1)

A resistor **X** is constructed from a rod of cross-sectional area $9.0 \times 10^{-6}\,m^2$ and length 0.012 m as shown in Fig. 1.1. The resistivity of the material of the rod is $2.4\,\Omega\,m$.

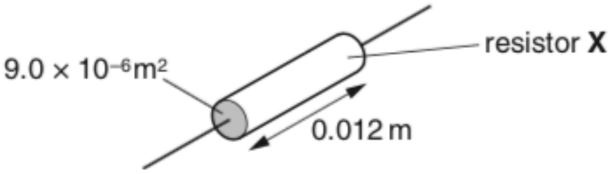


Fig. 1.1

(a) Show that the resistance of the resistor **X** is $3.2\,k\Omega$.

[2]

(b) The power rating of resistor **X** is 0.125W. Show that the maximum potential difference which should be applied safely across the resistor is 20V.

[2]

(c) A student needs a resistor of the same resistance as **X** but with a power rating of 0.50W. The only resistors available are identical to **X**. It is suggested that four of these resistors could be connected as shown in Fig. 1.2 to solve the problem. The potential difference across the combination of resistors is 40V.

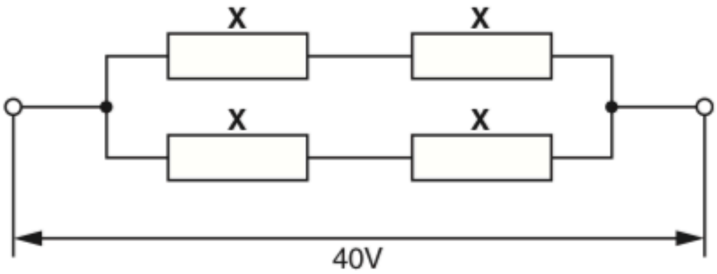


Fig. 1.2

(i) Show that the total resistance of the combination in Fig. 1.2 is 3.2 kΩ.

[2]

(ii) Show that the power dissipation in each resistor is 0.125 W.

....

....

....

.... **[2]**

(d) Another resistor **Y** is constructed from the same material but has twice the length and twice the diameter of resistor **X**.

(i) Show that the resistance R_Y of **Y** is half the resistance R_X of resistor **X**.

[2]

(ii) The two resistors **X** and **Y**, where $R_Y = R_X/2$, are connected in series to a d.c. power supply as shown in Fig. 1.3.

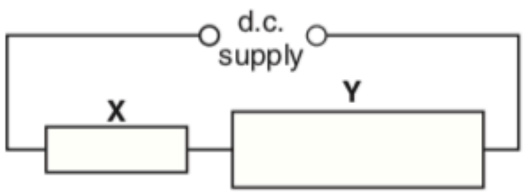


Fig. 1.3

State and explain which resistor dissipates greater power.

....

....

....

....

.... **[3]**

[Total: 13]

2)

This question is about the rigid copper bars which carry the very large currents generated in a power station to the transformers. Fig. 1.1 shows such a copper bar.

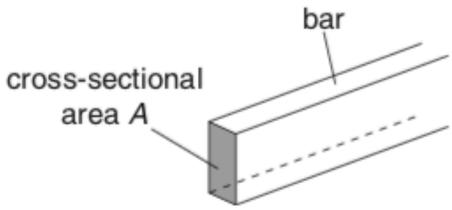


Fig. 1.1

(a) Write down a suitable word equation to define the *resistivity* of a material.

....

....

.... **[1]**

(b) **(i)** The cross-sectional area *A* of the bar is $6.4 \times 10^{-3}\,m^2$. Calculate the resistance of a 1.0 m length of the bar. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega m$.

resistance = ... Ω **[2]**

(ii) The bar carries a constant current of 8000 A. Calculate the power dissipated as heat along a 1.0 m length of it.

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

(iii) The bar is 9.0 m long. Estimate the total energy in kW h lost from the bar in one day.

energy = ... kW h **[2]**

(iv) Calculate the cost per day of operating the copper bar. The cost of 1kW h is 15p.

cost = ... p **[1]**

(c) Calculate the mean drift velocity *v* of the free electrons in the copper bar. The number of free electrons per unit volume in copper is $8.4 \times 10^{28}\,m^{-3}$.

v = ... $m\,s^{-1}$ **[3]**

[Total: 12]

3)

(a) Define the *resistivity* ρ of a metal wire.

....

....

.... **[2]**

(b) In the UK the National Grid is used to transmit electric power. Each pylon supports 24 cables. See Fig. 2.1. Each cable consists of 38 strands of aluminium. See Fig. 2.2.

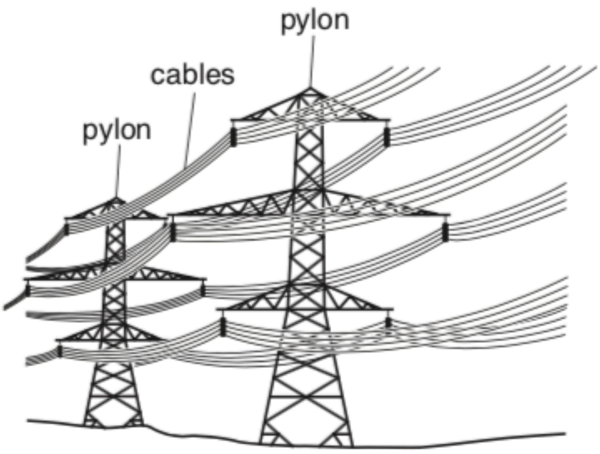


Fig. 2.1

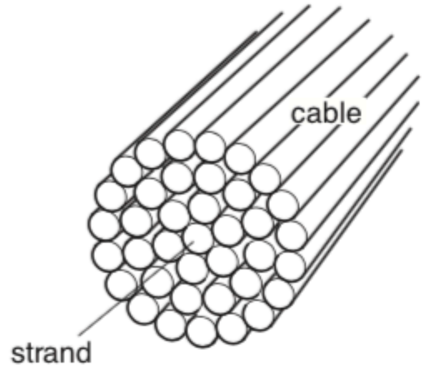


Fig. 2.2

(i) The resistance per km of a cable is 0.052 $\Omega\ km^{-1}$. Explain why the resistance per km of a single strand is approximately 2.0 $\Omega\ km^{-1}$.

....

....

.... **[2]**

(ii) The resistivity of aluminium is 2.6 x 10^{-8} Ω m. Calculate the cross-sectional area A of a single strand of the cable.

A = ……..………….…m^2 **[2]**

(c) The input voltage to each cable in Fig. 2.1 is 400 kV. The cable carries a current of 440 A. Calculate

(i) the input power to one cable

input power = ... W **[2]**

(ii) the number of cables required to transmit the power from a 2000 MW power station

number of cables = ...**[1]**

(iii) the power lost as heat per km of cable

lost power = ...**[3]**

(iv) the percentage of the input power that is available at a distance of 100 km from the power station.

percentage of power =..............................% **[2]**

[Total: 14]

4)

An electric heater has a constant resistance of 42.5 Ω. It is connected to the 230 V mains supply by wires of total resistance 2.50 Ω. See Fig. 2.1.

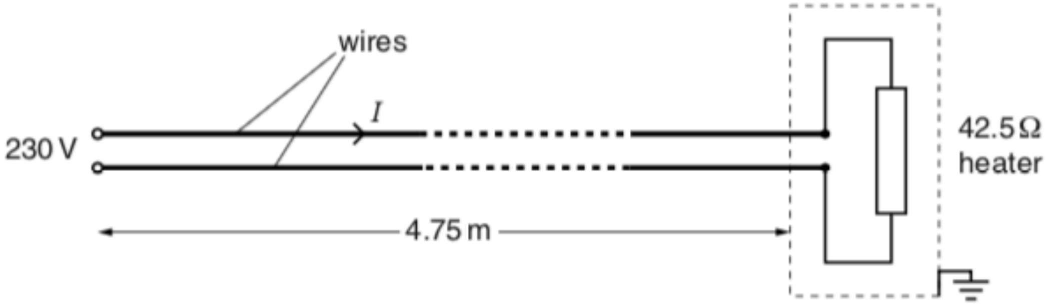


Fig. 2.1

(a) **(i)** Show that the current I in the wires is about 5 A.

[2]

(ii) Calculate the total power P dissipated in the heater and wires. Give your answer to three significant figures.

P = ... W **[3]**

(iii) Suggest a suitable value for the fuse in the plug connecting the cable to the mains supply.

fuse value = ... A **[1]**

(b) Calculate the cost, to the nearest penny, of using this heater for 4.0 hours, when 1 kW h costs 21p.

cost = ... p **[2]**

(c) The wires used to connect the heater to the supply have a total length of 9.50 m. The wires are made of copper. The resistivity of copper is $1.70 \times 10^{-8}\,\Omega\,\text{m}$.

Calculate the cross-sectional area *A* of the wire.

A = ... m^2 **[3]**

(d) Suggest and explain **one** disadvantage of connecting the heater to the mains supply using thinner copper wires.

....

....

....

....

.... **[3]**

[Total: 14]

5)

(a) State the difference between the directions of conventional current and electron flow.

....

.... **[1]**

(b) Circle one or more of the combinations of units which could act as a unit for current.

J s   C s^{-1} V Ω^{-1} J C^{-1}

[2]

(c) Fig. 1.1 shows a current I in a thick metal wire **X** connected to a longer thinner wire **Y** of the same metal as shown in Fig. 1.1.

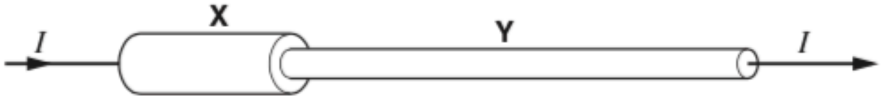


Fig. 1.1

(i) State why the current in **Y** must also be I.

....

.... **[1]**

(ii) Wire **Y** has half the cross-sectional area of the thicker wire **X** and is three times as long.

The resistance R_X of **X** is 12.0 Ω.

1 Show that the resistance R_Y of **Y** is 72 Ω.

2 Calculate the total resistance R of both wires.

R = ... Ω **[4]**

(iii) The mean drift velocity v_X of electrons in **X** is $2.0 \times 10^{-5}\,m\,s^{-1}$.

Use the fact that **X** has twice the cross-sectional area of the thinner wire **Y** to calculate the mean drift velocity v_Y of electrons in **Y**. Show your working.

v_Y = ... $m\,s^{-1}$ **[2]**

[Total: 10]

6)

(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.

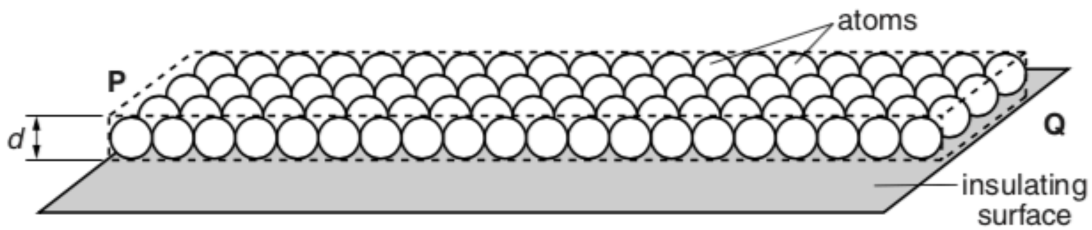


Fig. 3.1

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

....

....

....

.... **[2]**

[Total: 12]

7)

The power of a 230V mains filament lamp is 40W.

(a) Define *power*.

....

.... **[1]**

(b) The lamp is connected to the 230V supply. Calculate

(i) the current I in the filament

I = ... A **[2]**

(ii) the resistance R of the filament.

R = ... Ω **[1]**

(c) The cross-sectional area of the wire of the filament is $3.0 \times 10^{-8}\,m^2$. The resistivity of the filament when the lamp is lit is $7.0 \times 10^{-5}\,\Omega\,m$. Use your answer to **(b)(ii)** to calculate the length L of the filament wire.

L = ... m **[3]**

(d) Explain whether the filament of a 60 W, 230 V lamp is thicker or thinner than that of the 40 W, 230 V lamp. The length and material of the filament are the same in both lamps.

....

....

....

....

....

....

....

.... **[3]**

(e) The 40 W filament lamp is left on for 8 hours.

(i) Calculate the charge *Q* passing through the lamp in this time.

Q = ... C **[2]**

(ii) **1** Define the *kilowatt-hour*.

....

.... **[1]**

2 Calculate the cost of leaving the lamp switched on. The cost of 1 kWh is 22 p.

cost = ... p **[2]**

[Total: 15]

8)

Fig. 1.1 shows the $I-V$ characteristic of a slice of semiconducting material.

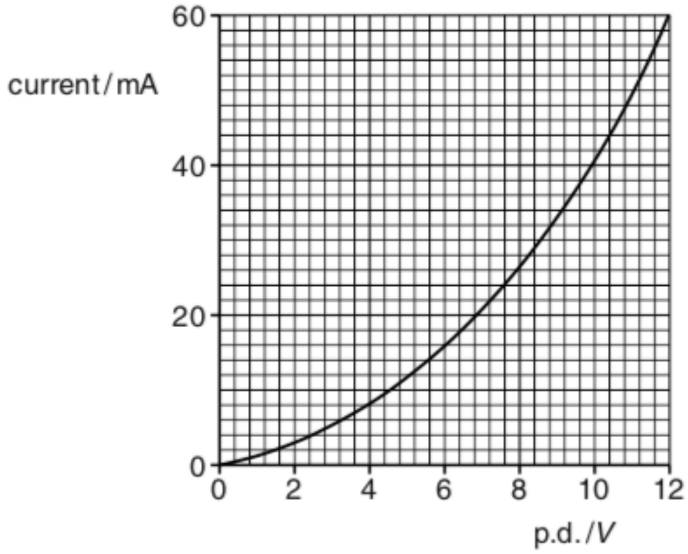


Fig. 1.1

(a) **(i)** Define *resistance*.

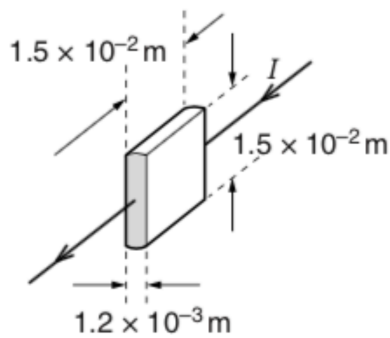
....

.... **[1]**

(ii) Show that the resistance of the slice is about 250 Ω when there is a current of 40 mA in it.

[2]

(b) The dimensions of the slice are shown in Fig. 1.2.



(d) A metal such as copper is classified as a *conductor*. Graphite behaves as a *semiconductor*.

(i) Describe why the resistivity of copper is less than that of graphite.

....

....

....

.... **[2]**

(ii) State with a reason what effect an increase in temperature has on the electrical properties of each of these two types of material.

....

....

....

....

....

.... **[2]**

....

....

....

....

....

....

....

....

.... **[4]**

[Total: 10]

9)

The maximum power input to a domestic fan heater is 2.6 kW when connected to the 230 V mains supply. The electric circuit of the fan heater consists of two heating elements (resistors) rated at 1.5 kW and 1.0 kW, a motor rated at 100 W and three switches.

(a) **(i)** Show that the resistance of the 1.5 kW heating element is about 35 Ω.

[2]

(ii) The 1.5 kW heating element is made from a wire of cross-sectional area $7.8 \times 10^{-8}\,m^2$ and resistivity $1.1 \times 10^{-6}\,\Omega\,m$. Calculate the length of the wire.

length = ... m **[3]**

(b) With only the first switch closed, the fan rotates; closing the second switch gives the heater an output of 1.5 kW and closing the third switch increases the output to 2.5 kW. The elements will not heat up unless the fan is switched on. The heater cannot give an output of 1.0 kW.

Complete the circuit diagram of Fig. 1.1 to show the fan, the heating elements and the switches connected so that the heater will work as described. Label the switches and the elements.

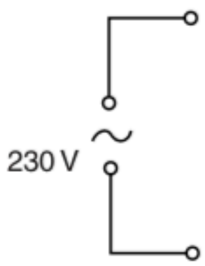


Fig. 1.1

[3]

(c) Both heating elements are made of wire of the same resistivity and length.

(i) Explain, without calculation, why the diameter *d* of the 1.0 kW heater wire must be less than the diameter *D* of the 1.5 kW heater wire, designed for use with a 230 V supply.

....

....

.... **[2]**

(ii) Show that *d* is approximately equal to 0.8 *D*.

[3]

(d) Circle the correct fuse for the plug of this appliance from the values below.

3 A **5 A** **10 A** **13 A**

Justify your choice.

....

....

.... **[2]**

(e) **(i)** Define the *kilowatt-hour*.

....

.... **[1]**

(ii) Calculate, to the nearest penny, the cost of using the heater for 4.0 hours with only **one** of the heating elements switched on. The cost of 1 kWh is 18 p.

cost = ... p **[2]**

10)

(a) Write a suitable word equation to define the *resistivity* of a material.

....

.... **[1]**

(b) A student investigates the electrical properties of the graphite 'lead' in a pencil.

(i) The pencil is 150 mm long. The 'lead' is a cylindrical graphite rod of diameter 2.0 mm. The resistance of the rod is 8.0 Ω. Calculate the resistivity ρ of graphite.

ρ = ... unit .... **[4]**

(ii) The graphite rod is removed from the pencil and used as a variable resistor, labelled 8.0 Ω in the circuit of Fig. 1.1. At a particular point **X** the current in ammeter $\mathbf{A_1}$ is twice the current in ammeter $\mathbf{A_2}$.

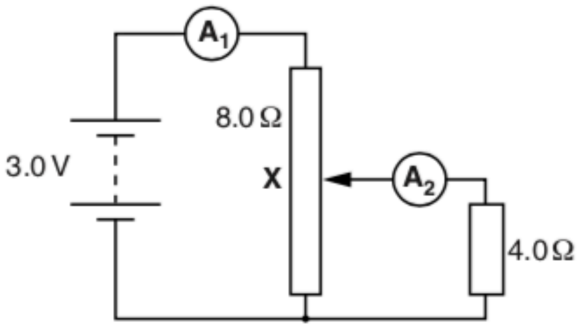


Fig. 1.1

1 Explain why **X** must be the mid point of the graphite rod.

....

....

....

....

....

.... **[3]**

2 Calculate the current in $\mathbf{A_1}$.

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

(c) Calculate the mean drift velocity v of the free electrons in the graphite rod when there is a current of 0.40 A in it.

number of charge carriers per unit volume = $3.6 \times 10^{26}\,m^{-3}$

v = ... $m\,s^{-1}$ **[3]**

(d) A metal such as copper is classified as a *conductor*. Graphite behaves as a *semiconductor*.

(i) Describe why the resistivity of copper is less than that of graphite.

....

....

....

.... **[2]**

(ii) State with a reason what effect an increase in temperature has on the electrical properties of each of these two types of material.

....

....

....

....

....

.... **[2]**