1 **(a)** Define *resistance*.

.....

..... **[1]**

(b) The smallest conductor within a computer processing chip can be represented as a rectangular block that is one atom high, four atoms wide and twenty atoms long. One such block is shown in Fig. 3.1.

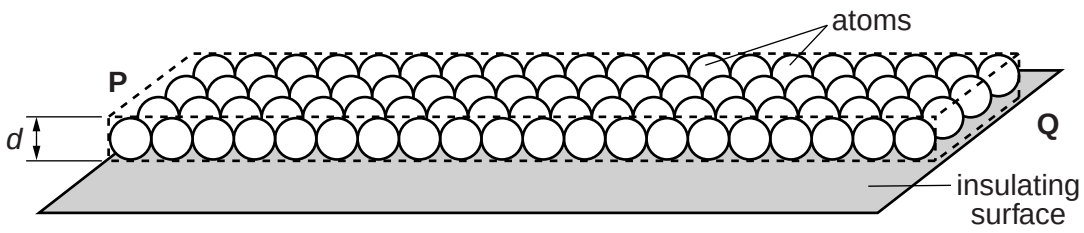

Fig. 3.1

The block is made from phosphorus atoms of diameter $d = 3.8 \times 10^{-10}$ m. The atoms are deposited on an insulating surface. This ensures that the atoms touch each other.

(i) Show that the resistance between the ends **P** and **Q** of this block is greater than 200 Ω. The resistivity of phosphorus is 1.7×10^{-8} Ω m.

[3]

(ii) Show that the number density of free electrons within the block is about 2×10^{28} m^{-3}. Assume that each phosphorus atom contributes one free electron.

[1]

(iii) Calculate the current between **P** and **Q** when the mean drift velocity of free electrons in the block is $1.9 \times 10^{-5}\,\text{m}\,\text{s}^{-1}$.

current = ... A **[2]**

(iv) There are about 10^9 of these tiny conductors in a single chip each carrying the current calculated in **(iii)**. Estimate the total power dissipated in these conductors in a single chip.

power = ... W **[3]**

(c) It takes about $4 \times 10^{-4}\,\text{s}$ for an electron to pass from **P** to **Q** but the electrical signal, an electromagnetic wave, is transmitted across the block in about $3 \times 10^{-17}\,\text{s}$. Explain why these times are so different.

.....

.....

.....

..... **[2]**

[Total: 12]

2 Fig. 3.1 shows a circuit consisting of a battery of electromotive force 16.0 V and negligible internal resistance, two resistors and a thermistor.

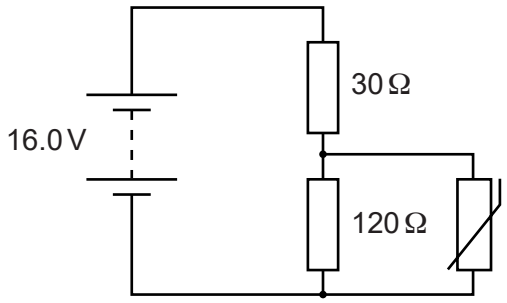

Fig. 3.1

(a) (i) Define the term *electromotive force* (*e.m.f.*).

.....

.....

..... **[2]**

(ii) Explain the meaning of the term *internal resistance*.

.....

.....

..... **[1]**

(b) The thermistor has a resistance of 360 Ω at 20 °C. Calculate

(i) the total resistance *R* of the thermistor and the resistor of resistance 120 Ω at 20 °C

R = ... Ω **[2]**

(ii) the potential difference *V* across the thermistor.

V = ... V **[3]**

(iii) It is suggested that the thermistor in the circuit of Fig. 3.1 is used to monitor temperatures between 20 °C and 200 °C. Describe how the potential difference across the thermistor and the current in it will vary as the temperature increases above 20 °C.

In your answer you should explain why the potential difference and current vary as the temperature increases.

.....

.....

.....

.....

.....

.....

..... **[4]**

(c) The battery in Fig. 3.1 is rechargeable.

(i) Calculate the charge stored in the battery when it is charged for 8.0 hours at a constant current of 1.2 A.

charge = …… unit …….. **[3]**

(ii) After charging, the battery loses energy at a constant rate of $1.4\,J\,s^{-1}$. The e.m.f. of the battery remains constant at 16.0 V. Calculate how many hours it takes for the battery to discharge.

discharge time = ... h **[3]**

[Total: 18]

3 **(a)** A 12V 36W lamp is lit to normal brightness using a 12V car battery of negligible internal resistance. The lamp is switched on for one hour (3600 s). For the time of 1 hour, calculate

(i) the energy supplied by the battery

energy = ……..J **[2]**

(ii) the charge passing through the lamp

charge = …….unit…….**[3]**

(iii) the total number of electrons passing through the lamp.

number of electrons = ……. **[2]**

(b) The wires connecting the 36W lamp to the 12V battery are made of copper. They have a cross-sectional area of 1.1×10^{-7} m^2. The current in the wire is 3.0 A. The number *n* of free electrons per m^3 for copper is 8.0×10^{28} m^{-3}.

(i) Describe what is meant by the term *mean drift velocity* of the electrons in the wire.

.....

.....

..... **[2]**

(ii) Calculate the mean drift velocity v of the electrons in this wire.

v = ……..m s^{-1} **[3]**

[Total: 12]