PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 3: ELECTRIC CIRCUITS

ELECTRICAL CIRCUITS AND INTERNAL RESISTANCE

SCORE	PERCENTAGE
/450	%

STEMUP

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Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $R = V/I$ **(1)** • $V = 2.2$ V **(1)**	Example of calculation $VV = 17.5 \times 10^{-3}$ A $\times$ 560 Ω $= 9.8$ V $\therefore VV_{LED} = (12 - 9.8)$V $= 2.2$ V	**2**

(ii)	An explanation that makes reference to the following points: **Either** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The combination has a smaller fraction of the total circuit resistance **(1)** • Hence a smaller fraction of the supply p.d. falls across the lamp **(1)** **OR** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The total circuit resistance decreases and the current increases **(1)** • So the p.d. across the resistor increases (so the p.d. across the lamp must decrease) **(1)** **OR** • Current flows through voltmeter **(1)** • So circuit current increases **Or** current through resistor increases **(1)** • So the p.d. across the resistor increases **(1)**		**3**

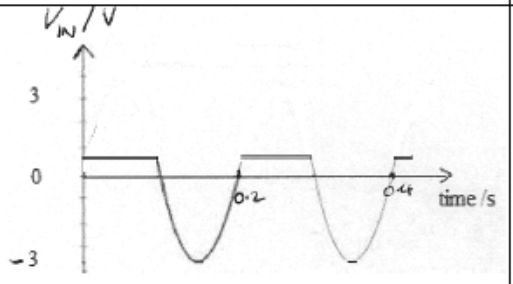
Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• The IV graph of an ohmic conductor is a straight line through the origin **Or** V is directly proportional to *I* **(1)** • Hence Ohm's law is not obeyed for the LED **(1)**	MP1 accept converse argument MP2 dependent on MP1	**2**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	**Either** • $V_{LED} = 2\,V$ (from graph) (1) • Use of $V_{LED} + V_R = 5\,V$ (1) • Use of $R = \frac{V}{I}$ (1) • $R = 170\,\Omega$ (1) **Or** • Use of $R = \frac{V}{I}$ (1) • $V_{LED} = 2\,V$ (from graph) (1) • Use of $R_{LED} + R = 278\,\Omega$ (1) • $R = 170\,\Omega$ (1)	Example of calculation: $2\,V + V_R = 5\,V$ $\therefore V_R = 3\,V$ $R = \frac{3\,V}{18 \times 10^{-3}\,A} = 167\,\Omega$	**4**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $V_{rms} = \frac{V_o}{\sqrt{2}}$ (1) • $V_{rms} = 2.4\,V$ (1)	Example of calculation: $V_{rms} = \frac{3.4}{\sqrt{2}} = 2.4\,V$	**(2)**

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Energy is conserved **Or** Kirchoff's law **Or** potential difference is energy per unit charge (1) • So the sum of p.d.s in a series circuit must equal the e.m.f. applied (1) (MP2 is dependent on MP1)	accept work done for energy accept V_{in} for emf Alternative: Current is the same in both components (1) $IV_{IN} = IV_R + IV_D$ and I cancels (1)	**(2)**
(iii)	• Alternate half cycles of sine curve (with peak about 3 V) (1) • Horizontal line in 1st half cycle and negative half cycle of a sine curve in 2nd half cycle (1) • horizontal lines/spaces at a value of potential difference of 0.6 V to 0.8 V (1)		**(3)**

Q4.

Question Number	Answer	Mark
	B	1

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Series circuit with power supply, heater and ammeter. (1) • Voltmeter connected in parallel with heater (1)		2

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Ammeter in series with LED and voltmeter in parallel with LED (1)		1

Q7.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand <u>OR</u> remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs <u>OR</u> reduces the life of the remaining bulbs (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs (1) <u>OR</u> use of $V = IR$ and addition of resistances in series to determine current in healthy strands <u>OR</u> use of resistance in parallel and series to determine total resistance • $I = 2.9$ A (1) • 2.9 A < 3 A so fuse does not blow (1)	<u>Example of calculation:</u> Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use a micrometer	(1)		
	• $A = \pi\left(\frac{d}{2}\right)^2$ <u>OR</u> $A = \pi r^2$ and $r = \frac{d}{2}$	(1)		
	• repeats readings in different planes/positions	(1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(iii)	• calculates area = $0.13\ (\text{mm}^2)$	**(1)**	<u>Example of calculation:</u> $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$	
	• use of $y = mx + c$	**(1)**		
	• I = 2.8 A	**(1)**	$I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$	
	• 2.8 A < 3 A so the wire is suitable to use as a fuse wire	**(1)**	Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

Q8.

Question Number	Answer	Mark
(a)	Variable resistor in series (1) Ammeter in series and voltmeter in parallel with cell (1) (If there are extra fixed resistances they can be ignored, as long as the terminal p.d. is being measured. Assume the ammeter has zero resistance, so its precise placement doesn't matter as long as it is in series)	2
(b)	Best fit straight line drawn (1) Substitution of values from student's line for gradient using at least half current axis ($\Delta I \geq 80$ mA) (1) $\mathcal{E} = 3.9$ V to 4.1 V (1) $r = 1.6\ \Omega$ to $2.5\ \Omega$ (1) Example of calculation gradient = (3.7 V – 4.0 V) / 0.16 A = – 1.9 Ω	4
(c)	Start y-axis at 3.0 V (accept reference to points from 3.0 to 3.75 V) (1) This will allow plots to be made more accurately **Or** This will allow intercept and change in V to be determined to more sf **Or** this will allow read-offs to be made with more precision (1) (Only award this mark if first mark awarded)	2
	Total for Question	8

Q9.

Question Number	Answer	Mark
(a)	Lowest / minimum frequency (of light / photons incident on a metal) that will cause electrons to be emitted (from surface) **Or** the frequency of (light / photons) that will cause electrons to be emitted (from the surface of a metal) with zero kinetic energy (1) (accept only just emitted)	1
(b)	Conversion of eV to J (1) Use of $E = hf$ (1) $f = 5.5 \times 10^{14}$ Hz (1) Example of calculation $\varphi = (2.28\ \text{eV} \times 1.6 \times 10^{-19}\ \text{C})$ $= 3.65 \times 10^{-19}$ J $f = 3.65 \times 10^{-19}\ \text{J} / 6.63 \times 10^{-34}\ \text{J s} = 5.50 \times 10^{14}$ Hz	3
	Total for Question	4

Q10.

Question Number	Answer		Mark
(a)	Negative gradient (accept curve)	**(1)**	
	Straight line (dependent on first marking point)	**(1)**	
	Reference to terminal p.d. = e.m.f. – 'lost volts' **Or** $V = \varepsilon - Ir$	**(1)**	
	Intercept on V axis = ε **Or** Intercept on y axis = ε **Or** ε = value of V on graph when $I = 0$ (accept from labelled graph)(mark not awarded if line passes through origin)	**(1)**	
	Gradient = $-r$ **Or** magnitude of gradient is r (accept gradient = $-r$ marked on graph)	**(1)**	**5**
***(b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	Ammeter explanation:		
	If ammeter has resistance, current decreased	**(1)**	
	but doesn't affect the determination because current through cell/r is measured **Or** doesn't affect the determination because the voltmeter measures the terminal p.d. for that current	**(1)**	
	OR		
	The resistance of the ammeter contributes to the load/circuit/total resistance	**(1)**	
	Values of p.d. corresponding to given values of current will be unchanged	**(1)**	
	Voltmeter explanation:		
	If voltmeter has smaller resistance it would draw current	**(1)**	
	measured current not current through cell/r	**(1)**	**4**
	Total for question		**9**

Q11.

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Question Number	Acceptable Answer	Additional Guidance	Mark
	• See $I = I_1 + I_2$ **(1)** • Use of $I = \frac{V}{R}$ with the same V for every term **(1)** • Algebra to show $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2}$ **(1)**	If student assumes that $R_1 = R_2 = R \rightarrow R_{eff} = \frac{R}{2}$, then MP1 and MP2 only For MP3, can assume algebra if equation seen Example of derivation $I = I_1 + I_2 \quad I = \frac{V}{R}$ $\therefore \frac{V}{R_{eff}} = \frac{V}{R_1} + \frac{V}{R_2}$	**3**

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• p.d. across capacitor increases **Or** p.d. across resistor decreases **(1)** • p.d. across capacitor increases to 5V **(1)** • p.d. across resistor starts at 5V and reduces to 0V **(1)** • Exponentially **(1)**		**4**

Q13.

Question Number	Answer	Mark
	(high resistance) so very little /negligible/zero current in the voltmeter **Or** because otherwise a current would pass through the voltmeter **Or** so the total resistance of the parallel combination isn't changed **Or** because otherwise total resistance of parallel combination would be reduced (1) because that would change /increase the current in the ammeter **Or** because that would mean the current through the ammeter was different to (larger than) the current through the component (1)	**2**
	Total for question	**2**

Q14.

Question Number	Answer		Mark
(a)	Series sketch with two bulbs	**(1)**	
	Connected in series: because when one is removed there is a break in the circuit **Or** because when one is removed there is no current **Or** so the bulbs could have different p.d.s	**(1)**	
	Not connected in parallel because: if one removed, still complete circuit (for the other) **Or** if one removed, still current (through the other) **Or** full mains voltage would have blown small bulb	**(1)**	**3**
(b) (i)	Use of $P = IV$ $I = 0.17$ (A) (at least 2 sf required) Example of calculation 40 W = $I \times 230$ V $I = 0.17$ A	**(1)** **(1)**	**2**
(b)(ii)	Use of appropriate equation $R = 1300\ \Omega$ Example of calculation $P = V^2/R$ 40 W = $(230\text{ V})^2 / R$ $R = 1323\ \Omega$	**(1)** **(1)**	**2**
(b)(iii)	Use of $R = V/I$ $R = 13\ \Omega$ Example of calculation $R = 2.5$ V / 0.2 A $R = 12.5\ \Omega$	**(1)** **(1)**	**2**
(c)	Current – both require about the same (not just both have 0.2 A)	**(1)**	
	Potential difference – total (required) p.d. is very close to mains supply **Or** (operating) p.d. for mains bulb much greater than (operating) p.d. for torch bulb	**(1)**	**2**

(d)	Lower resistance **(1)** (smaller current, so) lower temperature (so less vibration of lattice ions) **Or** (smaller current, so) smaller drift velocity **(1)** fewer collisions of electrons with lattice ions **Or** less frequent collisions of electrons with lattice ions **(1)** Less energy dissipation (as heat) **Or** less ke lost in collisions **(1)**	**4**
	Total for question	**15**

Q15.

Question Number	Answer	Mark
	current same in series **Or** current is different if not in series **(1)** to ensure the total resistance in the circuit isn't increased **Or** to ensure no pd lost **(1)** because that would reduce the current being measured **(1)** [Just saying current changes or resistance changes is not sufficient for MP2 and 3. Candidates who **only** refer to what would happen if ammeter in parallel can only score MP1]	**3**
	Total for question	**3**

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $R = V/I$ **(1)** • $V = 2.2$ V **(1)**	Example of calculation $VV = 17.5 \times 10^{-3}$ A $\times$ 560 Ω $= 9.8$ V $\therefore VV_{LED} = (12 - 9.8)$V $= 2.2$ V	**2**

(ii)	An explanation that makes reference to the following points: **Either** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The combination has a smaller fraction of the total circuit resistance **(1)** • Hence a smaller fraction of the supply p.d. falls across the lamp **(1)** **OR** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The total circuit resistance decreases and the current increases **(1)** • So the p.d. across the resistor increases (so the p.d. across the lamp must decrease) **(1)** **OR** • Current flows through voltmeter **(1)** • So circuit current increases **Or** current through resistor increases **(1)** • So the p.d. across the resistor increases **(1)**		**3**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D A *is not correct because as it is 2A + 1A* B *is not correct because 2A +2A* C *is not correct because 2A + 3A*	6 A	**1**

Q3.

Question Number	Acceptable Answer	Additional Guidance	
	An explanation that makes reference to the following points: • The number of (free) charge carriers (per unit volume) in the thermistor decreased **(1)** **(1)** • (Hence) the resistance of the thermistor increased **(1)** • And a larger fraction of supply p.d. is across the thermistor	MP1: Electrons okay for charge carriers MP3: Current in circuit decreases, so p.d. across fixed resistor decreases, therefore p.d. across thermistor increases	**3**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $V = IR$ for the ammeter **(1)** • calculates current through the shunt **(1)** • Shunt resistance = 9.0×10^{-3} (Ω) (dependent on MP2) **(1)** Alternative if using $1/R$ rule for parallel resistors • use of $V = IR$ for the ammeter • Calculates equivalent resistance of the circuit • Uses $1/R$ rule to calculate shunt resistance = 9.0×10^{-3} (Ω)	Example of calculation: $V = 1.0 \times 10^{-3}\ \text{A} \times 18\ \Omega = 0.018\ \text{V}$ $I = 2.0A - 0.001\ \text{A} = 1.999\ \text{A}$ $R = \frac{0.018\ \text{V}}{1.999\ \text{A}} = 9.0 \times 10^{-3}\ \Omega$ Alternative: $V = 1.0 \times 10^{-3}\ \text{A} \times 18\ \Omega = 0.018\ \text{V}$ $R_T = \frac{0.018\ \text{V}}{2\text{A}} = 0.009\ \Omega$ $\frac{1}{0.009} = \frac{1}{18} + \frac{1}{R_S}$ $R_S = 9.0 \times 10^{-3}\ \Omega$	**3**

Q5.

Question Number	Answer	Mark
	B	**1**

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	• R_T = 0.7 – 0.8 kΩ [read from graph] **(1)** • Use of $V=IR$ (with 3.5 V and R_T) to find I **and** $V=IR$ (with V = 5.5 V) to find R **(1)** • R=1100 – 1300 Ω **(1)**	Accept use of $Vo = Vs\left(\frac{R_1}{R_1 + R_2}\right)$ Or $V_{out}/(V_s - V_{out}) \times R_T = R$ Example of calculation: $I = \frac{3.5}{750} = 0.0047$ A $R = \frac{5.5}{0.0047} = 1170\ \Omega$	**3**

Q7.

Question Number	Answer	Mark
	D Step 4	**1**
	Incorrect Answers: A – this step uses the conservation of energy B – this step is just a statement of Ohm's law C – this step uses the conservation of energy	

Q8.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand <u>OR</u> remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs <u>OR</u> reduces the life of the remaining bulbs (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs (1) <u>OR</u> use of $V = IR$ and addition of resistances in series to determine current in healthy strands <u>OR</u> use of resistance in parallel and series to determine total resistance • $I = 2.9$ A (1) • 2.9 A < 3 A so fuse does not blow (1)	<u>Example of calculation:</u> Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use a micrometer	(1)		
	• $A = \pi\left(\frac{d}{2}\right)^2$ <u>OR</u> $A = \pi r^2$ and $r = \frac{d}{2}$	(1)		
	• repeats readings in different planes/positions	(1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(iii)	• calculates area = $0.13\ (\text{mm}^2)$	**(1)**	<u>Example of calculation:</u> $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$	
	• use of $y = mx + c$	**(1)**		
	• I = 2.8 A	**(1)**	$I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$	
	• 2.8 A < 3 A so the wire is suitable to use as a fuse wire	**(1)**	Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	A The p.d. across the resistor added to the p.d. across the thermistor must equal 6 V. This occurs when the current is 0.5 A.	0.5	**1**
	B assumes all the p.d. is across the thermistor C assumes that resistor and thermistor connected in parallel D assumes that the p.d. across the resistor and thermistor is more than 6 V		

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• $Q_T = Q_1 + Q_2 + Q_3$ (1) • $Q/t = I$ hence $I_T = I_1 + I_2 + I_3$ (1) • $I = \varepsilon/R$ hence $\frac{\varepsilon}{R_T} = \frac{\varepsilon}{R_1} + \frac{\varepsilon}{R_2} + \frac{\varepsilon}{R_3}$ (1)		(3)

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• A statement applying the conservation of energy to the circuit (1) • Use of Ohm's law for each term /individual pd leading to the cancelling of currents in the equation (1) • $R_T = R_1 + R_2 + R_3$ (1)	Example of calculation $\mathcal{E} = V_1 + V_2 + V_3$ $\mathcal{E} = IR_T = IR_1 + IR_2 + IR_3$ $R_T = R_1 + R_2 + R_3$	3

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	A uses the parallel resistors equation $\frac{1}{R_T}=\frac{1}{R}+\frac{1}{R}=\frac{2}{R}$	$\frac{R}{2}$	1
	B assumes resistors in parallel have the same total R as each individual R C is the addition of both resistances as if they were in series D is the product of both resistances		

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• See $I = I_1 + I_2$ (1) • Use of $I = \frac{V}{R}$ with the same V for every term (1) • Algebra to show $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2}$ (1)	If student assumes that $R_1 = R_2 = R \rightarrow R_{eff} = \frac{R}{2}$, then MP1 and MP2 only For MP3, can assume algebra if equation seen Example of derivation $I = I_1 + I_2 \quad I = \frac{V}{R}$ $\therefore \frac{V}{R_{eff}} = \frac{V}{R_1} + \frac{V}{R_2}$	3

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of y-sensitivity value (1) • $V_0 = 4.0$ V (1)	Example of calculation: $V_0 = 2 \times 2.0\ V = 4.0$ V	2
(ii)	• Use of $I = \frac{V}{R}$ (1) • Use of $I_{rms} = \frac{I_0}{\sqrt{2}}$ Or use of $V_{rms} = \frac{V_0}{\sqrt{2}}$ (1) • $I_{rms} = 0.019$ A ECF from(i) (1)	Example of calculation $I_0 = \frac{4.0\text{ V}}{150\ \Omega} = 0.0267$ A $I_{rms} = \frac{0.0267\text{ A}}{\sqrt{2}} = 0.0189$ A	3
(iii)	• Use of $R = R_1 + R_2$ (1) • Use of $P = I^2R$ (or other valid power equation) (1) • $P = 0.096$ W ECF from(i) and (ii) (1)	Example of calculation: $R = 150\ \Omega + 120\ \Omega = 270\ \Omega$ $P = I^2R$ $= (0.019\text{ A})^2$ $\times 270\ \Omega = 0.0964$ A	3

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V = IR$ **(1)** • Use of $V_{total} = V_{meter} + V_{multiplier}$ **(1)** • Choice of $R = 2500\ \Omega$ **(1)**	Example of calculation V across meter $= 0.0016\ A \times 625\Omega = 1.0\ V$ V across multiplier $= 5.0\ V - 1.0\ V = 4.0\ V$ $R_{multiplier} = \frac{4.0\ V}{0.0016\ A} = 2500\ \Omega$ MP3 dependent on MP1 or MP2	**3**

Q17.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{R} + \frac{1}{R_1} = \frac{1}{R_2}$ **(1)** • $R = 72\ (\Omega)$ **(1)**	Example of calculation $\frac{1}{R} = \frac{1}{120\ \Omega} + \frac{1}{180\ \Omega} = 0.0139\ \Omega^{-1}$ $\therefore R = \frac{1}{0.0139\ \Omega^{-1}} = 72.0\ \Omega$	**2**

Q18.

Question Number	Answer	Mark
	B Equivalent R = $(1/R + 1/2R)^{-1}$	**1**
	Incorrect Answers: **A** – wrong expression **C** – wrong expression **D** – wrong expression	

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	Either • Use of equation(s) to determine the total resistance of the voltmeter and 40 Ω resistor in parallel (34.3 Ω) **(1)** i.e. potential divider formula or Ohm's law **(1)** • Use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ **(1)** • $R_v = 240$ (Ω) **Or** • Use of Ohm's law to determine the current through voltmeter (0.0075 A) **(1)** i.e. current in 40 Ω resistor calculated (0.045 Ω) **and** subtracted from current in 80 Ω resistor (0.0525 Ω) **(1)** • Use of Ohm's law with 1.8 V to calculate the resistance of the voltmeter • $R_v = 240$ (Ω)	<u>Example of calculation</u> $\left(\frac{R}{80\ \Omega + R}\right) 6\ \text{V} = 1.8\ \text{V}$ $R = 34.29\ \Omega$ $\frac{1}{34.29\ \Omega} = \frac{1}{40\ \Omega} + \frac{1}{R_V}$ $R_V = 240.2\ \Omega$	**3**

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$ for resistors in parallel **(1)** • Use of $R_T = R_1 + R_2$ for resistors in series **(1)** • $R_T = 47\ \Omega$ **(1)**	<u>Example Calculation</u> $\frac{1}{R_P} = \frac{1}{30} + \frac{1}{40}$ $R_P = 17\ \Omega$ $R_T = 20+17+10 = 47\ \Omega$	**3**

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $R = V/I$ **(1)** • $V = 2.2$ V **(1)**	Example of calculation $VV = 17.5 \times 10^{-3}$ A $\times$ 560 Ω $= 9.8$ V $\therefore VV_{LED} = (12 - 9.8)$V $= 2.2$ V	**2**

(ii)	An explanation that makes reference to the following points: **Either** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The combination has a smaller fraction of the total circuit resistance **(1)** • Hence a smaller fraction of the supply p.d. falls across the lamp **(1)** **OR** • The effective resistance of the combination is less than the resistance of the lamp **(1)** • The total circuit resistance decreases and the current increases **(1)** • So the p.d. across the resistor increases (so the p.d. across the lamp must decrease) **(1)** **OR** • Current flows through voltmeter **(1)** • So circuit current increases **Or** current through resistor increases **(1)** • So the p.d. across the resistor increases **(1)**		**3**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D A *is not correct because as it is 2A + 1A* B *is not correct because 2A +2A* C *is not correct because 2A + 3A*	6 A	**1**

Q3.

Question Number	Acceptable Answer	Additional Guidance	
	An explanation that makes reference to the following points: • The number of (free) charge carriers (per unit volume) in the thermistor decreased **(1)** **(1)** • (Hence) the resistance of the thermistor increased **(1)** • And a larger fraction of supply p.d. is across the thermistor	MP1: Electrons okay for charge carriers MP3: Current in circuit decreases, so p.d. across fixed resistor decreases, therefore p.d. across thermistor increases	**3**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of $V = IR$ for the ammeter **(1)** • calculates current through the shunt **(1)** • Shunt resistance = 9.0×10^{-3} (Ω) (dependent on MP2) **(1)** Alternative if using $1/R$ rule for parallel resistors • use of $V = IR$ for the ammeter • Calculates equivalent resistance of the circuit • Uses $1/R$ rule to calculate shunt resistance = 9.0×10^{-3} (Ω)	Example of calculation: $V = 1.0 \times 10^{-3}\ \text{A} \times 18\ \Omega = 0.018\ \text{V}$ $I = 2.0A - 0.001\ \text{A} = 1.999\ \text{A}$ $R = \frac{0.018\ \text{V}}{1.999\ \text{A}} = 9.0 \times 10^{-3}\ \Omega$ Alternative: $V = 1.0 \times 10^{-3}\ \text{A} \times 18\ \Omega = 0.018\ \text{V}$ $R_T = \frac{0.018\ \text{V}}{2\text{A}} = 0.009\ \Omega$ $\frac{1}{0.009} = \frac{1}{18} + \frac{1}{R_S}$ $R_S = 9.0 \times 10^{-3}\ \Omega$	**3**

Q5.

Question Number	Answer	Mark
	B	**1**

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	• R_T = 0.7 – 0.8 kΩ [read from graph] **(1)** • Use of $V=IR$ (with 3.5 V and R_T) to find I **and** $V=IR$ (with V = 5.5 V) to find R **(1)** • R=1100 – 1300 Ω **(1)**	Accept use of $Vo = Vs\left(\frac{R_1}{R_1 + R_2}\right)$ Or $V_{out}/(V_s - V_{out}) \times R_T = R$ Example of calculation: $I = \frac{3.5}{750} = 0.0047$ A $R = \frac{5.5}{0.0047} = 1170\ \Omega$	**3**

Q7.

Question Number	Answer	Mark
	D Step 4	**1**
	Incorrect Answers: A – this step uses the conservation of energy B – this step is just a statement of Ohm's law C – this step uses the conservation of energy	

Q8.

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(i)	An explanation that makes reference to the following points: • total resistance of strand decreases (1) • this increases the current in the strand <u>OR</u> remaining bulbs are brighter (1) • greater power / energy consumption with blown bulbs <u>OR</u> reduces the life of the remaining bulbs (1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs (1) <u>OR</u> use of $V = IR$ and addition of resistances in series to determine current in healthy strands <u>OR</u> use of resistance in parallel and series to determine total resistance • $I = 2.9$ A (1) • 2.9 A < 3 A so fuse does not blow (1)	<u>Example of calculation:</u> Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times 8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times 8.0\ \Omega)+(5\times 3.0\ \Omega)}\right)$ $I = 2.9$ A Allow credit for a consistent conclusion from an incorrect calculation of current	**(3)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use a micrometer	(1)		
	• $A = \pi\left(\frac{d}{2}\right)^2$ <u>OR</u> $A = \pi r^2$ and $r = \frac{d}{2}$	(1)		
	• repeats readings in different planes/positions	(1)		**(3)**

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• current directly proportional to cross-sectional area		**(1)**

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(iii)	• calculates area = $0.13\ (\text{mm}^2)$	**(1)**	<u>Example of calculation:</u> $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$	
	• use of $y = mx + c$	**(1)**		
	• I = 2.8 A	**(1)**	$I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$	
	• 2.8 A < 3 A so the wire is suitable to use as a fuse wire	**(1)**	Wire is suitable as I < 3 A Allow credit for a consistent conclusion from an incorrect calculation of current Accept converse working to find diameter of 3 A fuse wire	**(4)**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
	A The p.d. across the resistor added to the p.d. across the thermistor must equal 6 V. This occurs when the current is 0.5 A.	0.5	**1**
	B assumes all the p.d. is across the thermistor C assumes that resistor and thermistor connected in parallel D assumes that the p.d. across the resistor and thermistor is more than 6 V		

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• $Q_T = Q_1 + Q_2 + Q_3$ (1) • $Q/t = I$ hence $I_T = I_1 + I_2 + I_3$ (1) • $I = \varepsilon/R$ hence $\frac{\varepsilon}{R_T} = \frac{\varepsilon}{R_1} + \frac{\varepsilon}{R_2} + \frac{\varepsilon}{R_3}$ (1)		(3)

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• A statement applying the conservation of energy to the circuit (1) • Use of Ohm's law for each term /individual pd leading to the cancelling of currents in the equation (1) • $R_T = R_1 + R_2 + R_3$ (1)	Example of calculation $\mathcal{E} = V_1 + V_2 + V_3$ $\mathcal{E} = IR_T = IR_1 + IR_2 + IR_3$ $R_T = R_1 + R_2 + R_3$	3

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	A uses the parallel resistors equation $\frac{1}{R_T}=\frac{1}{R}+\frac{1}{R}=\frac{2}{R}$	$\frac{R}{2}$	1
	B assumes resistors in parallel have the same total R as each individual R C is the addition of both resistances as if they were in series D is the product of both resistances		

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• See $I = I_1 + I_2$ (1) • Use of $I = \frac{V}{R}$ with the same V for every term (1) • Algebra to show $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2}$ (1)	If student assumes that $R_1 = R_2 = R \rightarrow R_{eff} = \frac{R}{2}$, then MP1 and MP2 only For MP3, can assume algebra if equation seen Example of derivation $I = I_1 + I_2 \quad I = \frac{V}{R}$ $\therefore \frac{V}{R_{eff}} = \frac{V}{R_1} + \frac{V}{R_2}$	3

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of y-sensitivity value (1) • $V_0 = 4.0$ V (1)	Example of calculation: $V_0 = 2 \times 2.0\ V = 4.0$ V	2
(ii)	• Use of $I = \frac{V}{R}$ (1) • Use of $I_{rms} = \frac{I_0}{\sqrt{2}}$ Or use of $V_{rms} = \frac{V_0}{\sqrt{2}}$ (1) • $I_{rms} = 0.019$ A ECF from(i) (1)	Example of calculation $I_0 = \frac{4.0\text{ V}}{150\ \Omega} = 0.0267$ A $I_{rms} = \frac{0.0267\text{ A}}{\sqrt{2}} = 0.0189$ A	3
(iii)	• Use of $R = R_1 + R_2$ (1) • Use of $P = I^2R$ (or other valid power equation) (1) • $P = 0.096$ W ECF from(i) and (ii) (1)	Example of calculation: $R = 150\ \Omega + 120\ \Omega = 270\ \Omega$ $P = I^2R$ $= (0.019\text{ A})^2$ $\times 270\ \Omega = 0.0964$ A	3

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $V = IR$ **(1)** • Use of $V_{total} = V_{meter} + V_{multiplier}$ **(1)** • Choice of $R = 2500\ \Omega$ **(1)**	Example of calculation V across meter $= 0.0016\ A \times 625\Omega = 1.0\ V$ V across multiplier $= 5.0\ V - 1.0\ V = 4.0\ V$ $R_{multiplier} = \frac{4.0\ V}{0.0016\ A} = 2500\ \Omega$ MP3 dependent on MP1 or MP2	**3**

Q17.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\frac{1}{R} + \frac{1}{R_1} = \frac{1}{R_2}$ **(1)** • $R = 72\ (\Omega)$ **(1)**	Example of calculation $\frac{1}{R} = \frac{1}{120\ \Omega} + \frac{1}{180\ \Omega} = 0.0139\ \Omega^{-1}$ $\therefore R = \frac{1}{0.0139\ \Omega^{-1}} = 72.0\ \Omega$	**2**

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	Either • Use of equation(s) to determine the total resistance of the voltmeter and 40 Ω resistor in parallel (34.3 Ω) (1) i.e. potential divider formula or Ohm's law (1) • Use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ (1) • $R_v = 240$ (Ω) **Or** • Use of Ohm's law to determine the current through voltmeter (0.0075 A) (1) i.e. current in 40 Ω resistor calculated (0.045 Ω) **and** subtracted from current in 80 Ω resistor (0.0525 Ω) (1) • Use of Ohm's law with 1.8 V to calculate the resistance of the voltmeter (1) • $R_v = 240$ (Ω)	Example of calculation $\left(\frac{R}{80\ \Omega + R}\right) 6\ \text{V} = 1.8\ \text{V}$ $R = 34.29\ \Omega$ $\frac{1}{34.29\ \Omega} = \frac{1}{40\ \Omega} + \frac{1}{R_V}$ $R_V = 240.2\ \Omega$	3

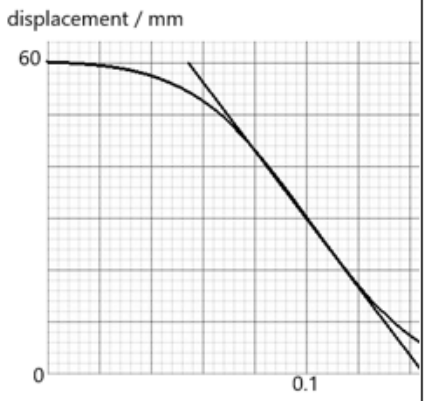
Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$ for resistors in parallel (1) • Use of $R_T = R_1 + R_2$ for resistors in series (1) • $R_T = 47\ \Omega$ (1)	Example Calculation $\frac{1}{R_P} = \frac{1}{30} + \frac{1}{40}$ $R_P = 17\ \Omega$ $R_T = 20+17+10 = 47\ \Omega$	3

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Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• uses ratio of lengths to determine p.d. across potentiometer • V = 9.6 (V)	(1) (1)	Example of calculation: p.d. across potentiometer = $\frac{115\text{ mm}}{60\text{ mm}} \times 5\text{ V} = 9.6\text{ V}$	2
(ii)	• determines p.d. across R • apply $V = IR$ to potentiometer to determine current **Or** uses ratio of resistances = ratio of p.d.s • $R = 3000\ \Omega$	(1) (1) (1)	Example of calculation: current in circuit = $\frac{9.6\text{ V}}{12000\ \Omega} = 8.0 \times 10^{-4}$ A p.d. across $R = 12 - 9.6 = 2.4$ V $R = {}^{2.4\text{ V}}/_{8.0 \times 10^{-4}\text{A}}$ R = 3000 Ω (show that value gives 2400 Ω)	3
(iii)	• A battery has internal resistance • There is a p.d. across the internal resistance • Terminal p.d. less (than e.m.f.) **Or** refers to $V = E - Ir$	(1) (1) (1)	Accept "lost volts" for MP2 V must be the subject	3
(iv)	• tangent drawn on the curve • uses a triangle base of at least 0.06 s • attempt to find a gradient • velocity = 0.68 m s^{-1} so velocity not exceeded allow range from to 0.60 m s^{-1} to 0.80 m s^{-1}	(1) (1) (1) (1)	MP2 dependent on MP1  v = gradient = $\frac{60\text{ mm}}{0.144 - 0.056}$ v = 682 mm s^{-1}	4

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V	(1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire $=Ir$ between A and loop (1) Increases from 0V to 1.5V linearly (1)	3
	• Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5}=\frac{R}{R_T}$	(1)		
	• potential difference proportional to length of wire	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s	(1)	Example of calculation Gradient $=\frac{1.1\text{V}-0.2\text{V}}{1.0\text{s}}=0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m $v=0.9\ \text{Vs}^{-1}\times\frac{2.00\text{m}}{1.5\text{V}}=1.2\ \text{ms}^{-1}$	4
	• Scales p.d. to give distance	(1)		
	• Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s=\frac{(u+v)}{2}t$ **and** correct V read from graph	(1) (1)		
	• velocity = 1.0 m s^{-1} – 1.3 m s^{-1}			

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v=u+at$	(1)	Example of calculation $1.5\,\text{ms}^{-1}=1.2\,\text{m s}^{-1}+\text{a}\times0.5\,\text{s}$ $a=\frac{0.3\,\text{m s}^{-1}}{0.5}=0.6\,\text{m s}^{-2}$ $0.6\,\text{m s}^{-2}=9.81\,\text{m s}^{-2}\sin\theta$ $\theta=3.6°$	4
	• Use of $a=g\sin\theta$	(1)		
	• Calculates a value for a, θ or v (using a SUVAT AND $a=g\sin\theta$)	(1)		
	• Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1)		

Q3.

Question Number	Answer	Mark
	B	1

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• The (voltmeter) reading will increase (1) • Resistance increases (with length) **Or** resistance ∝ length (1)	MP2: accept idea of a potential divider i.e. the ratio of the of BC to the total length AD will be greater, so the proportion of the total voltage will be greater ($\frac{BC}{AD}$ V) MP2: Do not award if there is also a reference to resistivity increasing	**2**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. • Use of $R = \rho l/A$ • the wider section will be half the resistance of the narrow section • The p.d. will be divided into 0.5V across wide section and 1.0V across the narrow section • The potential will vary linearly along each resistance section (as R is proportional to l) • This is because current is constant throughout length • When the voltmeter is across the whole length it will read the p.d. across the cell/ 1.5V **Or** when the voltmeter terminals are together it will read 0 V	IC points / IC mark / Max linkage mark available / Max final mark **6** / 4 / 2 / **6** **5** / 3 / 2 / **5** **4** / 3 / 1 / **4** **3** / 2 / 1 / **3** **2** / 2 / 0 / **2** **1** / 1 / 0 / **1** **0** / 0 / 0 / **0**	**6**

Q6.

Question Number	Acceptable answers		Additional Guidance	Mark
i	• As resistance increases with length of wire • potential (difference) proportional to length of wire	(1) (1)	Alt to MP1: Current same through whole length of wire and $V=IR$	2
ii	• Use of ratio of lengths = ratio of potentials • Potential at P = 1.13 V	(1) (1)	Alternative method uses ratio of resistances. Example of calculation: $=\frac{75.0}{100}\times 1.50$ $=1.125\text{V}$	2

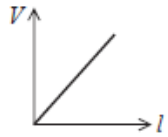
Q7.

Question Number	Answer	Mark
	B	1

Q8.

Question Number	Answer	Mark
	C	1

Q9.

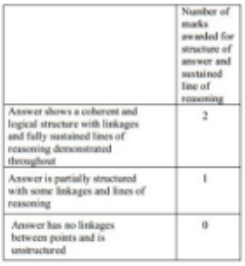
Question Number	Acceptable Answer	Additional Guidance	Mark
	A 		1

Q10.

Question Number	Answer		Mark
(a)(i)	Determines width of at least 9 coils Use of half of their diameter in πr^2 Area = (1.96 to 2.42) × 10^{-7} (m^2) Example of calculation 18 coils = 1.00 cm Diameter = 0.0100 m ÷ 18 = 5.56 × 10^{-4} m Area = π × (5.56 × 10^{-4} ÷ 2)^2 Area = 2.42 × 10^{-7} m^2	(1) (1) (1)	3
(a)(ii)	Use of $R=\rho l/A$ Resistivity magnitude = 4.4 × 10^{-7} (show that value gives 3.7× 10^{-7}) Unit Ωm Example of calculation $\rho=RA / l$ = 22 Ω x 2.4 × 10^{-7} m^2 / 12 m = 4.4 × 10^{-7} Ωm	(1) (1) (1)	3
(a)(iii)	A sensible response with some detail, e.g. • Avoid difficulty in reading a small scale while holding it and counting turns • it can be enlarged and done more accurately • compare with unravelling and using a micrometer • remains stationary, so easier to measure accurately • you can mark the coils as you go so you don't lose count (treat parallax as neutral and)	(1)	1
(b)	Use of ratio of lengths × pd V = 8.2 V Example of calculation V = (7.0 cm / 10.2 cm) × 12 V = 8.2 V	(1) (1)	2
	Total for question		9

Mark Scheme

Q1.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.
Indicative content:
IC1 Both circuits are suitable because they allow readings of p.d./current for the lamp
IC2 For circuit 1 the minimum p.d. across the lamp is 0 V (when the slider is at the left)
Or For circuit 2 the minimum p.d. across the lamp is greater than 0 V
For circuit 1 the maximum p.d. across the lamp is the supply p.d (when the slider is at the right)
IC3 For circuit 1 the maximum p.d. across the lamp is the supply p.d</td>
<td>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning
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<tr><th>IC points</th><th>IC mark</th><th>Max linkage mark</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
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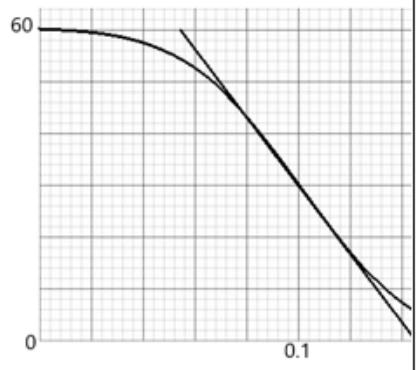
		(when the slider is at the right) IC4 For circuit 2 adjusting the resistor changes the circuit resistance (so the current is varied) **Or** for circuit 2 the battery p.d. is shared between lamp and variable resistor IC5 So for circuit 2 the minimum p.d. depends upon the resistance of the variable resistor, IC6 Circuit 1 is better because it allows a bigger range **Or** Circuit 1 is better because it allows p.d.s down to 0 V to be used		

Q2.

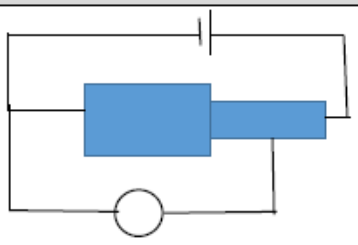
Question Number	Acceptable answers	Additional guidance	Mark
	• As temperature increases number of (free) charge carriers (in thermistor) increases so its resistance decreases **Or** As temperature increases number of charge carriers in conduction band increases so (thermistor) resistance decreases **(1)** • Thermistor resistance as a proportion of total resistance decreases **(1)** **Or** **(1)** Current increases so p.d. across resistor increases • P.D. (across thermistor) decreases	Accept electrons for charge carriers	3

Q3.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• uses ratio of lengths to determine p.d. across potentiometer • V = 9.6 (V)	(1) (1)	Example of calculation: p.d. across potentiometer = $\frac{115\text{ mm}}{60\text{ mm}} \times 5\text{ V} = 9.6\text{ V}$	2
(ii)	• determines p.d. across R • apply $V = IR$ to potentiometer to determine current **Or** uses ratio of resistances = ratio of p.d.s • R = 3000 Ω	(1) (1) (1)	Example of calculation: current in circuit = $\frac{9.6\text{ V}}{12000\ \Omega} = 8.0 \times 10^{-4}$ A p.d. across R = 12 – 9.6 = 2.4 V $R = {}^{2.4\text{ V}}/_{8.0 \times 10^{-4}\text{A}}$ R = 3000 Ω (show that value gives 2400 Ω)	3
(iii)	• A battery has internal resistance • There is a p.d. across the internal resistance • Terminal p.d. less (than e.m.f.) **Or** refers to $V = E - Ir$	(1) (1) (1)	Accept "lost volts" for MP2 V must be the subject	3

(iv)	• tangent drawn on the curve • uses a triangle base of at least 0.06 s • attempt to find a gradient • velocity = 0.68 m s^{-1} so velocity not exceeded allow range from to 0.60 m s^{-1} to 0.80 m s^{-1}	(1) (1) (1) (1)	MP2 dependent on MP1 displacement / mm  v = gradient = $\frac{60 \text{ mm}}{0.144 - 0.056}$ v = 682 mm s^{-1}	4

Q4.

Question Number	Acceptable answers		Additional guidance	Mark
	• cell connected to both ends of paper with correct polarity • voltmeter with one end connected to 0V end of paper and other to halfway along narrow strip of paper	(1) (1)		2

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• V at top/start = 0V **Or** recognition "potential divider" **Or** V increases (by implication) **Or** V at bottom = 1.5V	(1)	**Alternative MS** Constant Current (I) in wire (1) p.d. across section of wire = Ir between A and loop (1) Increases from 0V to 1.5V linearly (1)	3
	• Two sections of wire act as series resistors **Or** $R=\rho l/A$ **Or** comment about R proportional to length **Or** $\frac{V}{1.5}=\frac{R}{R_T}$	(1)		
	• potential difference proportional to length of wire	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s	(1)	Example of calculation Gradient $=\frac{1.1\text{V}-0.2\text{V}}{1.0\text{s}}=0.9\text{Vs}^{-1}$ As 1.5 V represents 2.00 m $v=0.9\ \text{Vs}^{-1}\times\frac{2.00\text{m}}{1.5\text{V}}=1.2\ \text{ms}^{-1}$	4
	• Scales p.d. to give distance	(1)		
	• Gradient determined using a base of triangle of at least 1.0 s **Or** use of $s=\frac{(u+v)}{2}t$ **and** correct V read from graph	(1) (1)		
	• velocity = 1.0 m s^{-1} – 1.3 m s^{-1}			

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Use of $v=u+at$	(1)	Example of calculation $1.5\,\text{ms}^{-1}=1.2\,\text{m s}^{-1}+\text{a}\times 0.5\,\text{s}$ $a=\frac{0.3\,\text{m s}^{-1}}{0.5}=0.6\,\text{m s}^{-2}$ $0.6\,\text{m s}^{-2}=9.81\,\text{m s}^{-2}\sin\theta$ $\theta=3.6°$	4
	• Use of $a=g\sin\theta$	(1)		
	• Calculates a value for a, θ or v (using a SUVAT AND $a=g\sin\theta$)	(1)		
	• Valid comparison of their calculated quantity and the stated quoted uncertainty.	(1)		

Q6.

Question Number	Answer	Mark
	D	1

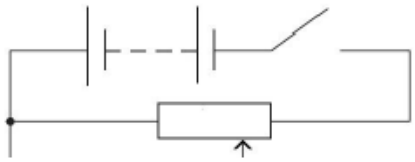
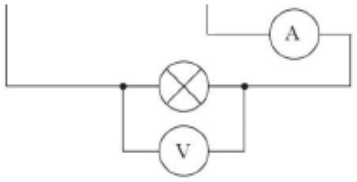
Q7.

Question Number	Answer	Mark
	B	1

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• The (voltmeter) reading will increase (1) • Resistance increases (with length) **Or** resistance ∝ length (1)	MP2: accept idea of a potential divider i.e. the ratio of the of BC to the total length AD will be greater, so the proportion of the total voltage will be greater ($\frac{BC}{AD}$ V) MP2: Do not award if there is also a reference to resistivity increasing	2

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• potential divider circuit diagram drawn as shown (1) • correctly incorporated into the given circuit (1)	 Switch not essential, accept potential divider with arrow drawn through resistor 	2

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• in circuit A, $V = IR_{lamp}$ and $I = \frac{V}{(R_{lamp} + R_{resistor})}$ (1) • when $R_{resistor}$ has its maximum value, $I \neq 0$ (1) • hence using circuit A the current will never be zero which is a limitation (1) OR range of p.d.s measured is limited • in circuit B the supply p.d. is divided up in the ratio of the two circuit resistances (1) $V_{lamp} = \frac{R_1}{R_1 + R_2} \times V$ OR • so by making R_1 equal to zero a full range of p.d. s (from 0 V to 12 V) can be applied which makes the circuit more suitable (1)		**(5)**

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. • Use of $R = \rho l/A$ • the wider section will be half the resistance of the narrow section • The p.d. will be divided into 0.5V across wide section and 1.0V across the narrow section • The potential will vary linearly along each resistance section (as R is proportional to l) • This is because current is constant throughout length • When the voltmeter is across the whole length it will read the p.d. across the cell/ 1.5V **Or** when the voltmeter terminals are together it will read 0 V	<table><tr><th>IC points</th><th>IC mark</th><th>Max linkage mark available</th><th>Max final mark</th></tr><tr><td>**6**</td><td>4</td><td>2</td><td>**6**</td></tr><tr><td>**5**</td><td>3</td><td>2</td><td>**5**</td></tr><tr><td>**4**</td><td>3</td><td>1</td><td>**4**</td></tr><tr><td>**3**</td><td>2</td><td>1</td><td>**3**</td></tr><tr><td>**2**</td><td>2</td><td>0</td><td>**2**</td></tr><tr><td>**1**</td><td>1</td><td>0</td><td>**1**</td></tr><tr><td>**0**</td><td>0</td><td>0</td><td>**0**</td></tr></table>	**6**

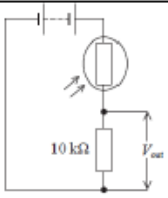
Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Reads current values at 3V for both components **(1)** • Current through fixed resistor R = 0.94 A **(1)**	Current values are 0.33 (A) and 0.61 (A) Allow tolerance of ± 0.01 A Allow tolerance of ± 0.02 A	**2**
(ii)	An explanation that makes reference to: • resistance of Y will be greater than resistance of parallel combination **(1)** • Y will have a greater share of the p.d **(1) OR** R will have a lower share of the p.d. **(1)** • so the reading on the voltmeter will increase. **(1)** **OR** • the current through R decreases **(1)** • as V = IR, the p.d. across R decreases**(1)** • so the p.d. across Y and the voltmeter reading will increase **(1)**	To score the final marking point candidates must score both MP1 and MP2	**3**

Q13.

Question Number	Acceptable Answers		Additional guidance	Mark
	• Uses ratio of resistances to pd's **Or** uses $I = \frac{V}{R_{total}}$ **and** $V = IR$	(1)	R_{total}=1750 Ω Example of Calculation $V_o = V_s\left(\frac{R_1}{R_1 + R_2}\right)$ $V_{LDR} = 24\text{ V}\left(\frac{1000\ \Omega}{750\ \Omega + 1000\ \Omega}\right)$ $= 13.7\text{ V}$ 13.7 > 13 so motor is on	3
	• Output pd =13.7 (V)	(1)		
	• Compares their answer to 13 (V) with conclusion consistent with their answer	(1)		

Q14.

Question Number	Answers	Additional Guidance	Mark
	B		**(1)**

Q15.

Question Number	Answer	Mark
	D $\frac{R_2}{R_1+R_2}V$	1
	Incorrect Answers: A – this looks similar to the correct formula but has an incorrect resistance as the numerator and does not have the total resistance as the denominator B – this looks similar to the correct formula with the correct resistance as the numerator but does not have the total resistance as the denominator C – This would give the PD across resistor R_1 and not R_2	

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• p.d. across capacitor increases **Or** p.d. across resistor decreases (1) • p.d. across capacitor increases to 5V (1) • p.d. across resistor starts at 5V and reduces to 0V (1) • Exponentially (1)		4

Q17.

Question Number	Answer	Additional Guidance	Mark
	B is the only correct answer	A is incorrect because this does not give the correct ratio C is incorrect because this does not give the correct ratio D is incorrect because this does not give the correct ratio	1

Q18.

Question Number	Answer	Mark
	B	1

Q19.

Question Number	Answer	Mark
	C	1

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• potential difference across the LDR = 3.6 V (1) **Or** $\frac{R}{(R+75\ \Omega)}$ seen **Or** $\frac{75\ \Omega}{(R+75\ \Omega)}$ seen • Use of $V = IR$ (1) **Or** resistance ratio × 6.0 V = corresponding p.d. • $R = 110\ \Omega$ (1)	MP2 use of $V = IR$ with 2.4 V or 3.6 V only Example of calculation $I = 2.4\ V/75\ \Omega = 0.032\ A$ Voltage across LDR = 6.0 V – 2.4 V = 3.6 V $R = \frac{3.6\ V}{0.032A}$ $R = 112.5\ \Omega$ **Or** use of ratios $\frac{75\ \Omega}{(R+75\ \Omega)} \times 6.0\ V = 2.4\ V$ $R = 112.5\ \Omega$	3

Q21.

Question Number	Acceptable answers	Additional Guidance	Mark
	Either • Calculates current correctly using $I=V/R$ (1) • $R = 1.10\ \Omega$ (1) **Or** • Use of ratios of lengths = ratios of resistances (1) • $R = 1.10\ \Omega$ (1) **Or** • Use ratio of resistances = ratio of p.d.s (1) • $R = 1.10\ \Omega$ (1)	Show that value gives 1.2 Ω Example of calculation: $I = \frac{1.125}{3.30} = 0.34A$ $R = \frac{0.375}{0.34} = 1.1\Omega$ Or $\frac{R}{3.30} = \frac{25}{75}$	2

Q22.

Question Number	Acceptable answers		Additional guidance	Mark
	Either • Use of equation(s) to determine the total resistance of the voltmeter and 40 Ω resistor in parallel (34.3 Ω) i.e. potential divider formula or Ohm's law • Use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ • $R_v = 240$ (Ω) **Or** • Use of Ohm's law to determine the current through voltmeter (0.0075 A) i.e. current in 40 Ω resistor calculated (0.045 Ω) **and** subtracted from current in 80 Ω resistor (0.0525 Ω) • Use of Ohm's law with 1.8 V to calculate the resistance of the voltmeter • $R_v = 240$ (Ω)	(1) (1) (1) (1) (1) (1)	Example of calculation $\left(\frac{R}{80\ \Omega + R}\right) 6\ \text{V} = 1.8\ \text{V}$ $R = 34.29\ \Omega$ $\frac{1}{34.29\ \Omega} = \frac{1}{40\ \Omega} + \frac{1}{R_V}$ $R_V = 240.2\ \Omega$	3

Q23.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use $V=IR$ to calculate current • Use $V=IR$ with V = 6.5 V to calculate LDR resistance • Light intensity = 185 (lux) (accept answers in range 180 lux -190 lux) **OR** • Use of potential divider principle • Use of $R_T = R_{LDR} + 4.5\text{k}\Omega$ to calculate LDR resistance **Or**	(1) (1) (1) (1) (1)	Example of Calculation. $2.5\ \text{V} = I \times 4.5\text{x}10^3\ \Omega$ $I = 5.6 \times 10^{-4}\ \text{A}$ $6.5\ \text{V} = 0.56\text{x}10^{-3}\ \text{A} \times R$ $R = 11700\ \Omega$	3

	Use of V_{LDR} = 6.5 V to calculate LDR resistance **(1)** • Light intensity = 185 (lux) (accept answers in range 180 lux -190 lux)		

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• (UV radiation consists of) photons **(1)** • One photon interacts with one electron **Or** energy of photon depends on frequency **(1)** • Electrons released if energy (of photon) greater than work function **Or** frequency is greater than threshold frequency **Or** energy supplied is sufficient to remove electron **(1)**	Accept quanta/packets of energy	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)(i)	• when slider at the bottom - reading on voltmeter is zero **Or** minimum resistance - reading on voltmeter is zero **(1)** • When slider at the top – reading on voltmeter is 1.5 V **Or** maximum resistance - reading on voltmeter is 1.5 V **(1)** • Potential difference split between top and bottom part of resistor (either side of slider) **Or** reading on voltmeter depends on the ratio of resistances (either side of slider) **Or** moving the slider changes the resistance that the voltmeter is across **(1)**		3

Question Number	Acceptable answers	Additional guidance	Mark
(b)(ii)	Maximum Kinetic Energy of electron = 0.6 (eV) **(1)**		1

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Question Number	Acceptable answers		Additional guidance	Mark
(c)	**Max 4** Valid because: • Moon and photocell both have vacuum • Both demonstration and theory use photoelectric effect Not valid because: • Different wavelengths in each case • On the moon there is dust not metal • Dust is free to move but the metal plate is fixed • On the moon UV removes electrons from (individual) <u>atoms</u> **and** in the demo light removes electrons from metal <u>surface</u> • Demonstration is based on photoelectric effect but effect on moon could be ionisation	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	Full marks can only be scored if a correct link is made between at least one physics point and the demonstration being valid or not valid Accept the same concept for photoelectric effect Accept one uses light the other UV Accept different materials for MP4	**4**

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• As temperature increases number of (free) charge carriers (in thermistor) increases so its resistance decreases **Or** As temperature increases number of charge carriers in conduction band increases so (thermistor) resistance decreases **(1)** • Thermistor resistance as a proportion of total resistance decreases **(1)** **Or** **(1)** Current increases so p.d. across resistor increases • P.D. (across thermistor) decreases	Accept electrons for charge carriers	**3**

Q2.

Question Number	Answer	Mark
	B	**1**

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Reads current values at 3V for both components **(1)** • Current through fixed resistor R = 0.94 A **(1)**	Current values are 0.33 (A) and 0.61 (A) Allow tolerance of ± 0.01 A Allow tolerance of ± 0.02 A	**2**
(ii)	An explanation that makes reference to: • resistance of Y will be greater than resistance of parallel combination **(1)** • Y will have a greater share of the p.d **(1) OR** R will have a lower share of the p.d. **(1)** • so the reading on the voltmeter will increase. **(1)** **OR** • the current through R decreases **(1)** • as V = IR, the p.d. across R decreases**(1)** • so the p.d. across Y and the voltmeter reading will increase **(1)**	To score the final marking point candidates must score both MP1 and MP2	**3**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A is not correct as the p.d. across the resistor will increase C is not correct as the resistance of the LDR will decrease D is not correct as the resistance of the LDR will decrease		**1**

Q5.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Uses ratio of resistances to pd's **Or** uses $I = \frac{V}{R_{total}}$ **and** $V = IR$ (1) • Output pd =13.7 (V) (1) • Compares their answer to 13 (V) with conclusion consistent with their answer (1)	R_{total}=1750 Ω <u>Example of Calculation</u> $V_o = V_s\left(\frac{R_1}{R_1 + R_2}\right)$ $V_{LDR} = 24\text{ V}\left(\frac{1000\ \Omega}{750\ \Omega\ + 1000\ \Omega}\right)$ $= 13.7\text{ V}$ 13.7 > 13 so motor is on	3

Q6.

Question Number	Answer	Mark
	B	1

Q7.

Question Number	Answer	Mark
	C	1

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• potential difference across the LDR = 3.6 V (1) **Or** $\frac{R}{(R+75\ \Omega)}$ seen **Or** $\frac{75\ \Omega}{(R+75\ \Omega)}$ seen • Use of $V = IR$ (1) **Or** resistance ratio × 6.0 V = corresponding p.d. • $R = 110\ \Omega$ (1)	MP2 use of $V = IR$ with 2.4 V or 3.6 V only Example of calculation $I = 2.4\ V/75\ \Omega = 0.032\ A$ Voltage across LDR = 6.0 V – 2.4 V = 3.6 V $R = \frac{3.6\ V}{0.032A}$ $R = 112.5\ \Omega$ **Or** use of ratios $\frac{75\ \Omega}{(R+75\ \Omega)} \times 6.0\ V = 2.4\ V$ $R = 112.5\ \Omega$	3

Q9.

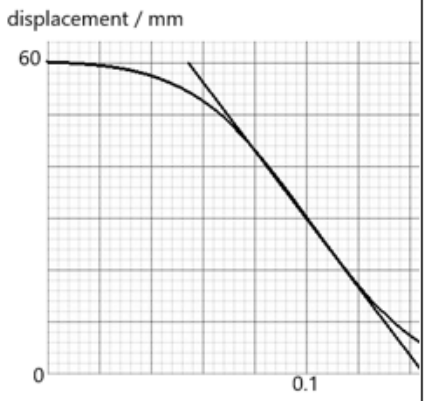
Question Number	Acceptable answers	Additional guidance	Mark
	D In the dark the resistance of the LDR will be very large so practically all the potential difference of 6V will be across it.	a little below 6 V	1
	A assumes the resistance of the LDR decreases to almost zero B assumes the resistance of the LDR decreases a little C assumes the resistance of the LDR increases a little		

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Current (in the circuit) decreases **(1)** • P.d. across the LDR decreases **(1)** • Voltmeter reading increases (MP3 dependent on MP1 or MP2) **(1)**	Accept approaches using potential divider theory • Pd from supply divides in ratio of resistances of the two components, eg. $V_{LDR} = \frac{R_{LDR}}{R_R + R_{LDR}} \times V_{Total}$ • As R_R increases, but R_{LDR} stays constant • So voltmeter reading increases (MP3 dependent on MP1)	**3**

Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• uses ratio of lengths to determine p.d. across potentiometer • V = 9.6 (V)	(1) (1)	Example of calculation: p.d. across potentiometer = $\frac{115\text{ mm}}{60\text{ mm}} \times 5\text{ V} = 9.6\text{ V}$	2
(ii)	• determines p.d. across R • apply $V = IR$ to potentiometer to determine current **Or** uses ratio of resistances = ratio of p.d.s • $R = 3000\ \Omega$	(1) (1) (1)	Example of calculation: current in circuit = $\frac{9.6\text{ V}}{12000\ \Omega} = 8.0 \times 10^{-4}$ A p.d. across $R = 12 - 9.6 = 2.4$ V $R = {}^{2.4\text{ V}}/_{8.0 \times 10^{-4}\text{A}}$ R = 3000 Ω (show that value gives 2400 Ω)	3
(iii)	• A battery has internal resistance • There is a p.d. across the internal resistance • Terminal p.d. less (than e.m.f.) **Or** refers to $V = E - Ir$	(1) (1) (1)	Accept "lost volts" for MP2 V must be the subject	3
(iv)	• tangent drawn on the curve • uses a triangle base of at least 0.06 s • attempt to find a gradient • velocity = 0.68 m s^{-1} so velocity not exceeded allow range from to 0.60 m s^{-1} to 0.80 m s^{-1}	(1) (1) (1) (1)	MP2 dependent on MP1  v = gradient = $\frac{60\text{ mm}}{0.144 - 0.056}$ v = 682 mm s^{-1}	4

Q2.

Question Number	Answer	Additional Guidance	Mark
	• Use of $V = IR$ **(1)** • Use of $P = I^2R$ **(1)** • Use of $P = \frac{E}{t}$ **(1)** • $E = 320$ J ECF from (a) **(1)** [show that answer gives 323 J] **Or** • Use of $V = IR$ to find I **(1)** • Use of $V = IR$ to find terminal pd **(1)** • Use of $W = VIt$ **(1)** • $E = 320$ J ECF from (a) **(1)** [show that answer gives 323 J]	Example of calculation $I = \frac{9\text{ V}}{(72+2.5)\ \Omega} = 0.121\text{ A}$ $P = (0.121\text{ A})^2 \times 72\ \Omega$ $= 1.05\text{ W}$ $E = 1.05\text{ W} \times 300\text{ s}$ $= 316\text{ J}$	**4**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• Calculates p.d. across internal resistance **(1)** • Use of $R = V / I$ **(1)** • Internal resistance = 6 Ω **(1)**	Example of calculation: $V_r = 8.2\text{V} - 5.5\text{V} = 2.7\text{V}$ $r = \frac{2.7\text{ V}}{0.45\text{ A}}$ $r = 6.0\ \Omega$	**3**

Q4.

Question Number	Answer	Mark
	D	1

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following: • The (terminal) p.d. (of the cell) decreases. (1) • $I=\frac{V}{R}$, so the current decreases as the (external) resistance in the circuit stays constant (1)	In MP1 do not accept voltage for p.d. MP2: Accept $I \propto V$ because (external) resistance in the circuit is constant, so the current decreases	2
(ii)	• Use of $I=\frac{V}{R}$ with $R = 220\ \Omega$ or $(220 + r)$ (1) • (Sum of e.m.f. = sum of p.d. leading to) use of $r=\frac{(\varepsilon - V)}{I}$ with I from MP1 (1) • $r = 30\ \Omega$ (allow answers in range $28\ \Omega - 32\ \Omega$) (1)	Answer in range with no working shown scores MP3 only Example of calculation $I=\frac{3.52\ \text{V}}{220\ \Omega}=1.60\times10^{-2}\text{A}$ $r=\frac{\varepsilon - V}{I}=\frac{(4.0\text{-}3.52)\ \text{V}}{1.60\times10^{-2}\text{A}}=30.0\ \Omega$	3

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is A B *is not correct because V decreases as I decreases* C *is not correct because I decreases as R increases* D *is not correct because I decreases as R increases*	decreases decreases	1

Q7.

Question Number	Answer		Mark
(a)	Variable resistor in series Ammeter in series and voltmeter in parallel with cell (If there are extra fixed resistances they can be ignored, as long as the terminal p.d. is being measured. Assume the ammeter has zero resistance, so its precise placement doesn't matter as long as it is in series)	(1) (1)	2
(b)	Best fit straight line drawn Substitution of values from student's line for gradient using at least half current axis ($\Delta I \geq 80$ mA) $\mathcal{E} = 3.9$ V to 4.1 V $r = 1.6\ \Omega$ to $2.5\ \Omega$ <u>Example of calculation</u> gradient = (3.7 V – 4.0 V) / 0.16 A = – 1.9 Ω	(1) (1) (1) (1)	4
(c)	Start y-axis at 3.0 V (accept reference to points from 3.0 to 3.75 V) This will allow plots to be made more accurately **Or** This will allow intercept and change in V to be determined to more sf **Or** this will allow read-offs to be made with more precision (Only award this mark if first mark awarded)	(1) (1)	2
	Total for Question		8

Q8.

Question Number	Answer		Mark
(a)	Negative gradient (accept curve)	**(1)**	
	Straight line (dependent on first marking point)	**(1)**	
	Reference to terminal p.d. = e.m.f. – 'lost volts' **Or** $V = \varepsilon - Ir$	**(1)**	
	Intercept on V axis = ε **Or** Intercept on y axis = ε **Or** ε = value of V on graph when $I = 0$ (accept from labelled graph)(mark not awarded if line passes through origin)	**(1)**	
	Gradient = $-r$ **Or** magnitude of gradient is r (accept gradient = $-r$ marked on graph)	**(1)**	**5**
***(b)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)		
	Ammeter explanation:		
	If ammeter has resistance, current decreased but doesn't affect the determination because current through cell/r is measured	**(1)**	
	Or doesn't affect the determination because the voltmeter measures the terminal p.d. for that current	**(1)**	
	OR		
	The resistance of the ammeter contributes to the load/circuit/total resistance	**(1)**	
	Values of p.d. corresponding to given values of current will be unchanged	**(1)**	
	Voltmeter explanation:		
	If voltmeter has smaller resistance it would draw current	**(1)**	
	measured current not current through cell/r	**(1)**	**4**
	Total for question		**9**

Q9.

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Question Number	Acceptable answers		Additional guidance	Mark
	• Identifies $\mathcal{E} = 1.36$ V	(1)	MP1: This may be implied in a calculation MP3: allow either e.m.f. to be sub for the use of mark MP5: descriptions of r and V both required MP5: conditional mark on MP4 Example calculation $I = 0.84$ V / 5.92 Ω $I = 0.142$ A 1.36 V = 0.84 V + 0.142 A × r $r = 3.66$ Ω	5
	• Use of $I = V/R$ with $R = 5.92$ Ω and $V = 0.84$ V	(1)		
	• Use of $\mathcal{E} = V + Ir$ **Or** equivalent to determine r	(1)		
	• $r = 3.7(\Omega)$	(1)		
	• Both are correct (because r has increased and $\mathcal{E}$ has decreased)	(1)		

Q10.

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

Q11.

Question Number	Answer	Mark
	C	1

Q12.

Question Number	Answer	Mark
	Use of $V = IR$ **(1)** Use of lost volts = emf − terminal pd **Or** use of total resistance − 6.6Ω **(1)** (quoting $\varepsilon = I(R + r)$ or $\varepsilon = V + Ir$ gets both marks) Internal resistance = 0.54 Ω **(1)** (rounding and different methods all give 0.5 Ω to 1 sig. fig .) Example of calculation $V = 0.21\ \text{A} \times 6.6\ \Omega = 1.39\ \text{V}$ $Ir = 1.5\ \text{V} - 1.39\ \text{V} = 0.11\ \text{V}$ $r = 0.11\ \text{V} \div 0.21\ \text{A} = 0.54\ \Omega$	3
	Total for question	**3**

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	D Work done per unit charge to move a charge around a circuit.		**1**

Q14.

Question number	Acceptable answers	Additional guidance	Mark
	• From graph: after 500 charging cycles internal resistance of cell is 327 mΩ **(1)** • Use of $V = \varepsilon - Ir$ **(1)** • Use of $\frac{V_{500}}{V_0} \times 100\%$ $\frac{V_{500}}{V_0} \times 100\% = 99.6\%$ **(1)** • So manufacturer's claim is correct **(1)**	Example of calculation: $V_0 = 3.6\ \text{V} - 0.800\ \text{A} \times 0.310\ \Omega$ $= 3.6\ \text{V} - 0.248\ \text{V} = 3.352\ \text{V}$ $V_{500} = 3.6\ \text{V} - 0.800\ \text{A} \times 0.327\ \Omega$ $= 3.6\ \text{V} - 0.262\ \text{V} = 3.338\ \text{V}$ $\frac{V_{500}}{V_0} \times 100\% = \frac{3.338\text{V}}{3.352\text{V}} \times 100\% = 99.6\%$ This last mark is awarded only if the conclusion is correctly supported by the calculation.	**4**

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• state or use of $\mathcal{E} = V + Ir$ **(1)** • $r = 28.6\ \Omega$ **(1)**	Example of calculation: 4.1 V = 3.7 V + 0.014 A × r $r = 28.6\ \Omega$	**2**
(ii)	• use of $I = P/A$ **(1)** • use of $P = IV$ **(1)** • calculation of efficiency of pointer **(1)** • analysis of data in passage to give efficiency of laser as approximately 40% **(1)** • comparing data analysed to draw a conclusion that the claim is not justified. **(1)**		**5**

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	B		**1**

Q17.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	V = ε − Ir	**(1)**

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	• Due to the internal resistance of the cell (1) • There is a potential difference across the internal resistance of the cell **Or** there will be 'lost volts' (1) **Or** $V = \mathcal{E} - Ir$		2

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $P = IV$ (1) • Use of $V = \varepsilon - Ir$ Or $V = 180 - 0.036I$ (1) • Converts kW to W and rearranges equation to that shown (1)	Example of derivation: $88\text{ kW} = I \times V$ $88\text{ kW} = I \times (180 - 0.036I)$ $88000 = 180I - 0.036I^2$ $0.036I^2 - 180I + 88000 = 0$	3
(ii)	• Use of $Q = It$ (1) • Time that batteries can deliver this power = 40 s so more than 7 s (1)	Example of calculation: $6.1\text{ A h} = 550\text{ A} \times \text{t}$ $t = 0.011\text{ h} = 40\text{ s}$	2