Chapter 5.4

Q1 The battery establishes an electric field inside the conductor and this field exerts a force on the free electrons accelerating them in a direction opposite to the field. The electrons thus acquire kinetic energy. The electrons will collide with one or more of the molecules in their path and will transfer some of their kinetic energy to the atoms. The atoms thus begin to vibrate more about their equilibrium positions increasing their kinetic energy. Since the temperature is a measure of the average kinetic energy of the molecules, the temperature of the metal goes up.

Q2 When it is first turned on the filament is cold and so its resistance low. The current that floes is thus larger than that that goes through the filament when it is hot.

Q3 The length of the conductor, its cross sectional area, the kind of material and the temperature.

Q4 The electric field inside the wire is uniform. Therefore doubling the length means that the potential difference across its ends will double but the current will stay the same. From $R = \frac{V}{I}$ the resistance will double as well.

Q5 If the radius is doubled the cross sectional area will increase by a factor of 4 and so the resistance will decrease by a factor of 4.

Q6 The mass of $1\ \text{m}^3$ of gold is 19 390 kg which corresponds to $\frac{1939000}{197} = 9.8\times10^4$ moles and so $9.8\times10^4 \times 6.02\times10^{23} = 5.9\times10^{28}$ molecules, atoms in this case. Hence we have 5.9×10^{28} free electrons per cubic meter.

Q7 We must use $I = neAv \Rightarrow v = \frac{I}{neA}$ to get

$$v = \frac{5.0}{5.8\times10^{28}\times1.6\times10^{-19}\times\pi\times(2\times10^{-3})^2} = 4\times10^{-5}\ \text{m s}^{-1}.$$

Q8 (a) The charge is $Q = It = 10\times1\times60\times60 = 3.6\times10^4\ \text{C}$. (b) The number of electrons is $\frac{3.6\times10^4}{1.6\times10^{-19}} = 2.2\times10^{23}$.

Q9 (a) Yes since the graphs are straight lines through the origin. (b) The resistance for wire A is lower and so this wire corresponds to the lower temperature.

Q10 Since the resistance is constant, $\frac{6.0}{1.5} = \frac{V}{3.5} \Rightarrow V = 14\ \text{V}$.

Q11 A graph of the data does not produce a straight line through the origin and so the device does not obey Ohm's law.

Q12 It obeys Ohm's law so the resistance is the same, $12\ \Omega$.

Q13 $R = \frac{V}{I} = \frac{220}{15} = 15\ \Omega$.

Q14 The cross sectional area will become 4 times as small and so the resistance will become 4 times as large (using $R = \frac{\rho L}{A}$).

Q15 (a) $V = IR = 2 \times 4 = 8\ \text{V}$ across the first and $V = IR = 2 \times 6 = 12\ \text{V}$ across the second.
(b) Since the potential at A is 24 V the potential at B will be $24 - 8 = 16\ \text{V}$. There is no potential difference between B and C since there is no resistance between these points. Hence the potential at C is also $16\ \text{V}$. The potential at D is $16 - 12 = 4\ \text{V}$.

Q16 (a) Lower left resistor (LL): $V = RI = 4.0 \times 1.0 = 4.0\ \text{V}$.
Upper left resistor (UL): $V = RI = 3.0 \times 2.0 = 6.0\ \text{V}$.
Hence the potential to the right of the LL resistor is $12 - 4.0 = 8.0\ \text{V}$ and to the right of the UL resistor it is $12 - 6.0 = 6.0\ \text{V}$. Hence the potential difference across the middle resistor is $2.0\ \text{V}$ and the current goes upwards. The current is $I = \frac{2.0}{4.0} = 0.50\ \text{A}$. Hence the current through the lower right (LR) resistor is $1.0 - 0.50 = 0.50\ \text{A}$ and the potential difference across it is $V = RI = 9.0 \times 0.50 = 4.5\ \text{V}$. The current through the top right (TR) resistor is $2.0 + 0.50 = 2.50\ \text{A}$ and the potential difference across it is $V = RI = 1.0 \times 2.50 = 2.5\ \text{V}$. The potential to the right of the TR resistor is $6.0 - 2.5 = 3.5\ \text{V}$. The potential to the right of the LR resistor must be the same. As a check: $8.0 - 4.5 = 3.5\ \text{V}$. (b) The potential difference between A and B is $12 - 3.5 = 8.5\ \text{V}$.

Q17 (a) From $P = VI$ we get $I = \frac{P}{V} = \frac{60}{220} = 0.27\ \text{A}$. (b) The (assumed) constant resistance is $R = \frac{V}{I} = \frac{220}{0.2727} = 807\ \Omega$. Hence $I = \frac{V}{R} = \frac{110}{807} = 0.14\ \text{A}$. (c) From $P = \frac{V^2}{R}$ we see that $\frac{60}{P_2} = \frac{V_1^2}{V_2^2} = \frac{220^2}{110^2} = 4 \Rightarrow P_2 = 15\ \text{W}$. (Or $P = VI = 110 \times 0.136 = 15\ \text{W}$.)

Q18 (a) The resistance is $R = \frac{V^2}{P} = \frac{220^2}{120} = 403\ \Omega$. (b)

$$403 = \frac{2.0\times10^{-6}\times L}{\pi\times(0.03\times10^{-3})^2} \Rightarrow L = 0.57\text{ m}.$$

Q19 (a) $E = Pt = 1.5\text{ kW}\times\frac{4}{60}\text{ hr} = 0.10\text{ kW h}$. (b) $E = Pt = 1500\text{ W}\times 240\text{ s} = 3.6\times10^5\text{ J}$.

Q20 We pay for the energy used and the energy is $E = Pt$. This is the same for both cases.