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]

2012 G441.

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

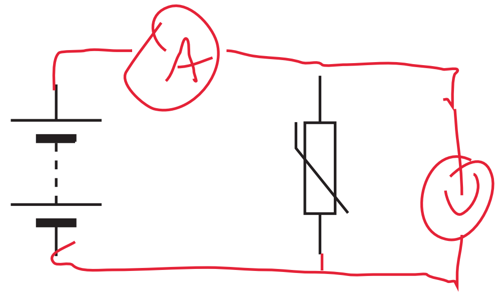

Fig. 11.1

(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.

$C = \frac{I}{V} = \frac{1.4 \times 10^{-3}}{5.6} = 2.5 \times 10^{-4}$

$\approx 3 \times 10^{-4}$

[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.

- BF = give ratio of particle between 2 state separated by E. i.e. in this case ratio of particle which can move or not.

[3]

- As T goes up, so does average energy/particle & so does BF.
- so e more likely to become free

(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

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

at 300 K
G = 2.5 × 10⁻⁴

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}

need to get G_0 out!

$$G_{300} = G_0 e^{-\frac{5\times10^{-20}}{1.4\times10^{-23}\times300}} = 2.5\times10^{-4} = G_0 \times 6.758\times10^{-6}$$

$$\Rightarrow G_0 = 37$$

$$G_{400} = 37 \times e^{\frac{-5\times10^{-20}}{1.4\times10^{-23}\times400}}$$

conductance = 4.9 × 10⁻³ .... S **[3]**

[Total: 9]

Lit 18

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 = ... $\mathrm{S\,m^{-1}}$ **[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 $\mathrm{m^3}$
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 $\mathrm{m^3}$ in copper = $8.5 \times 10^{28}\,\mathrm{m^{-3}}$

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

Turn over

(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]**

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....