PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 3: ELECTRIC CIRCUITS

ELECTRICAL QUANTITIES AND COMPONENTS

SCORE	PERCENTAGE
/715	%

STEMUP

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Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of Q = CV (1) • Use of $Q = Q_0 e^{-t/RC}$ (1) • Q/Q_0 = 0.01 (1) • t = 11.6 ms (1) • Use of $I = \frac{Q}{t}$ (1) • I = 12 A (1)	Example of calculation: $Q = CV = 56 \times 10^{-6}\ F \times 2500\ V = 0.14\ C$ $\ln\left(\frac{Q}{Q_0}\right) = e^{-t/RC}$ $\ln(0.01) = -\frac{t}{45\Omega \times 56 \times 10^{-6} F} \therefore t = 0.0116s$ $I = \frac{Q}{t} = \frac{0.14s}{0.0116s} = 12.1A$	**(6)**

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	Maximum 3 marks • There cannot be a p.d. across his body (1) • Electric field strength inside cage is zero (1) • As no potential gradient (1) • Current/electrons/charge would conduct through suit **Or** the current would not pass through body (1)	Accept reference to Faraday cage for MP2	**3max**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: • Electrons/charge transferred from negatively charged plate to positively charge plate through the resistor **(1)** • Hence the charge on capacitor decreases (exponentially) **(1)** • Until the charge on the capacitor equals 0/negligible **(1)**		**3**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1} **(1)** • Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of $B=F/IL$ and cancels I's **(1)** • Uses units of n = m^{-3} and completes agreement **(1)** Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2} **(1)** • Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of $B=F/IL$ and cancel I's or A's **(1)** • Uses base units of n = m^{-3} and completes agreement **(1)**	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3} Cm$ $= \frac{Nm}{c} = \frac{J}{C}$	**(3)**

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $Q = It$ **(1)** • use of $V = \frac{W}{Q}$ **(1)** • $W = 5.1 \times 10^8$ J **(1)**	Allow calculations based on power i.e. $VI = \frac{W}{t}$ Example of calculation: $Q = It = 25 \times 10^3 A \times 7.5 \times 10^{-3} s = 188$ C $W = QV = 188$ C $\times 2.7 \times 10^6 V = 5.08 \times 10^8$ J	**3**

Q6.

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

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	• Deduce the p.d. across the total resistance (1) • Use of $P = I^2R$ or V^2/R (1) • $P = 3.3 \times 10^{-3}$ W (1)	Example of calculation $I = \frac{6\ \text{V}}{3.3\ k\Omega + 2.7\ k\Omega} = 1.0\ \text{mA}$ $P = (1.0\ \text{mA})^2 \times 3300\Omega$ $= 3.3 \times 10^{-3}\ \text{W}$ Alternative $V = 6\ \text{V} \times \frac{3.3}{3.3 + 2.7} = 3.3\ \text{V}$ $P = \frac{3.3^2\ \text{V}^2}{3300\ \Omega} = 3.3 \times 10^{-3}\ \text{W}$	3

Q8.

Question Number	Answer		Mark
(a)	The capacitor stores charge **Or** capacitor charges from the supply The idea that the capacitor doesn't fully discharge before being recharged.	(1) (1)	2
(b)(i)	(6.4 + 4.4)/2 = 5.4 V	(1)	1
(b)(ii)	Use of $V = IR$ Average I = 5.4 V/(2.2 × $10^3\Omega$) = 2.5× 10^{-3} A ecf value form (b)(i)	(1) (1)	2
(b)(iii)	Time = 17 ms or 17.5 ms	(1)	1
(b)(iv)	Use of $Q = It$ Use of $C = Q/V$ Use of ΔV = 2.0 V C = 21 μF (ecf values of I and t from above) Example of calculation Q = 2.5× 10^{-3} A × 17 × 10^{-3} s = 4.25 × 10^{-5} C C = 4.25 × 10^{-5} C / 2.0 V C = 21 μF	(1) (1) (1) (1)	4
(c)	Uses a larger capacitance Because a larger time constant is needed **Or** stores more charge **Or** less $\Delta V \rightarrow \Delta Q/C$	(1) (1)	2
	Total for question		12

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Conversion of MeV to J (1) • See $Q_1 = 79 \times 1.6 \times 10^{-19}$ and $Q_2 = 2 \times 1.6 \times 10^{-19}$ (1) • Use of $V = \frac{Q}{4\pi\varepsilon_0 r}$ and $W = QV$ (1) • $r = 4.1\times10^{-14}$ m (1)	Example of calculation $E_\alpha = 5.5\times10^{6}\text{eV}\times1.6\times10^{-19}\text{J eV}^{-1} = 8.8\times10^{-13}\text{J}$ $8.8\times10^{-13}\text{J} = \frac{79\times1.6\times10^{-19}\text{C}\times2\times1.6\times10^{-19}\text{C}}{4\pi\times8.85\times10^{-12}\text{ F m}^{-1}\ r}$ $r = \frac{3.64\times10^{-26}\text{ N m}^2}{8.8\times10^{-13}\text{ J}} = 4.1\times10^{-14}\text{ m}$	4
(ii)	• Electrons are behaving like waves (1) • wavelength $= \frac{h}{\text{momentum}}$ (1) • Electron wavelength must be similar to the atomic spacing in the foil (1)	MP3: Accept electron wavelength must be similar to the distance between (adjacent) nuclei	3

Q2.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Use of $W = QV$ • Use of $KE = \frac{1}{2}mv^2$ • Use of $1u = 1.66 \times 10^{-27}$ kg • $v = 2.16 \times 10^5$ (m s^{-1})	(1) (1) (1) (1)	Example of calculation: $\frac{1}{2}mv^2 = eV$ $\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19}\text{C} \times 8.5 \times 10^3\text{V}}{(34.97 \times 1.66 \times 10^{-27})\text{kg}}} = 2.16 \times 10^5 \text{ms}^{-1}$	4

Q3.

Question Number	Answer	Mark
	B	1

Q4.

Question Number	Answer	Additional guidance	Mark
(a)(i)	thermionic emission		(1)

Question Number	Acceptable Answer		Additional guidance	Mark
(a)(ii)	• equate $\frac{1}{2}mv^2$ and VQ • $v = 2.3 \times 10^7$ m s^{-1}	(1) (1)	Example of calculation: $E = 1500\text{ V} \times 1.6 \times 10^{-19}\text{ C} = 2.4 \times 10^{-16}\text{ J}$ $v = \sqrt{\frac{2 \times 2.4 \times 10^{-16}\text{ J}}{9.11 \times 10^{-31}\text{ kg}}} = 2.3 \times 10^7$ m s^{-1}	(2)

Question Number	Acceptable Answer		Additional guidance	Mark
(b)(i)	• use of $F = EQ$ and $E = \frac{V}{d}$ OR see $F = \frac{VQ}{d}$ • equate $F = ma$ and $F = EQ$	(1) (1)		(2)

Question Number	Acceptable Answer	Additional guidance	Mark
(b)(ii)	• use of speed = distance/time (1) • $t = 8.7 \times 10^{-10}$ (s) (1) • use of a = $\frac{VQ}{dm}$ (1) • use of $s = ut + \frac{1}{2}at^2$ (1) with $u = 0$ and vertical acceleration to find s • $s = 3.3 \times 10^{-4}$ m (1)	Example of calculation: $t = \frac{0.02\ \text{m}}{2.3\times10^{7}\ \text{m s}^{-1}} = 8.7 \times 10^{-10}$ s $s = \frac{1}{2} \times \left(\frac{50\ \text{V} \times 1.6 \times 10^{-19}\ \text{C}}{0.01\ \text{m} \times 9.11 \times 10^{-31}\ \text{kg}} \right) \times (8.7 \times 10^{-10}\ \text{s})^2$ $s = 3.3 \times 10^{-4}$ m	**(6)**

Question Number	Acceptable Answer	Additional guidance	Mark
(c)	• use of $V = V_0/\sqrt{2}$ (1) • vertical line (1) • positive and negative deflection shown (1) • maximum deflection 75 V (1)	Example of calculation: $V_0 = 53\ \text{V} \times \sqrt{2} = 75\ \text{V}$	**(4)**

Q5.

Question Number	Acceptable answers	Additional guidance	Mark
	C	joule per coulomb.	1
	Incorrect Answers: A is reciprocal of volt B is definition of amp D is definition of watt		

Q6.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• Photoelectric equation stated in words **Or** $hf = \phi + \frac{1}{2}mv_{max}^2$ with ϕ defined	(1)	MP1: Accept hf_0 for ϕ [with f_0 defined], and $E_{k\,max}$ for $\frac{1}{2}mv_{max}^2$ MP2: eV_s does not have to be the subject of the equation MP5 is dependent upon MP4	5
	• Hence $eV_s = hf - \phi$ **Or** $E_{k\,max} = hf - \phi$ **and** $E_{k\,max} = eV_s$	(1)		
	• Compare with $y = mx + c$	(1)		
	• So plot a graph of V_s against f **Or** plot a graph of eV_s against f	(1)		
	• Gradient $= \frac{h}{e}$ **Or** gradient $= h$	(1)		

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
	• Uses V = J/C **Or** V = Nm/C **Or** V = Wb s^{-1}	(1)	Example of unit simplification: J/C should equal $\frac{N}{Am} \times A \div m^{-3}Cm = \frac{Nm}{C} = \frac{J}{C}$	(3)
	• Use of T = N/Cms^{-1} **Or** T = N/Am **Or** T = Wb m^{-2} **Or** Sub of $B=F/IL$ and cancels I's	(1)		
	• Uses units of n = m^{-3} and completes agreement	(1)		
	Alternative with base units: • Uses base unit of force = kg m s^{-2} **Or** base unit of energy = kg m^2 s^{-2}	(1)		
	• Uses base unit of charge = A s **Or** uses A = Cs^{-1} **Or** Sub of $B=F/IL$ and cancel I's or A's	(1)		
	• Uses base units of n = m^{-3} and completes agreement	(1)		

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• use of $Q = It$ (1) • use of $V = \frac{W}{Q}$ (1) • $W = 5.1 \times 10^8$ J (1)	Allow calculations based on power i.e. $VI = \frac{W}{t}$ Example of calculation: $Q = It = 25 \times 10^3 \text{A} \times 7.5 \times 10^{-3} \text{s} = 188$ C $W = QV = 188 \text{ C} \times 2.7 \times 10^6 \text{V} = 5.08 \times 10^8$ J	3

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Use of $F = BQv$ and $F = EQ$ (1) • Algebra to show $v = \frac{E}{B}$ (1)		2
(ii)	• Use of $W = QV$ *and* $E_k = \frac{1}{2}mv^2$ (1) • Use of $v = \frac{E}{B}$ (1) • $\frac{e}{m} = 1.7 \times 10^{11}$ C kg^{-1} (1)	Example of calculation: $v = \frac{E}{B} = \frac{1.4 \times 10^4 \text{ V m}^{-1}}{1.5 \times 10^{-3} \text{ T}}$ $\frac{e}{m} = \frac{v^2}{2V}$ $\frac{e}{m} = \frac{\left(9.33 \times 10^6 \text{ m s}^{-1}{}^2\right)}{2 \times 250 \text{ V}} = 1.74 \times 10^{11}$ C kg^{-1}	3

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Substitute eV for $\frac{1}{2} mv^2_{max}$ in $hf = \phi + \frac{1}{2} mv^2_{max}$ **(1)** • Rearranges to identify gradient = h/e **(1)** • Attempt to find gradient using large triangle **(1)** • $h = 7.6 \times 10^{-34}$ J s (range: 7.5×10^{-34} J s to 7.7×10^{-34} J s)	<u>Example of calculation</u> $hf = \phi + \frac{1}{2} mv^2_{max}$ $hf = \phi + eV$ $eV = hf - \phi$ $V = hf/e - \phi/e$ gradient = h/e gradient = (2.40 V – 1.00 V) ÷ (6.975×10^{14} Hz – 4.025×10^{14} Hz) gradient = 4.72×10^{-34} V s $h = 4.72 \times 10^{-34}$ V s × 1.6×10^{-19} C $h = 7.58 \times 10^{-34}$ J s	**4**

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
	• (Faint and difficult to see, so may not be seen at the correct p.d. and) recorded p.d. could be too high **(1)** • (Range of frequencies could mean light is seen before the light at the stated frequency and) recorded p.d. could be too low **(1)** • Discussion of these points, e.g. opposite effects, could cancel or could be systematic errors and not affect gradient **(1)**		**3**

Q12.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • The potential difference creates an electric field (1) • An (electric) field/force does work on the electrons (increasing their kinetic energy) **Or** an (electric) field/force accelerates the electrons (increasing their velocity) (1)		**2**

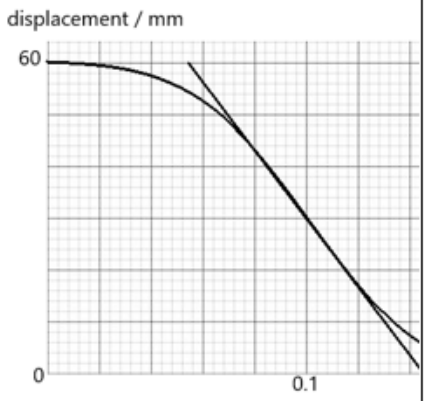
Mark Scheme

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
(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

Q3.

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**

Q4.

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**

Q5.

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

Q6.

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** • $V_{LED} = 2\,\text{V}$ (from graph) (1) • Use of $V_{LED} + V_R = 5\,\text{V}$ (1) • Use of $R = \frac{V}{I}$ (1) • R = 170 Ω (1) **Or** • Use of $R = \frac{V}{I}$ (1) • $V_{LED} = 2\,\text{V}$ (from graph) (1) • Use of $R_{LED} + R = 278\,\Omega$ (1) • R = 170 Ω (1)	Example of calculation: $2\,\text{V} + V_R = 5\,\text{V}$ $\therefore V_R = 3\,\text{V}$ $R = \frac{3\,\text{V}}{18 \times 10^{-3}\,\text{A}} = 167\,\Omega$	4

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Ohm's law requires current to be (directly) proportional to the (applied) p.d **(1)** • Hence the line should pass through the origin **(1)** • (There is scatter around the line drawn by the student so) the correct line may be a curve **(1)** • Conclusion that this graph does not meet the conditions for Ohm's law so the student's statement is invalid **(1)**	For MP1 accept Ohm's law requires $I \propto V$ In MP2, credit students who check values from graph to see if I doubles when V doubles In MP3, credit students who draw a curve onto the graph MP4 dependent upon MP2 OR MP3	**4**

Q8.

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**

Q9.

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**

Q10.

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 Ω – 32 Ω) **(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**

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $R=\rho l/A$ (1) • Using $A=0.5\times28$ ($\times10^{-6}$ m^2) (1) • Use of $V=IR$ (1) • $I = 22$ (mA) (1)	Example of calculation $R=\frac{1.6\Omega\text{m}\times0.6\times10^{-3}\text{m}}{0.5\times10^{-3}\text{m}\times28\times10^{-3}\text{m}}$ $R = 68.6\Omega$ $1.5V = I\times68.6\Omega$ $I = 1.5\text{V}/68.6\Omega$ $I = 0.022\text{A} = 22\text{mA}$	4

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $F=BIL$ ecf values from (i) (1) • Force = 5.3×10^{-6} N (1)	Use of show that values gives 4.8×10^{-6} N Example of calculation $F = 0.40\text{T}\times0.022\text{A}\times0.6\times10^{-3}\text{m}$ $F = 5.3\times10^{-6}\text{N}$	2

Q12.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: • A rise in temperature causes the amplitude of the vibrating ions to increase **(1)** • This causes the number of collisions per second between the ions and the moving electrons to increase **(1)** • So the rate of flow of electrons decreases (causing the resistance of the metal to increase) **(1)**	Allow reduce mean free path or drift velocity of electrons. Accept current decreases	3

Q13.

Question Number	Answer		Mark
(a)	Use of $\Phi = BA$ Converts cm to m Or mT to T $\Phi = 1.1 \times 10^{-4}$ Wb Example of calculation $\Phi = 6.0 \times 10^{-2}$ m $\times$ 2.4×10^{-2} m $\times$ 74×10^{-3} T $\Phi = 1.07 \times 10^{-4}$ Wb	(1) (1) (1)	3
(b)	Use of $\mathcal{E} = \Delta\Phi/\Delta t$ Use of time = distance/speed $\mathcal{E}$ = 5.3 mV (5.0 mV or 5.5 mV depending on value of Φ used, ecf value of Φ from (a)) **Or** Quotes $\mathcal{E} = Blv$ $l = 6.0 \times 10^{-2}$m used $\mathcal{E}$ = 5.3 mV Example of calculation Time = 0.024 m / 1.2 m s^{-1} t = 0.020 s $\mathcal{E} = 1.1 \times 10^{-4}$ Wb / 0.02 s = 5.5 mV	(1) (1) (1) (1) (1) (1)	3
(c)	Use of $I = V/R$ Use of $F = BIl$ $F = 9.8 \times 10^{-5}$ N (ecf value of $\mathcal{E}$ from (b)) This force is too small to be felt. (this comment must be consistent with their value of force) Example of calculation I = 5.5 mV/ /0.25 Ω = 0.022 A $F = 74 \times 10^{-3}$ T $\times$ 0.022 A $\times$ 0.060 m $F = 9.8 \times 10^{-5}$ N	(1) (1) (1) (1)	4
	Total for question		10

Q14.

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

Q15.

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

Q17.

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 $= 0.0016\text{ A} \times 625\Omega = 1.0$ V V across multiplier $= 5.0\text{ V} - 1.0\text{ V} = 4.0$ V $R_{multiplier} = \frac{4.0\text{ V}}{0.0016\text{ A}} = 2500\ \Omega$ MP3 dependent on MP1 or MP2	3

Q18.

Question number	Acceptable answers	Additional guidance	Mark
(i)	R= 47.4 Ω **(1)**	Example of calculation: R = 2.7 V/0.057 A = 47.4 Ω	**1**
(ii)	• Use of $\mathcal{E}=V+Ir$ **or** correct attempt to find r **(1)** • r = 57.9 Ω or find ratio $\frac{R}{r}$ **(1)** • Makes conclusion by comparing r and R, recognising maximum power supplied when $\frac{R}{r} = 1$ **(1)**	Answer consistent with calculated value. Example of calculation: $r = \frac{(6.0\ V - 2.7\ V)}{0.057\ A} - 50 = 57.9\ \Omega$	**3**

Q19.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</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 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.

Indicative content:
• (Maximum/Initial) current is equal to battery emf divided by R
Or current as switch closed
Or current as complete circuit
Or current due to battery
• Coil rotates
• (movement of) coil "cuts/changes" (magnetic) flux (linkage) / field
• Which induces an emf (according to Faraday's law)
• Opposes original emf/current according to Lenz's law
Or current reduced as effect opposes change
• The faster the coil rotates the larger this (back) emf/effect the smaller the current</td><td><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>
ic3 needs a link to coil moving
ic4 depends on ic3</td><td>6</td></tr>
</table>

Q20.

Question Number	Answer		Mark
(a)	The capacitor stores charge **Or** capacitor charges from the supply The idea that the capacitor doesn't fully discharge before being recharged.	(1) (1)	2
(b)(i)	(6.4 + 4.4)/2 = 5.4 V	(1)	1
(b)(ii)	Use of $V = IR$ Average I = 5.4 V/(2.2 × $10^3\Omega$) = 2.5× 10^{-3} A ecf value form (b)(i)	(1) (1)	2
(b)(iii)	Time = 17 ms or 17.5 ms	(1)	1
(b)(iv)	Use of $Q = It$ Use of $C = Q/V$ Use of ΔV = 2.0 V C = 21 μF (ecf values of I and t from above) Example of calculation Q = 2.5× 10^{-3} A × 17 × 10^{-3} s = 4.25 × 10^{-5} C C = 4.25 × 10^{-5} C / 2.0 V C = 21 μF	(1) (1) (1) (1)	4
(c)	Uses a larger capacitance Because a larger time constant is needed **Or** stores more charge **Or** less $\Delta V \rightarrow \Delta Q/C$	(1) (1)	2
	Total for question		12

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\Delta E = mc\Delta\theta$ (1) • Use of $\Delta E = L\Delta m$ (1) • Apply 5% to calculate energy saved (1) • Use of $P = VI$ or Use of $Q = It$ (1) • Use of $P = \frac{W}{t}$ or Use of $E = QV$ (1) • 2.69×10^5 J compared with 1.93×10^5 J for energy saved, and concludes claim invalid. (1) **Or** a phone could run for 5 days compared to 7 days and conclusion claim invalid **Or** a phone could run for 433 900 s compared to 604 800 s and conclusion claim invalid	Example of calculation: For aluminium when being heated up to m.pt.: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 902\ \text{J kg}^{-1}\text{K}^{-1} \times (660 - 293)\text{K}$ $\Delta E = 4.63 \times 10^3\ \text{J}$ For aluminium when melting: $\Delta E = 14 \times 10^{-3}\ \text{kg} \times 396 \times 10^3\ \text{J kg}^{-1} = 5.54 \times 10^3\ \text{J}$ Energy saved $= \frac{0.95}{0.05} \times (4630 + 5540)\text{J}$ Energy saved $= 1.93 \times 10^5\ \text{J}$ $P = 3.7\ \text{V} \times 120 \times 10^{-3}\ \text{A} = 0.444\ \text{W}$ $\Delta E = 0.444\ \text{W} \times 7 \times 24 \times (60 \times 60)\text{s} = 2.69 \times 10^5\ \text{J}$	6

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $P = VI$ for panel (1) • Use of $P = \frac{E}{t}$ (1) • Time = 13 hours (1)	Example of calculation: Total Power of panels= $380 \times 5.5\ \text{V} \times 0.45\ \text{A} = 940.5\ \text{W}$ Time to charge = 12000 / 940.5 = 12.8 hours	3

Q3.

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)**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q5.

Question Number	Answer	Mark
(a)(i)	Use of $P = IV$ (1) Power = 2900 W (1) Example of calculation Power = 12.5 A × 230 V = 2875 W	2
(a)(ii)	$P = E/t$ (1) Energy = 400 000 J (ecf from (i)) (1) Example of calculation Energy = 2875 W × 140 s = 402 500 J	2
(a)(iii)	Use of efficiency = useful energy output / total energy input (1) = 0.87 or 87% (ecf from (ii)) (do not award if > 100%) (1) Example of calculation Efficiency = 351 000 J / 402 500 J = 0.87 or 87%	2
(b)	Some energy transferred by heating the kettle / element / wires / surroundings **Or** Some energy transferred as sound (1) So not all of the (input) energy is transferred to (heating) the water **Or** so useful energy output is less than energy input **Or** only the energy heating the water is useful (1)	2
	Total for question	8

Q6.

Question number	Acceptable answers	Additional guidance	Mark
	D		1

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• Use of $P = VI$ (1) • P = 1900 W (1.9 kW) (1)	Example of calculation P=230 V × 8.20 A = 1890 W	2
(a)(ii)	• Use of $\Delta E = mc\Delta\vartheta$ • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • Δt = 112 s or 113 s [106 s or 107 s if show that value used] (1) ECF from (a)(i) (1)	Example of calculation $\Delta E = 0.655\ \text{kg} \times 4190\ \text{J kg}^{-1}\text{K}^{-1} \times (100 - 22.5)\text{K}$ $\Delta E = 2.13 \times 10^5\ \text{J}$ $\Delta t = \frac{2.13 \times 10^5 \text{J}}{1890\ \text{W}} = 112.5\ \text{s}$	3

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• After a short time of boiling in the flask, all the apparatus would be at 100 °C. **Or** so energy is not being used to heat up the flask **Or** so steam won't condense in the flask (1)		1
(b)(ii)	• Use of $\Delta E = mL$ (1) • Use of $P = \frac{\Delta E}{\Delta t}$ (1) • 1720 W (1.72 kW) (1)	Example of calculation $\frac{\Delta m}{\Delta t} = \frac{95 \times 10^{-3}\ \text{kg}}{125\ \text{s}}$ $= 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\frac{\Delta E}{\Delta t} = 7.6 \times 10^{-4}\ \text{kg s}^{-1}$ $\times 2.26$ $\times 10^{6}\ \text{J kg}^{-1}$ $P = 1720\ \text{J s}^{-1}$	3
(b)(iii)	• Comparison of answer to (a)(i) with answer to (b)(ii) (1) • Not all of the energy from the heater is used to turn water from liquid state into vapour (1) **Or** energy is being used to heat the heat exchanger (1) **Or** not all the steam condenses in the heat exchanger • Some energy is transferred to the surroundings	e.g. rate at which thermal energy is supplied to the water in the flask is greater than rate at which thermal energy is removed from the water in the heat exchanger. If answer for (b)(ii) is bigger than 2 kW,1 mark for correct comparison can be scored.	3

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A *is not correct because R decreases as more conduction electrons* C *is not correct because lattice vibrations not affected* D *is not correct because lattice vibrations not affected*	It increases because there is an increase in the number of conduction electrons.	1

Q9.

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

Q10.

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

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning Indicative content: IC1 As the magnet moves through the coil there is a change in magnetic flux linkage (with coil) **Or** as the magnet moves through the coil the coil cuts (lines of) magnetic flux **Or** as the magnet moves through the coil the coil cuts magnetic field lines IC2 An e.m.f. is induced across the coil IC3 This generates a current in the (capacitor) circuit IC4 The diode only allows current in one direction IC5 So capacitor is charged (repeatedly) IC6 When switch is closed capacitor discharges through the LED	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. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points: 6 → 4; 5–4 → 3; 3–2 → 2; 1 → 1; 0 → 0 Number of marks awarded for structure of answer and sustained line of reasoning: Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout → 2; Answer is partially structured with some linkages and lines of reasoning → 1; Answer has no linkages between points and is unstructured → 0 Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning	**6**

IC points	IC mark	Max linkage mark	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

Q2.

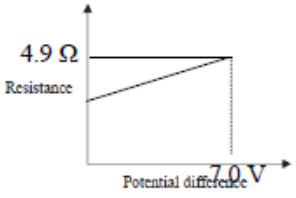
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• The IV graph of an ohmic conductor is a straight line through the origin **Or** V is directly proportional to *I* **(1)** • Hence Ohm's law is not obeyed for the LED **(1)**	MP1 accept converse argument MP2 dependent on MP1	**2**

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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
(a)	• Use of $R = V/I$ using pair of points from the graph (1) • $R = 4.9\,\Omega$ (1)	Example of calculation $R = 7.00\,V / 1.44\,A$ $R = 4.86\,\Omega$	**2**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Calculated resistance point plotted correctly at (4.9 Ω, 7.0 V) (1) • Resistance increases (constantly) with potential difference (1) • Positive intercept with y-axis (less than value from (a)) (1)	 MP3 conditional on MP2 being awarded.	**3**

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>* (c)</td><td>
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 structure and lines of reasoning
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative 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>
Indicative content

(As V increases) acceleration/velocity/energy of electrons increases
greater energy transfer in collisions with lattice / ions
increasing the temperature of metal/filament/ions
amplitude of vibrations of lattice/ ions increases
collision (rate) between lattice /ions and electrons increases
Or shorter distance between collisions
Or greater chance of collision
due to the increase in resistance, current doesn't increase in proportion to potential difference
Or due to the increase in resistance the ratio of I/V decreases

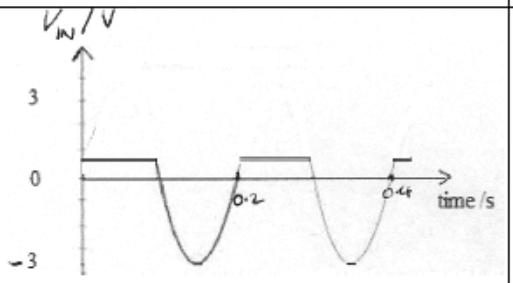
</td><td>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning 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 linkage between points and is unstructured</td><td>0</td></tr>
</table>
Accept charge carriers for electrons and only penalise once for omission of charge carriers or lattice ions

Linkage marks
<table>
<tr><th>Number of indicative content points awarded</th><th>Possible linkage marks</th></tr>
<tr><td>0, 1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6</td><td>2</td></tr>
</table>
MP1 don't award for 'increased rate of flow'

MP2 to award mark there must be the idea of increased/greater energy transfer between electrons and ions
</td><td>6</td></tr>
</table>

Q4.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(i)</td><td>
• Use of $V_{rms} = \frac{V_o}{\sqrt{2}}$ (1)
• V_{rms} = 2.4 V (1)
</td><td>
Example of calculation:
$V_{rms} = \frac{3.4}{\sqrt{2}} = 2.4$ V
</td><td>(2)</td></tr>
</table>

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)(1) • horizontal lines/spaces at a value of potential difference of 0.6 V to 0.8 V		(3)

Q5.

Question Number	Answer	Mark
	B filament bulb	1
	Incorrect Answers: A – this is not the graph for a diode C – this is not the graph for an ohmic resistor D – this is not the graph for a thermistor	

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	An answer which makes reference to: • Diode only lets current through in one direction (1) • (In positive half cycle of input) D2 and D4 conduct (1) **Or** In positive half cycle of input D2 conducts **Or** (In negative half cycle of input) D3 and D1 conduct (1) **Or** negative half cycle D3 conducts • Current towards X **Or** down through *R* **Or** X to Y		3
(ii)	• Read off corresponding values of *V* and *t* from graph (1) • Use of $lnV = lnV_o - \frac{t}{RC}$ (1) • $C = 3.5 \times 10^{-5}$ F (1) range 2.7×10^{-5} F to 3.5×10^{-5} F Alternate method • Use of $I = V/R$ • Use of $Q = It$ and $C = \Delta Q/\Delta V$ • $C = 2.7 \times 10^{-5}$ F to 3.5×10^{-5} F	eg this can be any *t* (in ms) and corresponding *V* Example of calculation $ln3.5 = ln4 - \frac{0.008\ \text{s}}{2200\ \Omega \times C}$ $C = 2.7 \times 10^{-5}$ F Alternate: $I = 3.8\ \text{V} / 2.2\ \text{k}\Omega = 1.73\ \text{mA}$ $Q = 1.73\ \text{mA} \times 8\ \text{ms} = 13.8 \times 10^{-6}\ \text{C}$ $C = 13.8 \times 10^{-6}\ \text{C} / 0.4\ \text{V} = 3.4 \times 10^{-5}\ \text{F}$	3

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q8.

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		

Q9.

Question Number	Answer	Mark
	B thermistor graph	**1**
	Incorrect Answers: A – ohmic conductor graph C – filament lamp graph D – diode graph	

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
	• in circuit A, $V = IR_{lamp}$ and $I = \frac{V}{(R_{lamp} + R_{resistor})}$	(1)		**(5)**
	• when $R_{resistor}$ has its maximum value, I ≠ 0	(1)		
	• hence using circuit A the current will never be zero which is a limitation OR range of p.d.s measured is limited	(1)		
	• in circuit B the supply p.d. is divided up in the ratio of the two circuit resistances OR $V_{lamp} = \frac{R_1}{R_1 + R_2} \times V$	(1)		
	• 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)		

Q12.

<table>
<tr><th>Question number</th><th>Acceptable answers</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 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.

<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>
</td><td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>* (continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<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>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
* (continued)	**Indicative content** • The supply creates a changing magnetic field in the iron core • Rate of change of flux in toothbrush coil is equal to rate of change of flux in charger coil (for an ideal transformer) • The changing flux linkage in the coil of the toothbrush induces an e.m.f. according to Faraday's law • $E = -N \, d\phi/dt$ so to step down the e.m.f. there must be fewer turns in the toothbrush coil • The e.m.f. in the toothbrush coil must be larger than the toothbrush battery • Diode is included so battery is not discharged by the alternating e.m.f.	Allow provides dc to charge battery or similar.	**6**

Q13.

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**

Q14.

Question Number	Answer		Mark
(a)	Operable circuit with bulb and power supply variable to 12 V (ignore meters) Ammeter correctly positioned Voltmeter correctly positioned (voltmeter may be across ammeter as well, or whole circuit – but not across any additional resistive components such as a variable resistor)	(1) (1) (1)	3
(b)(i)	The gradient of this graph is the rate of change of current with p.d. Resistance is the ratio of pd/current **Or** It is calculated using a value of pd ÷ the corresponding value of current **Or** it isn't a straight line so the gradient is not *R* (credit *R* not constant, so value at 6 V isn't applicable to other voltages)	(1) (1)	2
(b)(ii)	Use of $R = V/I$ $R = 4.76\ \Omega$ Example of calculation $R = 6.00\ V / 1.26\ A$ $R = 4.76\ \Omega$	(1) (1)	2
*(c)	**(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)** The resistance increases (Because) the temperature increases (accept heats up) Increasing the amplitude of the oscillation of the lattice ions Leading to more (frequent) collisions of electrons with lattice ions Allow converse marks for an explanation explicitly based on decreasing potential difference	 (1) (1) (1) (1)	4
	Total for question		11

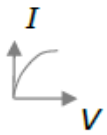
Q15.

Question Number	Answer	Mark
	C	1

Q16.

Question Number	Answer	Mark
	B	1

Q17.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is C A *is not correct because it shows constant resistance* B *is not correct because it shows decreasing resistance* D *is not correct because it shows an I independent of V*		1

Q18.

Question Number	Acceptable answers		Additional guidance	Mark
	• Diode	(1)		3
	• It conducts/allows current in one direction only	(1)	MP3 allow threshold voltage	
	• The diode conducts when the p.d. is beyond 0.2-0.7V **Or** For negative p.d.s the resistance is (very) high **Or** in the reverse/backward direction the resistance is (very) high **Or** at breakdown/large voltage the diode will conduct in the reverse direction	(1)		

Q19.

Question Number	Acceptable answers		Additional guidance	Mark
	• The diode only conducts (current) when the potential difference across it is (at least +) 0.7V	(1)		(2)
	• The diode does not conduct current when the p.d. is negative/reversed.	(1)		

Q20.

Question Number	Answer		Mark
	(As temperature of thermistor increases) its resistance decreases (do not credit the converse) (Large) increase in: *n* **Or** electrons (per unit volume) **Or** charge carriers (per unit volume) **Any One from (conditional on mark 2 and not awarded if there are contradictory statements about any of these quantities)** (slight) decrease in *v* / velocity / drift velocity *A* and *Q* remain constant Reference to $R = V/I$	**(1)** **(1)** **(1)**	**3**

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
	• Use of Area = width × thickness **(1)** • Use of $R = \frac{\rho l}{A}$ **(1)** • thickness = 9.4×10^{-4} m **(1)**	Example of calculation: $12 \times 10^{3}\Omega = \frac{0.49\ \Omega\ \text{m} \times 0.115\ \text{m}}{0.0050\ \text{m} \times t}$ thickness = 9.4×10^{-4} m	**3**

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)** • 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)**	**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**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Tangent drawn at 1.5 s (1) • 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) • velocity = 1.0 m s^{-1} – 1.3 m s^{-1} (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

Question Number	Acceptable answers	Additional guidance	Mark
(c)	• Use of $v = u + at$ (1) • 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)	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

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	• Calculation of mean (1) • Use of half range **Or** maximum difference from the mean (1) • % uncertainty = 1.4% (1)	Example of calculation $\bar{d} = \frac{(1.40+1.44+1.42+1.41)\ \text{mm}}{4}$ $= 1.42\ \text{mm}$ $\%U = \frac{(1.44-1.40)\ \text{mm}/2}{1.42\ \text{mm}} \times 100\%$ $= 1.41\%$	3
(ii)	• Use of $A = \pi r^2$ (1) • Use of $R = \frac{\rho l}{A}$ (1) • $\rho = 6.9 \times 10^{-7}\ (\Omega\ \text{m})$, so wire is made from stainless steel (1)	Example of calculation $A = \pi\left(\frac{1.42 \times 10^{-3}\text{m}}{2}\right)^2 =$ $1.58 \times 10^{-6}\ \text{m}^2$ $\rho = \frac{0.72\ \Omega \times 1.58 \times 10^{-6}\ \text{m}^2}{1.65\ \text{m}} =$ $6.9 \times 10^{-7}\ \Omega\ \text{m}$	3

Q4.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $A = \pi r^2$ with r (1) • Use of $R = \frac{\rho L}{A}$ (1) • With at least one of the following values (1) $R = 18.1\ \Omega \quad L = 1.30\ \text{m}$ (1) $A = \pi \times (0.13 \times 10^{-3}\ \text{m})^2$ • $\rho = (7.3 \rightarrow 7.4) \times 10^{-7}\ \Omega\text{m}$	MP3 accept $R = 18.15\ \Omega$ MP3. Allow calculation of ρ using given values and subtraction of total % uncertainty. Example of calculation: $A = \pi r^2 = \pi \times (0.13 \times 10^{-3}\ \text{m})^2 = 5.31 \times 10^{-8}\ \text{m}^2$ $\rho = \frac{RA}{L} = \frac{18.1\Omega \times 5.31 \times 10^{-8}\text{m}^2}{1.30\text{m}} = 7.39 \times 10^{-7}\ \Omega\,\text{m}$	4

Q5.

Question number	Acceptable answers	Additional guidance	Mark
(a)	• Use of: $R = \frac{\rho L}{A}$ **(1)** • $\frac{R_B}{R_A} = 0.5$ [accept 2:4 **or** 1:2 **or** 1/2] **(1)**	Example of calculation: $\frac{R_B}{R_A} = \frac{L_2 d_1^2}{L_1 d_2^2}$ $\frac{R_B}{R_A} = \frac{2Ld^2}{L(2d)^2} = \frac{2}{4} = 0.5$	**2**
(b)	• Correct transfer of data for gradient **(1)** • Large triangle used **(1)** • $\rho = 1.1 \times 10^{-4}$ Ωm **(1)** Conclusion: • 1.1×10^{-4} Ωm is greater than 3 x 10^{-5} Ωm, so resistivity increases when clay is added **(1)**	Answer to be consistent with calculated value. Example of calculation: Gradient = $\rho L = 16.5 \times 10^{-6}$ Ωm^2 $\rho = 16.5 \times 10^{-6}$ Ωm^2/0.15 m = 1.1×10^{-4} Ωm	**4**

Q6.

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)**

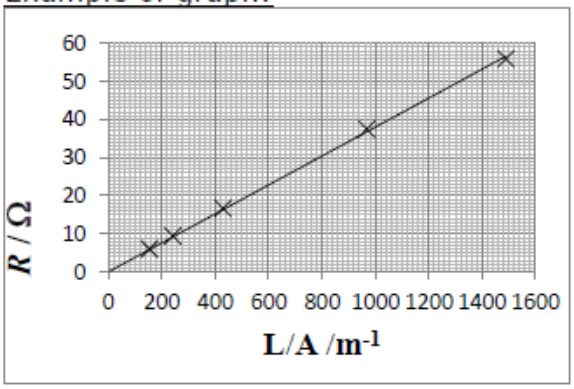
Question Number	Acceptable Answer		Additional guidance	Mark
(a)(ii)	• use of $V = IR$ and addition of resistances in series to determine current in strand with 5 blown bulbs OR use of $V = IR$ and addition of resistances in series to determine current in healthy strands OR use of resistance in parallel and series to determine total resistance	(1)	Example of calculation: Total current = sum of current in the four healthy strands + current in the unhealthy strand $I = 4\left(\frac{230\text{ V}}{50\times8.0\ \Omega}\right) + \left(\frac{230\text{ V}}{(45\times8.0\ \Omega)+(5\times3.0\ \Omega)}\right)$ $I = 2.9$ A	**(3)**
	• $I = 2.9$ A	(1)		
	• 2.9 A < 3 A so fuse does not blow	(1)	Allow credit for a consistent conclusion from an incorrect calculation of current	

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

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)** • use of $y = mx + c$ **(1)** • I = 2.8 A **(1)** • 2.8 A < 3 A so the wire is suitable to use as a fuse wire **(1)**	Example of calculation: $A = \pi\left(\frac{0.4\ \text{mm}}{2}\right)^2 = 0.13\ \text{mm}^2$ $I = \frac{1.28\ \text{A} \times 0.13\ \text{mm}^2}{0.06\ \text{mm}^2} = 2.8\ \text{A}$ 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)**

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• axes and labels (1) • suitable scale (1) • all points plotted correctly (1) • line of best fit drawn (1)	Example of graph: 	**(4)**
(a)(ii)	• attempt to measure gradient using large triangle (1) • ρ = (0.035 – 0.041) Ωm to 2 sf (1)		**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Two problems identified with solutions from: • taking only one reading could produce an unreliable result (1) • so take repeat readings of length and diameter (1) • metre ruler cannot be used to measure the diameter with sufficient precision (1) OR metre rule can only measure diameter at ends of cylinder • so use Vernier callipers instead (1) • comment about non-uniform shape (1) • so take repeat readings at different positions/ orientations (1)	Accept micrometer giving precision of 0.01 mm for diameter	**(4)**

Q8.

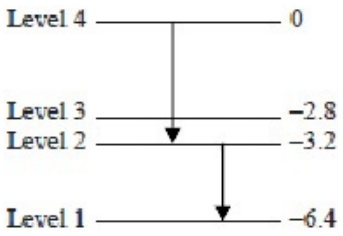
Question number	Acceptable answers	Additional guidance	Mark
	D		**1**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $R=\rho l/A$ (1) • Using $A=0.5\times28$ ($\times10^{-6}\,m^2$) (1) • Use of $V=IR$ (1) • $I = 22$ (mA) (1)	Example of calculation $R = \frac{1.6\Omega m \times 0.6\times10^{-3}\,m}{0.5\times10^{-3}\,m \times 28\times10^{-3}\,m}$ $R = 68.6\Omega$ $1.5V = I \times 68.6\Omega$ $I = 1.5V / 68.6\Omega$ $I = 0.022A = 22mA$	4

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $F=BIL$ ecf values from (i) (1) • Force = 5.3×10^{-6} N (1)	Use of show that values gives 4.8×10^{-6} N Example of calculation $F = 0.40T \times 0.022A \times 0.6\times10^{-3}\,m$ $F = 5.3\times10^{-6}N$	2

Q10.

Question Number	Answer		Mark
(a)	A statement which implies only certain energy levels are allowed e.g. Allowed/possible energy of atoms/electrons Discrete energy of an atom/electron	**(1)**	**1**
(b)	Identifies correct pairs of levels, 4 and 2 **AND** levels 2 and 1 Two arrows both showing correct direction [irrespective of identified levels]  	**(1)** **(1)**	**2**
(c)	**Max 3** Atom/electron gains energy and moves to a higher level **Or** atom/electron becomes excited atom/electron has discrete energies **Or** atom/electron can only move between fixed levels **Or** only certain energy changes are possible atom/electron falls to a lower level By emitting energy in the form of photons **Or** reducing their energy by emitting photons Photons have a specific energy/frequency **Or** reference to $E = hf$ **Or** photon energy $= E_2 - E_1$	 **(1)** **(1)** **(1)** **(1)** **(1)**	 **3**
(d)	Use of $E = hf$ with any of the possible energy differences Identifies ΔE as (±) 0.4 ($\times 10^{-19}$ J) $f = 6.0 \times 10^{13}$ Hz Example of calculation Smallest energy difference is 0.4×10^{-19} J $f = 0.4 \times 10^{-19}$ J / 6.63×10^{-34} Js $f = 6.03 \times 10^{13}$ Hz	**(1)** **(1)** **(1)**	**3**
(e)	Divides an energy by 1.6×10^{-19} Energy = 4.0 (eV) (no ue) Example of calculation Energy = 6.4×10^{-19} J /1.6×10^{-19} C Energy = 4.0 eV	**(1)** **(1)**	**2**

Q11.

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Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use of R = V/I **(1)** • Use of R = ρl/A **(1)** • ρ = 1.34 × 10^{-6} Ωm **(1)**	Example of calculation: R = 1.50 V/4.11 A = 0.365 Ω $\rho = RA/l$ = 0.365 Ω × π × (1.82 × 10^{-3}/2)^2 m^2 /0.707 m ρ = 1.34 ×10^{-6} Ωm	**3**
(b)	An explanation that makes reference to: • Calculates percentage uncertainty in *l* as 0.3% and in *d* as 1% **(1)** • Calculates percentage uncertainty in resistivity by doubling that for *d* and adding that for *l* **(1)** • Calculates range of values for ρ **(1)** • Using these values the technician could not conclude whether the wire was Kanthal or Nichrome **(1)**	Example of calculation: (0.2/70.7) x 100 % = 0.3 % (0.02/1.82) x 100 % = 1 % %U in ρ = 2 x 1% + 0.3 % = 2.3 % 1.34 ×10^{-8} x 0.0023 = 0.003 1.37×10^{-8} > ρ > 1.31×10^{-8} If answer to calculation is wrong, then credit can still be given for MP4 for comments consistent with the calculated value. If no calculation is completed then MP4 cannot be awarded.	**4**

Q12.

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**

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Q13.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• The measurement of resistance has an uncertainty of 0.6 %	(1)	MP1 accept use of 0.05 giving 0.3 % Example of calculation: Uncertainty in $R = \frac{0.1\Omega}{18.2\Omega} \times 100\% = 0.55\%$ Uncertainty in $L = \frac{0.05\,\text{m}}{1.25\,\text{m}} \times 100\% = 4.0\%$ Uncertainty in $d = \frac{0.01\,\text{m}}{0.27\,\text{m}} \times 100\% = 3.7\%$	4
	• The measurement of the length has an uncertainty of 4 %	(1)		
	• The measurement of the diameter has an uncertainty of 4 %	(1)		
	• The % uncertainty in diameter is doubled giving the greatest amount of uncertainty into the value for the resistivity	(1)		

Q14.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of πr^2	(1)		
	• Use of $R = \rho l/A$	(1)		
	• Length = 0.056 m	(1)	Example of calculation: Area $= \pi(0.95 \times 10^{-3}\text{m})^2 = 2.8(4)\times10^{-6}$ m^2 $l = \frac{9.0\times10^{-3}\,\Omega \times 2.8(4)\times10^{-6}\,\text{m}^2}{4.55\times10^{-7}\,\Omega\,\text{m}} = 0.0\,56$ m "Show that" value $l = 0.062$ m	3

Q15.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of $A = \frac{\pi d^2}{4}$ Or use of πr^2 (1) • Use of $R = \frac{\rho l}{A}$ (1) • Calculates $l - 1.5$ (1) • Height = 27.1 m so it is not taller than 30 m (1) **OR** • Use of $A = \frac{\pi d^2}{4}$ Or use of πr^2 • Calculate wire length wire for 30 m statue [$l = 31.5$ m] • Use of $R = \frac{\rho l}{A}$ • R = 4.7×10^{-3} Ω (> 4.3×10^{-3} Ω) so statue is not taller than 30 m	Example of calculation: $A = \frac{\pi d^2}{4} = \frac{\pi \times (1.2 \times 10^{-2}\text{m})^2}{4} = 1.13 \times 10^{-4}$ $l = \frac{RA}{\rho}$ $= \frac{4.3 \times 10^{-3}\Omega \times 1.13 \times 10^{-4}\text{m}^2}{1.7 \times 10^{-8}\ \Omega\ \text{m}}$ = 28.6 m Height = 28.6 m – 1.5 m = 27.1 m	4

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• As graphene is only 1 atom thick so the CSA/thickness is far smaller than for a sample of steel **Or** most applications need a thickness greater than one atom **Or** if more than one layer of graphene is used it will be weaker or the bonds between the layers will not be strong **Or** Graphene is difficult to manufacture because it has only one atomic layer (1) • Although graphene has a greater breaking stress it will break at a lower force (1)	MP1: accept graphene can only be 1 atom thick but steel can be any thickness (MP1, treat references to cost/energy as neutral)	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	• Use of depth of graphite = 100 × diameter of 1 carbon atom (1) • Use of cross-sectional area = depth × (0.5×10^{-3} m) (1) • Use of $\rho = \frac{RA}{l}$ (1) • $\rho = 3.6 \times 10^{-5}\ \Omega$ m **Or** 36 μΩ m	Example of calculation Depth of graphite = $100 \times 1.4 \times 10^{-10}$ m = 1.4×10^{-8} m CSA = 1.4×10^{-8} m × 0.50×10^{-3} m = 7.0×10^{-12} m^2 $\rho = \frac{1.029 \times 10^{6}\Omega \times 7.0 \times 10^{-12}\text{m}^2}{0.200\ \text{m}} =$ $3.6 \times 10^{-5}\ \Omega$ m	4

Question Number	Acceptable Answer		Additional Guidance	Mark
(c)	**Max 3** • Silicon will only release a (photo) electron for a limited range of frequencies/wavelengths	(1) (1)	MP1: accept single frequency for limited range	
	• Silicon releases only one (photo) <u>electron</u> per incident photon	(1)		
	• Greater current (for the same illumination) in graphene	(1)		
	• Graphene (cells are) more efficient **Or** graphene cells could be smaller / cheaper / thinner			3

Q17.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $V = IR$	(1)	<u>Example of calculation</u>	
	• Use of $R = \rho l/A$	(1)	$R_{min} = \frac{1.8\ V}{9.5 \times 10^{-8}\ A} = 189.5\ \Omega$	
	• (Min) resistivity = 160 (Ω m) **Or** (max) resistivity = 730 (Ω m)	(1)	$R_{max} = \frac{8.0\ V}{9.5 \times 10^{-8}\ A} = 842.1\ \Omega$	
	• Compacted clay pathways **and** limestone are present in the soil	(1)	$\rho_{min} = \frac{RA}{l} = \frac{189.5\ \Omega \times 0.650\ m^2}{0.75\ m} = 164.2$ Ω m	4
			$\rho_{max} = \frac{RA}{l} = \frac{842.1\ \Omega \times 0.650\ m^2}{0.75\ m} = 729.8$ Ω m	
			conclusion to be consistent with calculated values	

Q18.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Use of cross-sectional area = πr^2 Or $\frac{\pi d^2}{4}$	(1)	Example of calculation $A = \pi(1.9 \times 10^{-5}\ \text{m})^2 = 1.134 \times 10^{-9}\ \text{m}^2$ $R = \frac{(5.6 \times 10^{-8}\ \Omega\text{m})(1.6\ \text{m})}{1.134 \times 10^{-9}\ \text{m}^2} = 79.01\ \Omega$ $R_{max} = 14 \times 79.01\ \Omega = 1106.2\ \Omega$ $P = = \frac{(240\ V)^2}{1106.2\ \Omega} = 52.1\ \text{W}$	5
	• Use of $R = \frac{\rho l}{A}$	(1)		
	• Correct use of factor of 14	(1)		
	• Use of $P = \frac{V^2}{R}$	(1)		
	• $P = 52$ W	(1)		

Question Number	Acceptable answers		Additional guidance	Mark
(ii)	**Either**			4
	• Initially(the resistance is low so) current will be the greatest	(1)		
	• As $P = I^2R$, the greatest power is transferred	(1)		
	• Change in current has more effect as it is squared	(1)		
	• Heating effect greatest when R is lowest, so breaks when switched on.	(1)		
	OR			
	• p.d. is constant	(1)		
	• $P = V^2/R$	(1)		
	• Power is greatest when R is lowest	(1)		
	• Heating effect is greatest when R is lowest, so breaks when switched on	(1)		
	OR			
	• p.d. is constant	(1)		
	• Initially (resistance is low so) current will be the greatest	(1)		
	• As P=IV the greatest power is transferred			
	• Heating effect is greatest when R is lowest, so breaks when switched on			

Q19.

Question Number	Acceptable answers	Additional guidance	Mark
	• 270K corresponds to a resistivity of 2×10^{-8} (Ω m) (1) • Use of $P=VI$ (1) • Use of $R=\rho l/A$ (1) • Use of $P=I^2R$ (1) • Power losses from copper cables 19 kW so more than 7 kW and that the superconductor would save energy. MP5 dependant on MP2,3,4 (1) (Acceptable range for Power losses: 9.6 kW to 34 kW)	range allow $2 \times 10^{-8}\,\Omega\,m$ to $2.1 \times 10^{-8}\,\Omega\,m$ Example of calculation: $40\times10^{6}\ W = 110\times10^{3}\ V \times I$ $I = 364\ A$ $R = \frac{2\times10^{-8}\,\Omega m \times 1.050\times10^{3}\ m}{145\times10^{-6}\ m^2} = 0.145\,\Omega$ $P = 364^2\ A^2 \times 0.145\,\Omega = 19.2\,kW$	5

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	A description that makes reference to **two** of the following: • No need for further calculation **Or** gives a value for resistance without calculation (1) • No need for an additional power supply (1) • Uncertainties caused by two devices is (possibly) greater than that caused by one device (1)	Do not accept more precise **or** no parallax **or** quicker	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• (As applied force increases) the length (l) (of wire) increases/stretches **Or** the wire is longer (1) • the resistance increases with reference to $R = \frac{\rho l}{A}$ (1)	Reference to formula may be in terms of proportionality or direct quote of equation Do not accept change in resistivity	2

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	• Use of $GF = \frac{\Delta R}{\epsilon R}$ (1) • Substitution of $\epsilon = \frac{\Delta w}{w}$ into GF equation (1) • $\Delta w = 2.5 \times 10^{-5}$ m (1)	(x may seen in place of w) Example of calculation: $GF = \frac{\Delta R}{\epsilon R}$ $2 = \frac{0.001}{\Delta w / (5 \times 10^{-2})}$ $\Delta w = 2.5 \times 10^{-5}$ m Accept 2.5×10^{-3} cm / 2.5×10^{-2} mm	3

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	An explanation that makes reference to the following: • As small changes (in w) are multiplied many times **Or** can use a longer wire (on a small gauge) **Or** to achieve a greater change in the length (1) • (So) greater sensitivity **Or** larger changes in R (for a given change in width) (1)		2

Q21.

Question Number	Acceptable answers	Additional Guidance	Mark
	• Use of $R = \frac{\rho l}{A}$ (1) • Use of area formula with correct value of radius (1) • $R = 8.9\ \Omega$ (1)	Use of: any dimensionally correct substitutions eg using a diameter squared Accept R=8.62 as due to rounding Area Example of calculation: $R =$ $1.12 \times 10^{-6}\ \Omega$ m x 1m / $\pi(0.2 \times 10^{-3})^2$ m^2	3

Q22.

Question Number	Acceptable answers	Additional guidance	Mark
	D		1

Q23.

Question Number	Answer		Mark
(a)	Use of $R = \rho l/A$	**(1)**	
	$R = 17\ \Omega$	**(1)**	**2**
	Example of calculation $R = 4.9 \times 10^{-7}\ \Omega\ \text{m} \times 1.0\ \text{m} / 2.9 \times 10^{-8}\ \text{m}^2$ $R = 17\ \Omega$		
(b)	Area decreases	**(1)**	
	Resistance inversely proportional to area **Or** quote $R = \rho l/A$	**(1)**	
	So this change (also) increases resistance	**(1)**	**3**
	(Accept for 2nd mark, $I = nAqv$, I decreases if A decreases, $R = V/I$) (Final mark dependent on presenting a logical explanation linking area change and resistance – not just stating increased resistance.)		
	Total for question		**5**

Q24.

Question Number	Answer		Mark
(a)	best fit line use of gradient **Or** use of R/l from graph or table use of $\rho = RA/l$ resistivity = 4.7×10^{-7} Ω m (range 4.5 to 4.8×10^{-7} Ω m) <u>Example of calculation</u> gradient = 4.4 Ω ÷ 1.0 m = 4.4 Ω m^{-1} $\rho = A \times$ gradient = 1.06×10^{-7} $m^2 \times 4.4$ Ω m^{-1} resistivity = 4.66×10^{-7} Ω m	(1) (1) (1) (1)	4
(b)	temperature increases (with increasing current) resistance/resistivity would have increased (with temperature)	(1) (1)	2
(c)	Precaution Explanation E.g. ensure good contact (e.g. tight croc clips); so pd across contact resistance doesn't make V results inaccurate E.g. Avoid pressing too hard on wire; as a deformation would affect cross-sectional area and therefore resistance e.g. ensure wire is straight so length measurement is accurate e.g ensure eyes perpendicular to scale to avoid parallax errors **Do not credit:** diameter of wire since area is not in the table repeat and average high resistance voltmeter keep temperature constant	(1) (1)	2
	Total for question		8

Q25.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $\ln V = \ln V_o - \frac{t}{RC}$ **(1)** **Or** Draws initial tangent to curve and uses $T = RC$ **Or** Determines t when V has decreased to approx. 37% • Conversion hours to seconds **(1)** • Calculates resistance in range 2.4×10^{11} to 2.8×10^{11} (Ω) **(1)** • Use of $R = \rho l/A$ **(1)** • Resistivity in range 2.2×10^{15} Ω to 2.6×10^{15} Ω m so yes above 10^{14} Ω m **(1)**	<u>Example of calculation</u>: $ln6 = ln100 - \frac{20 \times 3600\ s}{R \times 0.1 \times 10^{-6}(s)}$ $R = 2.6 \times 10^{11}\ \Omega$ $2.6 \times 10^{11}\Omega = \frac{\rho \times 0.6 \times 10^{-6}\ m}{5.6 \times 10^{-3}\ m^2}$ Resistivity = $2.4 \times 10^{15}\ \Omega\ m$ Using $T = RC$ $7 \times 3600\ s = 0.1 \times 10^{-6}\ F \times R$ $R = 2.5 \times 10^{11}\ \Omega$ (allow T in range 7 – 8 hour)	5

Q26.

Question Number	Answer		Mark
(a)	The (maximum) length is (directly) proportional to the area	(1)	1
(b)(i)	Use of $\rho l/A = R$ $R = 1.34\ (\Omega)$ <u>Example of calculation</u> $R = 1.68 \times 10^{-8}\ \Omega\ m \times 80\ m \div 1.0 \times 10^{-6}\ m^2$ $R = 1.34\ \Omega$	(1) (1)	2
(b)(ii)	Use of $P = I^2R$ $P = 160$ W allow ecf from (i) <u>Example of calculation</u> $P = (11\ A)^2 \times 1.34\ \Omega$ $P = 162$ W (157 W if they use 1.3 Ω)	(1) (1)	2
(b)(iii)	Use of $V = IR$ **Or** use of $P = VI$ **Or** use of $P = V^2/R$ $V = 15$ V allow ecf from (i) and/or (ii) <u>Example of calculation</u> $V = 11\ A \times 1.34\ \Omega = 14.7$ V (14.3 V if 1.3 Ω is used)	(1) (1)	2
(c)	To prevent (use of a cable with) resistance that is too large (Accept answers that refer to maintaining or not exceeding a resistance of about 1.3 Ω) Meaning more energy / power / p.d. available for the shredder	(1) (1)	2
	Total for Question		9

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Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	• Makes a cylinder of longer length **Or** Makes a cylinder of smaller radius/area **(1)** • As $R = \frac{\rho l}{A}$, this change will increase the resistance **(1)** [MP2 dependent on MP1]		**2**

Q28.

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

Q29.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to the following points: • Resistance increases with decreasing intensity **(1)** • As distance increases light intensity decreases so resistance increases **(1)**		2

Q30.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $\rho = \frac{m}{V}$ **(1)** • $V = 8.1 \times 10^{-6}$ (m^3) **(1)**	Example of Calculation. $V = \frac{0.043\ \text{kg}}{5300\ \text{kgm}^{-3}}$ $V = 8.1 \times 10^{-6}\ \text{m}^3$	**2**
(ii)	• Use of $A=\pi r^2$ and $V = Al$ **(1)** • Use of $R = \frac{\rho l}{A}$ **(1)** • $R = 2.5\ \Omega$ (ecf from (a)(i)) **(1)**	Show that value gives 2.50 Ω Example of Calculation. $A = \pi(6 \times 10^{-3}\ \text{mm})^2 = 1.13 \times 10^{-4}\ \text{m}^2$ $8.1 \times 10^{-6}\ \text{m}^3 = (1.13 \times 10^{-4}\ \text{m}^3)\ l$ $l = 0.0716$ m $R = \frac{(4.0 \times 10^{-3}\ \Omega\ \text{m})(0.0716\ \text{m})}{(1.13 \times 10^{-4}\ \text{m}^3)}$ R = 2.54 Ω	**3**

Mark Scheme

Q1.

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**

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of πr^2 or $\pi d^2/4$ **(1)** • Use of $I = nAvq$ **(1)** • $v = 5.8$ to 6.0×10^{-7} m s^{-1} **(1)**	Example of calculation Cross sectional area $= \pi\frac{(12.2\times10^{-8}\text{ m})^2}{4} = 1.2 \times 10^{-4}$ m^2 $1.9\text{ A} = 1.7 \times 10^{29}$ m^{-3} $\times$ 1.2×10^{-4} m^2 $\times$ v $\times$ 1.6×10^{-19} C $v = 5.8 \times 10^{-7}$ m s^{-1}	**3**

Q3.

Question number	Acceptable answers	Additional guidance	Mark
	• Uses weight of displaced air = ρVg **(1)** • Finds resultant force = upthrust – weight **(1)** • Uses F = ma to find acceleration **(1)** • Acceleration = 0.161 m s^{-2} **(1)**	Example of calculation: Weight of air displaced = ρVg = 1.20 kg m^{-3}×2880 m^3× 9.81m s^{-2} = 33 903N Resultant upward force = 33 903 N – (3400 kg × 9.81m s^{-2}) = 549 N Acceleration = 549 N/3400 kg = 0.161 m s^{-2}	**4**

Q4.

Question Number	Answer	Mark
(a)	Mean velocity of charge carriers **(1)**	**1**
(b)(i)	*v* for Y is twice *v* for X **Or** *v* for X is half *v* for Y **(1)** $I = nqvA$ and *n* and *q* are constant **Or** *v* inversely proportional to *A* **(1)**	**2**
* **(b)(ii)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Resistance of Y is greater than the resistance of X **(1)** (*v* greater for Y…) therefore electrons gain more ke between collisions (with lattice ions) **Or** therefore more frequent collisions (with lattice ions) **Or** therefore more energy lost per collision (with lattice ions) **Or** therefore more energy lost in a given time in collisions (with lattice ions) **(1)** therefore greater pd required for a given current **(1)** (MP2 and 3 accept reverse argument in terms of *v* for X)	**3**
	Total for Question	**6**

Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to: • amplitude of lattice vibration increases **(1)** • resulting in more frequent collisions of electrons with lattice ions **(1)** • so this results in a smaller (mean) drift velocity $I=nAve$ and consequently the current decreases **(1)**	Must be the idea of a greater frequency of collisions, not just a greater number of collisions. Do not accept collisions between electrons. MP3 dependent on MP1 and MP2	**3**

Q6.

Question Number	Answer		Mark
	Identifies (electron) <u>diffraction</u>	(1)	
	(Electron) has wave properties/behaviour	(1)	
	(Electron) has wavelength similar to atomic size/spacing	(1)	3
	(do not accept defraction for 1st mark)		

Q7.

Question Number	Answer	Mark
	D	1

Q8.

Question Number	Acceptable answers	Additional guidance	Mark
	• Equates $F=Bev$ and $F=eE$ (1) • Substitutes $E = V/d$ (1) **Or** $F = eV / d$ seen • Replaces v with I / neA (1) • Substitute $A = d \times t$ and leads to given equation (1) Alternative: • Equates $F = BIl$ and $F = QE$ with Q identified as total charge (1) • Substitutes $E = V/d$ **Or** $F = QV / d$ seen • Substitutes $Q = neAl$ and cancels l • Substitute $A = d \times t$ and leads to given equation	Example of derivation: $Bev = eE$ $Bev = eV/d$ $\frac{BI}{neA} = \frac{V_H}{d}$ $V_H = \frac{BI}{net}$ Alternative: $BIl = QE$ Total charge $Q = neAl$ $BIl = neAlE$ $BI = neAV_H / d$ $V_H = BI / net$	(4)

Q9.

Question Number	Answer	Mark
	B	**1**

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A *is not correct because R decreases as more conduction electrons* C *is not correct because lattice vibrations not affected* D *is not correct because lattice vibrations not affected*	It increases because there is an increase in the number of conduction electrons.	1

Q11.

Question Number	Answer	Mark
(a)	Oscillations/vibrations (of molecules) parallel to direction of propagation (1) **Or** oscillations parallel to direction of wave travel **Or** oscillations parallel to direction of energy transfer Produces compressions and rarefactions (1)	2
(b)	Otherwise there wouldn't be a way of telling which bit of reflected sound originated with which bit of emitted sound **Or** so one returns before one emitted (1)	1
(ci)	time (= 1÷16 Hz) = 0.063 (s) (at least 2 sf) (1)	1
(cii)	Use of factor of 2 (1) Use of $v = s/t$ (1) distance = 48 m (1) (Use of 'show that' value gives 46m) Example of calculation 2 × distance = 1530 m s^{-1} × 0.063 s distance = 48 m	3
(ciii)	A shorter time between clicks because the distance is shorter **Or** more frequent clicks allow rapid motion to be perceived. **Or** allow position to be determined precisely/accurately. (1)	1
(d)	Speed in air lower than speed in water (1) So wavelength in air shorter than wavelength in water **Or** pulse length in air is shorter than pulse length in water **Or** attempt at numerical comparison of wavelength or pulse length (1) So bat echolocation will detect smaller targets **Or** detect smaller differences in position (conditional on MP2) (1) (Accept 'show more detail' or 'better resolution')	3
	Total for question	11

Q12.

Question Number	Acceptable Answer	Additional guidance	Mark
	B	1 : 4	**(1)**

Q13.

Question Number	Answer	Mark
(a)	**When illuminated:** Use of the word photon (1) photons/light cause emission of (photo)electrons (1) Idea that (photo) electrons form a current (1) photon energy greater than or equal to work function. (1) **In darkness:** No photons so no photoelectrons released (1)	**5**
(b)	Use of $E = hf$ (1) Conversion of eV to J (1) One of the 4 values below correct $f = 5.2 \times 10^{14}$ Hz or $\lambda = 5.8 \times 10^{-7}$ m for caesium $f = 8.8 \times 10^{14}$ Hz or $\lambda = 3.4 \times 10^{-7}$ m for zinc (1) Comment that Cs is in the visible range or Zn is ultraviolet – allow even without supporting calculation (1) **Alternative method** Allow assumed max freq/min wavelength for visible light then, calculation of work function, quoted in eV, comparison with given work functions, conclusion: Use of (1); work fn (1), in eV (1), comparison (1) Example of calculation $f = \varphi \div h = (2.14 \times 1.6 \times 10^{-19})$ J $\div$ 6.63×10^{-34} J s $= 5.2 \times 10^{14}$ Hz for caesium $f = \varphi \div h = (3.63 \times 1.6 \times 10^{-19})$ J $\div$ 6.63×10^{-34} J s $= 8.8 \times 10^{14}$ Hz for zinc	**4**
(ci)	Maximum displacement of the wave **Or** maximum displacement from the mean **Or** maximum displacement from equilibrium (1)	**1**
(cii)	**Max 3** Size of the gap (in the soundtrack) determines the amount of light (1) Amount of light determines number of photons (1) Number of photons determines number of (photo) electrons (released by phototube) (1) Number of electrons determines size of current (in the circuit) (1) (Combining MP 1 and 2 by writing "size of the gap determines number of photons" scores 1 mark. Combining MP 2 and 3 by writing "the amount of light determines number of (photo) electrons" also scores 1 mark)	**3**
	Total for question	**13**

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	C		1

Q15.

Question Number	Answer	Mark
	C $v \propto \frac{1}{R}$	**1**
	A – this answer is incorrect B – this answer is incorrect D – this answer is incorrect	

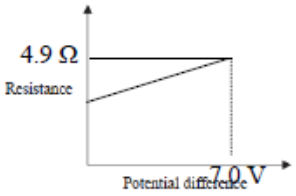
Mark Scheme

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	Acceptable answers	Additional guidance	Mark
(a)	• Use of $R = V/I$ using pair of points from the graph **(1)** • $R = 4.9\ \Omega$ **(1)**	Example of calculation $R = 7.00\ V / 1.44\ A$ $R = 4.86\ \Omega$	**2**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Calculated resistance point plotted correctly at (4.9 Ω, 7.0 V) **(1)** • Resistance increases (constantly) with potential difference **(1)** • Positive intercept with y-axis (less than value from (a)) **(1)**	 MP3 conditional on MP2 being awarded.	**3**

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>* (c)</td><td>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 structure and lines of reasoning
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative 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>
Indicative content
• (As V increases) acceleration/velocity/energy of electrons increases
• greater energy transfer in collisions with lattice / ions
• increasing the temperature of metal/filament/ions
• amplitude of vibrations of lattice/ ions increases
• collision (rate) between lattice /ions and electrons increases
Or shorter distance between collisions
Or greater chance of collision
• due to the increase in resistance, current doesn't increase in proportion to potential difference
Or due to the increase in resistance the ratio of I/V decreases</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage 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 linkage between points and is unstructured</td><td>0</td></tr>
</table>
Accept charge carriers for electrons and only penalise once for omission of charge carriers or lattice ions

Linkage marks
<table>
<tr><th>Number of indicative content points awarded</th><th>Possible linkage marks</th></tr>
<tr><td>0, 1</td><td>0</td></tr>
<tr><td>2, 3</td><td>1</td></tr>
<tr><td>4, 5, 6</td><td>2</td></tr>
</table>
MP1 don't award for 'increased rate of flow'

MP2 to award mark there must be the idea of increased/greater energy transfer between electrons and ions</td><td>6</td></tr>
</table>

Q3.

Question Number	Answer	Mark
	D	1

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Q4.

Question Number	Answer	Mark
	A dark and cold	**1**
	Incorrect Answers: B – correct description for LDR but incorrect for thermistor C – incorrect description for LDR but correct for thermistor D – incorrect description for LDR and incorrect for thermistor	

Q5.

Question Number	Answer	Mark
(a)	Mean velocity of charge carriers **(1)**	**1**
(b)(i)	v for Y is twice v for X **Or** v for X is half v for Y **(1)** $I = nqvA$ and n and q are constant **Or** v inversely proportional to A **(1)**	**2**
* **(b)(ii)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Resistance of Y is greater than the resistance of X **(1)** (v greater for Y…) therefore electrons gain more ke between collisions (with lattice ions) **Or** therefore more frequent collisions (with lattice ions) **Or** therefore more energy lost per collision (with lattice ions) **Or** therefore more energy lost in a given time in collisions (with lattice ions) **(1)** therefore greater pd required for a given current **(1)** (MP2 and 3 accept reverse argument in terms of v for X)	**3**
	Total for Question	**6**

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to: • amplitude of lattice vibration increases **(1)** • resulting in more frequent collisions of electrons with lattice ions **(1)** • so this results in a smaller (mean) drift velocity $I=nAve$ and consequently the current decreases **(1)**	Must be the idea of a greater frequency of collisions, not just a greater number of collisions. Do not accept collisions between electrons. MP3 dependent on MP1 and MP2	**3**

Q7.

Question number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: • A rise in temperature causes the amplitude of the vibrating ions to increase **(1)** • This causes the number of collisions per second between the ions and the moving electrons to increase **(1)** • So the rate of flow of electrons decreases (causing the resistance of the metal to increase) **(1)**	Allow reduce mean free path or drift velocity of electrons. Accept current decreases	**3**

Q8.

Question number	Acceptable answers	Additional guidance	Mark
	• The number of charge carriers increases with temperature **(1)** • So this lowers the resistance (despite the increase in lattice vibrations) **(1)**	Accept number of electrons.	**2**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• (Moving) electrons collide with lattice/ions **(1)** • Transfer of energy to (lattice) ions so they vibrate with larger amplitude/speed (and the temperature increases) **(1)**		**2**
(ii)	• Electrons/ions in the tube collide with mercury/phosphor atoms and excite electrons (in the mercury/phosphor atoms) **(1)** • Energy is released in the form of photons as the electrons move back down (to the ground state) **(1)**	Mention of work function scores 0 MP2 Allow de-excite for move back down	**2**

Q10.

Question Number	Answer		Mark
(a)	Operable circuit with bulb and power supply variable to 12 V (ignore meters) Ammeter correctly positioned Voltmeter correctly positioned (voltmeter may be across ammeter as well, or whole circuit – but not across any additional resistive components such as a variable resistor)	(1) (1) (1)	3
(b)(i)	The gradient of this graph is the rate of change of current with p.d. Resistance is the ratio of pd/current **Or** It is calculated using a value of pd ÷ the corresponding value of current **Or** it isn't a straight line so the gradient is not *R* (credit *R* not constant, so value at 6 V isn't applicable to other voltages)	(1) (1)	2
(b)(ii)	Use of $R = V/I$ $R = 4.76\ \Omega$ Example of calculation $R = 6.00\ V / 1.26\ A$ $R = 4.76\ \Omega$	(1) (1)	2
*(c)	**(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)** The resistance increases (Because) the temperature increases (accept heats up) Increasing the amplitude of the oscillation of the lattice ions Leading to more (frequent) collisions of electrons with lattice ions Allow converse marks for an explanation explicitly based on decreasing potential difference	 (1) (1) (1) (1)	4
	Total for question		11

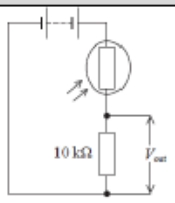
Q11.

Question Number	Answer	Additional Guidance	Mark
	B is the only correct answer	A is incorrect because amplitude does increase C is incorrect because rate of collision does increase D is incorrect because rate of energy transfer does increase	1

Q12.

Question Number	Answer		Mark
(a)	Oscillations/vibrations (of molecules) parallel to direction of propagation **Or** oscillations parallel to direction of wave travel **Or** oscillations parallel to direction of energy transfer	(1)	
	Produces compressions and rarefactions	(1)	2
(b)	Otherwise there wouldn't be a way of telling which bit of reflected sound originated with which bit of emitted sound **Or** so one returns before one emitted	(1)	1
(ci)	time (= 1÷16 Hz) = 0.063 (s) (at least 2 sf)	(1)	1
(cii)	Use of factor of 2 Use of $v = s/t$ distance = 48 m (Use of 'show that' value gives 46m) <u>Example of calculation</u> 2 × distance = 1530 m s^{-1} × 0.063 s distance = 48 m	(1) (1) (1)	3
(ciii)	A shorter time between clicks because the distance is shorter **Or** more frequent clicks allow rapid motion to be perceived. **Or** allow position to be determined precisely/accurately.	(1)	1
(d)	Speed in air lower than speed in water So wavelength in air shorter than wavelength in water **Or** pulse length in air is shorter than pulse length in water **Or** attempt at numerical comparison of wavelength or pulse length So bat echolocation will detect smaller targets **Or** detect smaller differences in position (conditional on MP2) (Accept 'show more detail' or 'better resolution')	(1) (1) (1)	3
	Total for question		11

Q13.

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

Q14.

Question Number	Acceptable Answer	Additional guidance	Mark
	D	the number density of the conduction electrons increases	**(1)**

Q15.

Question Number	Answer	Mark
	A amplitude of the vibrations of the lattice ions	1
	Incorrect Answers: B – the distance travelled by charge carriers between collisions will **decrease** if the temperature increases C – the drift velocity of conduction electrons will **decrease** if the temperature increases D – the number of conduction electrons per unit volume will **remain constant** if the temperature increases	

Q16.

Question Number	Answer	Mark
(a)	**When illuminated:** Use of the word photon (1) photons/light cause emission of (photo)electrons (1) Idea that (photo) electrons form a current (1) photon energy greater than or equal to work function. (1) **In darkness:** No photons so no photoelectrons released (1)	**5**
(b)	Use of $E = hf$ (1) Conversion of eV to J (1) One of the 4 values below correct $f = 5.2 \times 10^{14}$ Hz or $\lambda = 5.8 \times 10^{-7}$ m for caesium $f = 8.8 \times 10^{14}$ Hz or $\lambda = 3.4 \times 10^{-7}$ m for zinc (1) Comment that Cs is in the visible range or Zn is ultraviolet – allow even without supporting calculation (1) **Alternative method** Allow assumed max freq/min wavelength for visible light then, calculation of work function, quoted in eV, comparison with given work functions, conclusion: Use of (1); work fn (1), in eV (1), comparison (1) Example of calculation $f = \varphi \div h = (2.14 \times 1.6 \times 10^{-19})$ J $\div$ 6.63×10^{-34} J s $= 5.2 \times 10^{14}$ Hz for caesium $f = \varphi \div h = (3.63 \times 1.6 \times 10^{-19})$ J $\div$ 6.63×10^{-34} J s $= 8.8 \times 10^{14}$ Hz for zinc	**4**
(ci)	Maximum displacement of the wave **Or** maximum displacement from the mean **Or** maximum displacement from equilibrium (1)	**1**
(cii)	**Max 3** Size of the gap (in the soundtrack) determines the amount of light (1) Amount of light determines number of photons (1) Number of photons determines number of (photo) electrons (released by phototube) (1) Number of electrons determines size of current (in the circuit) (1) (Combining MP 1 and 2 by writing "size of the gap determines number of photons" scores 1 mark. Combining MP 2 and 3 by writing "the amount of light determines number of (photo) electrons" also scores 1 mark)	**3**
	Total for question	**13**

Q17.

Question Number	Answer	Mark
	C	1

Q18.

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 $P = IV$	**(1)**	
	$I = 0.17$ (A) (at least 2 sf required)	**(1)**	**2**
	Example of calculation $40\ \text{W} = I \times 230\ \text{V}$ $I = 0.17\ \text{A}$		
(b)(ii)	Use of appropriate equation	**(1)**	
	$R = 1300\ \Omega$	**(1)**	**2**
	Example of calculation $P = V^2/R$ $40\ \text{W} = (230\ \text{V})^2 / R$ $R = 1323\ \Omega$		
(b)(iii)	Use of $R = V/I$	**(1)**	
	$R = 13\ \Omega$	**(1)**	**2**
	Example of calculation $R = 2.5\ \text{V} / 0.2\ \text{A}$ $R = 12.5\ \Omega$		
(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**

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(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**

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• increasing the current through the coil increases the heating effect (1) • this causes the resistance of the coil to increase (due to the collisions between conduction electrons and lattice ions) (1) • so for a given p.d. this would result in the current decreasing (1) • this would increase the focal length of the lens, hence the need to limit the current (1)	MP4 conditional mark, dependent on MP3 being awarded	**(4)**

Q20.

Question Number	Acceptable answers	Additional guidance	Mark
	• Increased temperature causes more energy transfer to lattice ions / atoms (1) • More charge carriers released / available (1) • $I = nAvq$, so relative increase in I (1) • Reference to $R = V / I$ to justify decrease in R (1)	Or reverse argument	4

Mark Scheme

Q1.

Question Number	Answer	Mark
	B	1

Q2.

Question Number	Answer	Mark
	A dark and cold	1
	Incorrect Answers: B – correct description for LDR but incorrect for thermistor C – incorrect description for LDR but correct for thermistor D – incorrect description for LDR and incorrect for thermistor	

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B **decreases** | **increases**	C and D are incorrect as the resistance decreases A is incorrect as *n* increases	1

Q4.

Question Number	Answer		Mark
	Identifies (electron) <u>diffraction</u>	(1)	
	(Electron) has wave properties/behaviour	(1)	
	(Electron) has wavelength similar to atomic size/spacing	(1)	3
	(do not accept defraction for 1st mark)		

Q5.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An explanation that makes reference to the following:		MP1 e.g. If the frequency of the light is high enough the electrons will gain energy from the light (and jump to the conduction band)	
	• The idea that the <u>electrons</u> gain energy from the light	(1)		
	• (As the lamp is moved towards the LDR) the intensity/brightness/illumination of light falling on the LDR increases	(1)	MP2 assume the answer is in terms of the lamp moving towards the LDR unless stated otherwise	
	• This increased the number of (conduction) electrons	(1)	MP3 accept charge carrier (density) for electrons	
	• Which reduced the resistance of the LDR	(1)		
	• decreasing the potential difference across the LDR **Or** increasing the potential difference across the fixed resistor/voltmeter	(1)		5

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B A *is not correct because R decreases as more conduction electrons* C *is not correct because lattice vibrations not affected* D *is not correct because lattice vibrations not affected*	It increases because there is an increase in the number of conduction electrons.	1

Q7.

Question Number	Acceptable Answers	Additional guidance	Mark
	Max 6 **Similarities** • An electron absorbs a photon **Or** electrons gain energy from a photon (1) • photons need a minimum amount of energy (1) • So light must be above a certain frequency (1) • increasing the light intensity increases the number of electrons (released per sec) (1) • Evidence for the particle model of light (1) **Differences** • In the photoelectric effect electrons are released from the surface (1) • But electrons remain within the LDR (1) • Photoelectric effect occurs in metals **Or** LDR is a semiconductor (1)		6

Q8.

Question Number	Answer		Mark
(a)	best fit line use of gradient **Or** use of R/l from graph or table use of $\rho = RA/l$ resistivity = 4.7×10^{-7} Ω m (range 4.5 to 4.8×10^{-7} Ω m) Example of calculation gradient = 4.4 Ω ÷ 1.0 m = 4.4 Ω m^{-1} $\rho = A \times$ gradient = 1.06×10^{-7} $m^2 \times 4.4$ Ω m^{-1} resistivity = 4.66×10^{-7} Ω m	(1) (1) (1) (1)	4
(b)	temperature increases (with increasing current) resistance/resistivity would have increased (with temperature)	(1) (1)	2
(c)	Precaution Explanation E.g. ensure good contact (e.g. tight croc clips); so pd across contact resistance doesn't make V results inaccurate E.g. Avoid pressing too hard on wire; as a deformation would affect cross-sectional area and therefore resistance e.g. ensure wire is straight so length measurement is accurate e.g ensure eyes perpendicular to scale to avoid parallax errors **Do not credit:** diameter of wire since area is not in the table repeat and average high resistance voltmeter keep temperature constant	(1) (1)	2
	Total for question		8

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	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**