

ELECTRICAL CIRCUITS

Q1/ (i) $Q = I t$

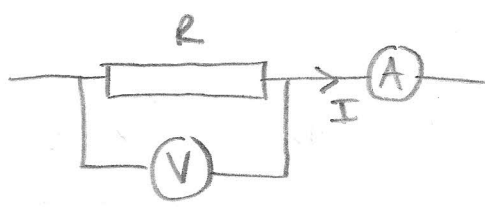
so $Q = 1.00 \times 10^{-9} \times 1.00 \times 10^{-9} \text{ (C)}$

$\therefore \# \text{ electrons} = \frac{Q}{e} = \frac{1.00 \times 10^{-18}}{1.602 \times 10^{-19}} = 6.24$

so **Six electrons**

(ii) $P = I^2 R \therefore I = \sqrt{\frac{P}{R}} = \sqrt{\frac{2.0}{10}} = 0.45 \text{ A}$

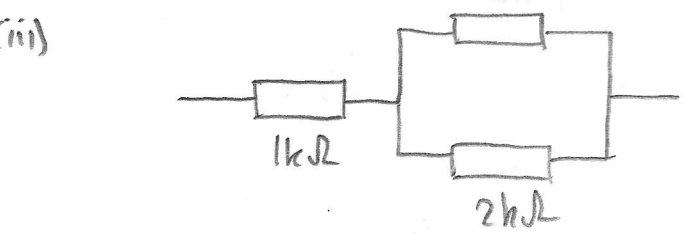
$V = IR \therefore V = 4.47 \text{ Volts}$



$P = \frac{V^2}{R}$ so if $V \rightarrow 2V$
 $R \rightarrow \frac{1}{2}R$

$P \rightarrow \frac{(2V)^2}{\frac{1}{2}R} \Rightarrow P \rightarrow 8 \frac{V^2}{R} \text{ i.e. } P \rightarrow 8P$

so multiply power dissipated by a factor of eight.



$R = 1 + \frac{1}{\frac{1}{3} + \frac{1}{2}} \text{ (k}\Omega)$

$= 2\frac{1}{5} \text{ k}\Omega \leftarrow \text{Don't express as fractions} \Rightarrow \text{infinite precision!}$
 $= 2.2 \text{ k}\Omega$

(iv) $eV = E = 1.602 \times 10^{-19} \times 5000 \text{ (J)}$
 $= 8.01 \times 10^{-16} \text{ J}$

(KE of electron if conversion of electrical energy is 100% efficient)

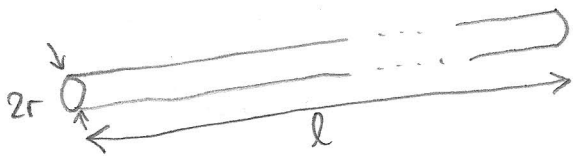
so $\frac{1}{2} m_e v^2 = eV \leftarrow \text{Classical KE formula.}$

$v = \sqrt{\frac{2eV}{m_e}}$

$\frac{v}{c} = \sqrt{\frac{eV}{\frac{1}{2} m_e c^2}} = \sqrt{\frac{1.602 \times 10^{-19} \times 5000}{\frac{1}{2} \times 9.109 \times 10^{-31} \times (2.998 \times 10^8)^2}} = 0.14$

(i) so 14% of the speed of light mean relativistic effects probably cannot be ignored.

(v)



$$2r = 1 \text{ mm}$$

$$R = 1 \Omega$$

$$\rho = 1.68 \times 10^{-8} \Omega \text{m}$$

↑
resistivity of
copper.

$$R = \frac{\rho l}{\pi r^2}$$

so

$$l = \frac{\pi R r^2}{\rho}$$

$$\therefore l = \frac{\pi \times 1 \times (0.5 \times 10^{-3})^2}{1.68 \times 10^{-8}}$$

$$l = 46.7 \text{ m} \rightarrow \text{calculator memory.}$$

Now $l \rightarrow 3l$ and $R \rightarrow 0.5 \Omega$ i.e. $R \rightarrow R/2$

$$r = \sqrt{\frac{\rho l}{\pi R}}$$

so

$$2r = 2 \sqrt{\frac{\rho l}{\pi R}}$$

$$2r = 2 \sqrt{\frac{\rho \cdot 3l}{\pi R/2}}$$

$$2r = 2 \sqrt{\frac{\rho l}{\pi R}} \times \sqrt{6}$$

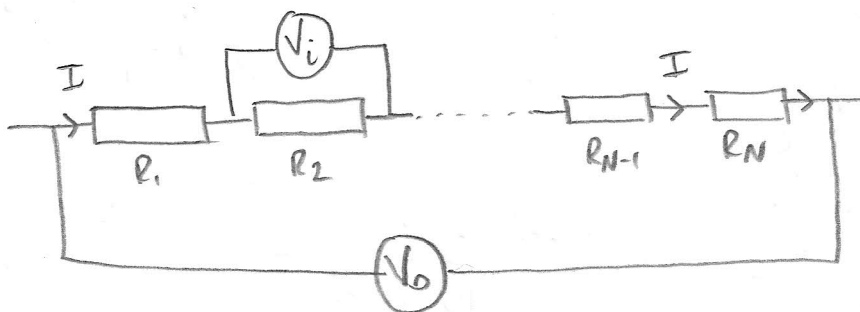
$$\text{so } 2r = \underbrace{1 \text{ mm}}_{\text{previous diameter}} \times \sqrt{6}$$

$$= 2.45 \text{ mm}$$

Check by direct substitution:

$$2r = 2 \times \sqrt{\frac{1.68 \times 10^{-8} \times 3 \times 46.7}{\pi \times 0.5}} = 2.45 \times 10^{-3} \text{ m} \quad \checkmark$$

(vi)



Kirchoff I
(i.e. conservation of
charge) \Rightarrow current
 I_i flowing

through resistor $R_i = I = \text{constant}$. If this were not
the case, charge would be gained or lost in the circuit.

(2)

So if $R_i = V_i / I_i$ (definition of resistance)

and $V_0 = V_1 + V_2 + \dots + V_N$ { Kirchhoff II or conservation of energy) and $I_i = I$

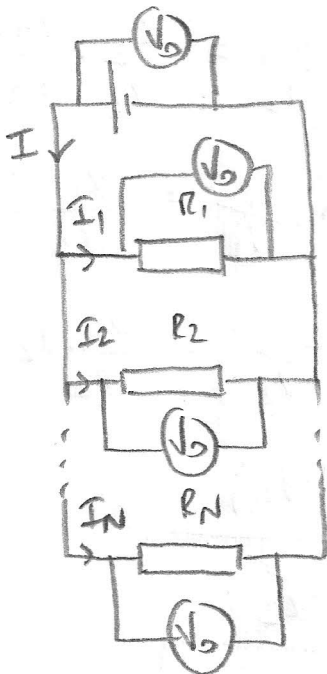
$$\Rightarrow V_0 = I (R_1 + R_2 + \dots + R_N)$$

Now total resistance is V_0 / I

$$\therefore R_{\text{TOT}} = R_1 + R_2 + \dots + R_N$$

So resistances in series add.

(vii)



Each resistor is connected to the same cell, so "feels" the same electric field and \therefore PD across each loop is $= V_0$.

Now current I drawn from cell (wired power supply providing voltage V_0)

$$\text{is } I = I_1 + I_2 + \dots + I_N$$

(Kirchhoff I). Now $I_i = V_i / R_i$
and $V_i = V_0$

$$\therefore I = V_0 \left(\frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N} \right)$$

If total resistance $R_{\text{TOT}} = \frac{V_0}{I} \Rightarrow \frac{I}{V_0} = \frac{1}{R_{\text{TOT}}}$

$$\therefore \frac{1}{R_{\text{TOT}}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_N}$$

So resistances add in reciprocals when wired in parallel.