SECTION A

You should spend a maximum of 40 minutes on this section.

Write your answer for each question in the box provided.

Answer **all** the questions.

1 Which pair contains one vector and one scalar quantity?

A velocity acceleration

B displacement force

C kinetic energy work done

D momentum distance

Your answer ☐ **[1]**

2 The unit of electrical resistance is the ohm Ω. 1 Ω is the same as

A $1\ C\ V^{-1}$

B $1\ S^{-1}$

C $1\ C^2\ J^{-1}\ s^{-1}$

D $1\ A\ V^{-1}$

Your answer ☐ **[1]**

3 Which quantity is followed by a reasonable estimate of its order of magnitude?

A weight of an apple 10^0 N

B volume of a table tennis ball 10^3 cm^3

C wavelength of infra-red radiation 10^4 m

D temperature of Sun's surface 10^5 K

Your answer ☐ **[1]**

The following information is for use in questions **15** and **16**.

Two heater coils **X** and **Y** dissipate the same power when coil **X** runs at 12 V and coil **Y** runs at 6 V. The coils are made from equal lengths of wire of the same material, but different diameter.

15 Which one of **A** to **D** below is equal to the ratio $\frac{\text{resistance of } \mathbf{X}}{\text{resistance of } \mathbf{Y}}$?

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

Your answer ☐ **[1]**

16 Which one of **A** to **D** below is equal to the ratio $\frac{\text{diameter of wire } \mathbf{X}}{\text{diameter of wire } \mathbf{Y}}$?

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

Your answer ☐ **[1]**

11 Fig. 11.1 is an incomplete circuit diagram to measure the conductance of an electrical component called a thermistor.

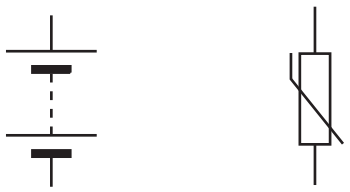

Fig. 11.1

(a) Complete the circuit diagram, including an ammeter and voltmeter. **[2]**

(b) At 300 K, the current in the thermistor is 1.4 mA when the p.d. across it is 5.6 V.
Show that the conductance of the thermistor is about 3×10^{-4} S.

[1]

(c) The electrical behaviour of a thermistor can be modelled as follows:

- most electrons are bound to atoms
- those few electrons with an extra energy $\mathcal{E}$ are able to move freely

(i) Use ideas about the Boltzmann factor to explain why the conductance of a thermistor increases with increasing temperature.

Your answer should use correct spelling and grammar.

[3]

(ii) The Boltzmann factor can be used with the model to predict that the conductance G of the thermistor at temperature T is given by the relationship

$$G = G_0 e^{\frac{-\varepsilon}{kT}}.$$

Use your answer to **(b)** to calculate the conductance of the thermistor at 400 K.

$\varepsilon = 5.0 \times 10^{-20}$ J
$k = 1.4 \times 10^{-23}$ J K^{-1}

conductance = ... S **[3]**

[Total: 9]

6 This question is about conduction in metals and in semiconductors.

(a) A copper wire of length 1.5 m and radius 2.5×10^{-4} m has a resistance of 0.13 Ω at 20 °C. Calculate the conductivity of copper at this temperature.

conductivity at 20 °C = ... $S\,m^{-1}$ **[3]**

(b) A simple model of conduction suggests that each copper atom in the wire contributes one or more electrons to a cloud of free electrons that behave rather like particles in a gas. These electrons drift through the wire under the influence of an electric field.

The current I is given by the equation $I = nave$ where:

n is the number of free electrons in the material per m^3
a is the cross-sectional area of the wire
v is the drift velocity of the electrons
e is the electronic charge.

Calculate the drift velocity of the electrons when the copper wire in part **(a)** carries a current of 2.3 A. The number of free electrons per m^3 in copper = $8.5 \times 10^{28}\,m^{-3}$

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

(c)* The conductivity σ of semiconductors such as ntc thermistors increases dramatically with temperature T. The relationship is given by the equation

$$\sigma = C\, e^{-E/kT}$$

where C is a constant, k is the Boltzmann constant and E is the energy required to ionise an atom in the semiconductor.

Use the relationships given in the question to explain the effect of increasing temperature on the conductivity of metals and semiconductors, referring to the microscopic structure of the materials. No calculations are required. **[6]**

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