B4. Part 1 Electrical heater

(a) (i) use of $R\left(=\frac{pl}{A}=\right)\frac{1.1\times10^{-6}\times4.5}{6.8\times10^{-8}}$; ***[1]***
72.8Ω (73Ω)

(ii) $\frac{240^{\ 2}}{72.8}$ / shows appropriate alternative equation;
$790\,\text{W}$; ***[2]***

(iii) one-third length so E_2 has one-third resistance of E_1 / evaluates R (24Ω);
(same V so) $3\times$ power of E_1;
so total power $= 4\times E_1 = 3.2\,\text{kW}$; ***[3]***

***or** numerical method*

current in $R_1 = \frac{728}{240} = 3\,\text{A}$;
current in $R_2 = 9\,\text{A}$;
total current $= 12\,\text{A}$ and total power $= 3.2\,\text{kW}$;
*Award **[3]** for correct alternative working.*

(iv) the power output will be less;
because the total resistance is greater in the series case;
hence the current is less and power depends on I^2;
$P = \frac{V^2}{R}$; ***[3 max]***

SECTION B

B1. Part 1 Electrical fields and electrical resistance

(a) a conductor contains "free" electrons and insulators do not / *OWTTE*; ***[1]***

(b) to have a current electrons must be accelerated/move along the wire;
and so a (electric) force must act on them;
this is provided by the electric field; ***[3]***

(c) $8.8\times10^{-18}\text{ N}$; ***[1]***

(d) the ratio of potential difference across a device/load/resistor to current in the device/load/resistor; ***[1]***

(e) $\rho=\frac{RA}{l}$;

$=\left(\frac{1.5\times\pi\times1.2^2\times10^{-6}}{2.2\times10^{-2}}=\right)3.1\times10^{-4}\ \Omega\text{ m}$; ***[2]***

(f) $I=\left(\sqrt{\frac{P}{R}}=\right)\sqrt{\frac{1}{1.35}}$;

$=0.86\text{ A}$; ***[2]***

(g) (i) the power supplied per unit current / work done per unit charge in moving charge completely round the circuit / energy per unit charge made available by the source; ***[1]***

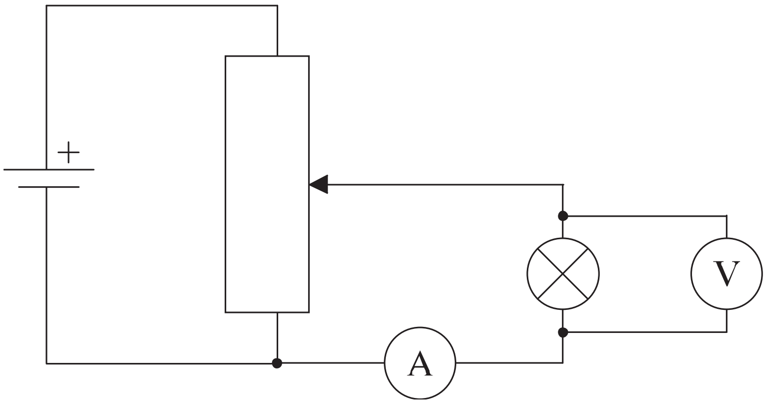
(ii) minimum resistance is $2.0\ \Omega$, maximum resistance is $2.5\ \Omega$;

so maximum power is $\left(\frac{2.0^2}{2.0}\right)=2.0\text{ W}$;

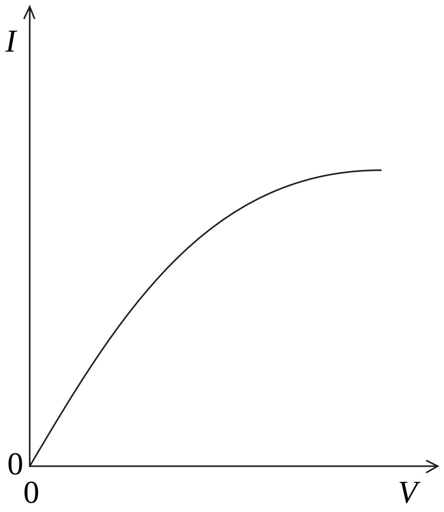
and minimum power is $\left(\frac{2.0^2}{2.5}\right)=1.6\text{ W}$; ***[3]***

B4. Part 1 Electric circuits

(a) any circuit in which the current will flow through the lamp;
variable resistor connected as a potential divider;
voltmeter across lamp;
ammeter in series with lamp; ***[4]***



(b) correct shape;
through origin; ***[2]***



(c) 0.24 A ; ***[1]***

(d) resistance calculated $= 5.2\,(\Omega)$;

$A = \left(\frac{\rho l}{R}\right) = 6.2\times10^{-8}\ \text{m}^2$;

radius $= \sqrt{\frac{A}{\pi}}$ seen/used;

$= 1.4\times10^{-4}$ m ; ***[4]***

(e) calculates resistance of lamps in parallel (2.6 Ω);
$V = \varepsilon - Ir$ used to give $V = 1.0\,\text{V}$;
1.0 V is lower than 1.25 V / power available to each lamp is 192 mW lower than 300 mW;
(terminal pd/power lower) hence not operating normally; { *Award **[0]** for only stating this bald answer.* ***[4]***
Watch for ECF from (d).
*Award **[4 max]** for any correct numerical argument involving energy or power calculations.*

SECTION A

A1. (a) (i) no
the graph is not linear / not a straight line; ***[1]***

(ii) a straight horizontal line through the initial points along the T axis;
a smooth curve through the remaining points (T = 4.4 to 7.0 K); ***[2]***
The straight line and curve do not need to be joined.

(b) $R = 0\Omega$; ***[1]***
Do not apply unit mark.

(c) (i) 4.2 – 4.4 K; ***[1]***

(ii) 4.3 K;
$\pm$ 0.1 (K); ***[2]***
allow ECF from (c)(i)

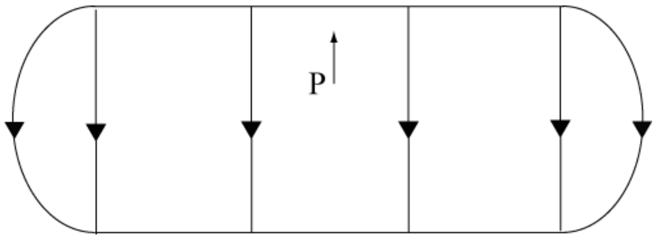
(iii) more sensitive thermometer / thermometer with a finer graduated scale / by taking resistance measurements at smaller temperature intervals; ***[1]***
*Award **[0]** for electronic digital thermometer **only**.*

(d) the data are for low temperatures well below room temperature;
no reason to assume the trend will continue to room temperature;
the data shows R varying sharply at T_C and another such transition might take place below room temperature;
mercury is a liquid at room temperature; ***[2 max]***
Award any other sensible answer.

SECTION B

B1. Part 1 Electric fields and electric circuits

(a) (i)



uniform field equal spacing of lines;
edge effect;
direction; ***[3]***

(ii) as shown; ***[1]***

(b) combine $F = qE$ and $F = ma$;

to get $E = \frac{ma}{q}$;

$E = 5.0 \times 10^3\ \text{N C}^{-1}$ / V m^{-1}; ***[3]***

(c) $V = \frac{1.9 \times 10^{-17}}{1.6 \times 10^{-19}}$;
$= 120\ \text{V}$ ***[1]***

(d) (i) 3.0 W; ***[1]***

(ii) power dissipated in battery $= (0.25^2 \times 4.0) = 0.25\ \text{W}$;
power dissipated in circuit $= (3.0 - 0.25) = 2.8\ (2.75)\ \text{W}$; ***[2]***

(iii) power dissipated in lamp $= (3.0 \times 0.25) = 0.75\ \text{W}$;
power dissipated in resistor $= (2.75 - 0.75) = 2.0\ \text{W}$;
resistance $\left(= \frac{2.0}{0.25^2}\right) = 32\,\Omega$; ***[3]***

or

resistance of lamp $= 12\,\Omega$;
$12 = 0.25\,(R + 16)$;
$R = 32\ \Omega$;

or

V across $R = 8.0\,\text{V}$;
$R = \frac{8.0}{0.25}$;
$= 32\,\Omega$;

A2. (a) (i) ratio of potential difference to current / $\frac{V}{I}$ with terms defined; ***[1]***

(ii) resistance $= \frac{230^2}{980}$;

$= 54\,\Omega$; ***[2]***

*Award **[2]** for bald correct answer.*

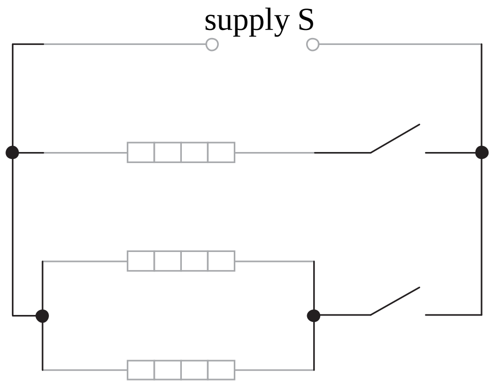
(iii) $L = \frac{RA}{\rho}$;

$= \frac{54 \times \pi \times \left[1.75 \times 10^{-4}\right]^2}{1.3 \times 10^{-6}}$;

$(L \approx 4\,\text{m})$ ***[2]***

Must see re-arrangement of data booklet equation or completely correct substitution as shown in second line for first mark.

(b) *e.g.*



switch connected so that P can be achieved;
another switch connected so that $2P$ and $3P$ can be achieved; ***[2]***

*Award **[0]** if three or more switches used. Allow any correct alternative including case where single resistor is permanently connected to supply. There are many variants, this diagram is only one example.*

A3. (a) region/area/volume (of space);
where a mass/charge experiences a force; ***[2]***

(b)

Particle	*Charge on particle*	*Initial direction of motion of particle*	*Direction of force on particle*	*Type of field*
A	*uncharged*	*stationary*	*in direction of field*	gravitational;
B	*negative*	*along direction of field*	*opposite to direction of field*	electric; *(accept electrostatic)*
C	*positive*	*normal to direction of field*	*normal to direction of field*	magnetic;

[3]

B4. Part 1 Domestic shower

(a) (i) the amount of energy/heat required to raise the temperature of 1kg of a substance through $1\text{K} / 1^{\circ}\text{C}$; ***[1]***

(ii) energy supplied by heater in $1\text{s} = 7.2\times10^{3}\text{ J}$;
energy per second $=$ mass per second $\times$ sp ht $\times$ rise in temperature;
$7.2\times10^{3} =$ mass per second $\times 4.2\times10^{3}\times 26$;
to give mass per second $= 0.066\text{ kg}$; ***[4]***

(iii) energy is lost to the surroundings;
flow rate is not uniform; ***[2]***
Do not allow "the heating element is not in contact with all the water flowing in the unit".

(iv) $P = VI \quad I = \dfrac{P}{V}$;

$= \dfrac{7.2\times10^{3}}{240} = 30\text{ A}$; ***[2]***

(v) when operating at 7.2 kW the element is at a higher temperature/hotter than when first switched on;
therefore, resistance is greater (and so current is smaller) / *OWTTE*;

or

element is cold /*OWTTE* when first switched on;
therefore, smaller resistance than when hot (and so current is larger); ***[2]***

(b) $P = \dfrac{V^2}{R}$;

$\dfrac{240^2}{R_{240}} = \dfrac{110^2}{R_{110}}$;

$\dfrac{R_{110}}{R_{240}} = \left(\dfrac{110}{240}\right)^2$;

$= 0.21$

or

from $P = VI$

$240 I_2 = 110 I_1$ to give $I_2 = \dfrac{11}{24} I_1$;

$I_2^{\,2} R_2 = I_1^{\,2} R_1$;

$\dfrac{R_1}{R_2} = \dfrac{I_2^{\,2}}{I_1^{\,2}} = \left(\dfrac{11}{24}\right)^2$;

$= 0.21$ ***[3 max]***