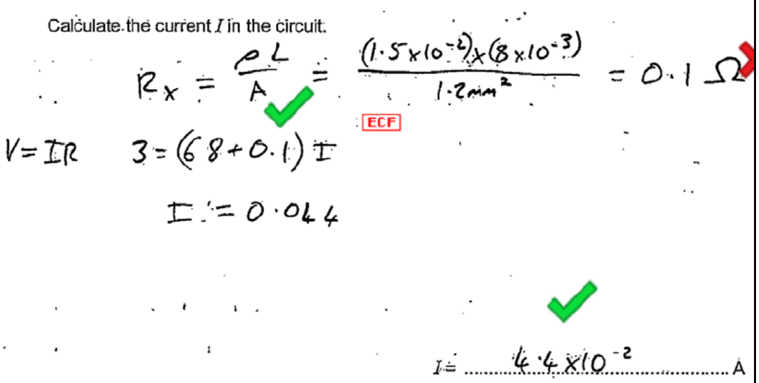
			Total	**1**	
1 8			D	1	**Examiner's Comments** All of the questions showed a positive discrimination, and the less able candidates could access the easier questions. The questions in Section A do require careful reading and scrutiny. Candidates are advised to reflect carefully before recording their response in the box. Candidates must endeavour to use a variety of quick techniques when answering multiple choice questions.
			Total	**1**	
1 9			B	1	
			Total	**1**	
2 0			**B**	1	
			Total	**1**	
2 1			B	1	
			Total	**1**	
2 2			B	1	
			Total	**1**	
2 3			B	1	**Examiner's Comments** The correct response is **B**. This is another question which was correctly answered by around two thirds of the candidates. The simple solution is through determining the current through **Z** and the p.d. across it thereby finding the product. Working demonstrated some tortuous routes, such as calculating all the resistances, which does indicate a lack of confidence about circuit calculations. However, in many cases this did lead to the correct answer.
			Total	**1**	
2 4			D	1	
			Total	**1**	
2 5			B	1	**Examiner's Comments** The correct response is **B**. This question was correctly answered by around two thirds of candidates. There appeared to be various routes to the correct solution; many opted to work out a current in terms of R, but the more elegant working was in terms of simple ratios which demonstrated a good understanding of p.d. in a series circuit. Encouragingly, very few candidates opted for response **A**, which was a p.d. below that of the thermistor alone. It should be noted that a couple of candidates put a '7' in the answer box – as correct working

					had been shown by them, and leading to the correct numerical value this was credited by examiners. However, this cannot be guaranteed to occur in other cases and candidates are to be encouraged to put only the correct letter.
			Total	**1**	
26			C	1	
			Total	**1**	
27			**B**	1	**<u>Examiner's Comments</u>** Candidates answered this question well. A range of techniques could be used to get to the correct answer **B**. This is illustrated by the two exemplars below. **Exemplar 2**  Lamp **X** emits a power of 2.0 W and lamp **Y** emits a power of 6.0 W. What is the potential difference across the lamp **X**? **A** 1.0 V **B** 4.0 V **C** 12 V **D** 16 V $P = IV$ $P \propto V$ Your answer B This shows the thought processes of a top-end candidate. The current in the series circuit is constant, hence the potential difference must be proportional to the power dissipation. These two lines is all it took for this candidate to identify the correct answer **B**. **Exemplar 3**

					 Lamp **X** emits a power of 2.0W and lamp **Y** emits a power of 6.0W. What is the potential difference across the lamp **X**? **A** 1.0V **B** 4.0V **C** 12V **D** 16V Your answer B Here's another equally valid technique, which may have been a bit time–consuming for this grade D candidate. The total power dissipated has been used to determine the current in the circuit. The correct value of 4.0 V across lamp **X** has been calculated using this current and the equation $P = VI$. It is worth noting the sensible approach of annotating the figure. This would have helped to steer away from the popular distractor C.
			Total	**1**	
2 8			D	1	**Examiner's Comments** The correct response is **D**. This question also proved to be challenging as not many candidates will have come across this style of circuit before. Therefore in most cases, it will have to have been worked out from application of conventional current flow. It would likely be evident that LED **Q** is lit, probably accounting for the very few candidates selecting response **B**. Many candidates incorrectly selected response **A**, presumably as its polarity is the same as **Q**.
			Total	**1**	
2 9			B	1	
			Total	**1**	
3 0			**A**	1	
			Total	**1**	
3 1	a		1. λ	B1	
			2. $\frac{3\lambda}{2}$ or 1.5λ	B1	**Examiner's Comments** This was well answered with few responses referring to degrees. Some candidates gave generalised answers in terms of n. Other candidates thought it was the third minima.

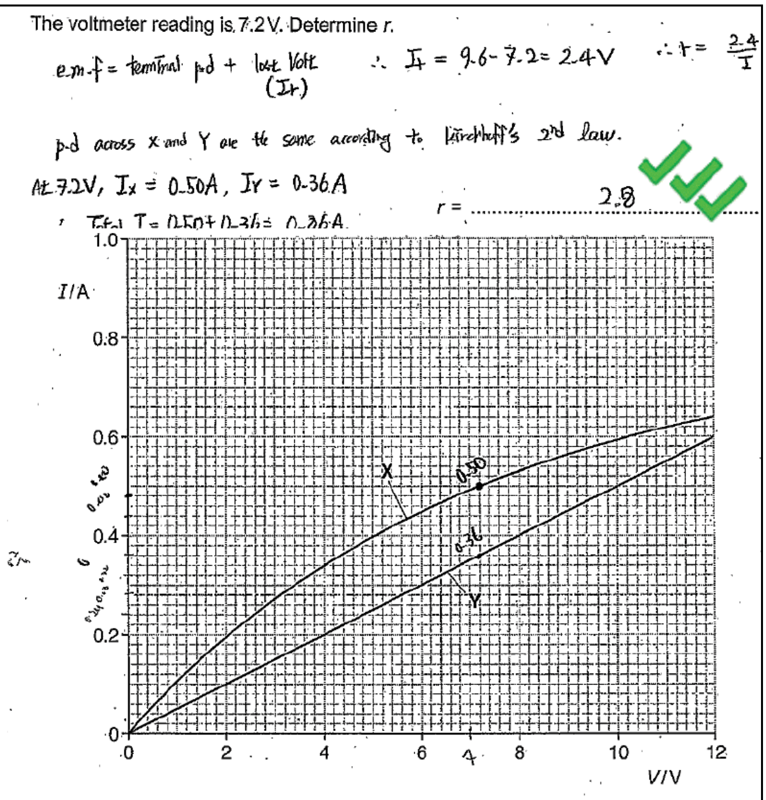
	b		$\lambda = \frac{ax}{D}$ stated <u>and</u> D and λ are constants. Separation decreases (AW)	M1 A1	**Allow** $x \propto a^{-1}$ **Allow** other correct answers, e.g. in terms of path difference and angles **Examiner's Comments** Candidates needed to explain that the fringe spacing was inversely proportional to the slit spacing – this was often missing. Candidates should be encouraged to identify the constants in any expression when answering this type of question.
			Total	**4**	
32	a		$V = \frac{R}{R+0.25R} \times 6.0$ V = 4.8 (V)	C1 A1	**Allow** other correct methods.
	b		The total resistance of the voltmeter and resistor in parallel is less than *R*. (AW) A suitable alternative device stated, e.g. digital voltmeter, oscilloscope or data-logger (connected to a laptop).	B1 B1	
			Total	**4**	
33	a		current = 0.01 (A) p.d. = 0.01 × 50 (= 0.50 V)	M1 A1	<u>**Examiner's Comments**</u> This was an accessible question on determining the p.d. across the LED using the data from **Fig. 19.2**. The universal approach was short and precise: V = 0.01 × 50 = 0.50 V. However, a significant number of candidates used a longer route involving the potential divider rule and the 250 Ω resistance of the LED.
	b		(V_{75} =) **0.5 + 2.5** (V) **or** (R_{LED}) = **250** (Ω) **or** (R_p =) **60** (Ω) (I_{100} =) **0.05** (A) (E = 3.0 + 0.05 × 100) E = 8.0 (V)	C1 C1 A1	**Allow** other correct methods **Note** there is no ECF from (**a**) **Allow** 1 SF for the p.d. of 3 (V) There is no ECF here from wrong physics (XP) from the parallel network **Allow** 1 SF answer of 8 <u>**Examiner's Comments**</u> The analysis of the circuit proved to be problematic with most of the candidates getting as far as calculating either the resistance of the LED as 250 Ω or the p.d. across the LED-50 Ω resistor combination as 3.0 V. The stages thereafter demonstrated all the usual misconceptions; these are summarised later. About a quarter of the candidates produced flawless solutions using a range of techniques

					from Kirchhoff's two laws to potential dividers. The simplest solution had the correct current of 0.050 A in the 100 Ω resistor, followed by the correct value of the e.m.f. of 8.0 V. This type of solution is shown in exemplar 7. **Misconception** These were the most common errors made in calculating the e.m.f. of the power supply. • Calculating the total resistance of the parallel network by omitting the resistance of the LED. • The current in the 100 Ω resistor was the same as the current of 0.010 A in the LED. • The current in the 100 Ω resistor was the same as the current of 0.040 A in the 75 Ω resistor. • Using the potential divider equation by completely omitting the LED-50 Ω resistor series network. **Exemplar 7**  (b) Calculate the e.m.f. *E* of the power supply. $R = \frac{2.5}{0.01} = 250\Omega$ 50 + 250 = 300 300/75 = 4 4×0.01 = 0.04 0.04 + 0.01 = 0.05 100 × 0.05 = 5 V 0.5 + 2.5 + 5 = 8V *E* = 8 V [3] This exemplar shows a perfect response from a middle-grade candidate. The response should have been written to 2 SF. However, because the answer was 8.0 V, a 1 SF response was allowed without incurring any penalty.
			Total	**5**	
3 4			Sum of e.m.f(s) is equal to the sum of p.d.(s) (in a loop of a circuit) Energy is conserved	B1 B1	**Allow** total / ∑ instead of 'sum' **Allow** voltage instead of p.d. **Not** ….sum of *IR* ….., unless *I* and *R* are defined Expect 'sum' at least once in the statement **Not** $\sum E = \sum V$, unless *V* and *E* are defined **Examiner's Comments** Many candidates jumbled up the first and second laws, but most candidates gave perfect answers. It was quite common to see hybrid statements such as *'sum of e.m.f.s at a point = sum of p.d.s coming out of the same point'*. Most did know that energy was conserved, but other incorrect suggestions were *charge, current and voltage*. The question discriminated well and rewarded those candidates that had learnt their definitions.

			Total	**2**	
35			Current less Cell has internal resistance **or** greater (total) resistance **or** p.d. across internal resistor **or** p.d. across resistor/10.0 (Ω)	B1 B1	**Allow** 'lost volts' / power lost in cell **Ignore** wires have resistance
			Total	**2**	
36			$R = \frac{\rho L}{A} = \frac{1.5\times10^{-2}\times8.0\times10^{-3}}{1.2\times10^{-6}}$ **or** 100(Ω) (total resistance =) 168 (Ω) (current = 3.0/168) I = 0.018 A	**C1** **C1** **A1**	Possible POT error here **Note** using $A = (1.2 \times 10^{-6})^2$ is wrong physics, hence this C1 mark is lost Possible ECF from incorrect value of R for this C1 mark and the next A1 mark **Allow** 2 marks 0.044 (A); A taken as 1.2×10^{-3}, which gives R = **0.1** and I = 3.0/**68.1** = 0.044 (A) **Not** I = 3.0/**68** = 0.044 (A) because this is wrong physics **<u>Examiner's Comments</u>** There were several challenges in this question. Success was dependent on knowledge of resistivity and series circuit. There was also the added complication of converting the 12 mm² to 12 × 10⁻⁶ m². The most common error was with powers of ten, with the resistance calculated as 0.1 Ω instead of 100 Ω – where 1 mm² was being taken as 10⁻³ m² rather than 10⁻⁶ m². **Exemplar 11**  This exemplar illustrates how even top–end candidates can lose a mark. The error in the powers of ten has been penalised by the examiner.

					This incorrect value has then been allowed through subsequent calculations. Two marks have been gained even though the final answer is incorrect. It is worth remembering the knowing your physics will always pay dividends.
			Total	**2**	
37		i	(When two or more waves meet at a point) the resultant displacement is equal to the sum of the displacements of the (individual) waves.	B1	**Allow**: net / total for 'resultant' **Not** amplitude **Examiner's Comments** This was poorly answered. Candidates gave confused answers, often referring to constructive and destructive interference. Most candidates had the idea that the waves needed to be added in some way. Common incorrect answers referred to the addition of the amplitudes. It was expected that candidates would state that the resultant displacement was equal to the sum of the displacements of the individual waves.
		ii	There is a constant / fixed phase difference (between the waves)	B1	**Allow** constant / fixed phase relationship **Ignore** 'the frequency / wavelength is the same' **Not** the same phase difference **Not** zero phase difference **Examiner's Comments** A good proportion of candidates scored this mark. A common error was just stating frequency and wavelength were the same.
			Total	**2**	
38			(V_R =) 2.7 (V) **or** (current =) 0.018 (A) (ratio = $\frac{0.018 \times 1.8}{0.018 \times 2.7}$) ratio = 0.67	C1 A1	**Note** the mark can be scored on circuit diagram **Note** values of powers are: 0.0324 W and 0.0486 W **Allow** 2/3; **Not** 0.66 (rounding error)
			Total	**2**	
39	a		$E = y$-intercept r = - gradient	B1 B1	E must be the subject R must be the subject **Do not accept** gradient = - r
	b	i	$\left(R = \frac{5.68}{0.025} =\right) 230\ \Omega$	A1	**Allow** 227
		ii	$\left(\frac{5.68^2}{\textbf{(c)(i)}} \text{ or } 0.025^2 \times \textbf{(c)(i)} \text{ or } 0.025 \times 5.68 = \right)$ 0.14 × 300 = 42 (J)	C1 A1	**Allow** ECF from (c) **(i)** 0.140 or 0.142 or 0.144 **Allow** 43 (J) (for 0.142 or 0.144)
		iii	$\left(Q = \frac{\text{(c)(ii)}}{5.68} \text{ or } 0.025 \times 300 = \right) 7.4$ or 7.5 C	B1	**Allow** ECF from (c) **(ii)**

				B1	
	c		$\Sigma E = \Sigma V$ or $\Sigma E = \Sigma Ir$ $E = V + Ir \Rightarrow V = E - Ir$	C1 A1	
			Total	**9**	
40			The voltmeter has large or infinite resistance.	B1	
			Hence the p.d. across the lamp or current in the lamp is small or zero (and the lamp is not lit).	B1	
			Refining design: remove voltmeter from the circuit or place the voltmeter across the lamp.	B1	
			Total	**3**	
41			I_X = 0.5 A <u>and</u> I_Y = 0.36 A OR I = 0.86 A 9.6V − 7.2V or 2.4 V $r = \frac{9.6-7.2}{0.86} = 2.8\,\Omega$	**C1** **C1** **A1**	**Allow** Alternative correct methods 2.79 Ω <u>**Examiner's Comments**</u> This question assessed candidates' knowledge of internal resistance as well as their understanding of series and parallel circuits. Many candidates correctly determined that the 'lost volts' was 2.4 V. Unfortunately, the total current in the circuit was more difficult for candidates to determine. Candidates needed to identify that the potential difference across each component was 7.2 V and use the graphs to determine the two current values. Again, good candidates clearly show their working. The advantage would be in that an error in reading information from the graph would still allow further credit. **Exemplar 5**

					 **Fig. 6.1** The candidate has clearly state the method and at the top stated that Ir = 2.4 V. The candidate has then clearly read the currents for each component at a potential difference of 7.2 V to then determine the total current. There is then a correct calculation to determine the internal resistance r.
			Total	**3**	
4 2			Any **three** from: • Total resistance of the lamps increases by a factor of 1.5. • Resistance of each lamp increases with current. • Resistance increases because of increased temperature. • Lamps are non-ohmic components.	B1×3	
			Total	**3**	
4 3			(V_A =) 6.0 (V) **or** (R_A =) 30 (Ω) For parallel lamps, any one from: ($V_{\|\|}$ =) 2.0 (V) **or** (I =) 0.10 (A) **or** (R_L =) 20 (Ω) **or** ($R_{\|\|}$ =) 10 (Ω)	C1 C1 A1	**Not** $R_{\|\|}$ = 15 (Ω); this is XP

			resistance = 40 (Ω)		
			Total	**3**	
4 4			Fig. 4.1: total resistance = 3*R*	C1	
			Fig. 4.2: total resistance = 2*R* / 3	C1	
			ratio = $\frac{V}{3R} \div \frac{V}{2R/3}\ \frac{V}{2R/3}\ \frac{V}{2R/3}$ = 0.22	A1	**Allow**: 2/9
			Total	**3**	
4 5		i	p.d. across 1.2 kΩ = 0.9 V	C1	
		i	$\frac{R_{LDR}}{1200} = \frac{5.1}{0.9}$determines current and R = 5.1 / I	C1	
		i	R_{LDR} = 6800 (Ω)	A0	**Allow**: 6.8 k(Ω)
		i	Or $5.1 = \frac{R}{R+1.2} \times 6.0$	C1	
		i	0.9*R* = 6.12 or 0.15*R* = 1020	C1	**Allow** $\frac{6.8}{6.8+1.2} \times 6.0 = 5.1$for two marks
		i	R_{LDR} = 6.8 (kΩ)	A0	**Allow**: 6800 (Ω) **Examiner's Comments** There were a number of correct methods using various arrangements of the potential divider equation. Candidates were able to arrange a complicated equation in a number of cases. Other candidates correctly determined the potential difference across the fixed resistor and then the current.
		ii	$(I = \frac{5.1}{6800} = \frac{6}{8000} = \frac{0.9}{1200})$		
		ii	current = 7.5 × 10^{-4} (A)	B1	**Examiner's Comments** Most candidates were able to calculate the current delivered by the battery. Candidates who did not score this mark often incorrectly assumed that the potential difference across the fixed resistor was 6 V.
			Total	**3**	
4 6			(The circuit does not work because) the LED is reverse biased / incorrect polarity of the cell (AW)	B1	**Allow**: (For the circuit to work) the LED must be forward-biased / 'reverse the LED' / 'reverse the cell'
			V must be greater than 2.6 (V for the LED to be lit)	B1	**Allow** ±0.1 V **Not** *V* must be equal to / 'at least' 2.6 V **Allow** this mark even if the LED is reverse biased
			Use two (or more 1.5 V) cells (in series) / use a supply greater than 2.6 (V) / use a 3.0 (V) supply	B1	**Note**: This B1 mark can be scored on Fig. 27.2 **Allow** this mark even if the LED is reverse biased **Examiner's Comments** This question was not answered well whencandidates failed to use

					their earlier answer in (a) to explain why the circuit shown in Fig. 27.2 did not work. It was only a small number of candidates who realised that the LED was in reverse bias and the solution would have been to either swap the terminals of the LED or the cell. Most candidates did not appreciate that the p.d. had to be greater than 2.6 V for the LED to emit light. A very small number of candidates opted to use two 1.5 V cells in series. Some candidates thought that swapping the resistor and the LED would solve the problem because then the *'resistor will not prevent the current from reaching the LED'*.
			Total	**3**	
47	a		current = $\frac{0.060}{2.4}$ or current = 0.025 (A)	C1	
			$R = \frac{6.0 - 2.4}{0.025}$	C1	
			R = 140 (Ω)	A1	**Note** answer to 3 sf is 144 Ω
	b		$I = Anev$ and A = 2.0 × 10^{-6} (m^2)	C1	
			0.025 = 2.0 × 10^{-6} × 1.4 × 10^{25} × 1.60 × 10^{-19} × v	C1	**Allow** any subject Possible ecf
			v = 5.6 × 10^{-3} (m s^{-1})	A1	
	c		The current is constant, therefore $v \propto n^{-1}$.	M1	
			The mean drift velocity is therefore smaller.	A1	
			Total	**8**	
48			p.d. across resistor = 1.50 − 0.62 = 0.88 (V)	C1	
			current = 0.88 / 120 = 7.33… × 10^{-3} (A)	C1	
			power = VI = 1.50 × 7.33 × 10^{-3} = 1.1 × 10^{-2} (W)	A1	
			Total	**3**	
49		i	In darkness LDR has more resistance / p.d. across LDR is large **or** In light LDR has less resistance / p.d. across LDR is small	B1	
			Clear idea that when the LED is on, this will force the p.d. across LED / LDR to decrease, forcing the LED to switch off (ORA) (The cycle of LED switching on and off is repeated)	B1	Note the explanation must be in terms of p.d. / potential divider. **Ignore** current

		ii	A sensible suggestion, e.g. Point the LED away from the LDR / increase distance (between LED and LDR) / insert a card between (LED and LDR)	B1	
			Total	**3**	
50			$I = I_1 + I_2$	M1	
			V is the same (for each resistor)	M1	
			$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2}$ leading to correct expression	A1	
			Total	**3**	
51		i	With the variable resistor set at zero / close to zero, the p.d. across the resistor is zero / small, so p.d. across lamp is 2.4 V / large.	B1	
		i	With the variable resistor set at its maximum value, there is a p.d. across the variable resistor, so p.d. across the lamp is not small.	B1	
		ii	The lamp is connected to the slider contact of a potentiometer arrangement.	B1	
		ii	Ammeter and voltmeter connected correctly.	B1	
			Total	**4**	
52			Any <u>three</u> from: • Fig. 23.3 - p.d. split equally / (p.d. across each =) **3.0** (V) • Fig. 23.3 - current = **0.36** (A) (from the graph) • Fig. 23.4 - p.d. = **6.0** (V) (across each or combination) • Fig. 23.4 - current (= 2 × 0.50) = **1.0**(0) (A)	M1× 3	**Note** that each of the M1 mark can be implied in a calculation **Note** 8.3.. (Ω) will score the **3.0** V and the **0.36** A marks **Note** 12 (Ω) will score the **6.0** V mark
			0.36 × 3 (= 1.08) is about 1.0 (A)	A1	**Note** this mark is for showing that I_P is about 3 times I_S <u>**Examiner's Comments**</u> This question produced a range of marks, with most candidates securing 2 or more marks. For the lamps in series, it was important to recognise that the potential difference across each lamp is 3.0 V. From the I-V graph, this meant a current I_S of about 0.36 A. For the lamps in parallel, the current in each lamp was 0.50 A because the potential difference across each lamp was 6.0 V. This meant that the current I_P was twice the current in each lamp; 1.00 A. The current I_P is about 2.8 times greater than current I_S. This final step of the analysis

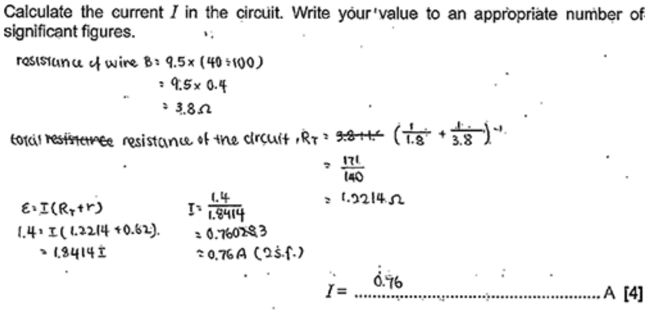
					was often omitted by most of the candidates. A significant number of candidates scored no marks here and about 10% of the candidates omitted this question altogether. **Misconception** The most common mistake made by candidates, across the ability spectrum, was to assume that each lamp had a constant resistance of 12 Ω in the series combination. A lamp is a non-ohmic component. At a potential difference of 3.0 V, the resistance of each lamp is about 8.3 Ω.
			Total	**4**	
5 3			V across 750 Ω = 45 − 0.03 × 1000 = 15 (V)	C1	several methods available, e.g.
			current in 750 Ω = 15/750 = 0.02 (A)	C1	find the total resistance = 45/0.03 = 1500 (Ω) resistance of parallel pair = 500 (Ω)
			current in **R** = 0.01 (A)	C1	R = $(500^{-1} - 750^{-1})^{-1}$ = 1500 (Ω)
			R = 15/0.01 = 1500 (Ω)	A1	or use potential divider argument.
			Total	**4**	
5 4			Resistance of LDR decreases / (total) resistance (of circuit) decreases (AW)	M1	
			Current / ammeter reading increases (AW)	A1	
			With increase in current the p.d. across (fixed) resistor / 1.2 kΩ resistor increases (AW)	B1	**Allow** p.d. across resistor increases / p.d. across LDR decreases / resistor has greater share of p.d. / LDR has smaller share of p.d.
			(For fixed e.m.f.) voltmeter reading decreases (AW)	B1	**Examiner's Comments** This part expected candidates to explain how the ammeter and voltmeter readings would change. Answers were sometimes convoluted and not clear; for example, it was not always clear as to whether candidates were referring to the resistance of the LDR, fixed resistor or the circuit. Candidates should be encouraged to structure their answers in a logical manner. Few candidates could explain clearly why potential difference across the LDR decreased.
			Total	**4**	
5 5			−1.0 V to 2.6 V: I = 0 / negligible and R = ∞ / (very) large (AW)	B1	
			2.6 V to 3.0 V: R decreases	B1	**Allow** ‘rapid decrease in R’

			3.0 V to 3.4 V: *R* decreases	B1	**Allow** 'slow decrease in *R*' **Not** *R* is constant (because it is a straight line)
			Justification of a B1 point in terms of *R* = *V/I*. For example to show: • *R* is infinite: *R* = 2.0/0 = ∞ • *R* decreases: *R* calculated once and has *R* = ∞, or *R* calculated twice	B1	**Not** *R* = gradient^{-1} **Ignore** powers of 10 and units **Note**: *V* and *I* values within ±1 small square **Examiner's Comments** Most candidates scored two or more marks, but examiners felt that there were many missed opportunities here. The most common error was to quote the resistance of the LED as zero when it was not conducting. Sadly, this was often supported by the calculation *R* = *V*/0 = 0. A number of candidates attributed the decrease in the resistance beyond 2.6 V to the '*increase in the temperature of the LED'*. The straight line section of the graph for the last voltage range led many candidates to quote Ohm's law and the statement that 'the resistance of the *LED is* constant'. A very small number of candidates opted to write about a bulb or a lamp. Top-end candidates effortlessly used *R* = *VII* to calculate the resistance at various p.ds and draw sensible conclusions from their calculations.
			Total	**4**	
5 6			Circuit with cell in series with an ammeter and variable resistor. A voltmeter is connected across the variable resistor / (terminals of the) cell	B1	**Allow** this B1 mark for a clearly drawn circuit with correct symbols for the cell, variable resistor, voltmeter and ammeter. **Allow** a battery symbol instead of symbol for a cell
			Measure current and p.d./voltage across variable resistor / cell	B1	**Allow** 'terminal p.d.' for p.d. across the cell **Allow** 'measure *I* and *V*' if the circuit is correct **Allow** 'measure voltmeter and ammeter readings' if the circuit is correct Possible ECF for incorrect symbol for variable resistor **Examiner's Comments** Candidates were familiar with this experiment and some gave answers using the bullet points as prompts. Although most candidates scored two or more marks, there were some missed opportunities. The most common error was the incorrect symbol for the variable resistor in the circuit. It was either a thermistor symbol or a hybrid. Some candidates also lost a mark for not clearly specifying the graph being plotted. Instead of *'Plot a graph of V against I and determine the gradient which is equal to the internal resistance*', examiners were faced with less robust statements such as '*Plot a graph and find the gradient*' or '*Use the data to draw a graph and use E = V +Ir to calculate r'*.
			Correct description of how to get multiple readings (of current or p.d) E.g. change the resistance of the variable resistor / use different value resistors, etc.	B1	
			(*E* = *V* + *Ir*) Plot a graph of *V* against *I* and the	B1	

			gradient (of the graph / line) is equal to (−) *r* (AW)		
			Total	**4**	
57			The resistance of the thermistor increases.	B1	
			The current in the circuit decreases.	B1	
			The p.d. across the resistor decreases because of $V = IR$ or $V \propto R$.	B1	
			The p.d. becomes constant. (AW)	B1	
			Total	**4**	
58		i	(Current causes) increase in temperature of thermistor Resistance of thermistor decreases (and hence *V* decreases) **or** Current in the circuit increases, p.d. across resistor increases (and hence *V*decreases)	B1 B1	**Allow** warms up / heat ups **Ignore** increase temperature of the circuit
		ii	V = 2.4 (V) or V_R = 3.6 (V) I = 0.30 (A) resistance = 8.0 (Ω) **OR** V = 2.4 (V) and a potential divider equation / idea 2.4 = $\frac{R}{R+12} \times 6.0$ or $\frac{R}{2.4} = \frac{12}{3.6}$ resistance = 8.0 (Ω)	C1 C1 A1 C1 C1 A1	**Not** V = 2.2 (V); misreading **Allow** ECF if V = 2.2 (V) is used **Allow** 8 (1 SF answer) **Not** V = 2.2 (V); misreading **Allow** ECF if V = 2.2 (V) is used **Allow** 8 (1 SF answer)
			Total	**5**	
59	a	i	Resistance of parallel combination = 40 (Ω) $I = \frac{4.2 - 1.5}{40 + 33}$ I = 0.037 (A)	**C1** **C1** **A1**	**Allow** $(1/60 + 1/120)^{-1}$ **Allow** 2 marks for $I = \frac{4.2 + 1.5}{40 + 33} = 0.078$ (A) **Examiner's Comment** The success in this question hinged on understanding the effect of two opposing e.m.f.s in a circuit and determining the total resistance of the circuit. About a third of the candidates produced well-structured and reasoned answer leading to the correct current of 0.037 A. Most candidates picked up a mark for determining the total resistance of

					the two parallel resistors (40 Ω). The total e.m.f. in the circuit is 2.7 V and the total resistance is 73 Ω. Those using a total e.m.f. of 5.7 V ended up with the incorrect current of 0.078 A; two marks were awarded for this answer. A small number of candidates tried to calculate the current using either using 1.5 V or 4.2 V or 33 Ω.
		ii	Any <u>two</u> from: The current decreases up to 1.5 V The current is zero at 1.5 V The current changes direction / is negative when < 1.5 V The current increases below 1.5 V	**B1×2**	**Allow** 'current is zero when the e.m.f.s are the same' **Examiner's Comment** Most of the answers here showed poor understanding of the circuit in Fig. 18.1. Nothing could be awarded for vague answers such as *'current decreases because $I \propto V$'* or *'e.m.f. decreases so current decreases'*. The current decreases as the e.m.f. of the supply approaches 1.5 V, at 1.5 V the current is zero, the direction of the current reverses and its magnitude increases when the e.m.f. of the supply gets below 1.5 V. About a quarter of the candidates gave credible answers.
	b		**Level 3 (5-6 marks)** Clear description including a reasonable estimate of r **and** clear limitations *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)** Some description with an attempt to estimate r **and** some limitations *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 *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1×6**	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. **Indicative scientific points may include:** **Description and estimation** • Correct circuit with (variable) resistor, ammeter and voltmeter • Correct symbols used for all the components • R changed to get different values for P • $R = V / I$ (using ammeter and voltmeter readings) or R measured directly using an ohmmeter with the variable resistor isolated from the circuit or R read directly from a resistance box • Power calculated using $P = V^2/R$ or $P = VI$ or $P = I^2R$ • The value of r is between 1.0 to 3.0 Ω • A smooth curve drawn on Fig. 18.2 (to determine r) • A better approximation from sketched graph or r is between 1.5 and 2.7 Ω • Any attempt at using $E = V + Ir$, with or without the power equation(s) to determine r - even if the value is incorrect **Limitations** • 'More data' required • Data point necessary at R = 2.0 Ω / More data (points) needed between 1 to 3 Ω • No evidence of averaging / Error bars necessary (for both P and R values) **Examiner's Comment** This was a level of response (LoR) question had three ingredients - drawing a viable circuit diagram that would enable the data shown in

					Fig.18.2 to be reproduced, using the figure to estimate the internal resistance of the cell and finally outlining any limitations of the data displayed in the figure. There is no one perfect model answer for a level of response question. A variety of good answers did score top marks. Most circuit diagrams were correct and well-drawn. There was the occasional mistake with the circuit symbol for a variable resistor; the thermistor symbol was a regular substitute. Most candidates drew a smooth curve on Fig. 18.2 and used this to estimate the internal resistance of the cell. Many also realised that the data points showed no evidence of averaging or error bars and that there were missing data points between 1.0 Ω and 3.0 Ω. Some candidates wanted *'more data points spaced regularly at interval of 0.5* Ω', which was a sensible suggestion. Some weaker candidates attempted to draw a straight line of best-fit through the data points and then tried to determine the internal resistance from the gradient. There was a good spread of marks amongst the three levels.
			Total	**11**	
60		i	(R_B =) 9.5 × 0.40 **or** 3.8 (Ω) (parallel resistance =) $[3.8^{-1} + 1.8^{-1}]^{-1}$ **or** 1.22…(Ω) (total resistance =) 1.22.. + 0.62 **or** 1.84 (Ω) $I = \frac{1.4}{1.22...+0.62}$ I = 0.76 (A)	C1 C1 C1 A1	Possible ECF from R_B Possible ECF from parallel resistance Possible ECF from total resistance **Allow** 3 marks for 0.66 A; R_B = 9.5 Ω used **<u>Examiner's Comments</u>** This circuit question required multiple steps to calculate the current *I* in the circuit. Firstly, the candidates had to determine the resistance of wire B, then sort out the parallel combination of resistors A and wire B, and eventually deal with the whole circuit which included the internal resistance of 0.62 Ω. The question discriminated well, with almost half of the candidates securing full marks. The responses were often well-structured and demonstrated skilled use of calculators. Some responses were spoilt by premature rounding of numbers, but generally, candidates were sensible in retaining numbers on their calculators for subsequent stages of the calculation. Exemplar 10 below shows an immaculate response from a middle-grade candidate. **Exemplar 10**

						 Calculate the current I in the circuit. Write your value to an appropriate number of significant figures. resistance of wire B = 9.5 × (40 ÷ 100) = 9.5 × 0.4 = 3.8 Ω total resistance of the circuit, R_T = $\left(\frac{1}{1.8} + \frac{1}{3.8}\right)^{-1}$ = $\frac{171}{140}$ = 1.2214 Ω $\varepsilon = I(R_T + r)$ 1.4 = I(1.2214 + 0.62) = 1.8414 I $I = \frac{1.4}{1.8414}$ = 0.760283 = 0.76 A (2 s.f.) I = 0.76 A [4] All the stages of the calculations are easy to see in this well-structured response. This candidate has not rounded any of the numbers between stages – a very admirable strategy. The final response is quoted to 2 significant figures as required. **Misconception** Some of the most common mistakes are summarised below: • Calculating the total resistance using either $(3.8^{-1} + 1.8^{-1} + 0.62^{-1})$-1 or (3.8 + 1.8 + 0.62). • Forgetting to include the internal resistance when calculating the current.
		ii		$P = IV$ **or** $P = I^2R$ **or** $P = \frac{V^2}{R}$ (P_{int} =) $0.76^2 \times 0.62$; (P_{total} =) 1.4 × 0.76; ratio = $\frac{0.76^2 \times 0.62}{1.4 \times 0.76}$ ratio = 0.34	C1 A1	Possible ECF from **(a)(i)** **Note** there are many other correct methods **Allow** 0.34:1 **Not** an answer expressed as a fraction, e.g 31/92 **Examiner's Comments** Most candidates scored 1 mark for using an appropriate power equation. The main obstacle here for the candidates was what quantities to use for the total power supplied by the cell. Quite often, the internal resistance was omitted and $0.76^2 \times 1.22$ was used for calculating the total power. Top-end candidates used the easier alternative of 1.4 × 0.76.
				Total	**6**	
61		i		$V = \frac{1.1}{6.8 + 1.4 + 1.1} \times 6$ 0. 71 (V)	**C1** **A1**	**Allow** $I = \frac{6}{(6.8+1.4+1.1)\times 10^3} = 0.00065$ **Allow** 0.7 **Examiner's Comments** Candidates who use the potential divider equation invariably gained

					the correct answer of 0.71 V. Alternatively, some candidates correctly determined the current and then determined the voltmeter reading.
		ii	As temperature of thermistor increases, resistance of thermistor decreases Total resistance of circuit decreases or current increases Greater proportion of p.d. across fixed resistor or p.d. across fixed resistor increase Reading on the voltmeter will increase	**B1** **B1** **M1** **A1**	**Examiner's Comments** Candidates were expected to explain how the voltmeter reading would change as the temperature of the thermistor increased. Good answers used a step-by-step approach. Candidates needed to explain how the potential difference of across the fixed resistor would change. It was essential that clearly defined terms were used – often candidates referred to V_1, R_2, or p.d. and resistance without indicating explicitly the meaning of V_1, R_2, or explaining which p.d. or resistance was being referred to.
			Total	**6**	
62	a		**Level 3 (5 – 6 marks)** Clear planning and correct identification of terminals and position of components *There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.* **Level 2 (3 – 4 marks)** Clear planning and correct identification of some components / terminals *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)** Some planning and / or an attempt at identifying component / terminals *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1 × 6**	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks,** **L2^ for 3 marks, etc.** **Indicative scientific points may include:** **Planning** • suitable circuit arrangements / diagrams drawn between two points which could be connected to the box terminals • use of R to limit current, e.g. to find CD terminals • logical plan of connection across terminals e.g. connect circuit to each pair of terminals in turn • identify terminals C and D as the circuit with the largest current / smallest resistance • A and B identified because CD known **or** the circuit including terminals AC / D has the smallest current / largest resistance **Identifying** • $V = IR$ quoted or used in calculations • $R_T = \Sigma R$ used to determine the 220Ω or the 470Ω resistors • For 220 Ω resistor (between AB or BC / D) current is 27 (mA) A **or** 19 (mA) with R • For 470 Ω resistor (between AB or BC / D) current is 13 (mA) **or** 11 (mA) with R • For both resistors (between AC / D) current is 8.7 (mA) **or** 7.6 (mA) with R • For wire (between CD) current is 0.060 A **Examiner's Comments** This level of response (LoR) question had two strands – planning how to determine the positioning of two resistors inside an unlabelled four terminal box and then verifying the values of their resistances. Some candidates concentrated on determining the labelling of the terminals;

					others assumed the positions and explained how the resistances could be determined. Many candidates made the task more difficult than necessary. For example it was intended that once terminals **C** and **D** had been identified, **C** could only be lower left and not lower right, and hence the positions of **A** and **B** were also identified. A very common circuit used to determine the resistances placed the supply between **A** and **C** with the given resistor **R** between **B** and **D,** leading to calculations requiring combinations of resistors in series and parallel. Many ignored the limiting resistor **R** and probed the box without it, a few stating that the current between **C** and **D** would be zero with the supply across **CD.** Some answers lacked any circuit diagram and some 15% failed to attempt the question. Weaker candidates were confused as to when the resistors were connected in series or in parallel. Generally, the responses were clearer in terms of planning than identifying. Comments such as *and then you can work out the arrangement of the resistors* were common without showing how this could be done. A small number of candidates introduced a voltmeter and others wanted to position the ammeter 'inside' the box.
	b	i		**B1**	two arrows needed **not** across resistor; allow a surrounding circle with arrows outside circle
		ii	**1** from graph 3.0 (kΩ) I = 4.0 / 3.0 = 1.33 × 10^{-3} A **or** R = 2.0 / 4.0 × 3.0 × 10^3 R = (6.0 − 4.0) / 1.33 × 10^{-3} = 1.5 × 10^3 (Ω) **2** at 2.4 V R_{LDR} = 1.0 kΩ giving 2.5 (W m^{-2})	**B1** **C1** **A1** **M1** **A1**	**allow** 3.1 ± 0.1 (kΩ) **accept** 1.3 mA; **accept** potential divider argument **allow** 1.5 kΩ; **special case:** using 2.4 V in place of 4.0 V gives R = 4.5 kΩ; give 1 mark out of 2 **ecf (b)(ii); allow** potential divider or I = 2.4 mA; **for special case:** R_{LDR} = 9.0 kΩ ; give 1 mark out of 2 allow 2.4 to 2.6 W m^{-2} **N.B. remember to record a mark out of 5 here** **Examiner's Comments** More than half of the candidates knew the correct circuit symbol for an LDR. The most common error was to draw an LED. More candidates used a potential divider approach to solve the problem than calculated the current in the circuit; many gaining full marks. Those who misread the question and reversed the voltages required to switch the lamp on and off were given some credit for their answers.
			Total	**12**	
6 3		i	R = 2.0 + 8.0 = 10 (Ω) (I = 1.2/10); I = 0.12 (A) (1.5 = 1.2 + 0.12r); r = 2.5 (Ω)	**C1** **C1** **A1**	**Allow** other correct methods **Allow** 2 marks for 4.5 (Ω); R = 18 Ω with I = 0.067 (A) **Examiner's Comments** This question required careful examination of a series circuit. The answer was very much dependent on knowing that 1.2 V was the p.d.

					across the 2.0 Ω **and** half of the resistance wire. Using total resistance other than 10.0 Ω led to incorrect value for the internal resistance. Less than about a third of the candidates secured full marks. Some of the most frequent difficulties were: • Assuming the p.d. across the 2.0 Ω resistor was 1.2 V. • Using 1.5 V as the terminal p.d. rather than 1.2 V. • Experiencing problems rearranging the equation $E = V + Ir$.
		ii	As *d* increases the (total) resistance (of the circuit) increases (ORA) and therefore the current / *I* decreases (ORA) Any one from: • Explanation of V increasing in terms of $V + Ir = E$ or $V + V_r$ = 1.5 or $V = E$ - lost volts • Explanation of V increasing in terms of potential divider • Analysis showing $V \approx 0.7$ V when d = 0 or $V \approx 1.3$ V when d = 1.0 m or any other value of V for a given d	**M1** **A1** **B1**	**Allow** 'As length (of wire) increases resistance increases' (ORA) **Allow** 'lost volts / p.d across r / Ir decreases, so V increases' **Examiner's Comments** The question required an explanation in terms of the current in the circuit as the distance d increased. Many candidates realised that the increase in the length of the resistance wire meant an increase in the total resistance of the circuit and hence, a smaller current in the circuit. Some went one step further and correctly concluded that V increases as the p.d. across the internal resistance decreases. A significant number of candidates either described the variation V with d without any explanation or guessed the physics. No credit could be given for answers such as 'the *graph gets less steep'* and *'the current changes because the electrons have to travel a longer length'*.
			Total	**6**	
6 4			*Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Typically, circuit including meters is correctly drawn on Fig. 4.2(b). Explanation of action of **both** circuits is correct. Presence of 100 Ω explained. *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)** Typically, circuit including meters is correctly drawn on Fig. 4.2(b). Action of only Fig. 4.2(b) circuit explained correctly. Purpose of 100 Ω stated but value not	B1	**Indicative scientific points may include** **circuit diagram** 1. resistor and LED in series 2. ammeter in series and voltmeter in parallel with LED 3. correct symbols for LED, ammeter, voltmeter, etc. 4. correct polarity of LED **action of circuit** 1. circuit completed on Fig. 4.2(b) 2. voltage across **AB** can be varied from 0 to 6 V 3. some justification; e.g. potential divider circuit 4. in Fig. 4.2(a) circuit voltage only varies from 6 to about 5.6 V as resistance can only be varied from 110 to 100 Ω (+ LED)/AW **presence of 100 Ω resistor**

			justified. *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)** Typically, circuit including meters is correctly drawn on Fig. 4.2(a). No correct explanations **or** basic information on the action of circuit **or** presence of 100 Ω resistor. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear* **0 marks** No response or no response worthy of credit.		1. the current in the circuit is limited by the resistor so ensures LED cannot burn out 2. at 6 V the potential divider across **AB** gives 2 V across LED as its resistance is about 50 Ω / AW
			Total	**6**	

6
5
			Level 3 (5–6 marks)
			Clear explanation, some description **and** both resistance values correct
			
			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)
			Some explanation, limited or no description **and** both resistance values correct
			OR
			Clear explanation, limited or no description **and** calculations mostly correct / one correct calculation
			OR
			Clear explanation, some description **and** no calculations
			
			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)
			Some explanation
			OR
			Some description
			OR
			Some calculation
				B1 × 6	**Indicative scientific points may include:**
					
					Explanation of trace
					
					• The 'trace' is because of light reaching and not reaching LDR
					• Resistance of LDR varies with (intensity) of light
					• In light
					  ○ resistance of LDR is low
					  ○ p.d. across LDR is low
					  ○ p.d across resistor (or V) is high
					  ○ current in circuit is large
					• In darkness
					  ○ resistance of LDR is high
					  ○ p.d. across LDR is high
					  ○ p.d across resistor (or V) is low
					  ○ current in circuit is small
					• V_{max} = 4.0 V; V_{min} = 2.0 V
					• Potential divider equation quoted
					• Substitution into potential divider equation
					
					Description of determining frequency
					
					• Time between pulses is constant because of constant speed
					
					• Time between pulses = 0.4 (s)
					• $f = 1/T$
					• frequency = 2.5 (Hz)

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks
No response or no response worthy of credit

Calculations

- Resistance of LDR is 150 (Ω) in light
- Resistance of LDR is 1500 (Ω) in darkness

Examiner's Comments

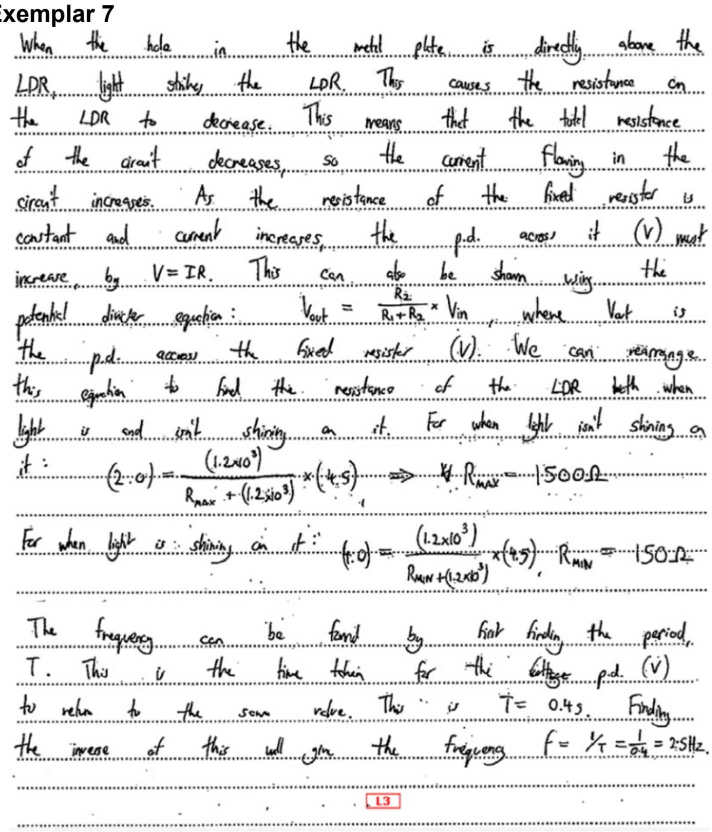
This was one of the two LoR questions. It required understanding of potential dividers, light-dependent resistor and rotation frequency of a spinning plate.

Examiners expect varied responses, and two very dissimilar answers can score comparable marks as long as the criteria set out in the answers' section of the marking scheme are met. Level 3 answers had the correct maximum and minimum resistance values of the LDR, a decent description and explanation of the trace shown in Fig. 17.2, and an outline of how the frequency of the spinning plate was determined. As mentioned earlier, eclectic answers are inevitable – verbose and concise answers can be at Level 3.

In Level 2 answers there were generally missed opportunities. Half-done calculation and descriptions either with some errors or lacking in depth. Level 1 answers had some elements of calculations or descriptions.

The two exemplars below, illustrate a Level 3 response and a Level 1 response.

Exemplar 7



When the hole in the metal plate is directly above the LDR, light strikes the LDR. This causes the resistance on the LDR to decrease. This means that the total resistance of the circuit decreases, so the current flowing in the circuit increases. As the resistance of the fixed resistor is constant and current increases, the p.d. across it (V) must increase by V = IR. This can also be shown using the potential divider equation: $V_{out} = \frac{R_2}{R_1+R_2} \times V_{in}$, where V_{out} is the p.d. across the fixed resistor (V). We can rearrange this equation to find the resistance of the LDR both when light is and isn't shining on it. For when light isn't shining on it: $(2.0) = \frac{(1.2\times10^3)}{R_{max} + (1.2\times10^3)} \times (4.5) \Rightarrow R_{MAX} = 1500\Omega$

For when light is shining on it: $(4.0) = \frac{(1.2\times10^3)}{R_{MIN} + (1.2\times10^3)} \times (4.5)$, $R_{MIN} = 150\Omega$

The frequency can be found by first finding the period, T. This is the time taken for the p.d. (V) to return to the same value. This is T = 0.4 s. Finding the inverse of this will give the frequency $f = 1/T = \frac{1}{0.4} = 2.5Hz$.

L3

This is a Level 3 response from a top-end candidate who scored 6

					marks. The description of the variation of the resistance of the LDR, the circuit current and the potential difference across the fixed resistor is perfect. The calculations of the LDR resistances are nicely embedded into the general explanation. The calculation of the frequency is all correct. This is a model answer for 6 marks. Compare and contrast this with the Level 1 response below. **Exemplar 8** When the light shines through the hole onto the LDR, the resistance decreases, causing the pd across the fixed resistor to increase, and vice versa when the light is blocked again. Determine the frequency by seeing how long the plate takes to rotate, so from pd increase to pd increase, 0.4 seconds frequency= $\frac{1}{T}$ frequency= 2.5 L1 This is a Level 1 response from an E-grade candidate. The description of the variation of the resistance of the LDR is correct. However, there are no calculations of the resistance of the LDR, as required in the question. Hence, a significant part of the question has been omitted. According to the marking criteria, this could only score Level 1. The examiner credited 2 marks for this response.
			Total	**6**	
6 6			* **Level 3 (5–6 marks)** Circuit including meter is correctly drawn. Explanation of action of circuit is correct. Concept of sensitivity understood and 750 Ω justified (4 marks) LDR wrong symbol or value of resistor not fully justified (5 marks). *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)** Circuit has correct symbol for LDR Action of circuit explanation limited 750 Ω stated but not justified Concept of sensitivity (4 marks)	B1	**circuit diagram** 1. resistor and LDR in series 2. ammeter in series or voltmeter in parallel with resistor 3. correct symbols for LDR, ammeter, voltmeter, etc. **action of circuit** 1. when light intensity increases R of LDR falls 2. so I in circuit increases or V across resistor increases or V across LDR decreases (meter reading increases). **meter and sensitivity** 1. need the largest change in current or voltage for a given change in light intensity

			Any point omitted or incorrect (3 marks). *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)** Correct symbol for LDR (1 mark) Action of circuit only addresses point (1 mark) Sensitivity poorly addressed (1 mark) (Maximum 2 marks) *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		2. choose resistor of 750 Ω to give the largest change on the meter **or** need a meter which can display small changes in value of current or voltage.
			Total	**6**	
6 7			* **Level 3 (5–6 marks)** Explanation is complete with E1, 2 and 3 For calculation expect C3 At least two limitations mentioned. *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)** Expect two points from E1, 2 and 3 Expect either C1 or C2 for the calculations Expect at least one limitation Limitation identified but calculations are inappropriate. *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)** Expect at least one point from explanation Expect C1 and an attempt at C2 Limitations given are inappropriate.	B1	**Explanation (E)** 1. Total resistance decreases as temperature increases (allow reverse argument) 2. Current in circuit increases as temperature increases or p.d. is in the ratio of the resistance values 3. Therefore, the p.d. across resistor increases or p.d. across thermistor decreases **Calculations (C)** 1. $I = V / R$ used to show current increases as temperature increases 2. Potential divider equation (or $I = V / R$ and $R = R_1 + R_2$) used to calculate the voltmeter reading at either 200 °C or 300 °C • V_{300} = 6.0 × 25/(25 + 500) = 0.29 V • V_{200} = 6.0 × 60 /(60 + 500) = 0.64 V) 3. Potential divider equation used to calculate the voltmeter reading at **both** 200°C and 300 °C **Limitation (L)** 1. The change in resistance is small when resistance of thermistor changes from 200 °C to 300 °C 2. Change in voltmeter reading is too small over this range 3. Non-linear change of resistance with temperature

<table>
<tr>
<td></td><td></td><td></td>
<td>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.

0 marks
No response or no response worthy of credit.</td>
<td></td>
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</tr>
<tr>
<td></td><td></td><td></td>
<td>Total</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>68</td><td></td><td></td>
<td>Level 3 (5–6 marks)
E and r calculated correctly and table completed correctly and clear description of P and R

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)
Table completed correctly and some description of P and R / some attempt at E and r
OR
E and r calculated correctly
OR
Some attempt at calculating E and r and some description of P and R

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 calculation of E and r
OR
Table completed correctly
OR
Limited description of relationship between P and R

There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.

0 marks
No response or no response worthy of credit</td>
<td>B1×6</td>
<td>Indicative scientific points may include:

Calculating E and r

$E = Ir + V$
gradient = (-) r
y-intercept = E
Line extrapolated to y-axis
E = 1.2 (V)
r = 0.8(0 Ω)

Table and description

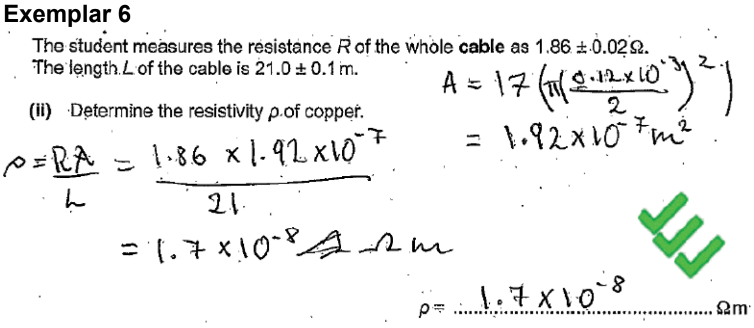
Table completed (ignore SF) – see below
R increases as V increases (or I decreases)
P increases and decreases
Maximum power is when internal resistance is equal to R (0.8 Ω)

<table>
<tr><th>V / V</th><th>I / A</th><th>R / Ω</th><th>P / W</th></tr>
<tr><td>0.20</td><td>1.25</td><td>0.16</td><td>0.25</td></tr>
<tr><td>0.40</td><td>1.00</td><td>0.40</td><td>0.40</td></tr>
<tr><td>0.60</td><td>0.75</td><td>0.80</td><td>0.45</td></tr>
<tr><td>0.80</td><td>0.50</td><td>1.60</td><td>0.40</td></tr>
<tr><td>1.00</td><td>0.25</td><td>4.00</td><td>0.25</td></tr>
</table>

<u>Examiner's Comments</u>

This is the first LoR question on the paper. This question is based on a standard physics practical, so the experimental set up should have been familiar to many candidates. While a holistic approach is taken to the marking, there are key points which should be present for the award of given levels. The question is structured in two main parts: the determination of E and r, and then the calculation of R and P for the table. However, each of these parts contain additional instructions which were often ignored by the candidates. For the emf and internal resistance, an explanation of the method used was required, the most usual way would be based around a rearrangement of $E = V + Ir$. For the resistance and power, a qualitative description of how they are related is needed, along with an appreciation that when the internal resistance equals the load resistance the power is at its maximum.</td>
</tr>
</table>

					For the most part, candidates carried out the calculations well, completing the table and identifying E and r correctly, but did not give suitable and detailed descriptions leading to them being limited to lower levels. Very few discussed the resistance and power relationship at all, despite it being a reasonably simple pattern. It is very important that candidates make note of all that is required in a LoR question if they are to access the higher levels. The vast majority of candidates did sufficient work to place them in Level 2. **Misconception** Many candidates missed opportunities to achieve a higher level by not explaining their reasoning and not describing the pattern of R with P.
			Total	**6**	
6 9			**Level 3 (5–6 marks)** Correct circuit diagram **and explanation including detailed calculations and** explanation of circuit for different light intensities. *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)** A diagram, some calculations / explanation. *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 diagram with incorrect position of voltmeter and limited calculations / explanation OR correct diagram with correct symbols. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	B1 × 6	**Indicative scientific points may include:** **Circuit Diagram** • Potential divider circuit • Correct symbols • Battery / power supply of at least 6.0 V • Voltmeter • Voltmeter correctly positioned across fixed resistor. **Explanation and calculations** • Potential divider equation • Appropriate value of fixed / variable resistor • V_{out} calculated when LDR is in very bright light / resistance value calculated • V_{out} calculated when LDR does not receive light / or resistance value calculated. **Explanation for different light intensities** • Use of variable resistor • Effect of increasing / decreasing the resistance of the fixed resistor.
			Total	**6**	

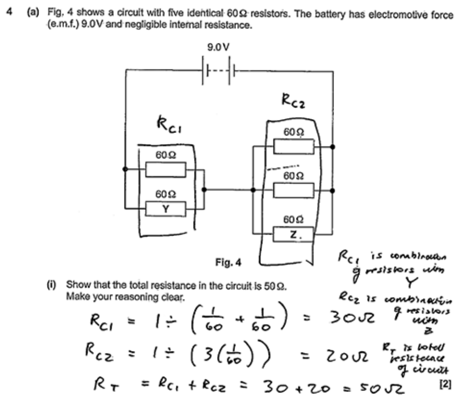
70		i	Micrometer Repeat readings <u>in different directions/along wire/different wires and</u> average	B1 B1	**Allow** calliper **Not** vernier scale **<u>Examiner's Comments</u>** Most candidates were able to identify a suitable measuring instrument such as a micrometer. To score the second mark candidates were expected to explain the purpose of repeating readings that the reading would be repeated in different directions or along the wire and the mean or average diameter would be determined. to assure that the outcome is precise.
		ii	$A = \frac{\pi \times (0.12\times10^{-3})^2}{4} = 1.13 \times 10^{-8}$ OR $\rho = \frac{1.86 \times A}{21}$ $\rho = \frac{17 \times 1.86 \times 1.1 \times 10^{-8}}{21}$ $\rho = 1.7 \times 10^{-8}$ (Ω m)	C1 C1 A1	**Note** ρ must be the subject **Allow** 2 marks for 1.0×10^{-9} (factor of 17 omitted) **Allow** 2 marks for 6.8×10^{-8} (diameter used instead of radius) **Allow** 2 marks for 0.017 (POT omitted) **<u>Examiner's Comments</u>** A very large number candidates did not take into account that the resistance of the cable was the resistance of 17 wires in parallel. Many candidates did not clearly show their working. Good candidates calculated the cross-sectional area of one wire and then correctly rearranged the resistivity equation from the data booklet. Some lower ability candidates had difficulty in calculating the cross-sectional area of the wire and there were often power of ten errors. **Exemplar 6**  This candidate has correctly approached the question by determining the total area of the copper in the cable and then correctly used the equation.

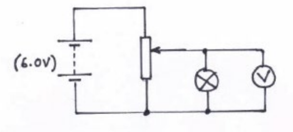
					Again, the equations used are clearly demonstrated.
		iii	$\frac{0.1}{21}$ or $\frac{0.02}{1.86}$ or $\frac{0.01}{0.12}$ $\left(\frac{0.1}{21}+\frac{0.02}{1.86}+2\times\frac{0.01}{0.12}\right)\times 100 = 18\,(.2)\%$	**C1** **A1**	**Allow** max/min methods ρ_{max} = 2.03 × 10^{-8} and ρ_{min} = 1.41 × 10^{-8} (B1) $\frac{\Delta\rho}{\rho}x100$ (B1) **Allow** 17.8% Do not penalise significant figures **Allow** 1 mark for 9.88% **Allow** 20% with evidence of working **Examiner's Comments** Many candidates clearly determined the percentage uncertainties on L, R and d which gained the first mark. A common final answer (which scored one mark) was 9.88% because candidates did not multiply the percentage uncertainty in d by two to allow for d^2. Some candidates attempted a maximum or minimum method − this was a long method and it was easy to make an error. When working out the maximum value, the maximum value of R and d needed to be used with the minimum value of L.
			Total	**7**	
71		i	Arrow in anticlockwise direction	B1	**Allow** this mark for correct direction shown on diagram either on or off connecting wires **Examiner's Comments** This question required the candidates to appreciate that the sum of the emfs will lead to an anticlockwise conventional current. This question was answered well by the majority of candidates, however a number put two directions on, one from each cell. **Misconception** The unusual setting out of the circuit meant that some candidates were unsure whether parts of the circuit were in series or parallel. This could have been overcome by following the circuit or even by redrawing it.
		ii	(E =) 4.5 – 2.4 **or** (R_T =) 0.80 + 0.50 + 1.2 4.5 – 2.4 = I × (0.80 + 0.50 + 1.2) I = 0.84 (A)	C1 C1 A1	E = 2.1 (V); R_T = 2.5 (Ω) Treat missing 1.2 resistance as TE **Allow** 2 marks for 2.8 (A); E = 6.9 V used **Examiner's Comments**

					This calculation required the candidate to set out the whole circuit in one. Around one third did not score any marks on this question as they attempted to treat each cell individually and then produce some form of average. Other common misunderstandings included treating the 0.5 ohm and 0.8 ohm resistors as if they were in parallel, and adding the emfs.
		ii i	($I = Anev$) $0.84 = \pi \times (2.3 \times 10^{-4})^2 \times 4.2 \times 10^{28} \times 1.60 \times 10^{-19} \times v$ $v = 7.5 \times 10^{-4}$ (m s^{-1})	C1 A1	Possible ECF from **(ii)** Note answer is 2.5×10^{-3} (m s^{-1}) for $I = 2.76$ (A) **Allow** 1 mark for 1.9×10^{-4}; diameter used as radius **<u>Examiner's Comments</u>** This question was well done by a large number of candidates, many of whom scored full marks by correctly following through with their value of current from the previous part. Few candidates used the diameter instead of the radius when determining the cross sectional area, and for the most part the setting out of the calculation meant that credit could be given even if arithmetic errors occurred later.
		i v	Sensible suggestion, e.g. use a water bath / fan / only switch on when taking readings Need to lower the temperature / reduce resistance of **R**	M1 A1	**Allow** keep the surroundings cold **Allow** to keep the temperature / resistance constant **OR allow** increase in temperature increases resistance **<u>Examiner's Comments</u>** Candidates were expected to provide any method of cooling the circuit, or preventing it heating in the first place. A wide variety of solutions were given and as long it is viable, it was credited. **Misconception** Some candidates gave perfectly viable solutions, but these involved changes to the circuit, which was not allowed in the question. It is very important to make sure than any response does fit what is being asked.
			Total	**8**	
7 2	a		Any <u>one</u> from: current, temperature, light intensity and amount of substance / matter	**B1**	**Not:** ampere, kelvin, candela and mole **Not** correct quantity with its unit, e.g. current in A or current (A) **Examiner's Comment** Most candidates could not state an unambiguous base quantity. There was no credit for a correctly named quantity accompanied by its S.I. unit, e.g. *'current in ampere'*. Some answers were just wrong; these include *force, charge, energy* and *kelvin.*

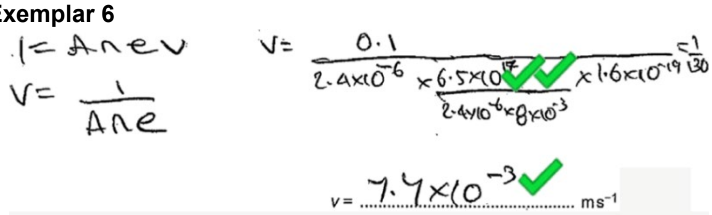
b	i	$R = \frac{\rho L}{A}$ **and** $A = \pi\left(\frac{d}{2}\right)^2$ $R_X = \frac{4\rho L}{\pi d^2}$ and $R_Y = \frac{8\rho L}{\pi d^2}$ Clear steps leading to $R = \frac{12\rho L}{\pi d^2}$	M1 A1	**Examiner's Comment** Most candidates were familiar with the equations $R = \rho L / A$ and $A = \pi d^2/4$. The modal score here was two marks. Most scripts had well-structured answers and demonstrated excellent algebraic skills. A variety of techniques were employed to determine the total resistance of the two resistors in series.
	ii	**1** Ruler / tape measure (for L) **and** micrometer (for d) R = 2.3(4) (Ω) $\frac{0.1}{9.5}$ or $2\times\frac{0.003}{0.270}$ **2** $\frac{0.1}{9.5} + 2\times\frac{0.003}{0.270}$ or 0.0327 or 3.: absolute uncertainty in R = 0.0327 × 2.34 = 0.077 R = 2.3 ± 0.1 (Ω) **3** (The actual) R is large(r) **because** (the actual) d is small(er) or (the actual) A is small(er) or $R \propto 1/d^2$	B1 C1 C1 C1 A1 B1	**Allow** (vernier / digital) calipers or travelling microscope for micrometer **Allow** other correct methods for getting 2.3 ± 0.1 (Ω) **Allow** 2 or more sf for this C1 mark **Note** 0.0105 or 1.05% or 0.0222 or 2.22% scores this mark, allow 2sf or more **Allow:** 2.34 ± 0.08 (Ω) **Note** use of R_X or R_Y instead of R can score the second and third C1 marks only **Allow:** The calculated R is small(er) **because** (the measured) A is large(r) or $R \propto 1/d^2$ **Examiner's Comment** Almost all candidates correctly identified the measuring instrument for L and d. Some answers were spoilt by mentioning both a ruler and a micrometer for measuring the length of the wire. This question produced a range of marks and discriminated well. According to the data shown in the table on page 13, the final value for the resistance R had to be given to 2 significant figures (SF), but an answer to 3 SF was also allowed. Top-end candidates produced flawless answers and quoted R as either 2.3 ± 0.1 Ω or 2.34 ± 0.08 Ω. Some candidates successfully calculated the maximum and the minimum values for R and then the absolute uncertainty from half the range. The most common mistakes being made were: • Omitting the factor of 2 when determining the percentage uncertainty in d^2. • Calculating the resistance of either resistor **X** or resistor **Y.** • Inconsistency between R and its absolute uncertainty, e.g. R = 2.3 ± 0.077 Ω. Some candidates realised that the actual value of R would be *'larger*

					because d was smaller or R ∝ 1/*d*²'. On most scripts, it was difficult to follow if the resistance was the **actual** one or the **calculated** one.
			Total	**9**	
7 3		i	Line of best fit drawn gradient = 2.8	B1 B1	Expect the extrapolated line to have a y-intercept in the range 0.60 to 0.85 **and** at least one data point on each side of the line **Allow** gradient of line in the range 2.60 to 3.00 **Examiner's Comments** In **(c)(i)**, the lines of best fit were generally very good, as were the gradient calculations with most candidates getting values in the range 2.60 to 3.00. Only a small number of candidates calculated the inverse of the gradient.
		ii	$E = I(r + R)$ **and** $R = \rho L/A$ $\frac{1}{I} = \frac{r}{E} + \frac{\rho}{AE}L$ (and comparison with $y = mx$ + c leads to gradient $\frac{\rho}{AE}$)	C1 A1	**Allow** $E = V + IR$ **and** $R = \rho L/A$ **Examiner's Comments** Most candidates struggled with **(c)(ii)**. Less than 1 in 10 candidates successfully used the equations $E = V + Ir$ and $R = \frac{\rho L}{A}$ to derive the expression $\frac{1}{I} = \frac{\rho}{AE}L + \frac{r}{E}$, and then identified the gradient as $\frac{\rho}{AE}$ by comparison with the equation for a straight-line $y = mx + c$.
		ii i	(ρ = gradient × AE) $\rho = 2.8 \times \pi \times (0.19 \times 10^{-3})^2 \times 1.5$ $\rho = 4.8 \times 10^{-7}$ (Ω m)	C1 A1	Possible ECF from **(i)** **Note** not using $A = \pi r^2$ is wrong physics (XP) **Allow** 1 mark for 1.9×10^{-6}, diameter used instead of radius **Examiner's Comments** Most candidates in **(c)(iii)** did exceptionally well to calculate the resistivity using the equation for the gradient. Calculations were generally well-structured, and the final answer showed good use of powers of ten and significant figures.
		i v	The graph / points just shift horizontally (AW) The gradient is unchanged (and ρ will be the same)	B1 B1	**Allow** shifted to the right or left / 'systematic error' / zero error / change in length stays the same / 'no change in vertical values' **Examiner's Comments** Finally, **(c)(iv)** provided good discrimination with many of the top end candidates realising the gradient of the line was unaffected, the line was just shifted horizontally. 'Systematic error' and 'zero error' were allowed as alternative answers for the horizontal translation of the line.

					Misconception There were some missed opportunities, with some candidates making the following mistakes. • In **(c)(ii)**, ignoring the internal resistance r of the cell shown in the circuit of **Fig. 18.1** to get the wrong expression $\frac{1}{I} = \frac{\rho}{AE}L$ • In **(c)(iii)**, a small number of candidates either used 0.38 mm as the radius of the wire to get a resistivity of 1.9 × 10^{-6} Ω m or forgot to convert the millimetres into metres to get a value of 0.48 Ω m. • In **(c)(iv)**, a significant number of low-end candidates, mentioned that resistivity of the wire did not depend on its physical dimensions, and therefore the resistivity value calculated will be the same. There was no reasoning in terms of gradient = $\frac{\rho}{AE}$
			Total	**8**	
74	a	i	$\frac{1}{R} = \frac{1}{60} + \frac{1}{60}$ or $\frac{1}{R} = \frac{1}{60} + \frac{1}{60} + \frac{1}{60}$ or $R = \frac{60}{n}$ or $R = \frac{6}{6}$ 30 Ω + 20 Ω = 50 Ω	M1 A1	**Examiner's Comments** This question was generally answered well although, a number of candidates did not take due care when writing the mathematical expressions. **Exemplar 6**  The candidate's response is logically structured showing the effective resistance of the two combinations of resistors and then clearly showing the adding of the two effective resistances together. This answer gained both marks.
		ii	$\frac{30}{50} \times 9$ or $I = \frac{9}{50} = 0.18$ A 5.4 V	C1 A1	**Examiner's Comments** For this question, many candidates incorrectly stated that the potential difference was 4.5 V. Other candidates tried determining the current

					but did not make clear their working. The simplest solution was to use the potential divider relationship.
		iii	$\left(I = \frac{5.4}{60} =\right)$ 0.090 A (0.09 x 120 =) 11 C or coulomb	C1 A1 B1	**Allow ECF** from **(ii)** **Allow** 10.8 **Note** 0.18 C scores two marks provided 0.09 A is seen **Note** 21.6 C scores one mark (for the correct unit) **Examiner's Comments** The majority of the candidates gained a mark for the unit of charge on this question. A common incorrect answer was 21.6 C where candidates had used the total current in the circuit rather than the current of 0.09 A in resistor Y. Some candidates did not change the time in minutes to a time in seconds.
		iv	(11 x 5.4 or 0.09 x 5.4 x 120)= 59 or 58 (J)	A1	**Note** 58(.3) if 10.8 C used **Allow ECF** from **(ii)** and/or **(iii)** **Not** 60 **Examiner's Comments** Candidates who multiplied the charge by the potential difference easily gained the mark in this question. Other candidates who used different methods often made mistakes.
	b		I = *nAve* or *v α I* larger current through **Y** than **Z** ORA drift velocity in **Y** is 1.5 times drift velocity in **Z** ORA	B1 B1 B1	**Allow** any correct rearrangement of $I = nAve$ **Allow** I_Y = 0.090 A and I_Z = 0.060 A OR I_Y / I_Z = 1.5 ORA **Examiner's Comments** In this question, many candidates correctly quoted the equation and stated that the mean drift velocity was directly proportional to the current. The majority of the candidates realised that there was a larger current in resistor Y than resistor Z; however, few candidates realised that the current was 1.5 times larger and therefore the mean drift velocity was 1.5 times larger.
			Total	**11**	
75		i	Correct circuit with a battery, potential divider, lamp and voltmeter. 	B1	
		ii	Correct symbols used for all components.	B1	**Allow**: A cell symbol for a battery

		ii	Description: The temperature of the filament increases. (AW)	B1	
		ii	The resistance of the lamp increases	M1	
		ii	from a non-zero value of resistance.	A1	**Allow** 'when cold the resistance is small'
		ii	Explanation: Resistance increases because electrons/charge carriers make frequent collisions with ions. (AW)	B1	
		iii	(*P* = *VI*) current in **X** is 3 times the current in **Y** Or area of **X** is 4 times smaller than area of **Y**	C1	**Allow** other correct methods.
		iii	*I* = *Anev* and ratio = $\frac{3}{0.25}$	C1	
		iii	ratio = 12	A1	
			Total	**9**	
76		i	$(R =) \frac{6.0}{0.150}$ R = 40 Ω	**M1** **A0**	**Allow** any correct value of V (± 0.1 V) divided by the correct value of I (± 10 mA) from the straight line for **R** <u>**Examiner's Comments**</u> The majority of the candidates scored 1 mark here for clearly using the graph to show the resistance of **R** to be 40 Ω. Most used a data point from the straight line. A significant number also used the idea that the gradient of the straight line is equal to the inverse of the resistance. However, candidates are reminded that resistance is equal potential difference divided by current, but in this context of a straight line through the origin, determining resistance from the gradient was allowed. Of course, determining the gradient of a curve is simply incorrect physics for determining resistance.
		ii	$(V_L =)$ 1.4 (V) **or** $(V_R =)$ 4.0 (V) **or** $(R_T =)$ 6.0/0.1 (Ω) $(V_{terminal} =)$ 5.4 (V) **or** $(V_r =)$ 0.6 (V) **or** $(r =)$ 60 − 54 (Ω) r = 6.0 (Ω)	**C1** **C1** **A1**	**Allow** full credit for other correct methods Possible ECF from **(i)** **Allow** ± 0.1 V for the value of p.d. from the graph **Note** getting to this stage will also secure the first C1 mark **Allow** 1 SF answer here without any SF penalt <u>**Examiner's Comments**</u> This was a discriminating question with many of the top-end candidates effortless getting the correct answer of 6.0 Ω for the internal resistance r. The most common error was omitting the resistance of the filament lamp in the calculation. This gave an

					incorrect value of 20 Ω for the internal resistance. Candidates doing this still managed to pick up 1 mark for the total resistance of 60 Ω.
		iii	$\rho = \frac{40 \times 2.4 \times 10^{-6}}{8.0 \times 10^{-3}}$ (Any subject) ρ = 0.012 (Ω m)	C1 A1	**Allow** ECF **Allow** 1 mark for either 0.018 for using 60 Ω, 0.016(2) for using 54 Ω or for 0.0018 for 6.0 Ω **<u>Examiner's Comments</u>** The success in this question depended on understanding the term n in the equation $I = Anev$ given in the Data, Formulae and Relationship booklet. A significant number of candidates took n to be the total number of charge carriers within the volume of **R**, instead of the number of charge carriers per unit volume (number density). Those who appreciated this had no problems coping with prefixes and powers of ten. The correct answer was 7.7 × 10^{-3} m s^{-1}. Using 6.5 × 10^{17} for the number density, gave an answer of 4.0 × 10^5 m s^{-1}; examiners credited 1 mark for this incorrect answer, mainly for the manipulating and using the equation $I = Anev$. **Exemplar 6**  This exemplar illustrates a perfect answer from a C-grade candidate. The equation has been rearranged correctly and the substitution is all correct and easy to follow. The number density n has not been calculated separately – it forms an integral part of the whole calculation. The one big benefit of this is that you do not end up with rounding errors. A decent technique demonstrated here. All correct for 3 marks.
		iv	$n = \frac{6.5 \times 10^{17}}{2.4 \times 10^{-6} \times 0.008}$ **or** n = 3.385 × 10^{25} (m^{-3}) $v = \frac{0.100}{2.4 \times 10^{-6} \times 3.385 \times 10^{25} \times 1.60 \times 10^{-19}}$ (Any subject) v = 7.7 × 10^{-3} (m s^{-3})	C1 C1 A1	**Note** do not penalise again for the same POT error **Allow** 1 mark for 4(.0) × 10^5 (m s^{-1}); n = 6.5 × 10^{17} used
			Total	**9**	