**Marking Scheme**

1.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 1 | *(a)* | (i) | Resistance of LDR / circuit increases [as light intensity decreases] (1)<br>[Hence] current decreases (1) | 2 | | | 2 | | 2 |
| | | (ii) | **Either:**<br>Current in LDR $= \frac{4.0}{2.4 \times 10^{3}}$ = [1.67 × 10^-3^ A] (1)<br>$R = \frac{5.0}{1.67 \times 10^{-3}}$ (1)<br>$R$ = 3.0 kΩ (1)<br><br>**Alternative:**<br>$4.0 = \frac{2.4 \times 10^{3} \times 9.0}{(2.4 \times 10^{3} + R)}$ (1) [substitution into potential divider equation]<br>Correct algebra (1)<br>$R$ = 3.0 kΩ (1)<br>**Alternative:**<br>$\frac{4}{5}$ (1) $= \frac{2.4}{R}$ (1)<br>$R$ = 3.0 kΩ (1) | 1 | 1<br>1 | | 3 | 2 | 3 |
| | *(b)* | | Light from lamp will decrease [LDR resistance and hence] $V$ across lamp low so lamp not activated (1)<br>Hence reason for on/off, e.g. lamp off → LDR in dark → $V_{out}$ high → lamp on | | 2 | | 2 | | 2 |
| | | | **Question 1 total** | **3** | **4** | **0** | **7** | **2** | **7** |

2.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 2 | *(a)* | (i) | Rate of charge flow<br>Accept $I=\dfrac{\Delta Q}{\Delta t}$ only if $\Delta Q$ and $\Delta t$ defined [accept $Q$ and $t$] | 1 | | | 1 | | |
| | | (ii) | J C$^{-1}$ and C s$^{-1}$ as units of $V$ and $I$ respectively clearly shown (1)<br>Correct division seen i.e. $\dfrac{\text{JC}^{-1}}{\text{Cs}^{-1}}$ seen (1)<br>Or from alternative correct expression, e.g. $R=\dfrac{V^2}{P}$<br>Or equivalent in terms of quantities. | 1 | 1 | | 2 | 1 | |
| | *(b)* | (i) | $I$ through $R_P$ = 1.2 A and $I$ through $R_T$ = 0.8 A (1)<br>$\dfrac{V_P}{V_T}=\dfrac{1.2R_P}{0.8R_T}$ (=1.5) seen (1)<br>Or<br>Parallel combination calculated as $\frac{2}{3}R$ (1)<br>Potential divider: $\dfrac{R}{R+\frac{2}{3}R}\times 9=1.5$ (1) | | 2 | | 2 | 1 | |
| | | (ii) | $2.5V_T = 9.0$ or $\dfrac{5V_P}{3} = 9.0$ (1)<br>$V_T$ = 3.6 V or $V_P$ = 5.4 V (1) Award 2 marks for either $V_P$ or $V_T$ calculated correctly.<br>$R_T=\dfrac{3.6}{0.8}$ = 4.5 Ω or $R_P=\dfrac{5.4}{1.2}$ = 4.5 Ω or $\dfrac{1.8}{0.4}$ = 4.5 Ω(1)<br>**Alternative:**<br>Total circuit $R=\dfrac{9.0}{1.2}$ = 7.5 Ω (1)<br>Parallel and series combination shown to be = $\dfrac{5R}{3}$ (1)<br>$\dfrac{5R}{3}$ = 7.5 and $R$ = 4.5 Ω (1)<br>**Alternative:**<br>Understanding that $V_p + V_T = 9$ (1)<br>$1.2R_p + 0.8R_T = 9$ (1) (award 2 marks for this only)<br>$R_p = R_T = R$ and $R=\dfrac{9}{2}$ = 4.5 Ω clearly shown (1)<br>Accept reverse argument. | | 3 | | 3 | 3 | |
| | *(c)* | | $P$ (circuit) = 10.8 W (1) (either $\dfrac{81}{7.5}$ or $(1.2)^2\times 7.5$ or $1.2\times 9$)<br>$P$ in $R_Q = (0.4)^2 \times 4.5$ = 0.72 W (1)<br>$\dfrac{10.8}{0.72}$ = 15 seen (1)<br>**Alternative:**<br>$P_s = P_Q$ since $I_s = I_Q$<br>$P_T = 4 \times P_Q$ since $I_T = 2 \times I_Q$<br>$P_P = 9 \times P_Q$ since $I_P = 3 \times I_Q$<br>Hence total circuit power = $P_Q + P_Q + 4P_Q + 9P_Q$<br>$= 15P_Q$<br>Award (1) for correct individual power analysis<br>Award (1) for correct reason linked to currents<br>Award (1) for showing correct total $P$ | | 3 | | 3 | 2 | |
| | *(d)* | | Circuit resistance increases, leading to total current decreasing. Power dissipated in circuit decreases (1)<br>$V$ across $R_Q$ has increased (from 1.8 V to 3.0 V), so $P_Q$ increases / $I$ through $R_Q$ has increased (from 0.4 A to 0.67 A) so $P_Q$ increases (1)<br>Hence ratio decreases (1) [only award from correct explanation]<br><br>Accept numerical explanation: e.g.<br>Circuit resistance is now 13.5 Ω and circuit current = 0.67 A (1)<br>circuit power shown to be 6 W and $P_Q$ shown to be 2 W (1)<br>Hence ratio decreases or is now 3 (1)<br><br>**Alternative:**<br>With T removed, $I$ through all remaining resistors is the same or $V$ across each is the same (1)<br>Use of $VI$ or $I^2R$ or $V^2/R$ or power / energy dissipated in all three resistors equal (1)<br>So total $P = 3 \times P_Q$ or which is less than $15P_Q$ (1) | | 3 | | 3 | | |
| | | | **Question 2 total** | 2 | 12 | 0 | 14 | 7 | 0 |

3.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 2 | *(a)* | | There are 6 J of energy/work done (converted from electrical to other forms) (1)<br>Per coulomb of charge between X and Y (1) | 2 | | | 2 | | |
| | *(b)* | (i) | Attempt to use equation to determine resistors in parallel (1)<br>Resistance of parallel combination = 3.7[2] Ω (1)<br>Total circuit resistance = 9.3 Ω ecf on parallel (1)<br>Current = $\frac{V}{R}$ = 0.64 A [accept 0.65 A] answer to 2 d.p. (1) | 1 | 1<br>1<br>1 | | 4 | 3 | |
| | | (ii) | Apply ecf from part (b) (i) PD across parallel = 0.65 × 3.7 ecf<br>OR pd across 5.6 Ω = 0.65 × 5.6 = 3.6 V (1)<br>Answer = 2.4 V (1) | | 2 | | 2 | 1 | |
| | | (iii) | Substitute values into $P = I^2R$ [ $P = 0.65^2 \times 3.7$] (1)<br>$P$ = 1.54 W – ecf (1) | 1 | 1 | | 2 | 2 | |
| | | | **Question 2 total** | **4** | **6** | **0** | **10** | **6** | **0** |

4.

| | | | |
|---|---|---|---|
| *(a)* | (i) | $R = \frac{1.6}{15\times10^{-3}\,(1)}$ (reading from graph, accept 14 × $10^{-3}$)<br>$R$= 107 Ω [answers in range 107 – 114 Ω] | 2 |
| | (ii) | [Very] high [accept infinite] | 1 |
| *(b)* | (i) | $V$ not proportion to $I$ / not a straight line [through the origin]<br>["Not through origin" insufficient on its own] | 1 |
| | (ii) | Bulb / thermistor [Not wire or superconductor, but accept superconducting device, e.g. superconducting electromagnet coil] | 1 |
| *(c)* | | $R = \frac{V}{I}\,(1)\,;\; R = \frac{10.4\,(1)}{15\times10^{-3}} = 693\ \Omega\ (1)$<br>**Alt 1**: $10.4 = \frac{R}{R+107}\times 12$ [or equiv.] (1)<br>manipulation e.g. 10.4$R$ + 112.8= 12(1); $R$ = 696 Ω (1)<br>**Alt 2**: $R_T = \frac{V}{I}$ or $\frac{12}{1.5\times10^{-3}}$ (1) = 800 Ω (1); $R$ 800 – 107 = 693 Ω (1) | 3<br><br><br><br>[8] |

5.

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 3. | *(a)* | | | In a <u>water</u> bath **or** in a beaker of <u>water</u> must imply heading (1)<br>Using ice cubes / taking water from fridge / in an ice bath or equivalent (1) | 1 | | 1 | 2 | | 2 |
| | *(b)* | (i) | | Straight line of best fit drawn (from 18 – 100 °C) with points either side **or** reference to very little scatter in the readings (1)<br>Reference to or comparison with $y = mx + c$ (1)<br>Positive intercept or positive gradient (1) | | 1 | 1<br>1 | 3 | | 3 |
| | | (ii) | I | 5.5 Ω, 5.6 Ω or 5.7 Ω **unit mark** [Accept attempts at 3 sf] | | 1 | | 1 | 1 | 1 |
| | | | II | **Either**<br>Readings from graph line inserted in $\frac{\Delta R}{\Delta \theta}$. Tolerate slips (1)<br>Gradient = 0.023 [± 0.002] [Ω °C⁻¹] **or** by implication (1)<br>$\alpha$ = 3.9 [± 0.4] $\times 10^{-3}$ °C$^{-1}$ **unit mark ecf** on $R_0$ and gradient (1)<br>**Or**<br>Value of $R_0$ and ($R$, $\theta$) values from another point on graph line inserted in equation. Tolerate slips (1)<br>Correct algebra (1)<br>$\alpha$ = 3.9 [± 0.4] $\times 10^{-3}$ °C$^{-1}$ **unit mark ecf** on $R_0$ | | | 1<br>1<br>1 | 3 | 3 | 3 |
| | | | | **Question 3 total** | **1** | **2** | **6** | **9** | **4** | **9** |

6.

*(a)* (i) $Resistance = \dfrac{pd}{current}$ (accept: voltage / if $V$ and $I$ written must be qualified) [1]

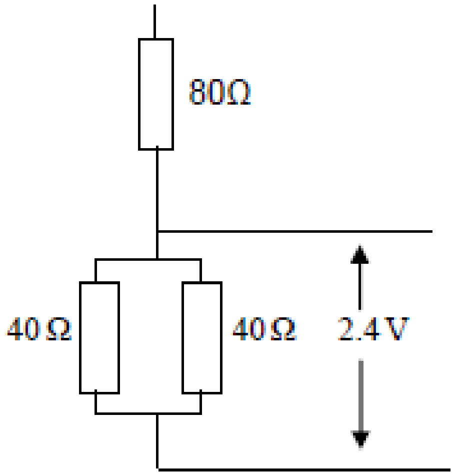
(ii) $V = \text{J C}^{-1}$ (1); $I = \text{C s}^{-1}$ (1); Convincing working (1) [3]
Don't accept use of t -award ecf for 3rd mark. Alternative route using power formulae is acceptable.

*(b)* (i) $I = \dfrac{V_{in}}{R_1 + R_2}$ [1]

(ii) $V_{out} = IR_2$ (1); $I$ (from (i)) used correctly (1) [2]

*(c)* (i) Any parallel combination shown (1); 40 [Ω] used correctly (1) [2]

(ii)




Resistor combination shown (1) ecf from *(c)*(i)

2.4 [V] or $V_{out}$ labelled correctly (1) [2]

| | | | |
|---|---|---|---|
| 7. *(a)* | (i) | $I \propto V$ (1)<br>Providing the temperature / physical conditions remain constant (1) | 2 |
| | (ii) | V $A^{-1}$ circled | 1 |
| *(b)* | (i) | see table below | 3 |
| | (ii) | **Either** $R = \frac{9}{0.18}$ (1) (= 50 Ω) → $R_P + R_Q = 50$ (1)<br>$R_{each}$ buzzer = 25[Ω] (1) ecf between 2nd and 3rd marks<br>**Or** $R = \frac{4.5\ (1)}{0.18}$ (1) = 25[Ω] (1) | 3 |
| | (iii) | $R_{Total} = 16\frac{2}{3}$ [Ω] (1) $I = \frac{9}{16\frac{2}{3}} = 0.54$ [A] (1)<br>ecf from (b)(ii) / no ecf for $R_{Total}$ | 2 |
| | (iv) | see working below | 3 |

(b)(i)

| Switch combination | P | Q | S | |
|---|---|---|---|---|
| X open, Y open | On | On | Off | |
| X closed, Y open | Off | On | Off | (1) |
| X open, Y closed | On | On | On | (1) |
| X closed, Y closed | Off | On | On | (1) |

(b)(iv)

**Either** ecf from (b)(ii) or (b)(iii) or both

$P_S = \left(\frac{2}{3} \text{ x } 0.54\right)^2 \text{ x } 25$ (1) $P_S = 3.24$ [W]

$P_Q = \left(\frac{1}{3} \text{ x } 0.54\right)^2 \text{ x } 25$ (1) $P_Q = 0.81$ [W]

**Or**

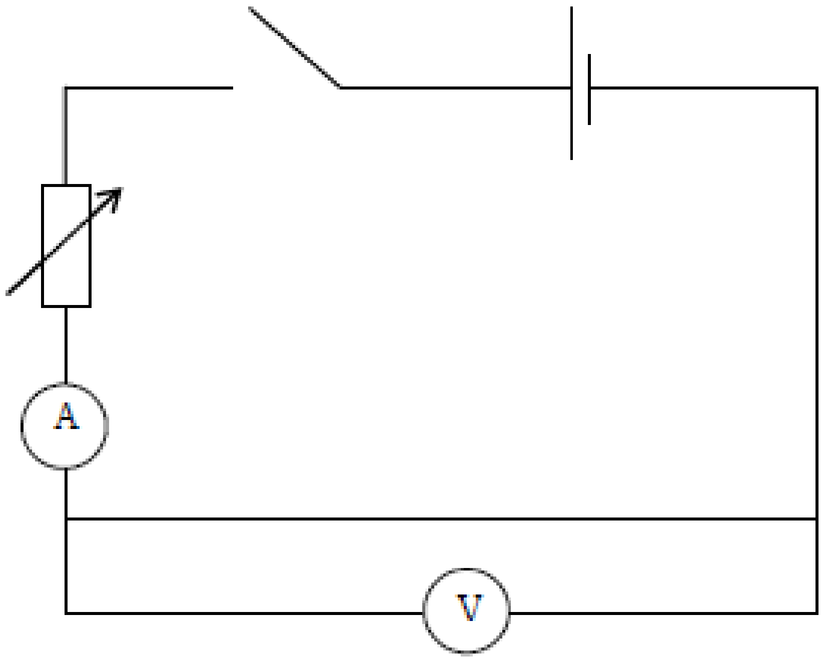
$P_S = \frac{9^2}{25}$ (1) = 3.24 [W] $P_Q = \frac{4.5^2}{25}$ (1) = 0.81 [W]

**Or**

$P_S = \frac{2}{3} \text{ x } 0.54 \text{ x } 9$ (1)= 3.24 [W] $P_Q = \frac{1}{3} \text{ x } 0.54 \text{ x } 4.5$ (1) = 0.81 [W]

→ $\frac{3.24}{0.81} = 4$ (1) or any correct algebraic solution = 3 marks

8. *(a)* (i)




Circuit (without voltmeter and ammeter) (1)

Voltmeter and Ammeter correctly positioned (1) 2

(ii) $R = \frac{10}{0.9}$ $= 11.11\ [\Omega]$ (1)

$A = 3.14\text{x}10^{-8}\ [\text{m}^2]$ (1)

$\rho = \frac{11.11 \text{ x } 3.14\text{x}10^{-8}}{3.2}$ (1) substitution $\rho = 1.09\text{x}10^{-7}\ [\Omega\text{ m}]$ (1)

ecf for R and A 4

(iii) Platinum and Tin 1

*(b)* $\rho = \frac{0.74\text{x}10^{-3}}{(3.14\text{x}10^{-8} \text{ x } 3.2)(1)} = 7365\ [\text{kg m}^{-3}]$ (1) ecf for A

Tin (1) ecf from density value 3

| | | | | |
|---|---|---|---|---|
| 9. | (a) | (i) | [For a metallic conductor] the potential difference and current are [directly] proportional/ $I \propto V$ (1), provided the temperature remains constant / all physical factors remain constant (1)<br>$V = IR$ only no marks | 2 |
| | | (ii) | It is constant / stays the same /increases as the temperature increases | 1 |
| | (b) | (i) | $A = 1.5(3) \times 10^{-8}$ [m$^2$](1)<br>$R = \dfrac{\rho l}{A} = \dfrac{95\times10^{-8}\times3.2}{1.5(3)\times10^{-8}}$ (1) = 199 [Ω] (1) | 3 |
| | | (ii) | $\dfrac{230^2}{200} = 265$ [W] allow e.c.f. from (b)(i) | 1 |
| | | (iii) | $\dfrac{1}{66.7(1)} = \dfrac{1}{200} + \dfrac{1}{R_2}$ (1)<br>$R_2 = 100$ [Ω] (1) | 3 |
| | | (iv) | $R_2$ (1) either reference to $\dfrac{V^2}{R}$ so lower $R$ / same V across lower R or reference to $I^2R$ so greater $I$ or reference to $IV$ so $I$ increased [for constant $V$] or correct calculation of $R_2$ (1) | 2 |
| | | (v) | $\dfrac{230}{66.7} = 3.5$ [A] allow e.c.f. from (b)(iii) | 1 |


| | | | |
|---|---|---|---|
| (a) | (i) | [For a metallic conductor] the potential difference and current are [directly] proportional/ $I \propto V$ (1), provided the temperature remains constant / all physical factors remain constant (1)<br>$V = IR$ only no marks | 2 |
| | (ii) | It is constant / stays the same /increases as the temperature increases | 1 |
| (b) | (i) | $A = 1.5(3) \times 10^{-8}$ [m$^2$](1)<br>$R = \dfrac{\rho l}{A} = \dfrac{95\times10^{-8}\times3.2}{1.5(3)\times10^{-8}}$ (1) = 199 [Ω] (1) | 3 |
| | (ii) | $\dfrac{230^2}{200} = 265$ [W] allow e.c.f. from (b)(i) | 1 |
| | (iii) | $\dfrac{1}{66.7(1)} = \dfrac{1}{200} + \dfrac{1}{R_2}$ (1)<br>$R_2 = 100$ [Ω] (1) | 3 |
| | (iv) | $R_2$ (1) either reference to $\dfrac{V^2}{R}$ so lower $R$ / same V across lower R or reference to $I^2R$ so greater $I$ or reference to $IV$ so $I$ increased [for constant $V$] or correct calculation of $R_2$ (1) | 2 |
| | (v) | $\dfrac{230}{66.7} = 3.5$ [A] allow e.c.f. from (b)(iii) | 1 |

10.

| Question | | | Marking details | Marks available | | | | Maths | Prac |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | | |
| 2 | *(a)* | | $I$ = 0.0012 A and $R_{tot}$ = 5000 Ω or $V_{therm}$ = 4.80 V<br>or $\frac{R_{th}}{1000\,\Omega} = \frac{4.8\text{ V}}{1.2\text{ V}}$ or any other correct and relevant potential divider equation or by implication (1)<br>$R_{therm}$ = 4 000 Ω (1)<br>$\theta$ = 15° ecf on $R_{therm}$(1) | | 3 | | 3 | 3 | |
| | *(b)* | | Graph gradient changes [with $\theta$] or graph not straight [or voltmeter reading doesn't vary linearly with $R_{therm}$] or $\Delta V$ not proportional to $\Delta R$ (1)<br>$n$ not constant [with varying $\theta$] / he is wrong [only award if backed up by reasonable argument] (1) | | | 2 | 2 | 1 | |
| | *(c)* | | So thermistor [accept: 'it'] doesn't heat up (1)<br>Reference to electrical heating [even of circuit or resistor] or masking response to surroundings (or equiv) (1) | | 2 | | 2 | | |
| | | | **Question 2 total** | 0 | 5 | 2 | 7 | 4 | 0 |

11.

| | | | |
|---|---|---|---|
| *(a)* | (i) | [Rate of] flow of charge / $I = \frac{Q}{t}$ or $\frac{dQ}{dt}$ with $Q$ defined | 1 |
| | (ii) | C $s^{-1}$ | 1 |
| *(b)* | (i) | $x = y + z$ | 1 |
| | (ii) | charge | 1 |
| *(c)* | (i) | $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ or $R = \frac{R_1 R_2}{R_1 + R_2}$ of by impl. (1)<br>$R_{\parallel}$ = 30 Ω (1); $R_{Total}$ = 40 Ω (1) [no e.c.f.] | 3 |
| | (ii) | [Current $x$ =] 0.15 A e.c.f.<br>[Accept equiv., e.g. $^6/_{40}$, but not 0.2A without working] | 1 |
| | (iii) | $V_1 = 0.15 \times 10$ [= 1.5 V] (1) [e.c.f.]<br>$V_2 = 6 - 1.5$ [= 4.5 V] [or $30 \times 0.15 = 4.5$ V] (1) [e.c.f.] | 2 |
| | (iv) | $y = \frac{4.5}{120}$ [= 0.038 A] (1)<br>$z = 0.15 - 0.038$e.c.f. [= 0.11 A] $\left[\text{or } \frac{4.5}{40} \text{ [= 0.11 A]}\right]$ (1)<br>[Accept solutions based upon ratios, e.g. $y = \frac{0.15}{4}$ ...] | 2<br>**[12]** |

| Question | | | Marking details | Marks Available |
|---|---|---|---|---|
| 2 | *(a)* | | $\text{V A}^{-1}$ and $\text{W A}^{-2}$ $2 \times (1)$ | 2 |
| | *(b)* | (i) | $V = 0.01 \times 450 = 4.5$ [V] | 1 |
| | | (ii) | 12 V – 4.5 V [**ecf**] = 7.5 [V] | 1 |
| | | (iii) | $R = \dfrac{7.5}{0.01}$ (1 for correct use of 7.5 or **ecf**) = 750 [Ω] (1) **or correct alternative** | 2 |
| | | (iv) | $\dfrac{1}{750} = \dfrac{1}{900} + \dfrac{1}{R}$ (1) (substitution)<br>$R_{\text{variable resistor}} = 4\,500$ [Ω] (1)<br><br>**Alternative solution to (iii) and (iv)**<br>$I$ through 900 Ω = $\dfrac{7.5}{900}$ = 0.0083 [A] (1)<br>$I$ through variable resistor = 0.0017 [A] (1)<br>$R_{\text{variable resistor}} = \dfrac{7.5}{0.0017} = 4\,500$ [Ω] (1)<br>Use of resistors in parallel formula to find total parallel resistance = 750 [Ω] (1) | 2 |

| Question | | | Marking details | Marks Available |
|---|---|---|---|---|
| | *(c)* | | [No mark for stating circuit resistance decreases]<br>Current in circuit increases (1) [accept explanation based on potential divider.<br>Hence pd across 450 Ω increases (1)<br>Hence pd across 900 Ω decreases (1) **this mark can't be awarded unless it is correctly substantiated**<br><br>**Alternative solutions:**<br>Resistance of parallel combination decreases (1)<br>pd across parallel combination decreases (1)<br>pd across 900 Ω decreases (1)<br>OR current through the variable resistor increases (1)<br>current through the 900 Ω decreases (1)<br>pd across the 900 Ω decreases (1) | 3 |
| | | | **Question 2 total** | **[11]** |

13.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 1. | *(a)* | (i) | The current [through a metal conductor at constant temperature] is proportional to the pd [across it]<br>Accept $I \propto V$ with well-defined symbols. | 1 | | | 1 | | |
| | | (ii) | Constant [or independent of current [or pd]] (1) | 1 | | | 1 | | |
| | *(b)* | (i) | pd across X = 0.70 [V] (1) or by impl so $R_X$ = 58 [Ω] (1)<br>**or**<br>total resistance = 183 [Ω] (1) or by impl so $R_X$ = 58 [Ω] (1) | | 2 | | 2 | 2 | |
| | | (ii) | $R_X$ = 16 [Ω] or equivalent (1)<br>So Ohm's law not obeyed (1) [not freestanding] **no ecf**<br>**or**<br>If $R_X$ stayed at 58 [Ω] (or 58.3 Ω), then $I$ = 27 (or 26) mA (1)<br>Not so, therefore Ohm's law not obeyed (1) **no ecf** | | | 2 | 2 | 1 | |
| | | (iii) | No. Filament resistance increases with increasing pd [or current] or equivalent **ecf** on calculated value of $R_X$ in (b)(ii) | | | 1 | 1 | | |
| | *(c)* | (i) | Temperature at which a material [that is classed as a superconductor] loses all its resistivity [accept resistance] [when cooled].<br>Accept "... below which a material [...] has no resistivity [accept resistance]" | 1 | | | 1 | | |
| | | (ii) | Coil for MRI machine, power cables, magnets / electromagnets or anything reasonable (1)<br>Can be kept below transition temp [cheaply] by liquid nitrogen [accept: superconducts in liquid nitrogen] (1) | 2 | | | 2 | | |
| | | | **Question 1 total** | **5** | **2** | **3** | **10** | **3** | **0** |

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 4 | *(a)* | | **Indicative content:**<br>**Description:**<br>D1: At very low temperatures resistance of superconductor is zero ohms<br>D2: Reference to transition temperature or critical temperature......<br>D3: .....where resistance suddenly drops to zero as temperature drops (or jumps up from zero as temperature rises)<br>D4: Above transition temperature resistance increases with temperature<br>D5: This increase in resistance with temperature is [approximately] linear<br>**[Sketch graph can show some of these points]**<br><br>Explanation:<br>**No explanation required for superconducting state.**<br>**Above transition temperature:**<br>E1: As temperature increases, the ions in the metal lattice vibrate more quickly<br>E2: Which makes it more likely that an electron will interact (accept collide) with the ion....<br>E3: So electrons lose kinetic energy and the drift velocity decreases<br>E4: .......and collisions will cause ions to gain kinetic energy making further collisions more likely<br>**5-6 marks**<br>Comprehensive description and explanation provided.<br>*There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.*<br><br>**3-4 marks**<br>Comprehensive description or explanation provided or limited attempt at both description and explanation.<br>*There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.*<br><br>**1-2 marks**<br>Limited attempt at description or explanation.<br>*There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.*<br><br>**0 marks**<br>No attempt made or no response worthy of credit. | 6 | | | 6 | | |
| | *(b)* | | One benefit to society given for each application:<br><br>**Particle accelerator 1 × (1) from:**<br>• Improve understanding of the nature of particles,<br>• Skilled workforce opportunities<br>• Have led to more powerful computing<br>• Particle discoveries used in everyday applications e.g. TV sets<br>• Well-reasoned economic benefits<br><br>**MRI scanner 1 × (1) from:**<br>• Improved diagnoses and treatment of many ailments<br>• Skilled workforce opportunities<br>• Benefits more people<br><br>Reasoned choice of application [1] | | | 3 | 3 | | |
| | | | **Question 4 total** | **6** | **0** | **3** | **9** | **0** | **0** |

15.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 1 | *(a)* | | $V$- Energy (per coulomb or unit charge) used in external resistor/circuit [1]<br>$E$- Energy (per coulomb/unit charge) transferred by source [or from chemical energy or from other forms] or used in whole circuit [1]<br>$Ir$ – energy (per coulomb/unit charge) wasted/lost in source or due to internal resistance [1]<br>Use of 'per coulomb' or 'unit charge' at least once [1] | 4 | | | 4 | | |
| | *(b)* | (i) | Circuit current = $\frac{1050\times10^{-3}}{2.5}$ = 0.42 [A] [1]<br>Total internal resistance = $\frac{0.5}{0.42}$ = 1.2 [Ω] ecf on $I$ [1]<br>$r_{cell}$ = 0.6 [Ω] [1] | | 3 | | 3 | 2 | |
| | | (ii) | Substitution into $I^2rt$ i.e. $(0.42)^2 \times 0.6 \times 60$ (ecf on $I$, $r$) [1]<br>**Alternative:**<br>Substitution into $\frac{V^2t}{r}$ i.e. $\frac{(0.25)^2\times60}{0.6}$ (ecf on $V$, $r$)<br>**Alternative:**<br>Substitution into $IVt$ i.e. $0.42 \times 0.25 \times 60$ (ecf on $I$, $V$)<br>Energy dissipated = 6.3 [J] [N.B. Alternative → 6.4 J] [1] | 1 | 1 | | 2 | 1 | |
| | *(c)* | | Either:<br>Total resistance of coils in parallel = 2.975 [Ω] [1]<br>and total circuit resistance = 4.175 [Ω] ecf [1]<br>New current in circuit = $\frac{3}{4.175}$ = 0.72 [A] [1]<br>**For the 4th mark:**<br>Rate of energy dissipation in each cell<br>= $(0.72)^2 \times 0.6$ = 0.31 [W] so Kiera correct (or ratio calculated to be approx. 3)<br>Or<br>Energy dissipated in each cell in one minute<br>= $(0.72)^2 \times 0.6 \times 60$ = 18.6 [J] so Kiera correct (or ratio calculated to be approx. 3) [1]<br>**Alternative:**<br>Total resistance of coils in parallel = 2.975 [Ω] [1]<br>and total circuit resistance = 4.175 [Ω] ecf [1]<br>New current = 0.72 [A] and pd drop across internal resistance = $0.72 \times 1.2$ = 0.86 [V] [1]<br>Rate of energy dissipation in each cell<br>**For the 4th mark:**<br>= $\frac{(0.43)^2}{0.6}$ = 0.31 [W] so Kiera correct (or ratio calculated to be approx. 3)<br>Or<br>Energy dissipated in each cell in one minute<br>= $\frac{(0.43)^2\times60}{0.6}$ = 18.6 [J] so Kiera correct (or ratio calculated to be approx. 3) [1] | | | 4 | 4 | | |
| | | | **Question 1 total** | **5** | **4** | **4** | **13** | **3** | **0** |

16.

| Question | | | | Marking details | AO1 | AO2 | AO3 | Total | Maths | Prac |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Marks available** | | | | | |
| 1 | *(a)* | (i) | | Energy (or work) /charge or energy (or work) per coulomb [accept joules per coulomb] (1)<br>The above put correctly into context, e.g. Energy given by battery / energy transfer from chemical [or to electrical]. [Free standing mark] (1) | 1<br>1 | | | 2 | | |
| | | (ii) | | **Method 1**<br>$I = \frac{4.33\text{ V}}{6.60\ \Omega}[= 0.656\text{ A}]$ or by implication (1)<br>$r = \frac{4.80[\text{V}] - 4.33[\text{V}]}{0.656[\text{A}]}$ = 0.71 / 0.72 / 0.7 Ω (1)<br>**Method 2**<br>Any correct and relevant pot div equation e.g.<br>$\frac{r}{6.6\ \Omega} = \frac{4.80\text{ V} - 4.33\text{ V}}{4.33\text{ V}}$ or $4.33 = \frac{4.80 \times 6.60}{r + 6.60}$ (1)<br>$r$ = 0.71 / 0.72 / 0.7 Ω (1)<br>See additional guidance for methods assuming 0.7 Ω | 1 | 1 | | 2 | 2 | |
| | | (iii) | I | More current (1)<br>Therefore greater $Ir$ [accept: greater lost volts] (1)<br>NB $V = E - Ir$ on its own doesn't score.<br>or<br>Ratio (ext res)/$r$ lower (1)<br>So ratio (ext pd)/(pd aross $r$) less (1)<br>or equivalents | 1 | 1 | | 2 | | |
| | | | II | Current in either resistor = $\frac{3.35}{3.30}$ [= 1.02 / 1.015 A](1)<br>Division by $e$ at any stage (1) [e.g. →61 C]<br>Electrons in 1 minute = 3.8 × $10^{20}$ C, ecf on $I$<br>[NB electrons through parallel combination = 7.6 × $10^{20}$ → (2)] | | 3 | | 3 | 2 | |
| | *(b)* | (i) | | $R = \frac{V^2}{P}$ or $\left[I = \frac{1000\text{ W}}{230\text{ V}} \text{ and } R = \frac{V}{I}\right]$ (1)<br>$R$ = 53 Ω [accept early rounding] (1) | 1 | 1 | | 2 | 2 | |
| | | (ii) | | 3.6 [MJ] | | 1 | | 1 | 1 | |
| | *(c)* | | | If electric heating is used rather than gas, for a given heating effect more <u>CO<sub></sub></u>$CO_2$ produced [ or more gas, a non-renewable resource [accept: fossil fuel] is used]. (1)<br>Greater contribution to climate change/global warming [so use of electric heaters *should* be discouraged] (1)<br>**Any one of...**<br>• [But] higher cost of electricity [per kW] is discouragement enough<br>• [But] not all power stations *are* gas-fired. [Some eg nuclear, wind, don't produce $CO_2$]<br>• [But] not all homes have gas available<br>• $CO_2$ absorbs long-wavelength infrared (or infrared emitted from Earth's surface) in context of climate change<br>• Any other relevant and non-trivial point e.g. safety issue with naked flames / CO emission / gas leaks<br>Example of point not worth credit: "it's none of anyone else's business how I heat my home" – the word in the question was "discouraged" / electric heaters more expensive to run | | | 3 | 3 | | |
| | | | | **Question 1 total** | 5 | 7 | 3 | 15 | 7 | 0 |

**Additional guidance for 1*(a)*(ii)**

**Method 3**
[Assuming that] $r$ = 0.7 Ω:
Total resistance = 7.30 Ω

$\therefore$ Current = $\frac{4.80[\text{V}]}{7.30[\Omega]}$ = 0.658 A (1)

Terminal pd, $V = E - Ir$ = 4.80 – 0.685×0.7
= 4.34 V, which is approximately as expected (1)
So the initial assumption is correct

**Method 4**
[Assuming that] $r$ = 0.7 Ω:
[Total resistance = 7.30 Ω]
Using the potential divider equation:

$V = E \times \frac{R}{R + r} = 4.80[\text{V}] \times \frac{6.60[\Omega]}{7.30[\Omega]}$ equation used correctly (1)

= 4.34 V, which is approximately as expected (1)

So the initial assumption is correct

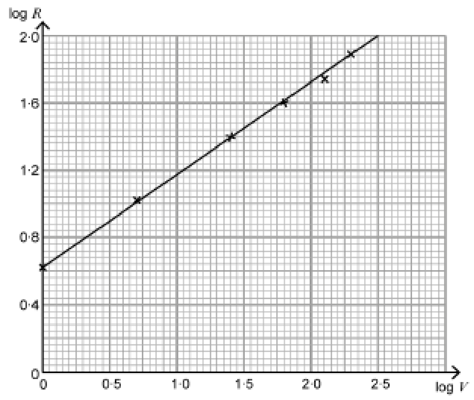
17.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 4 | *(a)* | (i) | Using $R=\frac{\rho l}{A}$ (1)<br>Area = $\frac{\pi d^2}{4}$ = 6.16 × 10$^{-8}$ m$^2$ (1)<br>Resistivity = 1.62 × 10$^{-8}$ Ω m **unit mark** (1) | 1 | 1<br>1 | | 3 | 2 | |
| | | (ii) | $p_l=\frac{0.1}{32.4}\times 100\%$ = 0.3% or statement – negligible (1)<br>$p_A = 2\times p_d$ = 7.1% (1)<br>Total percentage uncertainty = 12% (ecf) (1)<br>Abs unc (resistivity) = ± 0.2 × 10$^{-8}$ [Ω m] to 1 sf maximum (ecf) (1) | | 4 | | 4 | 4 | 4 |
| | | (iii) | Silver and copper lie within range of values (ecf) (1)<br>Material cannot be determined exactly from table (1) | | | 2 | 2 | | |
| | *(b)* | (i) | Current is flow of (free) electrons (1)<br>Flow is obstructed by collisions with ions (1)<br>Collisions increase as temperature increases (1)<br>Because of increased vibrations of ions/lattice *or* random speed of electrons increases (1) | 4 | | | 4 | | |
| | | (ii) | Using $R=\frac{V}{I}$ or proportional to $\frac{1}{I}$ OR temperature is inversely proportional to current (V constant) (1)<br>Determining constant for at least 3 values dependent on method<br>$k=\frac{R}{\text{Temperature}}$ or Temperature x $I$ (1)<br>Conclusion – not constant (accept directly proportional if temperature in kelvin) (1) | | | 3 | 3 | 2 | 3 |
| | | | **Question 4 total** | 5 | 6 | 5 | 16 | 8 | 7 |

18.

| Question | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 5 | *(a)* | (i) | All resistors connected in parallel (1)<br>Using $\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$ [or equiv] (1)<br>$R_{total}$ = 1.44 [Ω] (1) | 1 | 1<br>1 | | 3 | 2 | 3 |
| | *(b)* | (i) | (A4/emf) is the energy generated in the cell (1)<br>per coloumb (1)<br>Loss of energy in circuit in the load resistor (E4) (1)<br>$E-V$ is the energy is lost in internal resistance (1)<br>Energy is conserved (1)<br>Re-arrange gives $r=\frac{E-V}{I}$ (1) | 1<br>1 | 1<br>1<br>1<br>1 | | 6 | 1 | |
| | | (ii) | Substituting values in $\frac{\text{A7-E7}}{\text{D7}}$ (1)<br>$r$ = 0.15 [Ω] (1) | 1 | 1 | | 2 | 2 | |
| | | (iii) | Using $P=I^2R$ (1)<br>$P$ = 0.45 [W] (1)<br>0.50 W – has to be greater than the power dissipated (need reason) (1) | 1 | 1<br>1 | | 3 | 1 | |
| | | | **Question 5 total** | 5 | 9 | 0 | 14 | 6 | 3 |

19.

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>2</td><td>(a)</td><td></td><td>Varies value of variable resistor</td><td></td><td></td><td>1</td><td>1</td><td></td><td>1</td></tr>
<tr><td></td><td>(b)</td><td></td><td>Correct attempt e.g. $\ln R = \ln\left(kV^n\right)$ or $\ln R = \ln k + \ln V^n$ [or using $\log_e$ or using $\log_{10}$] [1]<br>Correct expression $\ln R = n\ln V + \ln k$ [or using $\log_e$ or using $\log_{10}$] [1]</td><td></td><td>2</td><td></td><td>2</td><td>2</td><td>2</td></tr>
<tr><td></td><td>(c)</td><td></td><td>
<table>
<tr><th>$V$ / V</th><th>$I$ / A</th><th>$R$ / Ω</th><th>ln($V$/V)</th><th>ln($R$/Ω)</th></tr>
<tr><td>1.00</td><td>0.52</td><td>1.9(2)</td><td>0.00</td><td>0.65</td></tr>
<tr><td>2.00</td><td>0.72</td><td>2.78 or 2.8</td><td>0.69</td><td>1.02</td></tr>
<tr><td>4.00</td><td>0.98</td><td>4.08 or 4.1</td><td>1.39</td><td>1.41</td></tr>
<tr><td>6.00</td><td>1.20</td><td>5.00</td><td>1.79</td><td>1.61</td></tr>
<tr><td>8.00</td><td>1.40</td><td>5.7(1)</td><td>2.08</td><td>1.74</td></tr>
<tr><td>10.00</td><td>1.54</td><td>6.49 or 6.5</td><td>2.30</td><td>1.87</td></tr>
</table>
$\ln V$ values correct or accept $\log_{10} V$ values [1]<br>
Use of $R = \dfrac{V}{I}$ and all $R$ and $\ln R$ values correct or accept $\log_{10} R$ values [1]
<table>
<tr><th>Log$_{10}$($V$/V)</th><th>Log$_{10}$($R$/Ω)</th></tr>
<tr><td>0.00</td><td>0.28</td></tr>
<tr><td>0.30</td><td>0.45</td></tr>
<tr><td>0.60</td><td>0.61</td></tr>
<tr><td>0.78</td><td>0.70</td></tr>
<tr><td>0.90</td><td>0.76</td></tr>
<tr><td>1.00</td><td>0.81</td></tr>
</table>
Accept 2 or 3 sig figs in all cases. Accept 4 sig. Figs for $\ln V$ at 10.00 V (= 2.302) [1]</td><td></td><td>3</td><td></td><td>3</td><td>3</td><td>3</td></tr>
<tr><td></td><td>(d)</td><td></td><td>Axes labelled either with no units i.e. $\ln R$ (or $\log_{10}R$) on $y$-axis and $\ln V$ (or $\log_{10}V$) on $x$-axis, or with $\ln\left(R/\Omega\right)$ and $\ln\left(V/\text{V}\right)$ respectively (or equivalent using) [1]<br>
Suitable scale e.g. large block – 0.2 on $y$-axis and 0.4 on $x$-axis for ln values and 0.2 on $x$-axis and 0.1 on $y$-axis on both axes for $\log_{10}$ values. [Linear, scales, with points occupying ≥ half available space] [1]<br>
All points plotted correctly within ±< small square division [2]<br>
5 points plotted correctly within ±< small square division [1]<br>
4 or less points plotted correctly within ±< small square division [0]<br>
Straight line of best fit drawn [1]<br>
e.g. for ln graph:<br>

</td><td></td><td>5</td><td></td><td>5</td><td>4</td><td>5</td></tr>
<tr><td></td><td>(e)</td><td>(i)</td><td>Attempt at taking gradient [1]<br>
$n = \dfrac{(2.0 - 0.65)}{2.5}$ = 0.5[4] [1] [answer gains both marks]<br>
$\ln k = 0.65$ or $k = e^{0.65}$ [1]<br>
$k$ = 1.9[2] [1] [answer gains both marks]<br>
N.B. ecf from graph for both values.<br>
Mark scheme to be applied as above for candidates using $\log_{10}$ values.</td><td>1<br>1</td><td>1<br>1</td><td></td><td>4</td><td>3</td><td>4</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$R = 1.9\,V^{0.5}$ (ecf on $n$ and $k$)</td><td>1</td><td></td><td></td><td>1</td><td>1</td><td>1</td></tr>
<tr><td></td><td>(f)</td><td></td><td>Required statement:<br>Results lie close to line of best fit suggests good quality<br>Accept: results fit with the expected theory<br>Don't accept it's a straight line or reference to measuring instruments</td><td></td><td></td><td>1</td><td>1</td><td></td><td>1</td></tr>
<tr><td></td><td></td><td></td><td>Question 2 total</td><td>3</td><td>12</td><td>2</td><td>17</td><td>13</td><td>17</td></tr>
</table>

20.

| Question | | | | Marking details | Marks available | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | AO1 | AO2 | AO3 | Total | Maths | Prac |
| 2. | *(a)* | | | Gives charge [electrical potential] energy<br>*Accept* pumps charge around circuit / does work on charge.<br>Accept electrons instead of charge | 1 | | | 1 | | |
| | *(b)* | (i) | | Total emf = 3 × 1.60 or 4.80 [V] (1)<br>Total resistance = (1.20 + (3 × 0.10)) or 1.50 [Ω] (1)<br>Current [$=\frac{V}{R}$]= 3.2 [A] (1)<br>N.B. If workings in reverse award a maximum of 2 marks | | 3 | | 3 | 1 | |
| | | (ii) | I | 12.3 [W] ecf (10.8 W if 3 A used)<br>e.g. using $P = I^2R = 3.2^2 \times 1.2 = 12.3$ [W] | | 1 | | 1 | 1 | |
| | | | II | 15.4 [W] ecf (14.4 W if 3 A used)<br>e.g. using $P = IE = 3.2 \times 4.8 = 15.4$ [W] | | 1 | | 1 | 1 | |
| | | (iii) | | Thermal or internal. *Accept* 'heat', 'dissipated' (1)<br>in internal resistance (1) | 2 | | | 2 | | |
| | *(c)* | | | 3.15 A or 3.2 A [*Accept*: even on short-circuit, extra cell gives only 3.0 A] (1)<br>No. Current less than [*accept* same as] before ecf on (b)(i) (1) | | | 2 | 2 | 1 | |
| | | | | **Question 2 total** | **3** | **5** | **2** | **10** | **4** | **0** |

21.

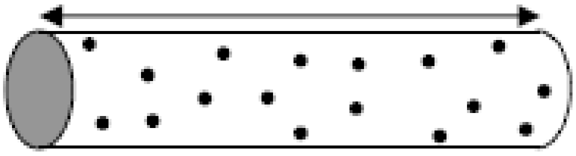
| | | | |
|---|---|---|---|
| *(a)* | | $V$- energy (per coulomb) used in [external] resistor / circuit. (1)<br>$E$- energy (per coulomb) transferred / supplied by source / in the whole circuit (1)<br>$Ir$- energy (per coulomb) wasted / lost in source / cell / internal resistance (1)<br>Use of 'per coulomb / unit charge' once. (1) | [4] |
| *(b)* | (i) | 4 [Ω] | [1] |
| | (ii) | Gradient attempted e.g. 60/10 (1) (or use of equation ecf from *(b)* (i))<br>emf = 6 [V] (1) | [2] |
| | (iii) | $1/I = 4$ [A$^{-1}$] or by implication (1)<br>$R = 20$ [Ω] (1)<br>Use of $I^2R$ i.e. $(0.25)^2 \times 20$ (ecf) (1) or correct substitution into both $V = IR$ and $P = IV$ or $V^2/R$<br>$P = 1.25$[W] (1) | [4] |
| *(c)* | (i) | emf = 12.0 [V] (ecf) <u>and</u> $r = 8.0$ [Ω] (ecf) | [1] |
| | (ii) | $R = 52.0$ [Ω] (ecf) | [1] |
| | (iii) | y intercept ($r \rightarrow 8.0\ \Omega$ (ecf)) (1)<br>Precise gradient e.g. through (5,52) (ecf) (1) | [2] |

| | | | |
|---|---|---|---|
| 22. *(a)* | | Electrical energy (or work done) transferred [to other forms passing] between two points (1) per coulomb of charge (1)<br>Definition of 1 V award 1 mark only | [2] |
| *(b)* | (i) | $V_{supply} = V_1 + V_2 + V_3$ | [1] |
| | (ii) | Energy | [1] |
| *(c)* | (i) | $R_1 + 12 = \frac{9}{0.5}$ (1)<br>Clear manipulation seen to show $R_1 = 6$ [Ω] (1) | [2] |
| | (ii) (I) | $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ to show effective parallel combination = 6 Ω (1) this can be implied<br>$V$ across upper 6 Ω resistor shown = 4.5 [V] (ecf on parallel combination) (1) | [2] |
| | (II) | Total resistance = 12 Ω (1)<br>$I = \frac{9.0}{12} = 0.75$ [A] (1) (accept $\frac{4.5}{6} = 0.75$ [A]) | [2] |
| | (III) | $1.2 = \frac{9}{(6 + R_{parallel})}$ (1)<br>$R_{parallel} = 1.5$ [Ω] (1)<br>$n \times (\frac{1}{12}) = \frac{1}{1.5}$ (1) ecf on 1.5 [Ω]<br>$n = 8$ (1)<br>Full marks for correct answer based on trial and error<br>**Alternative solution:**<br>$\frac{9}{1.2} = 7.5$ [Ω] (1)<br>$7.5 - 6 = 1.5$ [Ω] (1)<br>$\frac{12}{n} = 1.5$ [Ω] (1)<br>$n = 8$ (1) | [4] |

| | | | |
|---|---|---|---|
| 23. *(a)* | (i) | Correct and convincing use of $\rho = \frac{RA}{l}$ (including unit conversion) | [1] |
| | (ii) | $\left(\frac{2000}{11.2}\right)$ = 179 A **unit mark** | [1] |
| | (iii) | $v = \frac{I}{nAe}$ rearranged (or shown numerically) (1)<br>$n = 6.0 \times 10^{28} \times 3$ (1)<br>$v = 1.55 \times 10^{-5}$ [m s$^{-1}$] (ecf on $I$ and $n$) (1) | [3] |
| *(b)* | (i) | Same (or equivalent) | [1] |
| | (ii) | $v$ increased (1) because…; $A$ decreased, $I,n,e$ unchanged by implicaton (1) | [2] |
| | (iii) | Increased frequency / more collisions **between electrons and lattice** / atoms / ions or electrons carry greater kinetic energy (1) leading to **increased vibrational / kinetic energy of lattice atoms** (1) | [2] |

24.

$l$ or $(vt)$ [accept $v$ if stated dist travelled in 1 s]

(1) 

[NB free electrons not required to be labelled]

Number of free electrons = $nAvt$ [or $nAl$] (1)
Total change = $nAvte$ [or $nAle$] (1)
$I = \frac{nAvte}{t}$ with cancelling shown [or $\frac{nAle}{t}$, where $\frac{l}{t} = v$ shown] (1) 4

$2.0 = 1.0 \times 10^{29} \times 1.7 \times 10^{-6} v \times 1.6 \times 10^{-19}$ (1) [substitution]
$v = 7.4 \times 10^{-5}$ m s$^{-1}$ ((**unit**))(1) 2

collisions [accept obstructions](1)
between free electrons and copper atoms / ions / lattice (1) [accept: delocalised / moving / conducting electrons] 2

$R = \frac{P}{I^2}$ [or $P = I^2R$] (1); $R = \frac{0.1}{4}$ [=0.025 Ω] (1)
$\rho = \frac{0.025[\text{e.c.f.}] \times 1.7 \times 10^{-6}}{2.5}$ (1) [manipulation i.e $\rho = \frac{RA}{l}$ or with figures ]
$\rho = 1.7 \times 10^{-8}$ Ω m. (1) 4

| | |
|---|---|
| cross-sectional area | smaller (1) |
| $n$ | the same (1) |
| resistivity | the same (1) |

3

[15]

25.

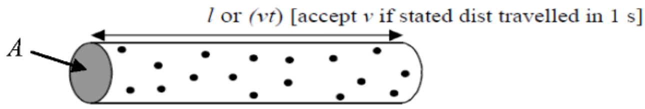
| | | | | |
|---|---|---|---|---|
| 2 | *(a)* | | Ammeter shown in series with bulb [or in series with bulb/voltmeter parallel combination] (1)<br>Voltmeter shown in parallel with bulb [or across bulb/ammeter series combination] (1) | 2 |
| | *(b)* | (i) | 2.0 A | 1 |
| | | (ii) | 6.0 Ω | 1 |
| | *(c)* | | Either: $\frac{1}{18}+\frac{1}{6(\text{ecf})}=\frac{1}{R_{\parallel}}$ (1); $R_{par}=4.5\ \Omega$ (1)<br>Subst into pot div equations: $12=\frac{4.5}{4.5+R}\times 16$ (1)<br>$R=1.5\ \Omega$ (1)<br>Or: $I_{18\,\Omega}=\frac{12}{18}$ [=0.67 A] (1); So $I_{total}=2.67$ A [ecf from *(a)*](1)<br>$R=\frac{4(1)}{2.67(\text{ecf})}=1.5\ \Omega$ (1) | 4 |
| | *(d)* | | Graph shown with positive gradient and linear through the origin for low values (1) and smoothly reducing gradient for higher values [NB – not negative gradients at end](1) | 2 |
| | | | | [10] |

26.

| | | | | |
|---|---|---|---|---|
| *(a)* | (i) | | Metal wire at constant temperature - straight diagonal line.<br>Filament of lamp - curved line. | [1] |
| | (ii) | | Straight line: $R$ constant throughout [or $V/I$ constant] as... (1)<br>....$T$ constant throughout (1)<br>Curve: Initially $R$ constant [or $V/I$ constant] as....(1)<br>Then $T$ increases (1) so $R$ increases - accept explanation in terms of particles (1) | [5] |
| *(b)* | (i) | | $I=2$ [A] | [1] |
| | (ii) | (I) | Voltage across X = 12 [V] | [1] |
| | | (II) | 12 V - 6 V = 6 [V] ecf from (I) | [1] |
| | | (III) | $R_2=\frac{6}{4}=1.5[\Omega]$ ecf from (II) | [1] |
| | | (IV) | $V$ across $R_1=3$ [V] (1)<br>$I$ through $R_1=6$ [A] (1)<br>$R_1=\frac{3}{6}$ (ecf on $I$ and/or $V$) = 0.5[Ω] (1) | [3] |

27.

| | | | |
|---|---|---|---|
| (a) | (i) | Diagram to include<br>• Correct electric circuit with ohmmeter or power supply with ammeter + voltmeter with correct symbols and positioning (1)<br>• Method of heating shown (1)<br>• Method of recording temperature shown (1) | 3 |
| | (ii) | Linear [or approximately linear] graph with positive gradient (1) and positive intercept on $R$ axis (1). | 2 |
| (b) | (i) | Conducting / delocalised / free electrons (1) collide (1) with metal lattice / atoms / ions (1) [not with other free electrons] | 3 |
| | (ii) | The greater the temperature the greater the vibrational energy of the lattice / metal ions (1) producing a greater chance [or rate] of collisions/ collisions more often / greater frequency of collisions (1) [not harder] . | 2 |

| Question | | | | Marking details | Marks Available |
|---|---|---|---|---|---|
| 3 | *(a)* | (i) | | [Free] electrons forced to move by applied pd (Need a reference to drift velocity or electron flow but does not need to be explicitly stated) (1)<br>They collide with atoms/nuclei/ions/lattice of the wire (1) don't accept particles or molecules | 2 |
| | | (ii) | | Power = $\frac{1.8}{60}$ = 0.03 [W] (1)<br>$R = \frac{0.03(\text{ecf})}{1.6^2}$ = 0.0117 [Ω] (1)<br>**Alternative solution possible** for the first 2 marks using $V = \frac{W}{Q}$ and $R = \frac{V}{I}$<br>$\rho = \frac{0.0117\text{x}2\text{x}10^{-6}}{0.4}$ (1) [**ecf** on $R$]<br>= $5.9 \times 10^{-8}$ [Ω m] (1) | 4 |
| | *(b)* | (i) | | <br>[NB free electrons not required to be labelled]<br>Number of free electrons = $nAvt$ [**or** $nAl$] (1)<br>Total change = $nAvte$ [**or** $nAle$] (1)<br>$I = \frac{nAvte}{t}$ with cancelling shown [or $\frac{nAle}{t}$, where $\frac{l}{t} = v$ shown] (1)<br>Volume defined either from diagram [e.g. $A$ and $l$ labelled as shown] or in body of derivation [e.g. vol = $Al$] and $n$ identified correctly– **for the first mark** | 4 |
| | | (ii) | | $1.6 = 6.4 \times 10^{28} \times 2 \times 10^{-6} \times v \times 1.6 \times 10^{-19}$ (1: substitution)<br>$v = 7.8 \times 10^{-5}$ [m s$^{-1}$] (1) | 2 |
| | | (iii) | (I)<br>(II)<br>(III) | **less than 1.6 A** identified/circled (1)<br>**the same as** identified/circled (1)<br>**half** identified/circled (1) | 3 |
| | | | | **Question 3 Total** | **[15]** |

| | | | | |
|---|---|---|---|---|
| 29. (a) | | | $n$- number of free/conducting electrons (charge carriers) per unit volume (1) accept free electron density<br>$v$- drift velocity (1) | [2] |
| (b) | | | LHS: $\mathrm{C\,s^{-1}}$ (1)<br>RHS: $\mathrm{m^{-3} \times m^{2} \times m s^{-1} \times C}$ (1)<br>Clear manipulation to show/state LHS = RHS (1) | [3] |
| (c) | (i) | | $v = \dfrac{I}{nAe}$ (1) (or correct substitution)<br>$v = 1.30 \times 10^{-4}\ \mathrm{m s^{-1}}$ (1) (-1 for slips in powers of 10)<br>$t = \dfrac{5.0}{1.30\times10^{-4}} = 3.85 \times 10^{4}$ [s] (1) **ecf** for incorrect value of $v$ | [3] |
| | (ii) | | Reduced CSA (or diameter) **<u>and</u>** $n$, $e$ constant...... (1)<br>...Increased $v$ ....... (1)<br>.....Hence reduced $t$ (1) | [3] |

| | | | |
|---|---|---|---|
| 30. (a) | (i) | Ruler and wire shown and labelled (1)<br>Moving pointer **or** jockey **or** crocodile clip indicated (1)<br>**Either**: Correctly positioned ohmmeter with no power supply; **or** correctly positioned voltmeter and ammeter with power supply (1)<br>[No labelling required for either method]. | [3] |
| | (ii) | Diagonal line through origin | [1] |
| | (iii) | CSA from <u>diameter of wire</u> (1)<br>Gradient from graph = $(R/l)$ **or** $(\rho/A)$<br>**Or** stated take a pair of $R$ and $l$ values from the graph (1)<br>$\rho$ = gradient × CSA **or** use of $\rho = RA/l$ (1) | [3] |
| (b) | (i) | $R = \dfrac{144}{32} = 4.5\ [\Omega]$ (1)<br>Correct substitution into $R = \rho l/A$ (1)<br>$l = 0.375$ [m] (1) (**ecf** on $R$) | [3] |
| | (ii) | $I = 2.7$ [A] (from $V/R$ **or** $P/V$ etc) (1) (**ecf** on $I$)<br>Correct substitution into $I = nAve$ (1)<br>$v = 1.24 \times 10^{-2}\ [\mathrm{m s^{-1}}]$ (1) accept $0.01\ \mathrm{m\,s^{-1}}$ | [3] |
| | | **Question 5 Total** | **[13]** |

| | | | |
|---|---|---|---|
| 31. *(a)* | (i) | Ruler and wire shown and labelled (1)<br>Moving pointer or jockey or crocodile clip indicated (1)<br>**Either**: Correctly positioned ohmmeter with no power supply; **or** correctly positioned voltmeter and ammeter with power supply (1)<br>[No labelling required for either method]. | [3] |
| | (ii) | Diagonal line through origin | [1] |
| | (iii) | CSA from <u>diameter of wire</u> (1)<br>Gradient from graph $= (R/l)$ **or** $(\rho/A)$<br>**Or** stated take a pair of $R$ and $l$ values from the graph (1)<br>$\rho =$ gradient $\times$ CSA **or** use of $\rho = RA/l$ (1) | [3] |
| *(b)* | (i) | $R = \frac{144}{32} = 4.5\,[\Omega]$ (1)<br>Correct substitution into $R = \rho l/A$ (1)<br>$l = 0.375$ [m] (1) (ecf on $R$) | [3] |
| | (ii) | $I = 2.7$ [A] (from $V/R$ or $P/V$ etc) (1) (ecf on $I$)<br>Correct substitution into $I = nAve$ (1)<br>$v = 1.24 \times 10^{-2}$ [m s$^{-1}$] (1) accept 0.01 m s$^{-1}$ | [3] |